EX-ANTE ANALYSIS OF ECONOMIC RETURNS FROM BIOLOGICAL CONTROL OF COCONUT MITE IN BENIN AND TANZANIA: A MARKET CHAIN PERSPECTIVE

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ABSTRACT

The economic impacts resulting from the biological control of coconut mite in Benin and Tanzania are scrutinized using an *ex ante* analytical framework. The study sought to assess the empirical evidence about the benefits of biological control of coconut mite being implemented in the selected coconut growing areas in the two countries. The study also sought to enrich the knowledge base needed for formulating policies that will develop the coconut value chains in these two countries and others facing similar conditions. Results from the economic surplus model show that biological control will produce a welfare gain of US$15 5213.4 in Benin, whereas in Tanzania technology will create welfare gains of US$ 33 47006 per year. The estimated discounted economic returns expressed as Net Present Values (NPV) varied a great deal with varying interest rate. Considered at a discount rate of 12% for the period 2008–2027, Net Present Value was about US$ 20 7721 in Benin, and US$ 23 5611 in Tanzania. The Internal Rates of Return (IRR) or break-even discount rates are substantially high; being 13.21% in Benin and 52% in Tanzania respectively. The analysis of current coconut marketing chain shows that producers receive only 17% and 8% of the prices paid by consumers in Benin and Tanzania respectively. The coconut subsector is hampered by challenges that range from production, processing to marketing. Despite these challenges there are possibilities to develop coconut value chains in these countries if critical challenges are addressed. Areas that need attention for developing the coconut subsector include; (i) increasing productivity and production at the farm level, (ii) to achieve increased production, the industry should expand the planting and replanting programme so that supply increases to feed growing markets. Apart from renovation

of old coconut plantations, research efforts through public support should be directed toward improving low performing coconut varieties as well as sustaining the success of biological control of coconut mite. (iii) Strengthening farmers' organizations/platforms to enable them to undertake collective action for efficient marketing of their products, improved bargaining power for better prices with their buyers, and better coordination in obtaining available services and resources from the government, NGOs and the private sectors may also contribute to improving the sub-sector.

DECLARATIONS

I, JOFREY MASAHI OLEKE, do hereby declare to Senate of Sokoine University of Agriculture that the work presented here is my original work and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This work is dedicated to my parents Mr. Christopher Oleke and Marr Yusuph who laid the foundation of my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

€	Euro
ΔTS	Change in Total Surplus
APCC	Asian and Pacific Coconut Community
ASDP	Agricultural Sector Development Strategy
B/C	Benefit cost ratio
Bt	*Bacillus thuringiensis*
CFA	Central African Frank
COGENT	Coconut Genetic Resources Network
CRD	Cameroon Red Dwarf
CRI	Coconut Research Institute
CS	Consumer Surplus
DALDO	District Agricultural and Livestock Development Officer
DI	Diversification Index
DREAM	Dynamic Research Evaluation for Management
EAT	East African Tall
ESRF	Economic and Social Research Foundation
EV	Equivalent Variation
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistics
FRG	Federal Republic of Germany
GCC	Global Commodity Chain
GDP	Gross Domestic Product
GMO	Genetically Modified Organisms

GNP	Gross National Products
GTZ	*Gesselchaft fur Techniche Zusamenarbeit*
IDA	International Development Association
IDS	Institute of Development Studies
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
INRAB	*Institut National des Recherches Agricoles du Benin*
IPM	Integrated Pest Management Programme
IRR	Internal Rate of Return
LD	Lethal Disease
MAFC	Ministry of Agriculture, Food and Cooperatives
MARI	Mikocheni Agricultural Research Institute
METL	Mohammed Enterprises Tanzania Ltd
MT	Metric
MVR	Multiple Virus Resistant
MYD	Malayan Yellow Dwarf
NBS	National Bureau of Statistics
NCDP	National Coconut Development Programme
NPV	Net Present Value
PRD	Pemba Red Dwarf
PRSV	Philipines Ring Spot Resistant
PS	Producer Surplus
RIT	Rennell Island Tall
SDR	Drought Resistant Rice

SLT	Sri Lanka Tall
SMEs	Small and Medium Enterprises
SNAL	Sokoine National Agricultural Library
SPSS	Statistical Package for Social Sciences
TAG	Tagnanan Tall
TSH	Tanzanian Shillings
UFIFA	University of Florida Institute of Food and Agriculture
USD	The United state Dollar
VCO	Virgin Coconut Oil
VIF	Variance Inflation Factor
VTT	Vanuatu Tall
WAT	West African Tall
WOTRO	*Wetenschappelijk Onderzoek van de Tropen en Ontwikkelingslanden*

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The coconut palm, one of the ten most important plants on the planet Earth, is a perennial oleaginous plant, cultivated in all the tropical coastal regions (Duke, 1983). It provides one of the world's most useful agricultural products, the coconut from which we mainly obtain oil and copra. However, every part of the coconut palm can be used in a variety of ways. The coconut's great versatility in providing earnings gives it the titles; "king of plants" and "jewel of the tropics" (Woodroof, 1970). Over 500 million coconut palms are cultivated around the globe being one of the most important crops of the tropics (Child, 1974). It is estimated that in tropical regions, particularly in India and in the Pacific, coconuts are the main or only source of fats and protein in the diet of more than 400 million people – approximately 7% of the world's population (FAOSTAT, 2008)

Among its most important uses the coconut is a food source, which provides supplements for body fluids and minerals. It acts as an antihelminthic as well as a source of oil for food, cosmetics and pharmaceuticals industries. The oilcake remaining after oil is pressed from copra is used as animal feed (Woodroof, 1970). The coconut shell is used directly as fuel, filler and extender in the synthesis of plastic and in making household articles. In more recent times, coconut palm wood has been successfully utilized to make furniture in a number of coconut growing countries such as the Philippines, India, Indonesia, Sri Lanka, Fiji, the Tonga Islands and many others (Arancon, 1996). In Africa and Tanzania in particular, poles and leaves are used as building materials in many rural areas and to making furniture for high end markets.

The coconut plant is grown in 92 countries that spread along the tropical belt of the world (FAOSTAT, 2008). The production centres can be divided into four geographical areas: (i) Southern Asia: covering the Philippines, Indonesia (Java), India, Srï Lanka and Malaya, (ii) Central and South America: covering Mexico, Brazil, Florida, Jamaica, Honduras and Cuba (iii) Oceania: Fiji Islands, New Guinea, New Caledonia, Salomon Islands, Samoa, and (iv) Africa: covering Mozambique, Tanzania, Ghana, Kenya, Benin and Madagascar. Asia and Oceania generate five sixth (5/6) of the total world production of coconuts and have the highest yield. The American continent on the other hand generates one sixth (1/6) of the world coconut with moderate yield, while in Africa the yield and production are limited and contributes to about one sixth of the world coconut (Eynard and Eynard, 1983).

Worldwide, the total area under coconut during 2008 was estimated at 11 million hectares producing 55 million in 2008. Asia remains the largest producing region at 46 million, or 85% of global production based on data for 2008 (FAOSTAT, 2008). Indonesia and the Philippines were the world's two largest producers, with an estimated production of 16.3 million tons and 14.4 million respectively representing 30% of the global total supply (FAOSTAT, 2008). In the western hemisphere, South America is an important producing region contributing 6% of the production. Africa contributes 4.1% to the global total. The main producing countries include;

Mozambique, Tanzania, Ghana, Kenya, Benin and Madagascar (FAOSTAT, 2008). The FAOSTAT (2008) ranked Tanzania the eleventh producer of coconut globally, with estimated production at 370 000 of nuts per year while Benin is relatively a small producer with production estimated at 22 000 per annum. In both Tanzania and Benin, coconut is mostly cultivated in the coastal areas, and there are also some coconuts around large lakes in Tanzania, but to only a limited extent.

In the Republic of Benin, coconut is the third important crop among main cash crops along with cotton, oil palm and groundnut providing more than 45% of the cash to farmers who depend on it. Coconut plantations in Benin cover around 15 000 ha, which represents about 8.5 % of the total land area, mostly located within 25 km of the Atlantic sea coast. Some of the plantations are 50 to 70 years old. Most of the plantations comprise of the West African Tall (WAT) variety, which is also expanding at about 100 ha per year. There has also been substantial expansion of hybrid varieties during recent years due to promoting planting of the PB 121 hybrid whose area has been increasing over recent years (Adje, 2000), especially during the last 12 years. Dwarf varieties are also increasingly found near dwellings or in public places for decoration (Sanoussi, 2007).

In Tanzania, coconut is also an important crop along the coastal belt, supporting livelihoods of more than 200 000 households (NBS, 2010). The coconut is important as the main source of income for farmers in the coastal belt of Tanzania where 8% of the country's population live. It is also a source of cooking oil substituting for other types of cooking oil, especially in rural areas where there are ongoing, but unsuccessful thus far (Pimentel, 2000). Hence the search for technically effective and economically viable solutions is continuing. Biological control is one of such solutions under consideration. Its efficacy is assessed in this study.

1.2 Problem Statement and Justification

The coconut mite (*Aceria guerreronis*) has been reported to cause great losses to farmers and to the coconut industry as a whole worldwide. The mite kills coconut seedlings by feeding on growing tips (Aquino and Arruda, 1967) leading to; decreasing yield of coconut and loss of income, food insecurity and poverty for farmers and other participants in the coconut value chain. A survey carried out by the Coconut Research Institute (CRI) in Sri Lanka during 2001, where harvested nuts were monitored for one year, placing them into two groups; 'mite free' (undamaged) and 'mite infested' (damaged) nuts revealed that the proportion of mite-infested nuts was 94.4% in Anuradhapura, 94.5%, in Pollonnaruwa, 90.5%, 81.1% in Rajangane Puttalam and 69.8% Kurunegala with a mean of 77.9 (Peiris *et al.*, 1995). Estimated losses in copra yields resulting from coconut mite damage have ranged from 10% to 40% in Benin (Mariau and Julia 1970). Losses due to extensive premature dropping of fruits have been reported ranging from 60% in Colombia (Zuluaga and Sa′ nchez, 1971) to 70% in Venezuela (Doreste, 1968), and 10–100% (average 21%) in Tanzania (Seguni, 2002). Peiris (1995) estimated loss of income for coconut growers in Sri Lanka caused by rejected nuts and small sized nuts to be 7% and 43% respectively. In Tanzania, losses of farmers' income due to coconut mite infestation is estimated to be about 30-50% (Seguni, 2008).

A wide range of chemicals have been employed to control the mite over the past two decades but the results have not been satisfactory. Good plant husbandry has also been recommended to alleviate the damage of mites on coconut production but to no avail. The coconut mite has proved to be difficult to control. In the meantime, research has been directed toward identifying resistant coconut varieties and effective biological control agents (Pimentel, 2000).

Strategies to control the coconut mite involving biological control and quarantine methods require knowledge of the ancestral localities and plant hosts of the mite. In Brazil, Benin and Tanzania a study was conducted to assess coconut mite abundance and damage to coconut plants relative to the predator fauna (in Lawson *et al.*, 2007). The study established that in all the localities, coconut mite infestation was heavy, implying that the effects of these pests on production and income is probably high. Similar work had been conducted independently in Sri Lanka, showing that coconut mites were abundant, causing great losses to farmers (Fernando *et al.,* 2003). Evaluation of the data collected to date indicates that coconut mite abundance and damage to coconut plants and nuts are far less in Brazil than in Benin, Tanzania and Sri Lanka, even though the predator fauna associated with coconut mite in Brazil is richer than what is found elsewhere. Research has established that the fauna in coconut growing areas of Brazil harbor pests that feed on the coconut mite, hence serving as natural predators.

This discovery from Brazil was used in the current study to explore more effective biological control methods based on mite predators inhabiting coconut fauna and their possible application outside Brazil. Research has shown that the predators (*Neoseiulus baraki, N. paspalivorus* and *Proctolaelaps bickleyi)* are biologically more efficient in reducing coconut mite populations as shown from areas in Brazil, where they occur naturally (WOTRO[1] Coconut final, 2007). The current research programme, of which this study is a part, undertook experimental releases in Benin and Tanzania of one known and newly identified natural enemy of the coconut mite from Brazil. The programme is also expected to contribute to our fundamental understanding of factors that affect the success of biological control for one of the most challenging pests. This in turn is expected to improve livelihoods of people who depend on coconuts from increased production and marketing services.

This study is part of a larger programme whose goal is to enhance coconut productivity and profitability in affected countries of Africa by developing a sustainable biological control programme for coconut mites. The biological control of coconut mite is being implemented in Benin and Tanzania. These countries have been selected due to the economic importance of the crop for the livelihood of farmer and other market chain actors. Benin is not only one of the west African countries that is most affected by coconut mite but it also exports[2] her coconut to other countries. While Tanzania is the largest producer of coconut in sub-Saharan Africa, production of coconut has decreased over the past twenty years due to

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[1] Wetenschappelijk Onderzoek van de Tropen en Ontwikkelingslanden (Netherlands Organisation for Scientific Research)

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attacks by pests and deseases. Furthermore coconut marketing in Tanzannia is not linked to external market.

With increased emphasis on the economic aspects of scientific research, the benefits of economic analysis as means for evaluating outcomes of some aspects of research programme has become apparent (Coulibally *et al.,* 2004). Economic evaluation using an *ex-ante* analysis serves this purpose. Uncertainly, regarding the actual outcome can be accommodated, and the results of the analysis can provide guidance on the magnitude of a potential economic gain or losses of a research programme.

This study quantified the distribution of benefits from biological control of coconut mites among coconut value chain actors. The consumer surplus approach is often used to provide general feedback on the level of expected benefits of research on people's welfare but, it does not disaggregate the relative share acruing each actor along the chain. Hence, the consumer surplus approach treats both farmers and traders as producers (Neuenschwander, 1994). In order to bridge this gap, the marketing chain approach was used to determine the distribution at benefits for each node along the coconut chain, representing different actors.

Thorough analysis of the market chain and developing strategies to increase competitiveness is not only a matter of maximizing profit; it should also take into account a fair distribution of gain along the market chain. As such the method seeks to identify interventions that generate a more equitable distribution of the benefits. This aspect is crucial if the design of strategies is to achieve a major goal in poverty reduction through the provision of benefits for producers, i.e. those with least resources. Furthermore, marketing chain analysis was conducted to identify points of inefficiency along the chain for actors that need intervention to foster development of the coconut sub-sector. In addition assessment was made of key policy issues to be addressed in developing a vibrant coconut value chain in Benin and Tanzania, including institution for facilitating such value chain development.

Many studies have indicated the economic benefits of investing in biological control. Norgaard (1988) and Zeddies *et al.* (2000) demonstrated the high level of returns from biological control of cassava mealy bug in Africa while Coulibally *et al.* (2004) applied an economic surplus model to assess the economic benefits of the classical control of cassava green mite in West Africa. For country specific studies, De Groote *et al.* (2003) calculated the economic impact of biological control of water hyacinth in Southern Benin while Bokonon-Ganta *et al.* (2001) surveyed mango producers to assess the economic impact of biological control of the mango mealy bug in Benin. Biological control programmes have been recognized as the most cost effective, permanent and environmentally friendly control method (Julien *et al.,* 1999). The study by Alene *et al.* (2006) provides a good summary of past economic studies on biological control of major pests in sub-Saharan Africa.

Since the widely publicized success of the Africa-wide biological control of the cassava mealy bug (Neuenschwander, 1994), successful classical biological control projects have been undertaken in collaboration with partners of the National Agricultural Research Systems (IITA and NARS) against the mango mealy bug, the cassava green mite, and the water hyacinth. The economic impacts of the resulting biological control of coconut mite in Benin and Tanzania are scrutinized using an *ex ante* analytical framework. While many studies have been done to address the economic impact of biological control, none of them has addressed the problem of coconut mite in Benin and Tanzania, a gap that this study addressed. Worldwide, the application of economic surplus models concentrates on the general welfare change due to technological or policy change. There is a knowledge gap regarding the distribution of benefits among marketing chain actors. Apart from informing on the likely benefits of biological control of coconut mite, results of this study also provided suggestions for improving efficiency along the coconut marketing chain in order to develop a vibrant coconut sub-sector in Benin and Tanzania with possible adaptation in other countries as well.

1.3 General Objective

The overall objective of this study was to estimate the size and distribution of the economic surplus likely to be generated from the biological control of coconut mite and the distribution of profits among actors along the coconut marketing chain in selected countries coconut growing countries in Benin and Tanzania.

1.4 Specific Objectives

The study's specific objectives are;

(i) To estimate the total economic surplus expected from introducing biological control of coconut mite and the distribution of such benefits amongst producers and consumers in Benin and Tanzania, and determine if the intervention (biological control) is economically viable.

(ii) To conduct a sensitivity analysis on the value of benefits arising from biological control, given changes in key variables including; the discount rate and the probability of success of the technology after it is introduced in the study area

(iii) To describe the coconut marketing chain and identify key actors, service providers, facilitating organizations and the policy environment for the purpose of identifying opportunities and constraints and discern appropriate interventions to address prevailing problems, in order to facilitate transformation from a market chain to a vibrant value with coordinated actions among the actors and with service providers and well aligned with policy.

(iv) To estimate the distribution of benefits within the coconut marketing chain in Benin and Tanzania to serve as indicators of efficiency of marketing systems in these countries.

1.5 Research Hypotheses

On the basis of specific objectives one and two, two hypotheses were tested as follows;

(i) The first null hypothesis states that; there is a net increase in economic surplus resulting from the introduction of biological control of coconut mite while its alternative hypothesis states: There is no net increase in economic surplus resulting from the introduction of biological control of coconut mite. Using mathematical notation these can be written as;

$$H_0; \Delta TS > 0 \qquad (1)$$

$$H_1; \Delta TS \leq 0 \qquad (2)$$

Where, ΔTS is the net change in economic surplus after introducing biological control of coconut mite in the study areas.

(ii) The second null hypothesis states that; the Net Present Value (NPV) of the biological control programme is greater than zero over the time horizon considered for simulation. The alternative hypothesis states that; the NPV is less or equal to zero in order to make investment interesting over the time (t) considered. Mathematically these notations are written as;

$$H_0; NPV = \sum_{r=0}^{r} \frac{B_t - C_t}{(1+r)^t} > 0 \qquad (3)$$

$$H_1; NPV = \sum_{r=0}^{r} \frac{B_t - C_t}{(1+r)^t} \leq 0 \qquad (4)$$

Where, B_t is the stream of future benefits over the time horizon (t) and C_t is the cost associated with the biological control programme at different discount rates.

(iii) The third null hypothesis relates to the internal rate of return (IRR), which is the discount rate when a project or development intervention breaks even such that the NPV is zero. In Benin and Tanzania the discount rates normally used to evaluate development projects are in the range of 10 –

biological control of mites in Benin and Tanzania are both greater than 12%. The alternative hypothesis is that the IRR in both countries is less than 12. Mathematically;

$$H_0; IRR > 12 \qquad (5)$$

$$H_1; IRR < 12 \qquad (6)$$

(iv) The forth null hypothesis states that; the percentage distribution of gross margin (GM) is equal for all along actors coconut marketing chain. The alternative hypothesis states that the percentage distribution of gross benefit is not equal along the coconut marketing chain. The mathematical notation;

$$H_0 : \%GM_1 = \%GM_2 = ...\%GM_n \qquad (7)$$
$$H_1 : \%GM_1 \neq \%GM_2 \neq ....\%GM_n \qquad (8)$$

1.6 Research Questions

Specific objective three was addressed by the following research questions;

(i) Who are the main actors, service providers along the coconut market chains in Benin and Tanzania?

(ii) What are the constraints and opportunities for each group of actors and service providers along the market chain?

(iii) What are the key policies along the coconut market chains in Benin and Tanzania.

1.7 Organization of the Study

Two aspects were analyzed in this study. First the study sought to estimate the likely economic benefit expected to accrue to farmers and others in the market chain after introducing predators for the biological control of coconut mite. Second, the study undertook coconut market chain analysis to assess the current situation of coconut production and marketing in order to establish who would benefit from the technology. This component of the study also identified constraints, that need to be addressed and existing opportunities for improving coconut value chain in Benin and Tanzania. The literature on different aspects of coconut production is outlined in chapter two. It covers a review of the existing coconut production and marketing systems as well as research on pests and diseases in Benin and Tanzania. The chapter also presents discussions on analytical aspects including the rationale for analytical tools which are used in this study.

The third chapter discusses the theoretical frameworks presented along with different analytical tools to accommodate each specific objective of the study. Chapter four presents results from the survey and simulation analysis of the consumer surplus model. The final section summarizes the findings. Then, in chapter five conclusions are made based on the findings followed by recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Coconut in Benin and Tanzania

In the coastal areas of Benin and Tanzania, coconut is a major crop that supports the livelihoods of many communities, providing food and cash income. In Benin the coconut sub-sector provides lucrative activities for men and women in the coastal zone where coconut is grown, contributing about 36% of the total cash income in the household (Oleke *et al.*, 2010). Often, farmers produce and sell the nuts to enterprising women for 15 francs (US$ 0.03) per nut on average, who in turn process the nuts to make oil, sweets, and appetizers for sale. For well-organized plantations, Sonnousi (2007) estimated that coconut production can bring in net income of 150 000 - 180 000 francs (US$ 300 - US$ 360) per hectare per year. Coconut is cultivated on more than 15 000 ha in Benin representing about 8% of the total land area cultivated.

In Tanzania, coconuts are produced in Dar es Salaam, Coast, Tanga, Lindi, Mtwara, Zanzibar, Pemba, Mafia and inland region of Morogoro and on the shores of large lakes (Lake Nyasa, Tanganyika and Victoria). A survey conducted by the National Bureau of Statistics (NBS) in 2010 registered 116,184 coconut holdings (NBS, 2010). About 95 % of the coconuts are grown by small-scale farmers, the rest are under medium and large-scale plantations (Kullaya, 1999). The population of coconut palms in Tanzania was estimated at about 25 million covering more than 310 000 ha of land during 2004 (NBS, 2004).

According to Oleke *et al.* (2010) the crop contributes about 50% of the household cash income in coastal areas of Tanzania. In Zanzibar (Tanzania), coconut production was for a long time (since the 1980s) the second most important economic activity after cloves, in terms of foreign exchange earnings (Kullaya, *et al.*, 2002). In Tanzania it is estimated that about 40% of the coconut production is marketed as fresh coconuts while 20% is processed into copra and coconut oil (Kullaya, *et al.,* 2002) and the rest is consumed at the household levels. Fresh coconuts are mainly used as coconut milk *("tui")* that is used for cooking (Magitta, 1989). Copra is processed into coconut oil which is used for household cooking and industrial purposes – notably for making soap (Magitta, 1989).

2.2 World Coconut Distribution

Coconut trees are grown in tropical countries mainly for their high oil content of the endosperm (copra), which is widely used in food and non-food industries. Large coconut production areas are found along coastal regions in the wet tropical areas of Asia (in the Philippines, Indonesia, India, Sri Lanka, and Malaysia), Central and South America and Africa (Tanzania, Kenya, Mozambique, Ghana, Nigeria and Benin). In these countries millions of people make a living from the coconut palm and its many products (van Dam *et al.,* 2003).

There are many different types of palms. The coconut palm, (*Cocos nucifera)*, is the only type of palm tree that produces coconuts. Within this species, however, there are different varieties of coconuts that are classified as tall or dwarf types. The tall varieties are most common. Tall and short varieties can cross-pollinate, which means they share genetic material, leading to much variation in the fruits characteristics. Different types of the tall and dwarf coconuts varieties are often named according to where they are grown, for example; the West African Tall (West Africa), East African Tall (East Africa), and West Cost Variety (Indian and Sri Lanka). Other tall varieties are named based on different criteria. For example, the Laccadive Ordinary and Laccadive Small are mainly found in India, Sri Lanka and Indonesia (Ikisan, 2009).

Dwarf coconuts are mostly self-pollinated, which means there are fewer variety types. As the name indicates, they are shorter than the tall variety, which makes them more popular for growing in home gardens and parks. Dwarf coconut trees produce more fruit than tall trees, but the coconut are generally smaller in size. Like the tall varieties, dwarf species are usually named by their country of origin and the colour of the young fruit, which is often included as part of the name. Some of varieties include; the Cameroon Red (Cameroon), Malayan Yellow, Nias Green (Malaysia), and the Pemba Red Dwarf or simply Pemba Dwarf which occurs everywhere along the East African coast (Tanzania and Kenya). The Pemba dwarf is also reported to be spreading to other countries such Mozambique, Madagascar and the Philippines (Kullaya, *et al.*, 2002).

2.3 Historical Background of the Coconut Industry in Benin and Tanzania

Coconut products have been Benin's principal export crop since the 1960s, when production was high. Benin exported about 500MT of coconut oil annually until 1990s. Thereafter, production of most cash crops, including coconut fell (between the 1970s and 1980s) because of drought and state mismanagement (Sanoussi, 2005). By the 19990s coconut oil exports had dropped to only about 100MT annually. Since then, there has been some improvement but to date Benin's export of coconut oil has only reached about 150 MT per year.

Adje (2000) reported that recognizing the importance of the crop for the livelihood of people who depend on this crop, the government of Benin has initiated a programme for renovation and expansion of old plantations under which about 10 000 hectares of coconut plantations have been revived since the 1990s. These efforts to replanting coconuts have increased the number of small and large coconut holdings from 755 farms in 1996 to 1 343 farms in the year 2000 as shown in Table 1. Despite this expansion, annual coconut production was still decreasing due to drought, diseases and pest attacks (Table 2). Total production of coconuts declined from 423 000 in 2004 to only 200 000 per annum in 2009 representing a 22% decline during a five year interval, or 4.4% decline per annum.

Table 1: Coconut plantations in Benin

Category	1996			2000		
	Plantation size	Farms		Plantations size	Farms	
Area (Ha)	Average (Ha)	No of farms	% (%)	Area (Ha)	No of farms (Ha)	% (%)
0.5-5	2.8 ha	453	60	2.8 ha	875	65.1
6-9	6.4 ha	293	38.81	6.4 ha	452	33.65
10-100	4.5 ha	9	1.19	45 ha	12	0.89
100-500	-	-	-	250	2	0.15
>500	-	-	-	540	2	0.15
Total	2.56	755	100	-	1343	100

Source: Adje, 2000

Table 2: Area harvested and yield of coconut in Tanzania and Benin

Year	Tanzania[t] Area harvested (Ha)	Yield (Hg/Ha	Yield (Tons)	Benin[b] Area harvested	Yield (Hg/Ha	Production (Tons)
2004	322420	10932	423000	12013	16666	32000
2005	231080	11935	460000	13210	18795	27100
2006	230921	20933	360000	12000	17912	20000
2007	220000	11834	40000	12050	16804	20250
2008	231760	11736	380000	12900	17567	25000
2009	226531	12133	200000	12700	15944	23255

[t] Data from Ministry of Agriculture, Food and Cooperatives, Tanzania,
[b] Data from Semi Podji, Benin, * Own calculation as annual data on prices received by farmers (called Producer prices)

In Tanzania, the decreasing trend of coconut production can be traced back to the colonial and post independent period when many coconut plantations were owned by European and Indian settler. At that time, Tanganyika was exporting coconut products to different countries. For example, Tanzania (including Zanzibar) exported coconut oil up to 1976. After the Arusha Declaration which was announced in 1967 most private capital in Tanzania, both indigenous and foreign, was nationalized in accordance with the principle of *Ujamaa* (Kullaya, 1991). Larger estates that were previously owned and managed by European and Indian settlers were taken by the government leading to low productivity due to poor management (Kullaya, 1991) the management of the nationalised coconut plantations and estates were also minimal except in Mafia where large coconut farms were left in private hands. Meanwhile, Tanzania experienced increasing consumption of fresh nuts due to a rising urban population. This trend occurred when overall production, was declining progressively. Thus, only smaller quantities of copra became available for sale to local mills or for export. As a result, since 1977, Tanzania became a net importer of copra and coconut oil (Kullaya, 1991). Currently coconut production in Tanzania is characterized by low productivity due to low genetic potential of the plants as well as pre and post harvest losses due to pests and diseases as discussed in the next section.

2.4 Pests and Diseases

The coconut, like many plants is subject to attack by various pests and diseases. Often, plants develop some defence mechanisms to local diseases and pests (Peiris, 2006). Coconut mite (*Aceria guerreronis* Keifer), Coreid bug (*Pseudotheraptus wayi*), the rhinoceros beetle and Coleoptera Scarabaeidae (*Oryctes monoceros*) have been identified as the most common coconut pests of economic importance affecting coconut production. In addition to these pests, the lethal disease (LD) is also a serious problem facing coconut farmers worldwide. It is caused by phytoplasma (a fungus), that kills millions of coconuts in Africa, along the coast of the Atlantic and Indian oceans, where Benin and Tanzania are located respectively. Symptoms for the disease include premature falling of nut, typical blackening of the inflorescences, progressive bronzing younger leaves, necrosis and rot of the spear leaves and decay of the root system, in that order (Mwinjaka *et al.*, 1999).

The coconut mite, which is the focus of this study, is distributed in many tropical countries where coconuts plants grow. In Sri Lanka Peiris *et al.* (1995) estimated the loss of copra due to coconut mite to be 77.9 % of the total production, while losses of income for coconut growers because of rejected nuts and small sized nuts were estimated to be 7% and 43% of the expected value of sales respectively. Moreover, estimated to be 7% and 43% of the expected value of sales respectively. Moreover, losses of potential coconut output due to extensive premature dropping of fruits have been reported ranging from 60% in Colombia (Zuluaga and Sa′ nchez, 1971), to 70% in Venezuela (Doreste, 1968), and 10% to 40% in Benin (Julia and Mariau, 1977). In Tanzania Seguni (2002) estimated the loss of copra due to coconut mite to range from 10–100% (average 21%) depending of the area, while losses of farmers' income due to coconut mite estimated to be about 30-50% (Seguni, 2008)[3]. The coconut mite was observed in all coconut growing regions of Tanzania, during extensive surveys in Tanzania in 1992 and 1996 (Varela, 1992; Meena, 1996). Most of the coconut varieties were affected, but there were site differences in the severity of infestation. The southern regions of Mtwara and Lindi had been more seriously affected compared to Costal and Tanga regions. Considering the magnitude of damage and loss due to the coconut mite, research systems within coconut growing countries such India, Sri Lanka and Brazil have been scrambling to search for solutions (Meena, 1996).

Table 3: Coconut mite attack in several coconut growing regions in Tanzania

Region	Number of palms	Number of nuts	Overall damage (%)
Pwani	188	10206	54.1
Lindi	255	21366	59.7
Mafia	208	13518	48.7
Mtwara	315	26458	48.7
Tanga	195	11404	65.7
Zanzibar	300	16505	54.3
Total/average	**1461**	**99457**	**55.2**

Source: Seguni, 2008

[3] Crop loss assessments were done by correlating different external damage symptoms on mature coconuts, based on damage scores 1-5. Thus, 0 = no visible scarring on the nut surface; 1 = slight scarring, only 1-5% of surface scarred; 2 = moderate scarring, 5-25% of surface; 3 = medium severe scarring, 25-50%; 4 = severe scarring, 50-75%; 5 = very severe scarring, 75-100% of surface scarred. The categories 4 and 5 relate to a significant 30-50% yield loss (Varela, 1992).

Table 4: Effect of mite damage on yield of harvested nuts of the hybrid PB121 in Tanzania

Damage category	Number of nuts	Fresh weight (g)	Dry weight (g)	Yield loss (% loss in copra)
0	51	299.2	30.0	-
1	73	272.6	30.0	8.9
2	147	237.5	29.9	20.6
3	194	216.5	29.3	27.6
4	175	150.4	29.6	49.7
5	74	115.9	27.3	61.3

Source, Seguni, 2008

2.4.1 Spread of coconut mite

The history of the Coconut mite is controversial. There are debates on whether the pest is native to the Eastern or Western Hemisphere (UFIFAS, 2009). While this debate may have a historical significance, but what is important now is the fact that the pest has spread to all continents and it is particularly devastating in Asia and Africa. Research has established that coconut mite spreads via different means.

By wind, this mite is spread through long distances moving from one palm tree to other, from one garden to another, and this happens quickly. Mites also spread as affected mature or immature nuts are transported from one place to another. After being introduced into a new area most coconut mite species get stronger and quickly multiply more than the native species such that the introduced species become the enemies of native species. Bio-invasion involving exotic pests is an undesirable element of agriculture globalization since pests such as mites have managed to spread across countries and continents through this means. Increasing trade, tourism, transport and travel over the past century has dramatically enhanced the spread of organisms (Fernando *et al.*, 2003). As a result, biological invasions by non-indigenous species constitute a leading threat to natural ecosystems and biodiversity

(Pimentel, 2000). The coconut mite (*Aceria guerreronis* Keifer) is one of the exotic pests, which has spread through this mode and is currently posing a threat to many farmers whose livelihoods depend on the coconut sub-sector not only in Benin and Tanzania but around the world where coconut production is an important source of livelihood. Efforts to combat this pest have therefore assumed a global approach, involving studies that cut across national borders.

Recent research has shown that Brazil is likely to be original home of the most coconut mite species where it has the greatest diversity (Navia and Fletchman, 2005). The coconut mite was first observed as a pest of economic significance during the 1960s in the state of Guerrero, Mexico. The pest was later identified in Central America and the Caribbean, as well as in Brazil and several other countries in South America (Julia and Mariau, 1977; Moore *et al.,* 2000). In Africa, it has been recorded since 1967, first in Benin and later in other West African countries (Moore *et al.,* 2000). The mite was first recorded in Tanzania – the largest producer of coconut in Africa -during the 1980s (Seguni, 2002). Navia and Fletchman (2005) showed that West Africa was the likely source of the coconut mite population which infested Tanzania.

The coconut mite has recently reached the Indian sub-continent, appearing first in Sri Lanka in 1997 (Fernando *et al.,* 2003), and later in India during 1998 (Nair, 2000). Molecular analyses have shown that the Sri Lankan and Indian population of coconut mite probably originated from Africa (Navia and Fletchman, 2005).

Taken together, the invasion routes of coconut mites seem to be from South America through Central America, the Caribbean, and through Africa into Asia. The pest is likely to continue spreading eastward to countries in South and East Asia, the Pacific Islands and Oceania, where nearly 80% of world coconut is produced. This would lead to severe economic consequences, as production losses from mite damage can reach 60% (Nair and Koshy, 2000). For example recent invasion of the coconut mite into Sri Lanka has exacerbated existing problems of declining soil fertility and lack of new land for coconut plantations. All this has led to severe decline in factory output up 50% of the factories previously engaged in the coconut industry have shut-down (Peiris, 2006). In an effort to revive the coconut sub-sector, the Sri Lankan government has recently re-established the Ministry of the Coconut Industry, to address problems of declining coconut production among others facing the industry.

2.4.2 Control methods of coconut mite

Several methods of controlling coconut mite have been tested in many parts of the world (Moore, 1986). In most areas, chemical control has proved ineffective because the coconut mite feeds on protected areas of the nut (under the perianth covering the meristematic area of the nut). While differences have been found in cultivar response to coconut mite attacks, it has been difficult to incorporate such cultivars into a breeding programme because aerial application and chemical pesticides which have been recommended to reduce the magnitude of the problem, have had limited impact and therefore proved to be an ineffective solution. The mite solution to mite menace is yet to be developed.

Control strategies for coconut mites in India and Sri Lanka have recently been based on using systemic insecticides such as monocrotophos, dicrotophos and methamidophos. Use of insecticides, however, is not viewed as the best method for sustainable control of mites especially in Benin and Tanzania where coconut is a smallholder crop. Another alternative has involved Bio-pesticides (*Hirsutella thompsonii)* which have been used in India and Sri Lanka, but they have not been successful as well. Moreover, widespread adoption of chemical based control technologies has been seriously hampered by related high cost, difficulties in handling, and in accessing by rural populations. Neem seed oil based preparations have also been used in India and Sri Lanka showing little impact (Moore *et al*., 2000). Meanwhile (Fernando *et al*., 2003) reported the use of entomopathogenic fungi notably *Hirsutella species*, but the success of this fungus in controlling mites is dependent on moist field conditions, hence of limited use during the dry spells or in drier parts where coconut are grown.

As the search for solutions continues, phytosanitary measures in coconut gardens have been adopted as traditional way of controlling mites in India and Sri Lanka. The practice includes; cleaning the crown of the palm, keeping the plantation clean and burning all immature nuts fallen due to mite infestation, spraying biopesticides on the bunches and following palm health care practices. However, these methods were not efficient in controlling coconut mites in these areas (http://coconutboard.nic.in/protect1.htm). Intercropping with the multipurpose leguminous tree, (*Gliricidia sepium)* and mixed cropping have been recommended by the Coconut Research Institute (CRI) in Sri Lanka to control the mites and is widely practiced by farmers. However, this option has not provided a lasting solution either. As the search for cost effective and sustainable methods to control the coconut mite continues, using biological control seems to offer a glimpse of hope. In Sri Lanka, within six months after introducing laboratory bred predators (*Neoseiulus Bakari*), there was initial evidence that the coconut mite population was being suppressed and the introduced predators augmented in the locality (Fernando *et al.*, 2009). The suppression of mites was observed over a long period, after the initial introduction. Subsequently, farmers observed increased coconut production due to reduced damage of young nuts and the growing meristem.

In Benin and Tanzania very little is known about different methods of controlling coconut mite that are used by farmers or those recommended from research stations. While the pest appear to cause great yield looses in Benin, efforts to eradicate the mite have not been recorded anywhere. However, in Tanzania, the search for alternative control options continues. For instance, researchers have recommended that farmers should be using resistant coconut varieties of the EAT coconut subpopulation from Tanga region, where mite infestation rates have been observed to be low. This option is providing good results.

The EAT coconut population in East Africa is a collection of different phenotypes with nuts of different sizes, shapes (morphology) and colour. The current strategy of the Pest Control Section in Tanzania is to investigate these characteristics and relate them to incidences of mite damage and crop loss (Seguni, 2008). It is expected that subpopulations or individual palms may be resistant or tolerant to mites to a reasonable degree. These would be useful sources for multiplication and replanting in areas where significant plant population have been lost. For this purpose, the Pest Control Section of the Ministry of Agriculture Cooperatives and Food Security (MAFC) in Tanzania has initiated collaboration with the Asian and Pacific Coconut Community (APCC) to address the problem of low yielding coconut varieties (Seguni, 2008).

2.5 Research on High Yielding Varieties

Considering the importance of coconut for the livelihood of over 11 million people, who live along the coastal strip of tropical countries around the world, much research effort has been directed at addressing the main problems facing the subsector (Burnet, 2011). As most coconut-producing countries lack human and material resources to conduct expensive and time-consuming researches, the globes' research community has recognized that coordinated international support is essential if coconut plantations and holdings are to become more productive and beneficial to resource-poor coconut farmers. The Coconut Genetic Resources Network (COGENT) coordinates research activities of national, regional and global significance in various countries of Africa and the Indian sub-continent including; Benin, Côte d'Ivoire, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Seychelles and Tanzania. The research particularly focuses on germplasm exploration, collection, conservation and enhancement through collaboration on broader aspects of coconut research and development (COGENT, 2010).

In West Africa (Benin, Côte d'Ivoire, Ghana and Nigeria), research effort have similarly focused on addressing problems of low coconut productivity. There have been two dominant research projects in Benin. The first (SP 91-01) focused on breeding trials to establish germination precocity and seedling robustness of the West African Tall (WAT) variety. Several hybrids were developed by crossing; Malayan Yellow Dwarf with West African Tall (MYD x WAT), Malayan Red Dwarf with Rennell Island Tall (MRD x RIT), Malayan Red Dwarf with Vanuatu Tall (MRD x VTT), Cameroon Red Dwarf with Tagnanan Tall (CRD x TAG), Vanuatu Tall with Tagnanan Tall (VTT x TAG), and Sri Lanka Tall with Tagnanan Tall (SLT x TAG). All this was done at a research station in Côte d'Ivoire and subsequently used as common test materials for trials in all the countries[4] under the research programme. Results of the breeding efforts have shown an increased number of plantations as reported by Adje (2000). The second research project (PB 121) focused on improving the coconut production system through regeneration of plantations by intercropping with legumes and introducing mineral nutrition trials.

[4] Countries under the research program for coconut improvement included Benin, Côte d'Ivoire, Ghana, Mozabique, Tanzania and Nigeria

In Tanzania, three local hybrids were developed involving crosses of; East African Tall with Pemba Red Dwarf (EAT x PRD), East African Tall with Rennell Island Tall (EAT x RIT), and East African Tall with Vanuatu Tall (EAT x VTT). There have been independent efforts to introduce coconut hybrids in Tanzania since 1980s under the GTZ funded project. This project however faced many challenges. For instance the hybrids were similarly susceptible to die back from the lethal disease, implying that cross breeding did not provide effective control measures. Meanwhile farmers' preference for the EAT remained high because plants that survive have a longer productive life span of up to 80 years compared to a maximum of 6 years for hybrids (Kullaya, 1999). Hence the adoption rate of the hybrid coconut among farmers remains very low. For these reasons the project was closed in 2000.

In addition to production related problems, smallholder coconut farmers have also faced many challenges related to marketing. In the next section we present issues that relate to coconut marketing in Benin and Tanzania. Restie *et al.* (2006) argues that marketing may provide the incentives to maximizing profit through developing new products, technologies, markets and methods of exploiting them. In the next section the validity of this assertion under the prevailing policy and institutional arrangement, with the view of identifying areas for improvement.

2.6 Coconut Marketing

Globally, the main stakeholders in the coconut industry are coconut growers, coconut traders, oil processors, fibre millers, exporters and importers, and auxiliary service providers including financiers, and government departments and ministries

(Simplicio *et al.*, 2006). In Benin the institutional arrangements among actors involves vertical interaction for some components of the coconut marketing chain. The main actors are identified as being; farmers, local traders, whole sellers and transporters. Joint production is common in the industry, with some coconut growers also owning coconut oil extraction machines. Within each layer of the value chain there are several interconnected smaller value chains consisting of intermediaries (Adje, 2000). Stakeholders with functions and operations close to one another in the value chain interact more intensively.

In Tanzania the coconut market chain is less developed. It consists of farmers, collectors, traders, intermediaries, processors and consumers, the farmers being most dominant. Farmers normally sell de-husked nuts to traders who transport them to consumers and oil processors in the urban markets such as Dar es Salaam and Tanga. There is limited value addition among smallholders (Madulu *et al.*, 2008). Simplicio *et al.* (2006) argue that farmers must add value to their products by going into semi-processing to enhance product diversification. This however is hampered by lack of technology and funds to finance such investments. Meanwhile, the low price paid to farmers has served as a disincentive to improve production and quality. The interactions among actors, service providers and the enabling/disabling environment of the coconut market chain are discussed further in section 2.9.

2.7 Processing Coconut Products

Some of the coconut processed products that are produced and marketed include: (i) oil-based products such as virgin coconut oil (VCO) used for food and cosmetic products, (ii) copra-based products such as candy, pastries, sugar and vinegar, (iii) coir-based products such as rope, geotextile and doormats, (iv) shell-based products such as handcrafts (bowls, bags etc.), and (v) midrib-based products (of the leafs) such as baskets (Simplicio *et al.*, 2006). Restie *et al.* (2006) argue that in order to maximize the use of the whole coconut fruit it is necessary to adopt new processing technologies, which remains an important aspect of growth for the coconut industry. While countries such as Sri Lanka, the Philippines, India, Malaysia and Singapore have made progress in processing coconut into different products, little has been done to promote commercial processing of coconut in Benin, Tanzania and other African countries.

In Benin more than 50% of the coconuts produced are used for fresh or green nut consumption. Coconut is produced from small and medium scale industries (SMEs) are exported to neighbouring countries through informal channels. Benin lacks efficient coconut processing technologies like those used in Asian countries. As in the case of many developing countries, in Benin, coconut processing at the farm level uses traditional tools, which are arduous, time consuming and inefficient. Hence, fresh coconut command a higher price than oil extracted from the same amount of fresh coconut providing little incentives to invest in processing (Adje, 2000).

In Tanzania large scale coconut processing was previously (prior to nationalization in 1967) done by several firms including; coconut oil mills, desiccating plants and oleo-chemical companies all based in the capital – Dar-es-Salaam, Tanga, and other coastal towns. All these processing firms collapsed and are now closed. Currently, village-level processing of coconut products is only limited to extracting crude oil, which is normally done by smallholder coconut farmers, who then sell the oil to individual consumers through local shops. Although this is done by both men and women, making coconut milk and oil for cooking is mainly women's activity.

Research and Extension Services have been developing new innovations that are disseminated widely to encourage farmers to engage in semi-processing coconut for products diversification. To date, there are a few farmers' groups who process virgin coconut oil (VCO) around Bagamoyo (Pwani region) as well as in other regions including; Lindi and Tanga on mainland Tanzania as well as Unguja and Pemba in Zanzibar (Madulu *et al.*, 2008). Following the failure to introduce hybrid coconut varieties in order to improve productivity during the 1980 and 1990s, other productivity enhancing research efforts have continued. Some of these studies have included; Integrated Pest Management (IPM) strategies for combating major coconut pests in Tanzania, which have been implemented over the past 25 years by the Pest Control Section of the National Coconut Development Programme (NCDP) (Seguni *et al.*, 2008). All these efforts however have not yet borne significant positive impacts neither at the farm level nor at the aggregate industry level.

Meanwhile, Asian countries have successfully developed the coconut sub-sectors through research programmes. Thus, research contributes significantly to the economies of coconut producing countries. For example each year India and Sri Lanka export more than US$ 400 million worth of coconut products. Such products including coir and peat products, have been improved through processing to suit the market requirements. However, in Benin and Tanzania there is hardly any export of such products partly because there are no rigorous research and development initiatives to create new coconut products that are accepted by consumers.

Based on the objectives of this study as stated in chapter one, literature on the two analytical tools that are used are presented next. These include; the economic surplus and the market chain approach. The rationale for applying each of these analytical tools is also presented in sections 2.8 and 2.9.

2.8 Economic Surplus Model

Many impact assessment models have been proposed to assess the value of economic benefits before development project or technologies are introduced. Such methods include the Economic surplus approach, cost–benefit analysis, cost-effectiveness analysis and break-even analysis. Among these the economic surplus model has been widely used. This model has the advantage of incorporating several criteria related to economic efficiency and distribution of benefits into one or two measures. However this method can be difficult to apply to a large number of commodities or to a large area because the type of data required for such analysis is very large that are often difficult to collect. Like any *ex-ante* analysis, this model incorporates expert opinions or crude estimates on expected research impacts such as expected yield gain or expected future prices following policy change or upon completion of a development programme. Other factors that are considered include; adoption rates, demand and supply elasticities, and probabilities of success of the comparison. The most important indicator used to compare discounted cost and a benefit is the "internal rate of return" (IRR) or the percentage interest rate at which the present value of the cost is exactly equal to the present value of benefits. Another type of indicator for comparing the value of benefit and cost is the net present value (NPV), which is the amount by which total benefits exceed total cost, when these are discounted or compounded at some specific interest rate. The estimation of all this for the study are discussed in chapter four (4).

In the context of a biological control programme appraisal, the core assumption of using economic surplus analysis is based on the premise that controlling pests (in this case coconut mites) will reduce per unit cost of production due to improved productivity, hence lower average cost per unit of output. This assumes that the release of predators entails no additional cost on the part of the farmer. This assumption will hold if the cost of releasing the predators is fully borne by the research agency and not passed on to the farmer. However if a full economic analysis is done such cost would have to be borne by the beneficiaries; farmers and consumers. The subsequent downward shift of the supply curve will results in a new market equilibrium in which commodity prices are lower and quantities supplied at any price are higher. Thus, the consumer surplus unambiguously increases.

The producer surplus may increase or decrease depending on the type of economy and model specification (Master, 1996). Illustrative figures showing these shifts and relative changes are described in chapter three under the consumer surplus framework. In the context of this study, the role of *ex-ante* economic analysis is to determine the likely benefits from technology introduction.

2.8.1 Type and nature of market modelled

Economic surplus analysis considers the nature of the market for the commodity and the fact that prices may fall as production changes and supply increases (Lacewell and Taylor, 2009). In conducting economic surplus analysis market effects arising from whether the product is widely traded are considered. Economic surplus analysis can be used both as closed and open economy models. Closed models are used for commodities that are produced and consumed within the country. Open economy models are used for commodities linked to international markets (Norton *et al.*, 1993). In Benin where coconuts are exported to neighboring countries, small open economic model are considered. In Tanzania, given that almost all coconut that is produced is consumed domestically, the computation of change in economic surpluses when a new technology is introduced is analyzed using a closed economy model.

In his discussion of this analytical method, Master (1996) laid down three assumptions that must hold for conducting an economic surplus analysis: (i) the competitive demand price for a given unit which measures the value of that unit to the consumer; (ii) the competitive supply price for a given unit measuring the value of that unit to the supplier and (iii) when evaluating the net benefits or cost of a given action (project, programme, or policy), the cost and benefits accruing to each member of the relevant group (i.e. family, city, state, nation, world) should be added. Before performing economic surplus analysis, the analyst (or researcher) should choose an appropriate functional form of the supply and demand functions, the type of supply shift as well as the type of economy being modelled (Norton *et al.*, 1993).

2.8.2 The choice of research induced shifts

When there is a shift in the supply curve that is induced by technological change, there can also be three types of shifts as described by Linder and Jarrett (1978). They include; divergent (pivotal or proportional), parallel and convergent supply shifts (Figure 2). The type of supply shift appropriate for analysing a biological control programme must be determined by the researcher based on their understanding of the production system. The literature provides little guidance regarding the choice of the functional form and the type of shift. However, Lacewell and Taylor (2009) suggests that: "non-parallel shift will typically be the case because producers with low marginal cost (at the lower end of the supply curve) will tend to be those without serious pest problems, while producers with high cost will tend to be those facing serious pest problems who would tend to benefit the most from the new crop protection systems." In this context, it is clear that non-parallel shift refers to a pivotal-divergent shift rather than a convergent shift. Linder and Jarrett (1978) conclude "*ceteris paribus,* biological and chemical innovations are more likely to produce a divergent supply shift."

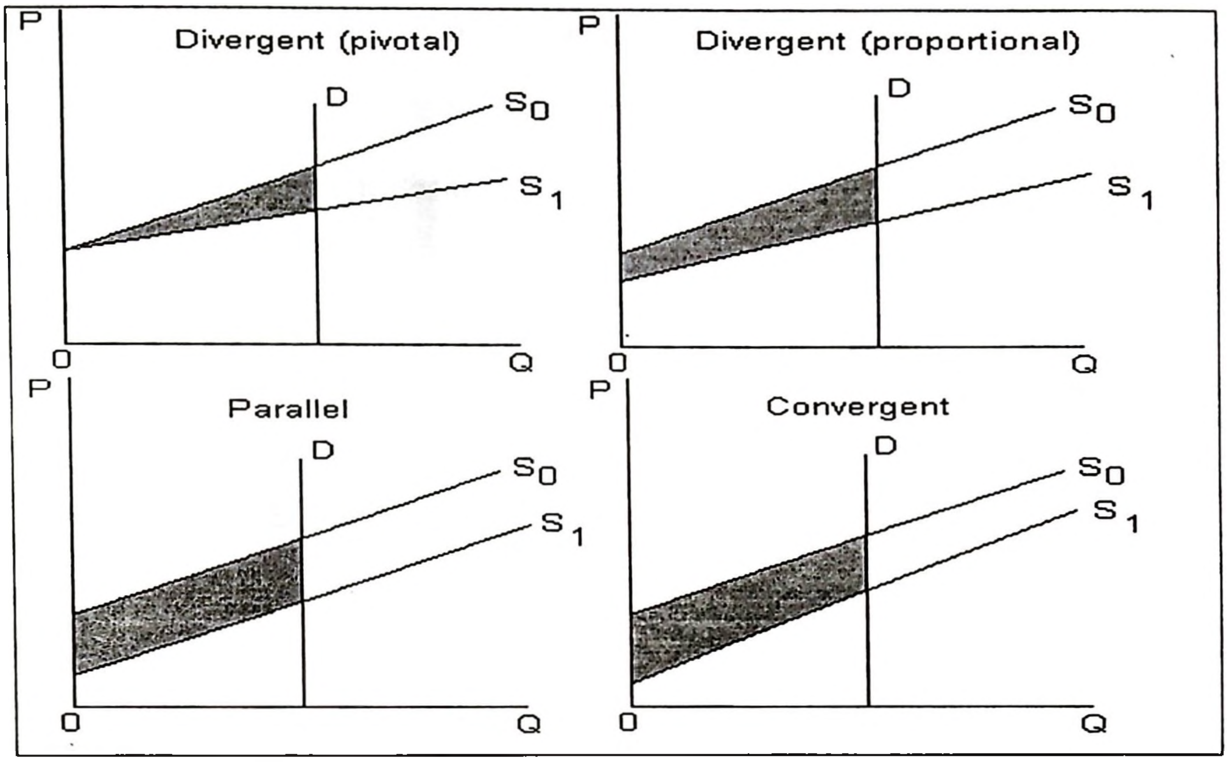

Figure 2: Types of Supply Shift

Source: Alston *et al.* (1995)

It is not immediately apparent that producers might suffer a loss under a pest control programme. Since adoption is not optional, it does not seem likely that there would be any adoption if the result were a loss in producer surplus. With a pivotal shift, however, producers only gain if demand is elastic (i.e. if $\varepsilon \leq 1$ and $\eta = 1$; where ε is the price elasticity of demand and η is the income elasticity of demand). For technologies that cause large reduction in cost, this may indeed be the case. Norton *et al.* (1993) suggests using a vertical parallel shift for simplicity and consistency in evaluating different programmes for different commodities. According to their study, producers always benefit from a parallel supply shift while they only benefit from a pivotal shift when demand is elastic.

2.8.4 Choice of functional form (demand and supply) and supply shift

This study appeals to the intuitive notion that the adoption of a new technology (yield-enhancing) generates a rightward shift of the supply curve. A number of researchers including Voon and Edwards (1992) and Mills (1998) have suggested that when the functional form of the supply and demand curves are unknown; they can be approximated by linear functions, which are also adopted for this study. The demand curve however, is assumed to be invariant to the introduction of the new technology although it could shift over time due to changes in population and income.

Researchers commonly use the linear and the constant elasticity supply and demand curves for estimating research benefits. Others have also suggested using kinked supply curves to avoid the erroneous inference that there could be a positive supply of goods at negative prices for a situation where supply is inelastic and linear (Rose, 1980; Norton *et ;al.*, 1987). Wohlgenant and Alston (1990) argue that when a parallel shift is used, as suggested by Rose (1980), the functional form is largely irrelevant, and that a linear model provides a good approximation of the true (unknown) functional form of supply and demand. Alston *et al.* (1995) further pointed out that there is no practical difference in using a linear supply curve with or without a kink in analyzing research benefits since the economic surplus is the same in both cases. Hence, despite its shortcomings, the linear functional form is used in this study since the assumption of linearity allows the use of simple algebra to calculate the magnitude of consumer and producer surplus as presented by Wohlgenant and Alston (1990).

2.8.5 The impact of technology on producers and consumers

The economic surplus approach is a powerful tool to estimate the potential benefits of an agricultural development programme or technology. In a study of Peruvian agriculture, Norton, *et al.* (1987) employed an ex-ante economic surplus framework to analyze the potential benefits of agricultural research and extension for five commodities (rice, corn, wheat, potatoes, and beans). The authors explicitly evaluated the impact of demand shifts and government pricing policies on the benefits of research and extension to producers and consumers. Results indicated that, for commodities that are traded internationally, producers receive a larger share of the benefits. The distribution of benefits from research and extension was also found to be sensitive to the price elasticity of demand, with higher elasticities favoring producers relative to consumers. Furthermore, while consumer benefits were unaffected by the nature of supply shifts (i.e., parallel or pivotal), producer gains were highly sensitive to the kind of supply shift.

Krishna and Quim (2007) studied the potential impacts of *Bacillus thuringiensis* (*Bt*) eggplant on economic surplus and the health of people in India. Comprehensive farm survey data were used to project farm level effects and future adoption rates. Simulation analysis showed that the aggregate economic surplus gains of Bt hybrids could be around US $108 million per year. Meanwhile Bayer *et al.* (2010) evaluated the economic impact of the regulatory process on four transgenic crops in the Philippines: *Bacillus thuringiensis* (*Bt*) for rice, ring spot virus resistant (PRSV) for papaya, *Bt* eggplant, and multiple virus resistant (MVR) for tomato. With *Bt* eggplant and MVR tomato, the Philippines is modeled as a small-closed economy while in the case of *Bt* rice and PRSV-resistant papaya, the country is considered a small-open economy. The net benefits (total surplus less total cost) are substantial being: $20.5/acre for *Bt* eggplant, $33.5/acres for MVR tomato, $257.2/acre for *Bt* rice, and $240.2/acre for PRSV papaya. Sensitivity analysis revealed that changing the regulatory cost has very minimal effect on the net benefits. However, varying the regulatory time and hence the commercial release date had substantial impacts on the benefits of the technologies (Alpuetro, 2008).

In their study, Islam and Norton (2007) assessed the potential economic impacts of transgenic Salinity and Drought Resistant (SDR) rice in Bangladesh. The ex-ante analysis projected that planting SDR rice over 10 years has economic surplus amounting to US$302.8 million if no international trade is assumed, of which US$184.1 million is producer surplus (PS) and US$119.7 million is Consumer Surplus (CS). The net present value (NPV) of benefits was US$215.7 million and the Internal Rate of Return (IRR) was 33.8%. Meanwhile Hareau *et al.* (2006) conducted an ex-ante evaluation of the economic impact of herbicide resistant transgenic rice in Uruguay, accounting for multinational market power. They came up with a US$1.82 million mean net present value for producers while US$0.55 million would accrue to the multinational firm. They mentioned that the relatively small benefit to multinational firms suggest that unless a firm has established strategic partnerships with local institutions or have access to wider regional markets, it will not undertake significant effort to develop transgenic varieties adapted to Uruguay (Alpuetro, 2008).

As discussed earlier in chapter one, while the economic surplus method is an effective tool for assessing research benefits, it generally ignores transaction cost, which results in overestimation of benefits attributed to individual value chain actors for activities with high transaction cost. To address this gap, market chain analysis is often used to determine the spread of profit margins along market chains in order to identify points of inefficiency which must be addressed so that benefits accruing from the research are distributed equitably to all chain actors. In the next section, we present some concepts that are applied in market chain analysis.

2.9 Market chain: Concept and Issues

Kaplinsky and Morris (2001) compared value chains and market chains by emphasizing the linkages and relationships between and within actors at each stage of production. This has considerable merit in highlighting the constraints and opportunities at and between stages of the chain and can thus be used to develop integrative policy recommendations that target chain inefficiencies while also addressing distributional issues.

Lunndy *et al.* (2004) describe market chain as the numerous links that connect all actors and transactions involved in the movement of agricultural products from the farm to the consumer. It is the path one good follow from their source of original production to the ultimate destination for final use. Functions conducted in a market chain have three things in common; they use up scarce resources, they can be performed better through specialization, and they can be shifted among channel members (FAO, 2005). In a less developed market chain, actors meet to the market and transact without coordination or collaboration. Market chain analysis therefore is detailed involving understanding the actors, activities, cost and opportunities related to the flow of particular product and associated services, starting with farmers and ending with the targeted buyers/ or consumers (Kotler *et al.*, 2002).

A value chain on the hand refers to the full range of activities that are required to bring a product (or a service) from conception, through different phases from production, processing, transportation and storage, up to final stage of consumption and disposal after being use (Kaplinsky and Morris 2001). Further, a value chain exists when all the stakeholders in the chain operate in such a way to maximize the generation of value along the chain (Berg *et al.*, 2006), which implies that coordination and collaboration exists among the actors for a common end. This implies supply chains underlie value-chains because, without them, no producer has the ability to give customers what they want, when and where they want, at the price they want. A value chain therefore represents the entire network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer.

In its broad approach, market chain analysis looks at the complex range of activities implemented by various actors to bring a raw material to the final product at the retail end of the chain (Berg *et al.*, 2006). The market chain defined broadly, starts from the production of raw materials, moving along the linkages (nodes) with other enterprises that are engaged in trading, assembling, processing up to the final consumers. This broad definition does not only look at the activities implemented by a single enterprise. Rather, it includes all the backward and forward linkages, until the level at which the raw material reaches the final consumers either in its raw form (temporal transformation) or in a processed form (chemical or physical transformation). This study used the market chain analysis methods to discern linkages among actors for the coconut industry in Benin and Tanzania because there was neither evidence of coordinated actions among actors along the chain nor indication among common goal they were trying to achieve collectively.

The importance of market chain analysis has been recently recognized as an effective ways to understand the movement of agricultural products from producers to customers. In the past, agricultural development programmes were often government-led focusing mostly on promoting the production of export-oriented, risky, high-value crops with uncertain market opportunities (Bailey and Norina, 2004). Policymakers often gave little attention to learn from the experience of past agricultural development programmes hence, institutional memory tended to be short and mistakes were often repeated. Consequently, scarce public funds have been wasted and agricultural development has been constrained. The economic contribution of crop production also tended to be insufficiently recognized by agricultural and national planners, and is underestimated in national accounts (Bailey and Norina, 2004). Conversely, Baker, (2006) demonstrates that in most countries, the focus has recently shifted to improving the performance and efficiency of agriculture and market chain analysis is one of the tools used to bring sub-sector wide improvement.

The agricultural sector in developing countries consists almost entirely of producers who face significant difficulties in accessing agricultural services. They have few or no opportunities of adding value to their primary products, which is a function of their limited access to credit, product markets as well as limited access to the information they need to make rational choices about technologies to use and what to produce for the market. As discussed earlier for example, in Benin and Tanzania, despite the growing interest in and recognition regarding the importance of value addition for coconut products, processing and marketing remain very limited and predominantly small scales.

Often, marketing activities including processing, transportation and marketing coconut products in Tanzania and Benin have been uncoordinated and informal. Most of the coconut produced is sold in domestic markets as raw produce, which are perishable, bulky, and only seasonally available. Small scale producers therefore face a demand that is limited by timing and relative price instability. This part of the study aims at assessing these inefficiencies through market chain analysis.

In analysing market chain, two approaches are often used, a conventional analytical approach or a participatory approach. In the traditional approach, consultants spend several weeks interviewing key informants and reviewing statistics. Then, they use the information to develop a strategy or programme that identifies the nodes along the chain, the chain actors, service providers, as well as the enabling or disabling environment (Bailey and Norina, 2004). This approach has the advantage that the design is based on good background information and analysis regarding the particular crop or product, and regarding the constraints and opportunities identified during the structured surveys and interviews. Some authors suggest that this approach is particularly appropriate for developing new markets or product (Pietrobelli and Saliola, 2008). However, this approach is seen as too rigid. Participatory marke chain analysis provides an alternative, which is based on five typical action areas that are implemented in sequence by representative stakeholders. These steps are namely; sub-sector selection, market chain mapping, consultations with lead firms and other chain participants, participatory value chain analysis, stakeholder validation and planning workshops (Baker, 2006). In Benin and Tanzania, this approach is used by various firms and NGOs who are involved in value chain development and development project initiatives.

Such studies have identified inequity in power relationships based on the governance of the supply chain and have highlighted potential points of entry (and exclusion) for smallholders (Humphrey and Napier, 2005). Moreover, by going beyond firm or activity-specific analysis, this approach allows for an assessment of the linkages between and amongst productive activities to also include processing and marketing. On the basis of such analysis, improvements can be made at all nodes where inefficiencies are identified.

Analysis of value addition activities has its historical origins in sectoral analysis, such as those introduced by the French filière approach (Raikes *et al.*, 2000). In this approach, the main idea is to highlight and map out specific physical commodity flows within a sector, including key stakeholders, though usually confining the analysis to domestic markets and ignoring dynamic adjustments to sector characteristics and relationships (Raikes *et al.*, 2000; Kaplinsky and Morris, 2001).

Furthermore, Porter (1980) defined the "value chain" as a representation of a firm's value-adding activities, based on its pricing strategy and cost structure. Porter's approach highlights actual and potential areas of competitive advantage for the firm. He argued that each individual firm has their own value chains that are embedded in value networks or value system, each of which have different functions within an industry or sector that influence (and are influenced by) other actors in the network. The salience of Porter's discussion was to highlight the interdependences and linkages between vertically arrayed actors in the creation of value for a firm. The modification and application of value chain ideas to development issues became more formalized in the mid- to late-1990s, particularly in the global commodity chain (GCC) approach of Gereffi and Korzeniewicz (1994). Global commodity chain and subsequent approaches focused predominantly on the value network of Porter in terms of looking at the relationships and linkages between firms, rather than solely at value creating functions within a firm.

Global commodity chain analysis further highlighted governance relationships between actors in the market chain. These ideas, along with the characterization of the chain itself and key stakeholders were codified in a handbook of research (Kaplinsky and Morris, 2001) and have since been widely used in a range of development applications (Gibbon, 2008)

While market chains analyses have provided a number of important insights on the linkages and relationships inherent in developing country markets, there are a number of limitations in current market chain analysis approaches. First, an important drawback of current methods is the lack of quantitative analysis embedded in the approach as cited by Raikes *et al.* (2000). Where quantitative analyses are present they are mainly focused on profitability and margins within the chain. Lalonde and Pohlen (1996) observed that available performance measures do not cross boundaries between firms in the chain. Raikes *et al.* (2000) noted further that the measurement of profits within the chain is problematic and usually confined to abstract relative estimates without quantification. To address this shortcoming Humphrey and Napier (2005) suggest using benchmarking indicators. These indicators include performance gaps, estimates of standards compliance cost, gross margin data, income distribution and employment.

These shortcomings notwithstanding, through the analysis of value-added within the chain, one can determine who benefits from participation in the chain and which actors could benefit from increased support or organization. This is particularly important in the context of developing countries (and agriculture in particular); given concerns that poor producers and consumers are often vulnerable to the process of globalization (Kaplinsky and Morris, 2001).

Market chain analyses are conducted through qualitative and quantitative methods, featuring a combination of primary survey, focused group work, informal interviews, and secondary data sourcing. The information is used to understand linkages and the chain structure as well as related services. On the basis of this, constraints and policy issues that require further exposition are identified. The entry point and the concentration of the market chain analysis are directly related to the desired development outcome from supporting the chain (Van den Berg *et al.*, 2010). The entry point and orientation of this analysis is therefore to understand how coconut market chain works better for the poor. Hence the tools used in the analysis are oriented toward analyzing the market chain from the point of view of the poor. The ultimate objective of improving market chains for the poor is two-fold. Firstly, is to increase the amount and value of products that the poor sell in the market chain. The second objective is to sustain or increase the share of the poor in the sector or increase the margins per product, so that the poor do not only gain more absolute income but also relative income compared to the other actors in the market/value chain (Van den Berg *et al.*, 2010). Similar to Van den Berg *et al.* (2010), UNIDO (2009) suggests the guidelines for analyzing market chain in the context of pro-poor and are adapted for this study as they are presented below;

(i) Mapping the coconut market chain to understand the characteristics of all chain actors and the relationships among them, the flow of goods through the chain, and of the destination and volumes of domestic and foreign sales.

(ii) Identifying the distribution of actors' benefits in the chain; this involves analyzing absolute and relative the margins and profit within the chain and therefore determining who benefits from participating in the chain and who would need support to improve performance and gains. The size of market margins is largely dependent upon a combination of (1) the quality and quantity of marketing services provided; (2) the cost of providing such services; and (3) the efficiency with which they are undertaken and priced (Scarborough and Kydd, 1992). For instance, a big margin may result in little or no profit or even a loss for the seller involved depending upon the marketing cost as well as on the selling and buying prices (Mendoza, 1991). However, under competitive conditions, the size of market margins would be the outcome of the supply and demand for marketing services, and they would be equal to the minimum cost of service provision plus "normal" profit (Scarborough and Kydd, 1992; Mendoza, 1991). Therefore, analyzing market margins is an important means of assessing the efficiency of price formation in and transmission through the system.

(iii) Defining upgrading needs within the chain; By assessing profitability within the chain and identifying chain constraints, upgrading solutions can be defined. These may include interventions such as improving product design and quality in order to move into more sophisticated product lines and gain higher value and/or diversify of production. Sometimes improvement may require reorganizing the production system or investing in new technology to upgrade the process and enhance chain efficiency

(iv) The role of governance is emphasized within the market chain where governance defines the structure of relationships and coordination mechanisms that exist among chain actors. By focusing on governance, the analysis identifies institutions that may require support to improve capabilities in the market chain, increase value added in the sector, and correct distributional distortions. Thus, governance constitutes a key factor in defining how the objective of upgrading a market chain can be achieved.

The literature on market chain analysis as discussed here is used to complement the economic surplus method in order to achieve the study's objectives.

This chapter reviewed the literature on various topics related to this study. The chapter presented the importance of coconut as a cash crop for farmers in Benin and Tanzania. The historical background of the coconut industry in both countries is presented. Currently coconut production is characterized by low productivity due to low genetic potential of the plants as well as pre and post harvest losses due to diseases and pests. A detailed literature review regarding coconut mites in relation to their distribution, effects, and control measures has been presented. The literature on economic surplus model and value chain has been also presented. Market chain analysis is used to highlight the constraints and opportunities at and between stages of the chain and can thus be used to develop integrative policy recommendations target to address distributional issues. Under the consumer surplus model, both closed and small open model were considered, discussing the nature of supply shift in relation to economic gains to consumers and producers. In the next chapter methodological issues are discussed in more detail.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Areas

The purpose of this study was to determine the size and distribution of benefits accruing from biological control of coconut mite which has devastated the coconut industry worldwide. The study limited the choice of study areas to African coconut growing countries because they lag behind other parts of the world to improve production and value addition. In West Africa there are four countries where coconuts are grown. They include Nigeria, Ghana, Benin and Côte d'Ivoire. Benin is the largest producer and exporter to her neighbors. In East Africa, coconuts are grown in Kenya, Mozambique and Tanzania-being the largest producer. Benin and Tanzania were chosen for this study on the basis of volume of production, importance of coconut production to the local population and the economy. The prevalence of coconut mites was another factor for choosing these countries.

In Benin, this study was conducted in three communes; Ouidah and Kpomasse, (Atlantique department) and Grand-Popo (Mono department) (Figure 3). These areas lie along the coastline measuring 121 kilometres. This represents a low-lying, sandy, coastal plain where the highest elevation is 10 meters above sea leve at most and about 10 kilometres wide on average. The climate is hot and humid. Annual rainfall in the coastal is about 36cm per month on averages (http://www.exxun.com/Benin/ob_geo_1.html).

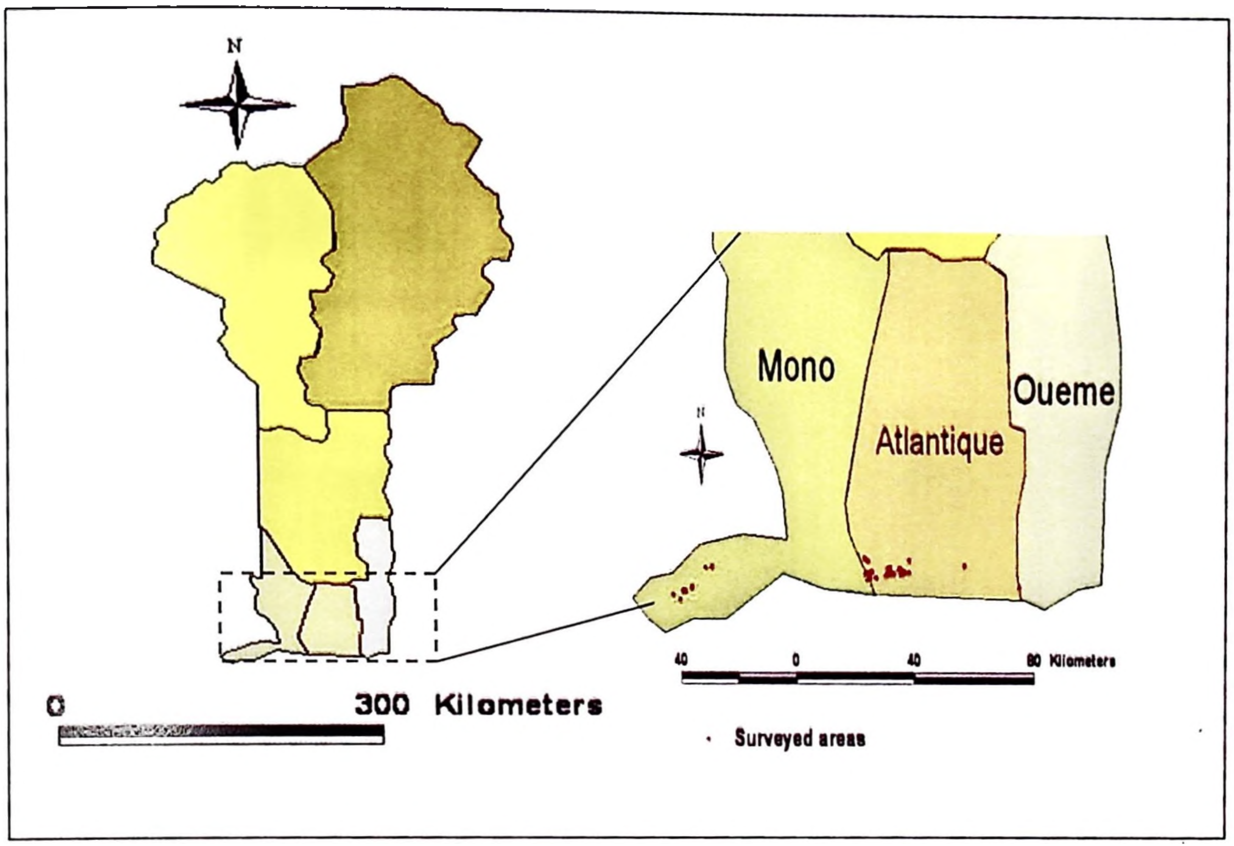

Figure 3: Map of Benin showing study communes

In Tanzania, coconut is mainly produced on the east coast, along the Indian Ocean covering a strip up to two hundred kilometres wide. There are however other localized coconut producing areas within interior regions, especially around large lakes (Lake Victoria, Tanganyika and Nyasa). This study was conducted in five districts selected from three regions along the Indian Ocean coast. They include; Pangani in Tanga region, Bagamoyo, Mkuranga and Kisarawe in Pwani region and Kilwa district in Lindi region (Figure 4).

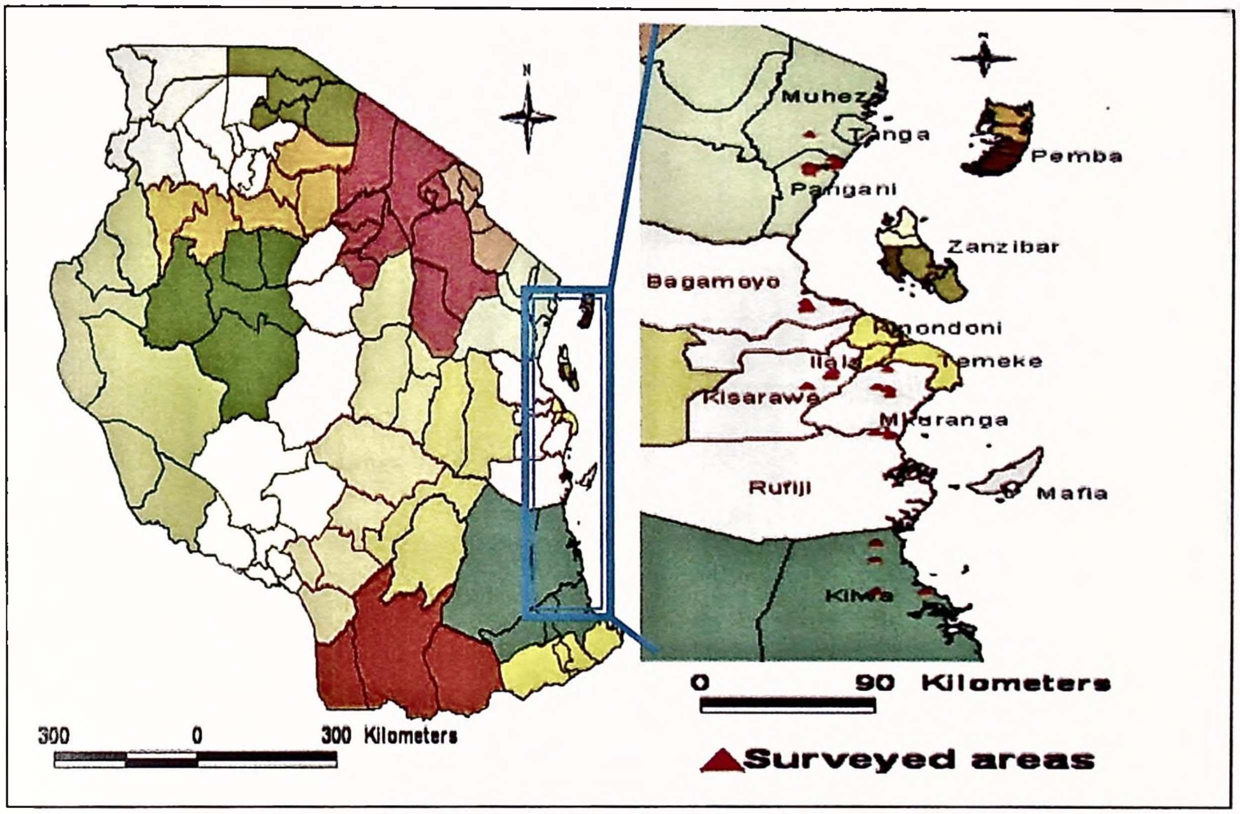

Figure 4: Map of Tanzania

Having described the areas for this study, the focus now is on methodological issues that were used for analysis of the coconut subsector, consistent with the study's specific objectives. Analysis of the coconut subsector in Benin and Tanzania intended to suggest policy actions that aim at developing a vibrant coconut value chains involving good coordination and strong collaboration. The study accomplishes this by estimating the benefit expected to accrue to different actors along the chain from introducing biological control of coconut mites.

3.2 Consumer Surplus Framework

After estimating the total economic surplus expected from introducing biological control of mites under specific objective one, the second specific objective aimed at conducting a sensitivity analysis on the value of benefits arising from biological control, given changes in key variables such as the discount rate and the probability of success of the technology being introduced in the study area. The analysis of economic benefits uses the concepts of supply and demand in a partial equilibrium, building upon the approach first utilized by Griliches (1957) in his pioneering study on hybrid corn. According to his study, adoption of a technological innovation leads to a downward shift in the supply curve, through reduction in the unit cost of production. The cost per unit of production may be reduced through loss reductions or increased yield. Adopting a new technology can therefore have a shifting effect of the supply curve. The value of this change, which is measured as increase in productivity per hectare attributable to the innovation is multiplied by the adopting area that is planted during a single year to give the gross annual research benefits (Alston *et al.*, 1995). From economic theory, a supply function can be derived from cost data of the production process. The model in the following subsections integrates all these considerations into a single analysis.

3.2.1 Measuring economic surplus

Producers will increase output provided a higher output or product price increases their marginal benefit such that it is larger than the marginal cost. This implies an upward sloping supply curve representing a positive relationship between product price and quantity (Wohlgenant and Alston, 1990). The supply function is also affected by other factors which could change the cost of production (cost of labour, land, fertilizer and seed). These serve as supply curve shifters. The supply curve is represented in equation (9).

The supply curve for coconut production before and after controlling for coconut mites as illustrated in Figure 5 are denoted by S_0S_0, and S_1S_1 respectively, the shift being induced by increased sales duc to reduced loss of coconuts following biological control. The demand curve, which is represented by DD (Figure 5), is not expected to shift during the period of the study since none of the demand shifters is expected to come into play. The initial price, quantity supplied and quantity demanded are P_0, S_0 and Q_0 respectively. The initial total consumer surplus from the consumption of coconut is equal to P_0AEP_1 while the producer surplus is equal to P_0AI_0. The total surplus (the sum of the producer surplus and consumer surplus) is given by the triangle P_0AI_0.

After introducing the new yield-enhancing farming technology, the supply curve is expected to shift out from S_0S_0 to S_1S_1, leading to a new equilibrium price P_1 and quantity Q_1. The resultant change in consumer surplus is then given by the area P_0AB P_1 and the area P_1BI_1 less P_0AI_0 represents the change in producer surplus. The consumers definitely gain because they buy more at a relatively lower price hence the area P_0AB is positive.

The product equilibrium price with adoption (P_w) and without adoption (P^*) can be derived by setting demand equal to supply as presented in equation 15;

$Q^d = Q^s$ .... (15)

If k=0, and knowing that γ has a negative sign, then;

$$P^* = \frac{\mu - \alpha}{\beta + \gamma} \qquad (16)$$

If K≠0

$$P_w = \frac{\mu - \alpha - \beta k}{\beta + \gamma} \qquad (17)$$

This implies that the research-induced change in price is given by:

$$P_w - P^* = \left[\frac{\gamma - \alpha - \beta K P_0}{\beta + \gamma}\right] - \left[\frac{\gamma - \alpha}{\beta + \gamma}\right] = \frac{-K\beta P_0}{\beta + \gamma} \qquad (18)$$

Based on the supply and demand functions before introducing the technology, we can show that the supply and absolute demand elasticities are

$$\varepsilon_s = \left(\frac{\partial Q_0 P_0}{\partial P Q_0}\right) \qquad (19)$$

Where ε_s is the elasticity of supply, and from the supply function earlier we get;

$$\varepsilon_s = \left(\beta \frac{P_0}{Q_0}\right) \qquad (20)$$

$$\beta = \varepsilon_s \left(\frac{Q_0}{P_0}\right) \qquad (21)$$

From the demand side the elasticity of demand is computed as;

$$\eta = \left(\frac{\partial Q P_0}{\partial P Q_0}\right) \qquad (22)$$

$$\eta = \left(\gamma \frac{P_0}{Q_0}\right) \text{...(23)}$$

$$\gamma = \left(\eta \frac{P_0}{Q_0}\right) \text{...(24)}$$

Converting the slope in equation 9 into elasticities, the resulting equilibrium market clearing price when the new technology is adopted becomes:

$$P_w = P^* - \frac{K\beta}{\beta + \gamma} \text{...(25)}$$

Since under equilibrium P* is equal to P_0 we can substitute this into equation 21 and 24 into 26 to get

$$P_w = P^* - \frac{K\frac{Q_0}{P_0}}{\left(\varepsilon_s \frac{Q_0 + \eta Q_0}{P_0}\right)} P_0 \text{...(26)}$$

or

$$P_w = P_0\left[1 - \frac{K\varepsilon_s}{\varepsilon_s + \eta}\right] \text{...(27)}$$

Where ε is the elasticity of supply and η is the absolute value of the price elasticity of demand.

Since the change in price is given as;

$P_w - P^* = \frac{-K\beta P_0}{\beta + \gamma}$, Following Alston *et al.* (1995), the absolute relative reduction in price (Z) is also defined as

$$Z = -\frac{P^*(P_w - P^*)}{P^*} = \frac{KP_0\varepsilon_s}{P^*(\varepsilon + \eta)} \text{...(28)}$$

To substitute elasticities for the slope, we need the elasticity of demand (η), expressed in absolute value. Thus the resulting equation is;

$$\left(\eta\frac{(P_1-P_0)}{P_0}\right)=\frac{Q_1-Q_0}{Q_0}\text{.......}(29)$$

While under equilibrium P*= P_0, P_1= Pw, Q*=Q_0 and Q_2=Q_w, Thus

$$\frac{P_1-P_0}{P_0}=Z,\text{.......}(30)$$

and

$$(Q_1-Q_0)/Q_0=Z\eta\text{.......}(31)$$

Hence, following the adoption of the new technology, the new equilibrium price and quantity can be written as:

$$P_w=P_0(1-Z)\text{.......}(32)$$

$$Q_w=Q_0/(1-\eta Z)\text{.......}(33)$$

The gains in consumer surplus (ΔCS) can therefore be derived and expressed algebraically as:

$$\Delta CS=(P_0-P_w)[Q_0+0.5(Q_w-Q_0)]\text{.......}(34)$$

and the corresponding change in producer surplus is also given by:

$$\Delta PS=(k+P_w-P_0)[Q_0+0.5(Q_w-Q_0)]^2\text{.......}(35)$$

It can therefore be shown that by substituting equations (30) and (31) into equations (32) and (33) the algebraic expressions for estimating the changes in the economic surplus for a parallel shift are as summarized in Table 5.

Table 5: Changes in the economic surplus

Change in	Geometric formula	Algebraic formula
Consumer Surplus	ΔCS=AreaP_0aeP_1=Area rectangle P_0abP_1+Area Triangle abe	$\Delta CS = P_0Q_0Z(1+0.5Z\eta)$..................................(36)
Producer Surplus	ΔPS=AreaP_1bcd=Area rectangle P1ecd+Area triangle bce	$\Delta PS = P_0Q_0(K-Z)(1+0.5z\eta)$.................(37)
Total	ΔTS=P_0abcP_1=Area rectangeP_0acb+Area triangle abc	$\Delta TS = \Delta CS + \Delta PS = P_0Q_0K(1+0.5Z\eta)$.....(38)

Source: Falck-Zepeda *et al.* (2007)

In order to estimate the economic surplus model as summarized above (shown in Table 5) a number of variables such as elasticities, production quantities, prices, adoption levels, yield and cost increase must be calculated as presented in the next sections.

3.2.2 Elasticises

In order to compute the producer and consumer surplus values, elasticities of supply and demands are required. Own-price, demand and supply elasticities are used to estimate benefits accruing from new agricultural technologies. Own-price elasticities refer to the % change in the quantity demanded or supplied, of a good due to a one % change in the price of the good (Alston *et al.,* 1995). Measuring own-price elasticity of a product for a particular country requires extensive data and a new study by itself. Thus, normally researchers rely on estimates of elastcities from previous studies. Few reliable estimates of price elasticities for coconut in Benin and Tanzania are available. As such, this study utilized estimates for similar and related products estimated in these countries. If the homogeneity condition holds, the price elasticity for a normal good is in many cases slightly higher than the income elasticity, but having opposite signs. In Tanzania Nyange *et al.* (2003) grouped coconut with other food items and estimated their elasticity of demand which fell within the range of -0.753 to 0.894. Meanwhile Leyaro (2009) reported income elasticities of demand for nuts and pulse in Tanzania to be between -1.03 and -1.46. Based on these findings, this study assumed the demand elasticity of coconut in Tanzania to be -1.245, falling within this range -1.03 to -1.46.

In Benin, the base price elasticity of demand was estimated by Ackah and Appleto (2008) for similar products (Palm oil and groundnut), which is -0.552. Furthermore, Rao (1989) estimated the agricultural supply response to prices for a wide range of crops in developing countries. They found crop specific acreage elasticity to vary from 0 to 0.8 in the short run and from 0.3 to 1.2 in the long run. Peterson (1979) used cross-country data from 53 countries to estimate appropriate long-run supply elasticity for agricultural products, which ranged from 1.27 to 1.66.

Meanwhile, Askari and Cummins (1977) estimated supply elasticities for a number of individual crops for Chile, India, Thailand and the United States. The authors reported that the supply elasticity for minor crops is large as it is easier for farmer to shift resources to other crops. Islam and Norton (2007) present a list of price elasticities of supply compiled from different studies. The short-run elasticities vary from 0.1 to 0.8, while the long-run elasticities vary from 0.3 to 1.5. These are consistent with a study of commodity price changes and consumer welfare in Tanzania by Leyaro (2009) who estimated the supply elasticities of coconut to be 0.6, which is also used in this study. Since no estimates for supply elasticity of coconut or related crops are available for Benin, we use the elasticity estimated for

Benin by Ackah and Appleto (2008) which fell within the range of 0.2and 0.6. For this study, we use the mean value of 0.4.

3.2.3 Quantities and prices

For this study the baseline levels of production were gathered from the Ministry of Agriculture, Food and Cooperatives, for Tanzania, and from the Coconut Research Institute-Semi Podji- in Benin. Coconut yields for 2008/2009 were estimated at 380 000 tones and 25 000 tons for Tanzania and Benin respectively. The farm level price of fresh coconut in Tanzania was $50.2 per ton during 2008/2009. In the case of Benin, farm gate price of fresh coconut was about 45$ per ton during the same period. Table 6 presents the quantities of coconut produced in each country for 5 years since 2004. It is not possible to assess the impact of research without data on the quantities coconuts produced corresponding prices. These are shown in Table 6.

Table 6: Area harvested, yield and prices of coconut in Tanzania and Benin

	Tanzania[t]				Benin[b]			
Year	Area harvested (Ha)	Yield (Hg/Ha	Yield (Tons)	Price ($/Tons)[1]	Area harvested	Yield (Hg/Ha	Yield (Tons)	Price ($/Ton)[1]
2004	322420	10932	423000	77.0	12013	16666	32000	68
2005	231080	11935	460000	57.3	13210	18795	27100	48
2006	230921	20933	360000	60.1	12000	17912	20000	57
2007	220000	11834	40000	74.7	12050	16804	20250	62
2008	231760	11736	380000	50.2	12900	17567	25000	45
2009	226531	12133	200000	75.7	12700	15944	23255	58

[t] Data from Ministry of Agriculture, Food and Cooperatives, Tanzania,
[b] Data from Semi Podji research station, Benin,
[1] Own calculation as annual data on prices received by farmers (called Producer prices)

3.2.4 Expected yield and cost increases

It may take time for the biological control agent to spread throughout the area infested with coconut mites. Pickett *et al.* (1996) showed that some agents spread very quickly while others spread at a much slower rate. For simplicity, in this study we assumed that if the programme is successful it will take 20 years. The simulation period included the time required for generation, distribution, spread and wear out of technology.

Due to the complexity of biological control, the computation of benefits in this analysis is based on the probability of research success. This is jointly determined by the definition of a successful research outcome and the length of time until success is achieved, which depends on the assumed value for research cost (Alston *et al.*, 1995). The technology for biological control of coconut mites using natural predators is still in the development stage. Hence, reliable farm level estimates of changes in yield after the predators spread fully can only be estimated. Based on interviews with scientists, the probability of success has been set at 90%. In order to deal with uncertainty in determining the research benefits, sensitivity analysis for the probability of research success was done *vis-à-vis* indicators of research benefits as discussed into details in chapter four.

The full impact of biological control is expected to be a 50% increase in coconut production from the base scenario in Tanzania and Benin, as estimated by scientists from the research programme who are involved in releasing predators. The cost of developing and using the technology is another important parameter to be considered.

Table 7: Actual research cost

Year		Year 1	Year 2	Year 3	Year 4	Total
Total cost (€)[5]		72 860	62 580	51 280	59 860	246 580
Total cost (US$)		105428.42	90553.26	74202.16	86198.4	356382.24
Follow up cost						
Budget line/item	**Source:**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Total**
Personnel:						
In-kind	Applicants	12	12	12	12	48
In-kind	Collaborators	10	10	10	10	40
Laboratory	UvA,IITA,NRS	10	10	10	10	40
Total	-	32	32	32	32	128

The University of Amsterdam through the WOTRO project provided a significant share of funding (98%) for research programme on classical biological control of coconut mite in Africa, whose implementation began in 2008. Researchers have projected that it could take about 4-6 years to collect, multiply and release predator in the field. The cost for the first four years up to the release of the predators and initial follow up is projected to be US$ 356382.24. This is based on actual and projected annual budget requirements (Table 7). After the release of predator there will be follow up cost which will be in kind or monetary as part of routine works of research and extension of national research systems. These are not included in this analysis for the reason that they are fixed cost of national research and extension system. They would be incurred even if the project for mites control was not there. For purposes of comparing cost and returns, future cost of the biological control programme were discounted to reflect reduced purchasing power over time (Jetter, 2005).

[5] Exchange rate €1=$1.44

3.2.5 Discounting, benefits and cost

The models described in section 3.2.1 correspond to a snapshot of one-year benefits. Once the predators are introduced, the supply curve shifts progressively as the effects of the predators increases. Since the research cost and benefit will spread over some years, to compare values in different years it is necessary to take account of time effects by discounting the cost and benefits of the programme to the same initial period.

According to the World Bank, for long term projects the discount rate for Benin was estimated to be between 11.5% and 12% (World Bank, 2011). On the other hand, in Tanzania the discount rate for long term projects ranges from 10% to 12% (http://www.bot-tz.org). To check for stability of estimated values a sensitivity analysis of the discounted net benefits of investment was done using different discount rates. Results of this analysis are discussed in chapter four.

Once the research-induced changes for economic surplus were obtained, the next step was to aggregate those measures into summary values of research benefits using indicators such as the net present value (NPV), the internal rate of return (IRR) and the benefit-cost ratio (B/C). From the literature on capital budgeting, the NPV of a research programme or project undertaken in time t is calculated as the sum of the stream of future benefits (B_t), minus the cost (C_t), associated with the biological control programme at different discount rates

$$NPV = \sum_{r=0}^{r} \frac{B_t - C_t}{(1+r)^t} \quad \text{.......(38)}$$

If the NPV is negative, then undertaking that project/programme is not worthwhile, while a positive NPV indicates that the research project is profitable (Jetter, 2005). The NPV is not always an accurate measure when it is used for ranking projects because it does not take into account the scale of the investment for each project. Alston *et al.* (1995) proposed to express the NPV per unit of research investment or per scientist, and then rank the programmes accordingly. Apart from NPV, Internal Rate of Return (IRR) is the discount rate at which the NPV is zero, where the research programme breaks even. This is analogous to solving for (r) represented in equation (38) and recast in equation (39).

$$0 = \sum_{r=0}^{t} \frac{B_t - C_t}{(1+r)^t} \quad \text{.......(39)}$$

If the IRR exceeds the minimum acceptable discount rate or the opportunity cost of investment, the project/programme is worth further consideration.

The benefit cost ratio (B/C) is another parameter for measuring a projects' worth. The B/C measures the economic efficiency whereas the NPV measures the economic feasibility of the programme, the larger the B/C and NPV, the more efficient and feasible the investment. The B/C ratio is computed as:

$$B/C_{ratio} = \sum_{r=0}^{r} \frac{B_t}{(1+r)^t} / \sum_{r=0}^{r} \frac{C_t}{(1+r)^t} \quad \text{.......(40)}$$

All these parameters (NPV, IRR and B/C ratio) were computed based on derivations presented in this section.

Objectives three and four of this study were; (iii) to assess the current situation of the coconut marketing chain to identify key actors, service providers, institutional and policy environment, opportunities and constraints for developing the sub-sector, and identify appropriate interventions to address prevailing problems and objective (iv) to estimate the cost and margins within the coconut marketing chain in Benin and Tanzania. In the subsequent section, we present the analytical framework guiding these analyses.

3.3 Analytical Framework for Coconut Market Chain

In this study, the main analytical premise in relation to coconut market chain is that different actors across the market chain behave based on the variables provided by enabling policies, market information and technological advancement. These actors (producers, traders, processors and consumers) interact based on capital requirement and market information from various sources. This part of the study (market chain) integrates analysis of the processes and functions around coconut market chain including; (i) the analysis of market chain actors (ii) enabling environment, and (iii) facilitating services (Appendix 4).

Based on the framework in appendix 4, the study mapped the coconut market chains in Benin and Tanzania. Such mapping helps to visualize networks in order to get a better understanding of connections between actors and processes in a value chain (Berg *et al.,* 2006). Depending on the complexity of the chain, mapping can include core processes, actors, flow of products, information, knowledge, volume of product as well as the number for actors and services providers.

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Having mapped the value chains, the next step was to undertake in-depth analysis of certain aspects of the market chains. One of these is the cost that an actor contributes to the value chain (his/her cost) and the returns an actor receives from participating in the value chain (his/her margins). Measuring cost and margins provides a measure of how pro-poor/equitable a value chain is and whether it is a good source of income for the poor on the basis of which recommendations can be made to improve the chain's efficiency and equity. The gross margin analysis was performed according to equation 41.

$$GM_{ij} = TVP_{ij} - TVC_{ij} \qquad (41)$$

Where:

GM= Gross Margin for actor i at node j

TVP= Revenue obtained by actor i at node j

TVC= Total variable cost incurred by actor i at node j

In the next section, procedures for data collections are described.

collected. Qualitative information was obtained through interviews with key informant using a checklist of guiding questions. The instruments for data collection were subjected to pre-testing for validation and reliability. In deciding on the sample size, the maximum possible margin of error for a given factor was assumed to be 0.2 with 95% confidence interval (Cochran, 1963). Considering these assumptions, a sample size of 300 coconut producing households was selected, 100 from Benin and 200 from Tanzania who represented about 0.12% and 0.1% of the total number of coconut holdings in each country respectively. In Benin, three communes from two departments were purposively selected from among eight coconut producing communes. With the help of commune agricultural extension officers, the list of coconut growing villages was prepared. Assuming that these villages consisted of coconut farmers, 100 farm household were randomly selected, representing about 0.12% of the coconut holdings (5000). In addition, 40 traders were randomly selected from the lists of 148 traders from Cotonou and Grand-Popo markets, representing the main markets for coconut in the study area (Table 8). In Tanzania data were collected from 200 coconut farmers spread across five coconut growing districts. With the help of District Agricultural and Livestock Development Officers (DALDOs), the lists of coconut growing villages were prepared for each district, based on which 13 villages were randomly selected.

Then, proportional sampling was employed to select 35 respondents from relatively small coconut farming communities and 40 respondents in medium and large sized coconut farming communities. In addition 40 traders were randomly selected from the lists of about 320 traders operating within markets in Tanga Municipality and

Ilala District within Dar es Salaam city. Furthermore, qualitative data were collected from interviews with staff from the DALDO's office and other key informant within the district in order to capture their views regarding the sector and to develop a consistent story of relevant institutions and their involvement and nature of influence on coconut production and marketing. A summary of the sample composition is presented in Table 8.

Table 8: Composition of Respondents - Farmers

Country	Region	District/Commune	No. Villages	Farmers				
				Male	%	Female	%	Total
Benin	Cotonou	Oidah	4	47	90	6	10	53
		Grand Popo	4	39	93	3	7	42
	Kpomase	Kpomase	1	4	80	1	20	5
Sub-total			**5**	**90**	**91**	**10**	**9**	**100**
Tanzania	Tanga	Pangani	3	28	80	7	20	35
	Pwani	Bagamoyo	2	35	77.7	10	22.3	45
		Kisarawe	2	32	95	8	20	40
		Mkuranga	3	38	80	2	20	40
	Lindi	Kilwa	3	40	100	0	0	40
Sub-total			**13**	**173**	**86.54**	**27**	**16.46**	**200**
G-total			**10**	**163**	**88.77**	**37**	**11.23**	**300**

3.4.2 Secondary data collection

The analysis of social and economic change was based on secondary data since it is impossible to conduct a new survey that can adequately capture past levels of development to serve as baseline information. Variables for which secondary data that was collected included; prices, coconut quantities, price elasticises, current production practice, yield, crop loses, potential gains and the probability of success for the proposed intervention. Some of these data are described in the coming sections. Sources of secondary data included reports and publications from Mikocheni Agricultural Research Institute (MARI), Sokoine National Agricultural Library (SNAL), Ministry Agriculture, Food and Cooperatives (MAFC), the

International Institute of Tropical Agriculture (IITA), Semi Podji, Benin and Internet Searches.

3.5 Data Analysis

As per objectives one and two of this study, economic surplus analysis was used to project the economic benefits of biological control of coconut mite by comparing the situation with and without the new technologies. Impacts were calculated over a period of 20 years, taking into account; (i) the base production and prices in each country as described earlier, (ii) the nature of coconut markets, (iii) projected yield and cost changes, (iv) estimated time for discovery, development and deployment of the biological control agents, (v) the probability of the research success and (vi) the discount rate for benefits and cost.

Table 9: Sources of some of parameters used

Variable	Benin		Tanzania	
	Data/Parameter	Source of data	Data/Parameter	Source of data
Production quantity, (Q_0) Ton/year	23121	Semi Podji research station, Benin,	311666.7	MAFC (2009)
Annual production area growth (%)	0.04	Semi Podji research station, Benin,	0.08	MAFC (2009)
Yield at the start of period of simulation ()	25,000	Semi Podji research station, Benin,	380,000	MAFC (2009)
Price, Po ($/ton)	45	FAOSTAT (2010)	50.2	FAOSTAT (2010)
Export volume, (Q_o-C_o) (ton)	8140	Semi Podji research station, Benin,	0	-
Consumption quantity, ton/country (2008)	14981	Semi Podji research station, Benin,	311666.7	MAFC (2009)
% yield increase, $\Delta(Y)$	50	Interviews with scientists (WOTRO Project, 2007)	50	Interviews with scientists (WOTRO Project, 2007)
% cost reduction, E(C)	0	-	0	-
Elasticity of supply (η)	0.4	Ackah and Appleto (2008)	0.6	Leyaro (2009)
Elasticity of demand (ε)	-0.552	Ackah and Appleto (2008)	-1.245	Leyaro (2009)
Maximum adoption rate (%)	90	Interviews with scientists (WOTRO Project, 2007)	90	Interviews with scientists (WOTRO Project, 2007)
Lag of R & D returns after first adoption (years)	6	Interviews with scientists (WOTRO Project, 2007)	6	Interviews with scientists (WOTRO Project, 2007)
Simulation period (years)	20	Interviews with scientists (WOTRO Project, 2007)	20	Interviews with scientists (WOTRO Project, 2007)

To assess the benefits of biological control equations 28-30 (section 3.2.1) were estimated using the Dynamic Research Evaluation for Management (DREAM) software developed for IFPRI by Wood *et. al.* (2001). The model calculates and analyzes the benefits derived from technological change, which are measured as economic surplus producers and consumers. The model also estimates indicators of social gains from investment in research. By introducing into the model the annual flows of investments in research and development, indicators of social gains such as the net present value (NPV), internal rate of return (IRR), and the cost/benefit (C/B) ratio were estimated. Results from the simulation of consumer surplus model and responses from interviews with coconut farmers and traders were coded and summarized using excel. These were then used to compute statistical means and standard deviations which are presented in the next chapter using graphs and tables for frequency distribution and cross tabulations. Other finding on the remaining study objectives are also presented in the next chapter.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Challenges Facing Coconut Farmers in Benin and Tanzania

While the literature on other control methods for coconut mite is presented in chapter two, this study concentrates on biological control of coconut mite as an alternative method of controlling coconut mite to address the problem of declining coconut productivity in Benin and Tanzania. Besides policy related challenges the subsector also faces other disabling factor that range from inadequate rainfall to marketing. Other challenges relate to old age of the plant population, declining soil quality, poor farm management, pests and diseases have already been discussed as contributing to low productivity. With the intention of presenting the findings on the simulation of benefits of using this technology, perceptions of farmers on challenges are also discussed based on farmers' response as presented in Tables 10 and 11 for Benin and Tanzania respectively.

Respondents in both countries ranked drought among the top three limiting factors for coconut production. The distribution of rainfall has a significant impact on productivity. Coconut palms need at least 1 500 mm of rain per annum, that is well-distributed throughout the year. The coconut zone of Benin has annual mean rainfall ranging from only 900 mm in the West to 1 200 mm in the East. This falls well-below the requirement, and is poorly distributed through the year.

Most of the respondents in Benin ranked drought as the most serious constraint (25%) leading to low coconut production in the sandy areas. This was followed by the occurrence of lethal disease (17%) and attack by pests including coconut mite (15%). Low production potential of the varieties (12%) ranked fourth followed by poor soils (9%) and theft (7%). Low prices (6%) was mentioned but ranked the lowest under marketing problems.

Table 10: Farmers' perception on the coconut production constraints-Benin (n=100)

Constraint	Severity			Total	Rank
	Highly severe	Severe	Less severe		
Drought	7%	11%	7%	25%	1
Lethal disease	1%	6%	9%	17%	2
Coconut mite and other insect attack	4%	9%	2%	15%	3
Low productivity of variety	5%	4%	4%	12%	4
Poor soils	7%	1%	-	9%	5
Theft	5%	2%	-	7%	6
Marketing problems	1%	2%	3	6%	7
Total	**37%**	**39%**	**27%**	**100%**	-

In Tanzania the lethal disease was ranked the highest by 37% of the respondents. followed by other coconut mite and other pests (17%). Drought came in third (15%) followed by lack of high yielding varieties (11%). Until 2000s, there were well established nurseries, maintained by research stations and model farmers. These provided good planting materials. There are many coconut trees within the study area but, most of them are left unattended, being totally in the bush. Currently, farmers rely on their current crop to get seedlings by collecting what has fallen on the ground and germinated naturally. In Benin however, there are some efforts for renovating coconut plantations through planting new trees. Poor processing technologies (9%) were ranked fifth while theft and marketing problems were ranked sixth and seventh respectively, each representing 6% of all respondents. As is the case with Benin marketing related problems were seen to be the lowest ranking among all the farmers perceived problems.

Table 11: Farmers' perception on production and marketing constraints-Tanzania (n=200)

Constraint	Severity			Total	Rank
	Highly severe	Severe	Less severe		
Lethal disease	20%	9%	7%	37%	1
Coconut mite and other pests	9%	6%	1%	17%	2
Drought	5%	7%	3%	15%	3
Lack of high yielding variety	5%	4%	2%	11%	4
Lack of processing technologies	4%	2%	3%	9%	5
Theft	4%	1%	1%	6%	6
Marketing problems	2%	2%	2%	6%	7
Total	**49%**	**31%**	**20%**	**100%**	-

Comparing between the two countries, it seems that drought is more severe in Benin. Although rainfall is relatively heavier in Tanzania, most of the study area faces dry from January to March affecting production of many crops. The problem of pests and pest related problems as reflected by sudden death of coconut plants (dieback) is more severe in Tanzania as reported by 37% of the respondents compared to only 25% in Benin. In both countries Lethal Yellowing (LY) is a common disease that has killed millions of coconut trees. Another problem is the Bole rot, which is caused by a fungus. This disease can wipe out many trees in a short period. Bole rot is responsible for many of the dead standing trees observed in the study area. Pests include the Coconut mite, Rhinoceros beetle (*Orctes monoceros)* and the Coreid bug (*Pseudotheratus wayi)*, which also attacks the terminal bud. In the next section, the simulated benefit of biological control of coconut mite is presented.

4.2 Determination of Cost and Benefit of Biological Control of Coconut Mite

A successful research investment will yield benefits over a number of years. As the adoption increases (resulting from improved production due to reduced damage from coconut mites) there will be a shifts in the supply curve and corresponding changes in benefits (see chapter 3 of this report). To facilitate the analysis of benefits the ceiling adoption lags had to be chosen. This is the length of time until maximum adoption is expected to occur. Elbasha *et al.* (1999) point out that in Sub-Saharan Africa, the adoption period of agricultural interventions is long at least 15-20 years. Since the Coconut mite predators are being released now, the benefits have not yet accrued to producers and consumers, the analysis of benefits and cost was done as a simulation, where benefits are estimated to last for over 20 years starting from 2008 when the cost of developing the technology was incurred by the WOTRO coconut research project. The simulation period included the time required for generation, distribution and spread of biological control agents. After this period it is assumed that the benefits of a technology will be overcome by other emerging factors such that the technology's lifecycle will have been completed. In our analysis we adopted the World Bank's discount rates for long term projects pegged at 12% for developing countries. To avoid contradictions arising due to the choice of an appropriate discount rate, we carry out a sensitivity analysis[6] (testing the robustness of the results) of the discounted net benefits of investment for biological control of coconut mites using three different discount rates. Furthermore, based on information from interviews with scientist it is estimated the research would have a 90% probability of success. However, this was subjected to different probabilities of

[6] Briggs *et al.* (2006) argue that the aim of sensitivity analysis is to quantify the level of confidence that a decision-maker has in the conclusions of an economic evaluation.

research success to evaluate how the net benefits would change. Varying interest rates and the probability of research success helped to answer the question, 'when these two parameters were changed what would be the effects on benefits of the programme?" The results of this analysis are described in the next section.

4.2.1 Spread Pattern/adoption curve

One of the parameters which are critical for analyzing benefits of a technological change is the pattern of its impact to farmers. The spread of insects often follows an S-shaped pattern, approaching its maximum level asymptotically (Alston *et al.*, 1995). For this purpose the model described in chapter three was adapted to simulate a sequence of supply-curve shifts attributable to biological control of coconut mite, representing the "with research" scenario. Thus, in estimating the economic surplus of increased productivity (associated with controlling coconut mite) the supply shift parameter was modelled as the change per unit cost of production, K, according to equation 30. The technology-induced supply shift K is therefore expressed as a net percentage decrease in production cost.

$$K_{j,t} = \left[\frac{\Delta Y_j}{\varepsilon_j} - \frac{\Delta C_j}{1+\Delta Y_j}\right] p_j * P_{j0} \qquad (41)$$

Where;

$K_{j,t}$ is the supply shift parameter in each country

ΔY_j is the yield change due to the biological control of coconut mite (new technology); ΔC_j the change in farm production cost due to control of coconut mites

ε_j is the elasticity of supply of the commodity

p_j is the probability of success of the control of coconut mite and

$P_{j,0}$ is the producer price of the commodity at the initial time.

Figure 7 shows the potential impact of research, being equivalent to the vertical shift in the supply curve due decrease in unit cost of production that can arise, or greater yields with the same level of inputs. In this study the decrease in cost due to biological control is represented by the factor K. Thus as, the technological induced supply shift is positive and increasing over time indicating that resources spent on biological control would have a positive impact on production. The two curves in Figure 7 differ from each other in terms of magnitude of cost reduction. Cost reduction is larger in Tanzania compared to Benin because Tanzania had a higher baseline production than Benin in 2008 (i.e. 380 000 for Tanzania and 25000 for Benin). Tanzania is also more devastated by mite that the impact of technology is more visible.

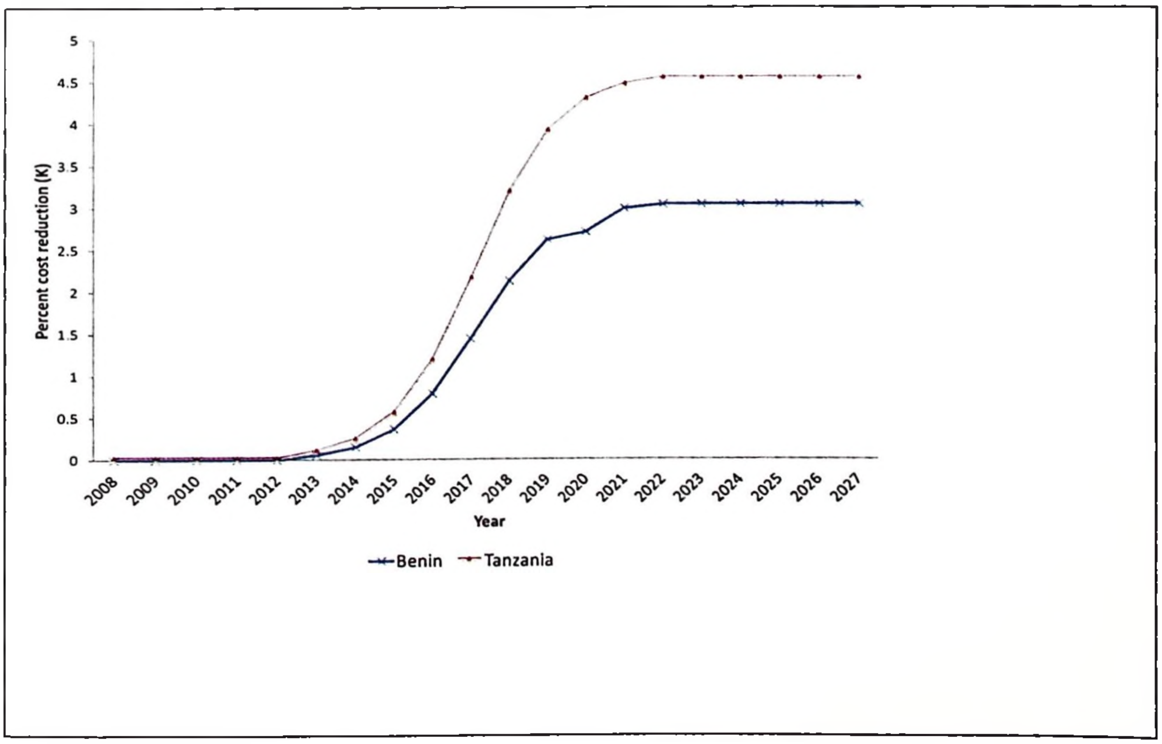

Figure 7: Adoption curve due to new technology (r=12%, p=90%)

4.2.2 Simulated equilibrium quantities

Parameters that were used to estimate the model's supply and demand were measured and defined in chapter three (3). The DREAM software was used to simulate the equilibrium quantities, prices as well as the cost and benefits of the research in the study area. DREAM allowed for exogenous shifts in supply and demand, thereby allowing for a sequence of yearly equilibrium prices and quantities to be generated with and without biological control scenarios. Figure 8 shows the supply and demand equilibrium points for the quantities of coconut produced and traded over the period of 20 years. In a small open model (Benin), it is assumed that coconut production will remain constant during the first five years and begin to increase as the effect of predators begins and continues to be felt. While the simulation model shows that production will remain constant (when interest rate 'r', and probability of success 'p', are 12% and 90% respectively), there may also be some decline in production over the period of five years due to other factors which are not exclusive of coconut mite attack. The first five years are designed for technology development and hence no increase in coconut production is expected. As shown in figure 8, the benefits from research, in terms of increased production, grow slowly at first. Over the entire period of simulation, analysis of time against yield (tonnes) shows that in Benin, yield will increase by about 65.09 per year (R^2=89.7%). Meanwhile, production without biological control shows a decrease in yield by 172 per year (R^2=93%).

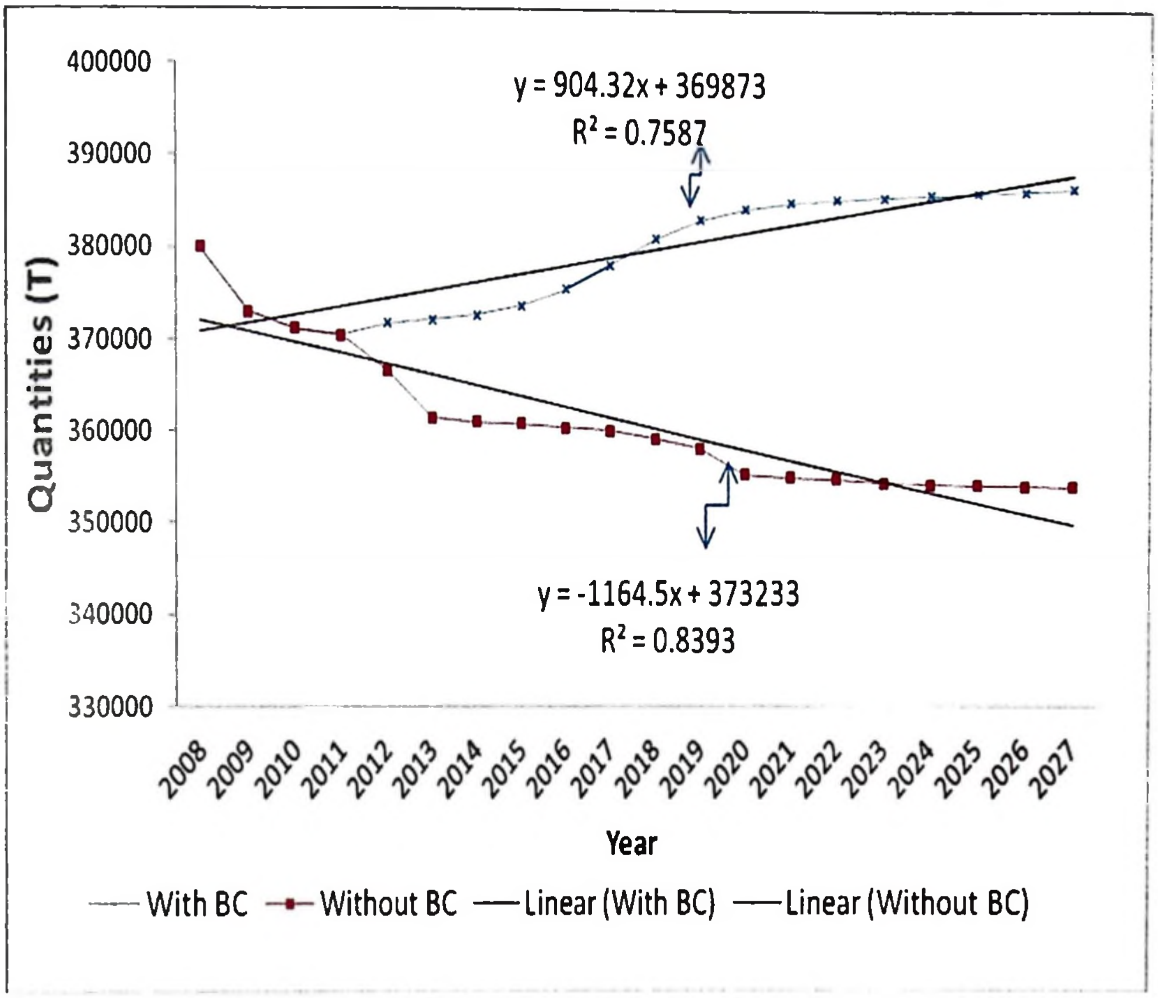

Figure 9: Equilibrium quantities due biological control of coconut mite in Tanzania (r=3.5, p=90%)

4.2.3 Change in quantities and prices due biological control

Results in Tables 12-13 show that there are simultaneous changes in yield and prices, while elasticises are assumed to be the same as those of the base year. The simulation results revealed an increase in coconut production after the release of biological control agents. As shown in Table 12 in the absence of biological control, coconut production in Benin is expected to fall from 25 000 tons in 2008 to 22190.4 tons in 2027 representing a 11.24% decline or 0.6% per annum. With biological control production will increase from 25 000 tons in 2008 to 25 870.6 tons representing a 3.5% increase or 0.17% growth per year.

Table 12: Changes in quantities due to Biological control of coconut mite in Benin

Year	Quantities (Tons) Production without biological control (b)	Production with biological control (a)	Change in quantity (a)-(b)
2008	25000	25000	0
2009	24910	24910	0
2010	24909	24909	0
2011	24803	24803	0
2012	24810	24810	0
2013	24630	25063.7	433.7
2014	24540	25094.1	554.1
2015	24050	25151.1	1101.1
2016	23901.1	25255.7	1354.6
2017	23822.1	25411.7	1589.6
2018	23792.2	25575.7	1783.5
2019	23620.2	25694.8	2074.6
2020	23600.3	25762.3	2162
2021	23583.3	25798.1	2214.8
2022	23140.4	25818.9	2678.5
2023	22150.4	25829.2	3678.8
2024	22110.5	25839.5	3729
2025	22100.5	25849.9	3749.4
2026	22180.6	25860.2	3679.6
2027	22190.7	25870.6	3679.9

Corresponding changes for Tanzania are such that without biological control production declines from 380 000 tons in 2008 to 353 923 ton in 2017. These represent a decline by 26 076 tons which is 6.9% over 20 year period or 0.34% per annum. Simulated production with biological would increase production by 6934.4 tons over the entire period which is about 1.8% or 0.09% per year.

Table 13: Changes in quantities due to Biological control of mite in Tanzania

Year	Quantities (Tons)		
	Production without biological control (b)	Production with biological control (a)	Change in quantity (a)-(b)
2008	380000	380000	0
2009	373040.3	373040.3	0
2010	371259.1	371259.1	0
2011	370478.1	370478.1	0
2012	366697.2	371697.2	5000
2013	361516.4	372144.9	10628.5
2014	361135.7	372705.3	11569.6
2015	360955.2	373713.3	12758.1
2016	360474.8	375518.4	15043.6
2017	360194.5	378189.5	17995
2018	359314.4	380998.4	21684
2019	358234.4	383056.7	24822.3
2020	355454.6	384250	28795.4
2021	355074.8	384910.4	29835.6
2022	354895.3	385319.4	30424.1
2023	354515.8	385552.4	31036.6
2024	354336.5	385785.5	31449
2025	354257.3	386018.9	31761.6
2026	354178.2	386252.3	32074.1
2027	353923.4	386934.4	331011.0

In terms of prices, the current national average prices set at 50.2 US$/ton for Tanzania and 45 US$/ton for Benin were assumed to apply from 2008/09. Simulation of price changes reveals a negative price change in Tanzanian coconut while in Benin the coconut prices are expected to remain steady because increased coconut production will not affect the regional/international price of the commodity, which remains constant, and all benefits are reflected by an increase in producer surplus after the shift in the supply curve. Moreover, for domestically traded coconuts, there would be no cross- country price effects, but even among regionally or internationally traded commodities, the cross-country price effects are negligible because the originating country has a small market share in regional or global markets (Napasintuwong and Traxler, 2009). These finding are similar to those of Mahmuda *et al.* (2008) regarding the distribution of returns to investment on research and development of soil borne disease management strategy for Brinjal in Bangladesh. The authors concluded that in a closed economy such as Bangladesh price-related benefits mostly accrue to both producers and consumers, whereas under small open economy benefits accrue to producers only.

Hence, changes in prices in Tanzania indicates that producers will benefit due to production gains from reduced loss of young coconuts and quality improvement, which can also be translated as lower average cost of production. Consumers will benefit from a fall in the real prices of coconut as discussed in the next section. In the case of Tanzania therefore it is expected that controlling coconut mites will increase marketable production and also increase farmers' income, despite a decline in price.

Table 14: Simulated changes in prices from biological control

Year	Benin Without (US$)	Benin With (US$)	Benin Change in Price	Tanzania Without (US$)	Tanzania With (US$)	Tanzania Change in Price (US$)
2008	45	45	0	50.2	50.2	0
2009	45	45	0	43.84	43.84	0
2010	45	45	0	42.82	43.82	0
2011	45	45	0	43.8	43.8	0
2012	45	45	0	43.77	43.77	0
2013	45	45	0	43.73	43.75	-0.02
2014	45	45	0	43.68	43.73	-0.05
2015	45	45	0	43.58	43.71	-0.13
2016	45	45	0	43.41	43.69	-0.28
2017	45	45	0	43.15	43.67	-0.52
2018	45	45	0	42.88	43.65	-0.77
2019	45	45	0	42.68	43.63	-0.95
2020	45	45	0	42.57	43.6	-1.03
2021	45	45	0	42.51	43.58	-1.07
2022	45	45	0	42.47	43.56	-1.09
2023	45	45	0	42.45	43.54	-1.09
2024	45	45	0	42.42	43.52	-1.1
2025	45	45	0	42.4	43.5	-1.1
2026	45	45	0	42.38	43.48	-1.1
2027	45	45	0	42.36	43.46	-1.1

As alluded to earlier for the case of Benin, under the small open economy, price of coconuts is not affected because consumers continue to face the same price and to consume the same quantity. The increase in supply is exported. Therefore total change in surplus is measured by the change in producer surplus. The consumer price doesn't change when the supply curve shifts.

may still benefit from improved quality and continuity of coconut supply. These findings are also consistent with those reported by Bayer *et al.* (2010) that there was no change in consumer surplus due to the use of a small open economy assumption for the study on the cost of compliance with biotechnology regulation on PRSV Papaya and *Bt* Rice in the Philippines. Another study by Napasintuwong and Traxler (2009) on an *ex-ante* impact assessment of GM Papaya adoption in Thailand also reported zero change in consumer surplus when a small open model was considered.

Table 17: Total benefit-Tanzania

Year	Producer Surplus	% of total benefit	Consumer Surplus	% of total benefit	Total Benefit	Total Cost	B-C
2008	0	0	0	0	0	-52714.21	-52714.21
2009	0	0	0	0	0	-45276.63	-45276.63
2010	0	0	0	0	0	-37101.08	-37101.08
2011	0	0	0	0	0	-43099.2	-43099.2
2012	0	0	0	0	0	0	0
2013	25033	75	8011	24	33044	0	33043.5
2014	62389	75	19965	24	82354	0	82353.7
2015	148847	75	47631	24	196478	0	196477.6
2016	323172	75	103415	24	426587	0	426586.7
2017	593993	75	190078	24	784071	0	784070.6
2018	881729	75	282154	24	1163883	0	42586.7
2019	1086933	75	347818	24	1434751	0	784070.6
2020	1195612	75	382594	24	1578208	0	1163883.1
2021	1244479	75	398233	24	1642712	0	1434751.7
2022	1265065	75	404821	24	1669886	0	1578207.7
2023	1265841	75	405069	24	1670910	0	1669885.8
2024	1266618	75	405318	24	1671936	0	1671935.6
2025	1267395	75	405566	24	1672961	0	1672961.4
2026	1268173	75	405815	24	1673988	0	1673987.9
2027	1268951	75	406064	24	1675015	0	1675015
Discounted Total	**2535611**	**76**	**811395**	**24**	**3347006**	**21.82**	**153393.6**

In the case of Tanzania, the producer, consumer and total surplus as well as the total cost and net benefits were calculated as presented in Tables 17. All the annual net benefit fifth year (2013) are positive, demonstrating that the benefits significantly outweigh the cost.

The surplus resulting from agricultural research expenditures was positive and substantial for every year in the period considered for simulation. The producers captured benefit valued at about US$ 2535 611 (75%) while consumers captured benefit amounting to about US$ 811 395 (24%) of the total benefits (US$ 3347 006) resulting from the investment. In both Benin and Tanzania, figures on the distribution of benefits, provide strong empirical evidence in favor of the first null hypothesis, that there is a net increase in economic surplus resulting from the introduction of biological control of coconut mite. The distribution of benefits established from this study is similar to that found by Napasintuwong and Traxler (2009) who conducted an *ex-ante* impact assessment of GM Papaya adoption in Thailand. They established that consumers gained more than producers in a closed economy model (US$ 1.04 billion).

4.2.5 Sensitivity analysis of returns in relation to the discount rate

In the analysis some of the parameters including; the discount rate and the probability of research success are uncertain because precise information for future periods is lacking. In order to determine the robustness of the simulated returns (net benefits, B/C and IRR) in view of such uncertainty, these parameters have been varied to check the corresponding changes in the benefits accruing to producers and consumers. Effects of the discount rate changes on returns to investment were estimated by increasing the discount rate from 12% to 20%, commonly used in long term project (15-20 years) in developing countries. High discount rates discourage investments with long-term benefits spread over a long period, which include research such as this one.

As shown in Table 18, the total discounted value of economic surplus is US$155213.3 at a discount rate of 12%. If the discounting rate is raised to 15% economic surplus drops to US$107869.1, while the internal rate of return (IRR) remains the same (13.21%). When a discounting rate is raised to 20%, it causes further drop in economic surplus to US$ 61002.8. This means the higher the discount rate the smaller the gain from the research project. As it is for net benefit, the sensitivity analysis results show that the higher the discount rate the lower the benefit cost ratio. For example, when the discounting rate is 12%, the B/C ratio is 1.01 whereas a 20% discount rate results into benefit cost of 0.43.

Table 18: Sensitivity analysis in relation to the discount rate (Benin)

Discount rate	Producer Surplus	Consumer surplus	Total Economic Surplus	Total cost	(B-C)	IRR
12	1552133	0	155213.3	1533393.3	1819	13.21
15	107869.1	0	107869.1	148477.36	-4608	13.21
18	76225.6	0	76225.6	143961.16	-67735	13.21
20	61002.8	0	61002.8	141151.04	-80148	13.21

The analysis for Tanzania shows that both consumers and producers will benefit from this technology (Table 19). Again, the interest rate is increased progressively from 12% to 20% the total economic surplus will decrease from US$ 3347005 to US$ 1315110 indicating that the higher the discount rate the less the benefit from the project. Furthermore increasing interest also lowers the benefit cost ratio. The benefit cost ratio decreases from 21.82 using 12% discount rate to 9.32 when 20% discount rate was considered. The results also show that IRR values are far higher than all the levels of the discount rates considered. Despite the fact that discount rates which were used affected benefit distributions, the higher value of IRR indicates that the investment was worth undertaking. Observations from this study are similar to those of Francisco (2007) on an ex-ante impact study of fruit and shoot borer resistant B_t eggplant production in the Philippines. He found that when the discount rate was reduced to 2.5%, a 50% decrease relative to the base case while the net return increased by 32%.

Table 19: Sensitivity analysis in relation to the discount rate (Tanzania)

Discount rate	Producer Surplus	Consumer surplus	Total Surplus	Total cost	Net benefit (B-C)	IRR
12%	2535610	811395.3	3347005	1533394	3193612	52.84
15%	1762003	563841.1	2325844	148477	2177367	52.84
18%	1244995	398398	1643393	143961	1499432	52.84
20%	996296	318814	1315110	141151	1173959	52.84

4.2.6 Probability of research success in relation to the internal rate of return

In this study a discount rate of 12% was assumed for computing the IRR as presented in Table 20. Results show that as the probability of research success increases the IRR also increases. Generally the simulation of a small open economy leads to a significantly lower IRR compared to that of a closed economy because Benin produces less coconut than Tanzania. Furthermore, since one of the criteria to establish the worthiness of the project is the IRR, these findings indicate that in order for this project to be beneficial it should be successful by more than 80% in Benin, whereas in Tanzania even at 20% probability of success the IRR is still higher than market discount rate. The high IRR in Tanzania indicates that biological control will generate more than 50% of the benefits. This is because the magnitude of mite devastation is higher (10-100%) than in Benin, with only 10-40%. High IRR has been also reported by other researchers using *ex-ante* economic impact evaluation. In their study on *ex ante* evaluation of nutrition and health benefits of biofortified cassava roots in Nigeria, Manyong *et al.* (2004) reported 186-244% IRR from investment in cassava production. Similar findings are also reported by Kipkoech *et al.* (2010) on the economic value of redistributing parasitoids for the control of the maize stem borer (*Busseola fusca)* in Kenya. The authors reported the IRR of 120.4 to 192.0% when the entire moist transitional and highland area of Kenya was included in the analysis. The study on potential impact of biological control of diamondback moth (*Plutella xylostella)* in cabbage production in Kenya also estimated an internal rate of return of 86%, indicating a high return to the investment (Macharian, *et al.,* 2005). These results corroborate results by Neuenschwander *et al.* (2008), who observed that technologies in high potential areas are likely to have substantially greater positive impacts on aggregate farm profits and incomes.

As a tool for investment, the calculated IRR should not be used to rate mutually exclusive projects, but only to decide whether a single project is worth investing in Briggs (2006). This is in contrast with the net present value, which is an indicator of the value or magnitude of an investment. This project indicates the IRR is above the minimum level of 12% even when the probability of success is lower than the expected (90%). In order to ensure that the success of biological control is sustained, there is a need to improve other farm factors such as general farm hygiene in order to argument the control of mites. Thus, if the extension services educate farmers to improve their coconut farms, there will be increasing benefits over time as mites are reduced by predators.

4.2.7 Sensitivity analysis of NPV and IRR in relation to probability of research success

The Net present value of the investment was similarly subjected to sensitivity analysis upon changing the probability of success (Table 19). Again, the probability of success was varied from 20% to 100%. When the probability is assumed to be 20% of the NPV is US$ 34192 in Benin and higher in Tanzania at US$557788. When the probability of research success is increased to 40% the NPV increases by 100% in both Benin and Tanzania. When 60% and 80% probability success were used, the resulting NPV increased by 50% and 41% respectively in Benin and by 50% and 33% in Tanzania, implying that as the probability of success increases the NVP increases at a decreasing rate in both countries. Results in Table 20 show that even if the mites are controlled by 40% which is lower than 45% (half of our baseline assumption of 90% probability of research success) the investment will still produce positive net benefit.

Table 20: Net present value for different probability of success

	Benin				Tanzania			
Probability of success	NPV	Change in NPV	% change	IRR (%)	NPV	Change in NPV	% change	IRR (%)
20%	34192	-	-	-0.05	557788	-	-	30.62
40%	68556	34364	100	5.69	1118822	561034	100	40.08
60%	103090	34534	50	9.32	1683103	564281	50	46.21
80%	145789	42699	41	12.06	2250630	567527	33	50.87
100%	172673	26884	18	14.13	2821403	570774	25	54.65

4.2.8 NPV and varying discount rate

Sensitivity analysis was also done for the NPV in relation to the discount rate as summarized in Table 21. The percentage decline in NPV when the discount rate is reduced from 20% to 12% is about 61%. Decreasing the discount rate from 15% to 12% causes a 30% increase in NPV. Decreasing the discount rate further increases the net present value even more. These results clearly demonstrate that even if the interest rate is set much higher than the base case (12%), the NPV will is still positive, indicating that the investment for biological control of coconut mite is economically viable.

Table 21: NPV and varying discount rate

Discount rate	Benin			Tanzania		
	NPV	Change in NPV (US$)	% Change	NPV	Change in NPV (US$)	% change
12%	207721	-	-	2535611	-	-
15%	144349	-63372	-30	1762004	-773607	-30
18%	101996	-42353	-29	1244995	-517009	-29
20%	81622	-20374	-19	996296	-248699	-19

These findings provide consistent evidence to confirm the general hypothesis that biological control of coconut mite is a viable technology. Sensitivity analysis shows that the results remain robust even when the discount rate is raised up to 20%, which is higher than that of the market rate. Similarly the investment remains viable in two countries even when the probability research is reduced to 80%, at which point the IRR is 12.06% in Benin, equal to the accepted discount. While research on biological control is important, addressing other production constraints is of immense importance. Together, these results suggest that if the governments and other stakeholders support the revival of coconuts farms and put in place adequate measures to ensure sustainability of this process, the welfare of all actors within the coconut sub-sector could be improved.

In the previous chapters it was pointed out that while the economic surplus method is an effective tool for assessing research benefits, it generally ignores transaction cost, which results in overestimation of benefits accruing to value chain actors with high transaction cost while underestimating those of low cost actors. As such this study aimed to supplement the consumer surplus approach with the coconut marketing chain analysis as presented in the next sections.

4.3 Coconut Market Chain in Benin and Tanzania

Ras and Vermuelen (2009) assert that within a market chain there is a clear distinction between actors and others who may be involved as service providers. Actors include all those who actually participate in the product transaction; producing or buying from one level and selling to the next level. Each actor therefore occupies a specific node in the market chain. Well developed value chains are characterized by; coordination, transparency, fairness, efficiency and rigor in pursuing commonly agreed objectives (Ras and Vermuelen, 2009). In the context of coconut value chain in Benin and Tanzania, interactions between these actors are shaped by enabling services, as well as enabling policies and institutions as they are mapped in Figures 10 and 11.

In both countries more than 90% of the coconuts produced are marketed in their raw form as fresh nuts, of which the largest amount is used for domestic consumption, either directly as food or indirectly as oil. In Benin about 60% of coconuts produced are consumed domestically as fresh coconuts, 5% are used for oil making while 35% of fresh coconuts are for export. In comparison, 96% of the nuts produced in Tanzania are consumed locally as fresh coconut, less than 4% is used in small scale oil processing, and a very small proportion is exported (Kwaku, *et al.,* 2010). Effective use of coconut products and by-products is an essential part of developing a vibrant coconut value chain. This could be achieved through transforming the whole coconut into other high-value products. The more processing a product undergoes, the higher the value addition it accumulates.

4.3.1 Description of coconut marketing chain actors

The coconut sub-sector in Benin and Tanzania consists of farmers, nut collectors, wholesalers, processors, retailers and consumers. The composition of the value chain is summarized in Table 22, and repeated in Figures 10 and 11. Smallholder farmers, who cultivate 2-3 ha constitute the largest part of the coconut marketing chain, being more than 88% and 90% of the chain actors in Benin and Tanzania respectively (Table 22). The annual production of coconuts ranges between 1868 and 28 000 nuts/year/farmer in Benin and 1200-52 000 nut/year/farmer in Tanzania.

Table 22: Primary coconut value chain actors in Benin and Tanzania

Primary Actors	Description of actors in Benin	Description of actors in Tanzania
Producers	• Mostly small scale (6-3ha) producers (>88%) • Few medium and large (> 3 ha scale (2%) • Production (1,868-28,000 nuts/year on average)	• Mostly small scale (0.6-3ha) producers (>90 %) • Few medium and large (> 3 ha) scale (1%) • 1200-52,000 nut/year
Collectors	• Collect nut from farmers and sell to traders • <4% of total chain actors	• Collect nut from farmers and sell to traders • Normally local people (9%)
Wholesalers	• Buy from farmer through brokers and export coconut to Nigeria • 2% of the 60% sold in Benin	• Work between urban market and production area, • Constitute about 400 traders in Tanzania
Market brokers	• Act between wholesalers and retailers both at the farms and market areas	• Distribute the load to retail buyer and normally work in the market area
Retailers	• Buy direct from farmers • Sell in the local markets • Sell to exporters to Nigeria • 2%	• Sell few nuts compared to wholesalers • Sell to individual consumers • About 1500 traders Tanzania
Oil processors	• Small facilities to manufacture oil, candy, etc • Buy from retailers or wholesaler • <1% of chain actors	• Small facilities to manufacture oil, soap, animal feeds etc • Buy from retailers or wholesalers • Buy left over nuts (normally broken nuts) from wholesalers in the market places
Consumers	• Buy their nuts from both farmers and retail markets	• Buy their nuts from retail markets and farmers
Coir processors	• Buy coir from retailers, to make handicraft, carpet and rugs, • <1%	• Buy coir from retailers in urban markets to make handicraft, carpet and rugs)

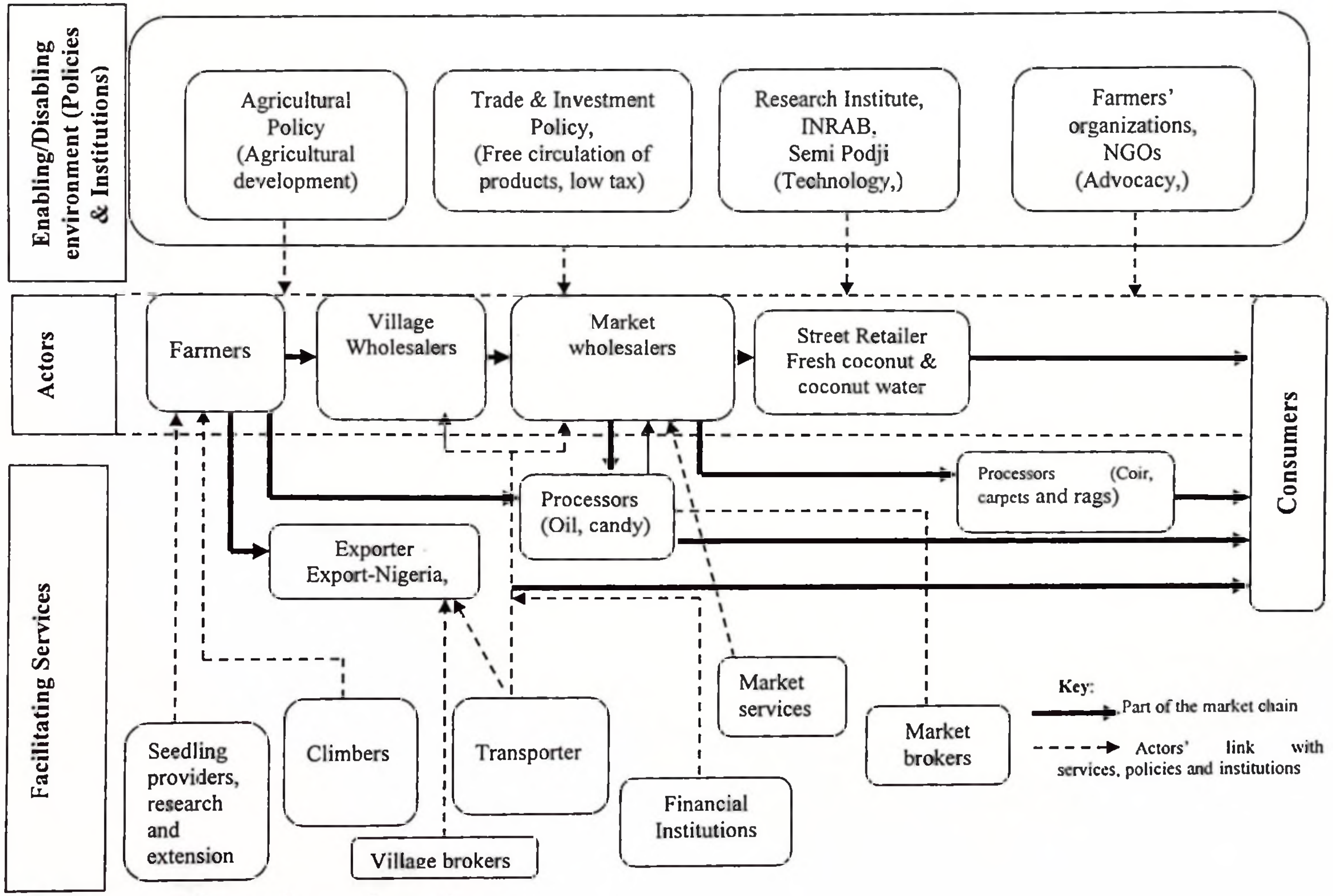

Figure 10: Coconut value chain map in Benin

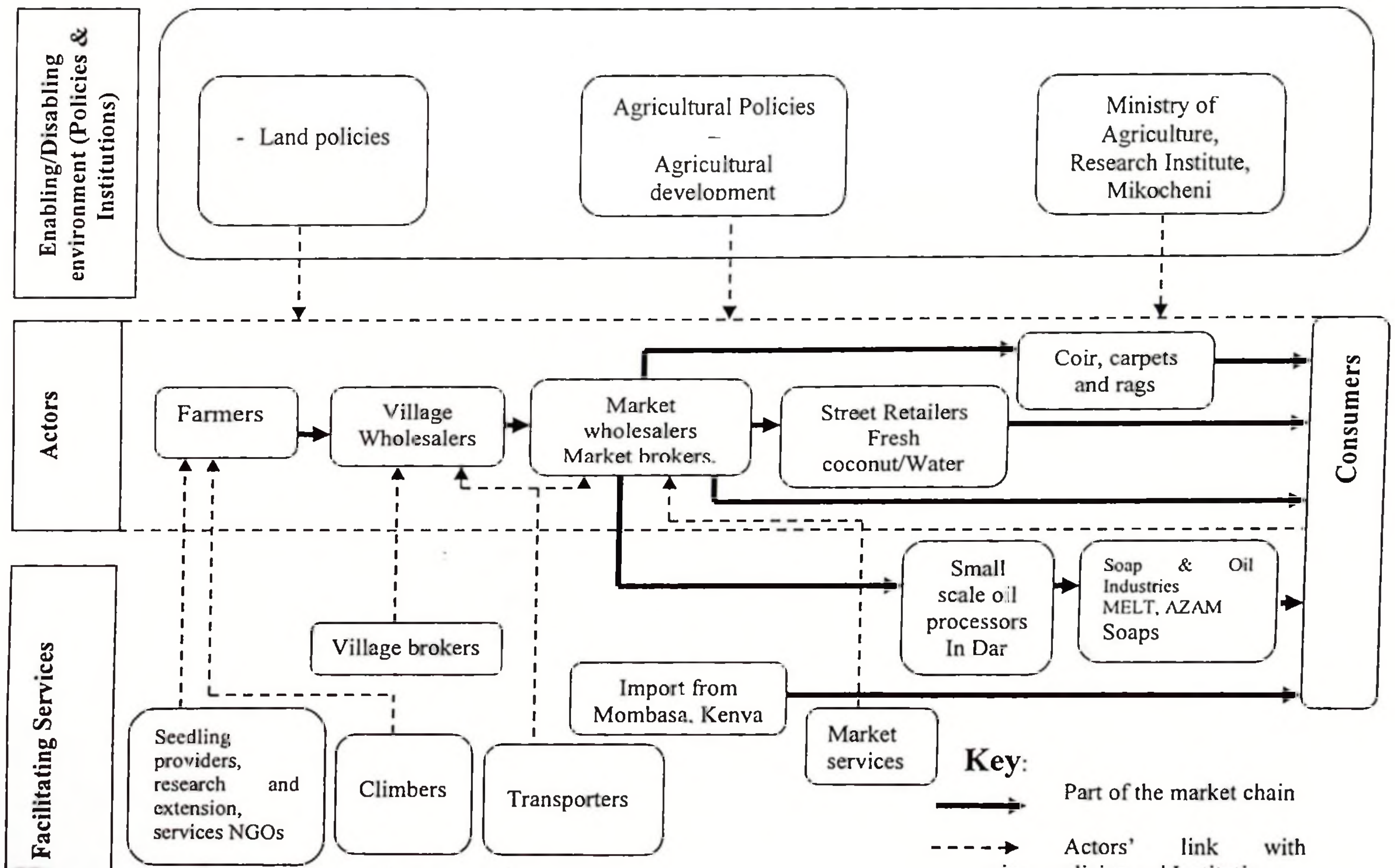

Figure 11: Coconut value chain map in Tanzania

4.3.2 Description of enabling/disabling services

In both Benin and Tanzania there is no formal coordination between coconut wholesalers/traders and farmers. Local traders interact with farmers providing the link with traders in urban centres or processors. The service providers for the coconut marketing chain in Benin and Tanzania are similar (see Figures 10 and 11). These services providers include government research and extension services, climbers, transporters and market brokers. Government research and extension services aim at increasing coconut production through development and dissemination of different technologies. As mentioned earlier, the village wholesalers normally buy coconuts through village brokers and assemble them in large piles for de-husking. This process is usually done by casual labourers who may also be climbers. De- husked nuts are then transported to the markets through trucks. Traders often use the same hired labour to load coconuts to the trucks. Upon reaching the urban markets offloading, sorting and grading operations are done by casual labourers. From this point coconut are then given to coconut market brokers for sale to market wholesalers or retailers.

Financial services are often provided by the traders directly or through their intermediaries. In Benin, these are usually members of groups such as Coconut Traders Association (e.g. Oukouihoue, Hounsoukoue Dogbadji, Togbin Idaho, Fidjrosse- Benin). In Tanzania traders often belong to Coconut Traders SACCOS in each market (e.g. Temeke, Ilala, Ngamiani, Kariakoo and Buguruni) where they can borrow money for their business. Some of these established traders may also get credit from commercial banks. Although commercial banks do not directly work with traders in Benin, they facilitate the transfer of money for coconut traders from Nigeria to Benin, thus facilitating easy trading.

4.3.3 Policies and institutions

As shown in Figures 13 and 14, there are several policies and institutions which create an enabling environment for developing the coconut value chain in Benin and Tanzania. As discussed in chapter two of this study, In Benin there are several success stories on the implementation of agricultural policies to improve coconut production and marketing. Through the national agricultural policy the government of Benin in collaboration with the CONGENT progamme has initiated the revival of coconut plantations. During recent years, there has been substantial extension of the area under coconut as farmers have adopted new hybrids (PB 121 and PB 111) from Seme-Podjo research station. The expansion rate has been estimated at 100 ha per year, along with a fair amount of the West African Tall (WAT), which is less productive compared to the hybrids. But the availability of hybrids to farmers is limited. Moreover, implementing the Trade and Investment Policy in Benin has encouraged cross border trading of coconuts, which has in turn increased the share of coconuts exported, thus expanding the market. Reduced restrictions on the movement of agricultural goods from Benin to other countries have increased producer prices for coconuts farmers as well as for other crops.

In Tanzania, the National Agricultural Policy is implemented under the Agricultural Sector Development Strategy (ASDP) and the KILIMO KWANZA resolution which addresses all issues related to agricultural development. The present policy emphasis is to expand production of domestic food and cash crops for ensuring food security and export crops for increased earnings. Under this policy, the Government of Tanzania adopted ASDS which sets the framework for achieving the sector's objectives and targets. This approach for enhancing the sector, it is believed, will help boost agricultural productivity which will impact positively on the reduction of poverty in the country (ESRF, 2010). Even though the coconut is the main cash crops in the coastal belt of Tanzania, the coconut production has declined during the last 10 years since 2000s (Oleke *et al.*, 2010). The coconut sub-sector has been characterized by many under-funded, short duration projects which could not generate sustainable impact (Kullaya *et al.*, 1999). To date, research and extension services for oil crops have been low leading to poor performance of the oilseed sub-sector including coconut (Kullaya *et al.*, 1999). The coconut as an orphan child lacks a sustained roadmap for growth and development in Tanzania. While other cash crops have regulatory bodies to oversee their development, coconut seems a neglected crop despite its contribution to the livelihood over 20000 farm families. Besides policy related challenges the sub-sector also faces other disabling challenges such as drought, pests and diseases as well as those related to marketing as previously discussed in section 4.6.

4.3.4 Coconut marketing in Benin

It is estimated that about 35% of coconuts produced in Benin are exported to neighbouring countries. Another 65% are traded domestically to the markets around the country (Appendix 5). There were up to 212 traders who are involved in coconut wholesaling and more than 400 are retailers countrywide. Normally farmers sell unhusked coconut to retailers or wholesalers who pay for de-husking. The wholesalers collect nuts from farmers through local collectors. At urban markets, the wholesalers in turn commission local market brokers who sell to retailers. There are wholesalers who buy large quantities from local traders and sell to the Nigerian markets (see Figure 14). These wholesalers hire transporters through brokers. Most of the Nigerian buyers who travel to Benin work for trading companies in Lagos and other Nigerian major cities such as Jos, Abuja, and Kano. The Nigerian market now absorbs more than 35% of coconut sold in Benin (Kwaku *et al.,* 2010). While in Benin the Nigerian buyers use local intermediaries who purchase and compile the coconuts from local traders who, in turn buy from farmers, moving from commune to commune. The Nigerian traders normally offer higher prices than local buyers. They also cover the cost of de-husking and transportation to their warehouses, which enables them to fill their trucks much quickly, hence a faster turnover of their capital. The coconuts are then shipped in trucks within Benin to the Nigerian border, where they are transferred to vehicles that take the shipments to Lagos and different destinations in Nigeria. From Lagos and other big cities such as Kano, the nuts are redistributed further to smaller towns where they are sold to retailers, local processors, and finally to consumers. Some of the coconuts imported into Nigeria are sent to Kano, where they are sold for consumption throughout northern Nigeria and in neighbouring Sahel countries.

Domestically the marketing channel in Benin is made up of various individuals who handle fresh coconut as it moves through the marketing processes. As mentioned earlier in this chapter fresh coconuts that are marketed in big towns are generally passed through six groups actors along the distribution chain of as shown appendix 5. Retailers obtain fresh coconut supply from the town wholesalers who assemble fresh coconut in the towns from the village wholesalers/collectors. Larger portions of coconut supply come from village wholesalers who assemble and transport fresh coconuts from the farmers.

Small scale coconut oil processing in Benin is carried in rural and urban areas, within the coconut producing communes. Small scale processing of coconut oil is limited to approximately 4500 litres per year. These companies are run by small entrepreneurs often poor extraction equipments. They contribute to about 9% of the oil from oil crops in Benin (Kwaku, *et al.*, 2010). Besides coconut oil, different other products can be made from coconuts. However, these possibilities have not been explored. For the coconut industry to be developed, full use should be made of all the by-products including converting the husk into coir and fibre dust (coco peat), which can be used as a potting medium. The coir can also be utilized for making mattresses and car seats. Shells can be converted into activated charcoal or flour, which are used as filler in mosquito destroyer agents. These products are however not produced in Benin.

4.3.5 Coconut marketing in Tanzania

In Tanzania the primary actors in the coconut sub-sector include farmers, traders and oil processors (Figure 14). As mentioned earlier, coconuts are mainly produced by small holders (>90%) cultivating about 0.6-3ha. Medium scale farmers cultivate 4-

10ha while large scale farmers owning more than 10ha account for only 1% of all the farmers, and they cultivate about 10% of the area under coconut production.

The wholesalers, directly or through village agents collect nuts from farmers, transport the nuts to urban markets where they commission market brokers (*Dalali*) to sell their consignment to the retailers. Market brokers sometimes become retailers and sell coconut to consumers. Within the larger wholesale markets such as Temeke Sterio, Kariakoo, Ilala, Buguruni (in Dar es Salaam), Morogoro, Tanga and Moshi there are brokers who receive the load of produce (on credit) and sell it on to retail traders. These brokers know each other, working closely such that they form a cartel which makes it difficult for new comers to enter. There is little transparency in the trade, which put farmers at a disadvantage.

It is estimated that there about 400 coconut wholesaler and about 1500 retailers who operate in urban markets in Tanzania (Personal communication with Ilala Market Authority, in Dar-es-Salaam Tanzania, 21/22/010). Wholesalers and brokers are often judged negatively by farmers since they manipulate weights and measures, mislead farmers and monopolize market information. Although their practices are sometimes dubious, they also take huge risks and perform important market functions such as: (i) linking buyers to farmers, (ii) delivering money to farmers and (iii) bulking and transporting loads of goods to urban centres. In their business traders sometimes get windfall profits but sometimes they make huge losses when transport facilitates break-down or when there is a quality loss. For them to survive in the business their gains must exceed their losses on average, hence the secrecy in their transactions so that when windfalls come their partners in the chain will not know and claim a share of the gains. If consumers had to deal directly with producers, the transaction cost would be very high.

From Tanzania, a small proportion fresh coconut have (about 10 000 tons per year) regularly been exported to the Comoro Islands. Nonetheless, as noted earlier, most of the produce is used locally for domestic use and for limited processing into oil. Discussions with coconut traders in the study area revealed that the volume of exported coconut has decreased during recent years due to low production. To fill the gap traders from Mombasa (Kenya) have seized the market opportunity and are now selling coconuts to Tanzania in major urban centers such as Dar-es-Salaam, Mwanza, Dodoma Arusha, Kilimanjaro and Zanzibar.

In Tanzania, small scale coconut oil processing is similarly carried out in the rural areas and urban centres. This is normally done by individual entrepreneurs. For example there are about 12 groups of people who process coconut in Dar es Salaam, producing up to 10 of crude coconut oil per month. This is sold to oil and soap industries such as the East and Coast Oil, and the Fats Industries a subsidiary of Mohamed Enterprise Ltd. Coconut oil processing groups are also found in Tanga and Lindi. The coconut research station in at Chambezi at Bagamoyo also has a small processing plant for research and training purposes. Improved extraction techniques are very important. Inexpensive equipments which are easy to operate can enable a wide range of processors in rural and urban areas to participate in value addition such as processing and benefit from it.

4.3.6 Distribution of benefits along marketing value chain in Benin and Tanzania

Most of the marketing activities performed in the chain involve exchange functions including; buying, selling, wholesaling and retailing. These go hand in hand with physical functions that include transportation, storage, processing and packaging as well as facilitating functions such as sorting, grading and financing. These activities add value to the product as indicated by the increasing prices when products move from lower to higher stages of the market chain. The marketing functions create value in terms of place, time, form and possession that provide utility to consumers. Marketing shares for fresh coconut trading between rural and urban areas of Benin as well as with neighbouring countries are summarised in Table 23. As described earlier, the coconut marketing chain starts with a farmer selling coconut to village wholesalers/broker. Urban wholesalers then buy from rural wholesalers. These either sell to urban areas in Benin or Nigeria. Farmers constitute the largest number of actors but they hold the lowest market power as they get only a small share of the prices paid by consumers. In Benin a farmer receives only 17% of the consumer prices per kilogram of nuts while village wholesaler, urban wholesalers and urban retailers combined get the remaining 83%. If farmers are sold coconuts directly to urban consumers, they will get about 85% of the consumer price (Sanoussi, 2005).

Farmers who can make their own deliveries to the Nigerian collection points stand to gain higher margins, but they also become exposed to more risk and their average cost are expected to be higher because they are handling smaller quantities.

Farmers are unable to add value to their products and to reach higher level markets. Consequently, they receive low prices for their products which provide limited incentives for improving farm productivity. Similar findings were reported by Pabuayon *et al.* (2009) who notes that coconut farmer's participation in marketing activities in the Philippines is quite limited, accounting for only 11% of the marketing share, and only at the lower marketing end of the chain. Often, they sell only the raw nuts (husked nuts or copra) for which receive the lowest price compared to other market participants.

Table 23: Cost, margins and share of total value added for fresh coconut marketing chain in Benin

Market participants/value addition	During the season		Off-seasons			Country average		
	FCFA/1kg[8] (a)	Margins as % of selling price (b)	FCFA[9]/1kg (c)	Margins as % of selling price (d)	Average buying price (e)	Average selling price (f)	Marketing margins g=(f-e)	% share of total value added h=(f-e/2600)
Farmers								
Selling price	21	-	48		-	34.5	-	17%
Village wholesalers		-		-	-	-	-	-
Buying price	21	-	48	-	-	34.8	-	-
Selling price	90	-	100	-	95		60.2	32%
Cost of handling		-	-	-	-	-	-	-
Transport	20		20	-	-	-	-	-
Net margin	49	54%	32	32%	-	-		-
Urban wholesalers		-			-	-	-	-
Buying price	90	-	100		95	-	-	-
Selling price	150	-	170		-	160	66	35%
Cost of handling		-			-	-	-	-
Handling	20	-	10		-	-	-	-
Transport	20	-	25		-	-	-	-
Total cost	130	-	135		-	-	-	-
Net margin	20	13%	35	20.5%	--	-		-
Urban retailers		-			-	-	-	-
Purchase price	150	-	170		160	-	-	-
Selling price	180	-	200		-	190	30	16%
Cost of handling		-			-	-	-	-
Transport	5	-	5		-	-	-	-
Handling	10	-	5		-	-	-	-
Variable cost	2	-	10		-	-		-
Net margin	13	2.2%	10	5%	-	-		-

[8] 1kg of coconut = 4 nuts
[9] Exchange rate at the time of data collection, 1US$=500 CFA franks

The supply of coconut in Tanzania also follows a seasonal pattern depending on the rain. The peak seasons falls between June and December for both countries. As expected the prices cycle follows a reverse pattern. Prices continue to decline from January to June. During this period processors find it profitable to engage in coconut trading to feed their processing plants, standing out as the main buyers. During the peak periods imports from Kenya to Tanzania decline.

Table 23 presents the marketing chain of fresh coconut in Tanzania. Each segment of the market chain has corresponding cost and margins, depending on the trading arrangement. Estimated figures for cost and related margins therefore provide a snapshot of trading during the peak season when most of the coconuts are harvested. Another snapshot represents trading during off-season when fewer nuts are harvested. As shown in Table 23 all traders in the chain earn high shares of marketing margins. The overall net margins vary significantly between different types of traders. For instance for urban wholesalers' turnovers are much higher than those of village assemblers and urban retailers. Generally in terms of gross margins (the difference between purchase and selling price), traders tend to benefit the most but the traders also require higher operating capital and they bear more risk, which is then imputed as part of the cost. For instance they have to deal with corruption at unscheduled and scheduled road blocks, breakdown of vehicle, and loss of money from dishonest intermediaries.

The current distribution of sales shows that a coconut farmer in Tanzania farmer receives only 8% of the prices paid by final consumer while traders (village assemblers, wholesalers and retailers) receive the remaining 92% of the share) of the price paid by final consumer for one kilogram of coconuts. Based on this analysis it is clear that farmers' share of the consumers' price is quite low which translates to low farm income. Since the majority of coconut farmers operate small farms, and they face low farm productivity, they therefore have low marketable surplus. Consequently, their income from coconut production tends to remain low. Any programme which increases production and addresses marketing challenges should have a positive impact not only on farmers but also on all coconut chain actors.

Table 24: Cost and margin within the fresh coconut marketing chain in Tanzania

	During the season		Off-seasons		Country average			
	Tsh[10]/1kg[11] (a)	Margins as % of selling price (b)	Tsh/1kg (c)	% of selling price (d)	Average buying price (e)	Average selling price (f)	Marketing margins (f-e)	% of total value added (f-e/2600)
Farmers								
Selling price	200	-	450	-		325	-	8%
Village assemblers/Large cellectors	-	-	-	-	-	-	-	-
Purchase price	200	-	1200	-	700		500	19%
Selling price	400	-	2000	-	-	1200	-	-
Cost	-	-		-	-	-	-	-
Transport	20	-	20	-	-	-	-	-
Net margin	180	45%	780	39%	-	-	-	-
Urban wholesalers	-	-	-	-	-	-	-	-
Purchase price	400	-	2000		700	-	-	-
Selling price	1200	-	2800			2000	1300	50%
Cost	-	-		-	-	-	-	-
Overhead	30	-	30	-	-	-	-	-
Transport	20	-	20	-	-	-	-	-
Total cost	70	-	70	-	-	-	-	-
Net margin	750	63%	1080	39%	-	-	-	-
Urban retailers	-	-		-	-	-	-	-
Purchase price	1200	-	2800	-	2000	-	-	-
Selling price	2000	-	3200	-		2600	600	23%
Cost	-	-	-	-	-	-	-	-
Transport	70	-	40	-	-	-	-	-
Other cost	20	-	20	-	-	-	-	-
Variable cost	90	-	90	-	-	-	-	-
Net margin	710	36%	220	7%	-	-	-	-

[10] Exchange rate at the time of survey was TSH 1230/US$

[11] 1kg of coconut = 4 nuts

4.4 Share of Benefits for Consumer Surplus Model and Marketing Chain

The relationship between consumer and producer has traditionally been conceived of as an exchange relationship in which each party trades one kind of value for another (Bagozzi, 1975). In this study, we focus on the exchange relationship between an end user (such as a person buying coconut product for home use) and the arrangement from which this end user buys a product or service (traders). Before an end user buys a product, a series of transformations are usually applied to to enhance its value and therefore make the product or service usable by consumers (Humphreys and Grayson, 2008). The distinction between exchange value and use value underlies the traditional definition of producer and consumers where a producer is defined as a person, company or country that makes or supplies goods or commodities for sale. A consumer on the other hand uses such commodity, exhausting its exchange values (Baker, 2006). For this purpose, farmers and all traders that engage in supplying coconuts are defined as producers. Only the end users are defined as customers as summarized in Table 25.

In Table 22 results the consumer/producer surplus model are discussed along with the distribution of the consumers' expenditures to different producers along the coconut market chain. Currently there is no established theory to compare the two concepts. This analysis is presented to compare current and future distribution of the benefits in the coconut market chain. Current benefits are presented as the margins and market shares along each node of coconut market chain, while future benefits are the results of surplus due to biological control of coconut mite. The aim is to identify how equitable the market chain is. While biological control is expected to result into increased production, coconut market chain actors may not benefit if the chain is not equitable. While the consumer surplus analysis results indicate that both producers and consumers will benefit from biological control of coconut mite through increased production and a decline in coconut prices, the distribution of consumer's share along the marketing chain shows that consumers are at the losing end due to low prevailing prices.

Table 25: Share of benefits for consumer surplus model and marketing chain

Country	Marketing chain participant	Consumer surplus model (% share of benefit)	Marketing chain (% Marketing share)
Benin	**Producers**		
	Farmers		17%
	-Rural traders	100%	32%
	-Urban wholesalers		53%
	-Retailers		16%
	Sub-total	100%	100%
	Consumers	-	-
Tanzania	**Producers**		
	Farmers		8%
	-Rural traders	76%	19%
	-Urban wholesalers	-	50%
	-Retailers	-	23%
	Sub-total	76%	100%
	Consumers	32.5%	-

In Benin for example while the simulated consumer surplus model shows that the biological control of coconut mite will benefit only producers, the coconut marketing chain shows that farmers gets only 17% of the prices paid by consumers. This means currently, a big share of benefit goes to intermediaries (traders). Meanwhile, simulated estimated benefits in Tanzania show that producers will get 76% of the total economic surplus (Tables 16 and 17). However, currently they only get only 8% of the prices paid by consumers while traders share between them 82% of the price paid by consumers (Table 24). In order to close the gap between what farmers get compared to traders there should be deliberate efforts to bring fairness along the coconut marketing chain. The marketing power of farmers lies in their consolidation and organization so that they are able to negotiate with other market actors as well as with government institutions in order to move up in the value chain. This calls for improved collaboration through platforms of stakeholders involved in coconut development so that this can be realized. The pressure and drive should ideally come from farmers. Often, however the challenge is to develop their capacity so that they play an active role to engage in value addition and maintain the needs of the market.

Although farmers both in Benin and Tanzania are currently getting a small share of the prices paid by consumers, there are several potentials that can be used to benefit all the market chain actors equitably. Benin and Tanzania could also learn from other countries where the coconut sub sector is more advanced. In the next section, these avenues for developing coconut the subsector are discussed,

4.5 The Potential for Expanding Coconut Sub-sector

There is a wide range of coconut products to be developed through value addition. In Benin for example, the domestic market and regional prospect for coconut products and by-products is bright as evidenced by the use of copra in the diets (Adje, 2000). The demand for coconut oil is increasing due to use of coconut milk in ointment manufacturing. Moreover, the market potential in high and rising in Nigeria for coco chemicals also presents better opportunities for sub-sector development. These products can be used in various applications such as soaps and detergent production in Benin and in neighbouring countries such as in Nigeria. Hence, increasing coconut production and value addition would benefit all actors along the coconut marketing chain.

Table 26: Potential industries for coconut processing in Tanzania

Name of factory	Factory capacity	Potential Market	Employment capacity
The East coast and Fats Ltd, Dar es Salaam, Tanzania	750 MT of crude palm oil per day	East and Central Africa	More than 500 workers
The proposed Coco peat factory, Pangani, Tanga	Transformation of 16 million coconut husks into 4320 MT of coir mixed, peat and fibre. 1920 MT of fibre in bales, yarn and retting.	Tanzania, Kenya, South Africa, Holland, France and China	170 workers and staff
Mikuni Milling Co. Ltd, N'gombeni Coconut Plantation, Mafia Island, Tanzania	Transform 10MT of coconut per year to 200MT of crude oil Manufacture 15MT of soaps	Tanzania, Kenya, Uganda, Rwanda and Burundi	300 workers and staff
Bakhresa Group of Companies	Natural Coconut Cream in 65ml aseptic tetra-pack	Tanzania, Kenya, Uganda, Rwanda and Burundi	-

In Tanzania domestic demand for coconut oil is similarly increasing due to the high content of lauric fatty acid in coconut oil. There is also a growing market potential for coco chemicals that are required by oil and soap industries in various applications such as soap and production of detergents. For example, Mohammed Enterprises in Tanzania Ltd (METL), the largest agricultural manufacturing firm in Tanzania invested $25 million to put up in Dar es Salaam an oil refinery plant (http/www.metl.net). The East Coast Oils and Fats Ltd., a subsidiary wholly owned by METL, has capacity to process 750 MT of crude palm oil per day, the largest plant of its kind in the region. Another potential market is based on utilizing the coconut husks. Coco peat is still imported into the country for use in the horticultural industry. A feasibility study by Mikocheni Agricultural Research Institute (MARI) in 2007 on coco-husk processing in Pangani district (Tanga region) revealed great potential for utilizing the many husks piled up in rural coconut growing areas (Table 25).

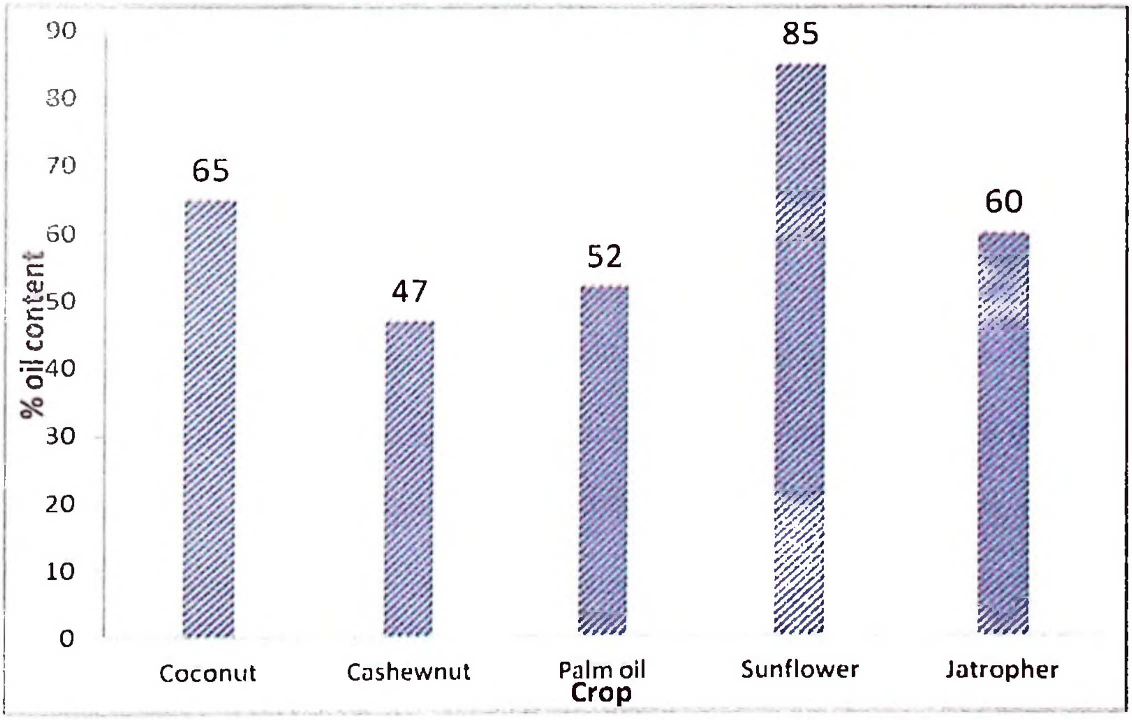

Figure 12: Comparison of oil sources

Source: Foerster *et al.* 2005

Apart from its oil, the coconut is an important crop which can be used for bio-fuels production, along with oil palm, sunflower Jatropha, cashew nuts and peanuts. Figure 12 presents the position of coconut (represented by palm oil) among a variety of important oil crops which could potentially be used for bio-fuels production. Thus, strengthening extension service for coconut cultivation would enable farmers to benefit more if the bio-fuel industry was to take hold or get established. However, fuel in faces many challenges. As the commercial potential of marginally productive rural lands increases in Tanzania due to growing interest in bio-fuels, the risk of large-scale dispossession of customary lands belonging to farmers and pastoralists increases. Out of 8,000 hectares of land for bio-fuel crops, some 1,705 hectares have been leased to investors for bio-fuel production and the aim of investors is to own 4,000 hectares for bio-fuel potential crops in Tanzania[12] creating tensions between them and local people (Kitundu, 2011). Despite these obstacles, the government could formulate guidelines and policies which will ensure equitable land distribution among both investors and local people, while ensuring food insecurity is addressed.

In developing the coconut subsector Benin and Tanzania could learn from other countries where the subsector is more advanced. There is a wide range of coconut product to be developed through value addition including coconut water, copra and coir. For instance coconut water is presented in a form that attracts high demand at strategic points along beaches through Central America and Asia. In Brazil Zico and Coco Vita companies have launched aseptically packaged pure green coconut water drinks that sell for up to US$ 4 each (300 ml). The two companies have been bought by coca Cola and Pepsi Cola and are now in the process of rapidly increasing production of coconut water (Landell, 2005).

[12] A study conducted by a team of experts from Sokoine University of Agriculture (SUA) in six districts including Kisarawe, Rufiji, Lindi, and Kilwa in Tanzania on biofuel production reveals while farmers benefited from these investment, one crucial issue is the country allowed investment in area blindly without proper policies protecting locals from land loss (Kitundu, 2011).

International trade in copra is quite small since major coconut growing countries process their own production. However, some of the smaller producers—especially in the Pacific—export copra through a few trading companies for onward sale to oil processing industries in Japan, Germany, Singapore and South Korea (Landell, 2005). Success of many firms within the coconut subsector in these countries has come following efforts to promote commercial production for a wide range of products from coconut. This has been supported by consistent investment in research to support good crop husbandry and renovation of old plantations Research has also worked closely with companies to develop new products for the market (APCC, 2010). These lessons can be emulated and adapted for Benin and Tanzania.

4.6 Summary of Findings

Apart from policy related challenges the coconut subsector faces other disabling factors that range from production to marketing. Among major disabling factors of the coconut subsector is the decline in production due to coconut mite attacks. The ccoconut mite has been reported to cause great losses to farmers and to the coconut industry worldwide. The mite kills coconut seedlings by feeding on growing tips leading to; decreasing yield of coconut which leads loss of income, food insecurity and poverty for farmers and other participants in the coconut market chain. Estimated losses in copra yields resulting from coconut mite damage have been estimated at 40% in Benin and 10–100% in Tanzania, where the average is 21%. The corresponding loss of income for coconut growers are 50% and 30-50% in Benin and Tanzania repectively. A wide range of chemicals and good plant husbandry practices have been recommended to control the mite over the past two decades but the results have not been satisfactory. Biological control is presented as alternative method of controlling coconut mites to address problem of declining coconut productivity and declining production in the two countries be potential for replication in other countries. The study sought to provide empirical evidence regarding the benefits of biological control of coconut mite among smaller-farmers in Benin and Tanzania. The economic impacts of the biological control intervention was analysed using an *ex ante* consumer surplus model, supported by market chain analysis.

The study established that the economic surplus resulting from agricultural research expenditures was positive and substantial for every year during the twenty year duration of the simulation. Biological control is expected to produce a welfare gain of US$155 213 in Benin, all accruing to producers. In Tanzania producers are expected to capture 76% of the benefits, amounting about US$ 2535 611. Consumers will capture the remaining 24% equivalent to US$ 811 395 out of the total benefits (US$ 3347 006) resulting from the investment. In both countries, figures on the distribution of benefits, provide strong empirical evidence in favor of the first null hypothesis, which stated that; "there is a net increase in economic surplus resulting from the introduction of biological control of coconut mite." For Benin, the project will be beneficial since the IRR is estimated at 13.21, which is higher than the discount rate of 12%. The results also show that the IRR values for Tanzania are higher (52%) than the discount rates of 12%, normally used for evaluating government funded projects. These findings indicate that for this project to be beneficial it should be successful by more than 80% in Benin, whereas in

Tanzania even at 20% probability of success the IRR is still higher than market discount rate. The difference in IRR up on changes in probability of research success is Benin and Tanzania is due to the fact that the extent of damage of the coconut crop due to coconut mites, lethal yellowing and other problems was much higher in Tanzania such that the control measures following biological control will bring higher marginal productivity gains and hence higher returns compared to Benin.

The second null hypothesis stated that; "the Net Present Value (NPV) of the biological control programme is greater than zero over the time horizon considered" The findings show that the NPV for Benin is US$ 207 721 for a discount rate 12 % while that of Tanzania is US$ 235 611, both being significantly greater than zero. When the IRR is varied from 12% to 20% the NPV remains positive. Likewise when the probability of research success is decreased from 100% to 20% the NPV decreases from US$ 172 673 to US$ 34 192 for Benin and from US$ 28 211 403 to US$ 557 788 for Tanzania. Based on these findings we fail to reject null hypothesis that the NPV is positive for the duration of this project. Several other studies on biological control (Bokonon-Ganta, 2002; Pingali *et al.,* 1994; Manyong *et al.*, 2000; Douthwaite *et al.*, 2001; Coulibaly, 2002; Neuenschwander *et al.,* 2008), similarly established that spending in agricultural research and extension yields some of the largest returns on investment compared to spending resources in other sectors of the economy. These findings have established IRR ranging from 186% to 244%. Other studies such as Kristnsons *et al.* (1996) on potential benefits of control and returns to research of African animal trypanosomosis established IRR of 50%. The study by Manyong *et al.* (2004) reported an IRR of 186-244 on nutrition and health benefits of bio-fortified cassava roots in Nigeria. In Tanzania, Isinika (1995) established IRR of 32% from investing in crop research in Tanzania.

However, economic surplus techniques do not provide information regarding the distribution of benefits among different groups of consumers and producers. While analysis of IRR and consumer surplus demonstrate significant positive returns, but the benefits are skewed towards producers, especially in Benin. Analysis of the marketing chain shows that in Benin farmers get only 17% of the prices paid by consumers. The farmers' share of the consumer price is much lower in Tanzania being only 8%. Thus, 83% of the consumer prices in Benin and 92% Tanzania goes to intermediaries (traders and transporters).

Under current marketing arrangements the corresponding net margins accruing to different actors also differ across the market chain. For example in Benin consumers pay 190 francs but farmers receive only 48 francs. This difference (142 franc) represents margins which are shared among other actors along the chain. Village assemblers receive 49 Francs as net margins per kilogram of coconut compared to farmers, urban wholesalers and urban retailers who get 20 Francs and 12 Francs representing (54%), 5%, 13% and 2.2% respectively. In the case of Tanzania, urban wholesalers receive higher net margins compared to farmers, village assemblers and urban retailers who get 200 TZS, 180 TZS and 710 TZS of the total margin representing 45%, 63% and 36% respectively. In order to close the gap between what farmers get relative to traders there should be efforts to bring fairness along the coconut marketing chain. This can be done through deliberate value chain methyl esters, tertiary amines, alkanolamides and glycerine. The East Coast Oils and Fats Ltd., a subsidiary wholly owned by METL, has capacity to process 750 MT of crude palm oil per day which could use coconut to produce these products. Another product with potential demand is coco peat which is used in the horticultural industry. This raw material is currently imported, but it could be locally produced using coconut remains. In addition there is potential of raising bio-fuel demand in the local market and for export. Currently bio-fuel from Meru, Bagamoyo, and Rufiji districts are being used on trial in Arusha.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study sought to assess the impact of biological control using natural predators of coconut mites in Benin and Tanzania, which are the leading coconut production countries in Africa. In particular, the study pursued the following specific objectives; (i) to estimate the total economic surplus expected from introducing biological control of coconut mite and assess the distribution of such benefits amongst producers and consumers, (ii) to estimate possible changes in the value of benefits of biological control upon changes of key variables including; the discount rate and the probability of research success, (iii) to assess the current status of the coconut marketing chain to identify key actors, service providers, institutional, policy environment, opportunities and constraints for developing the sub-sector. Market chain analysis helped to identify appropriate interventions to address prevailing problems, and (iv) to estimate the distribution of margins within the coconut marketing chain in Benin and Tanzania.

Benefits derived from biological control of coconut mite were measured as economic surplus of producers and consumers. By introducing into the model the annual flows of investments in research and development, indicators of social gains such as the net present value (NPV), internal rate of return (IRR), and the cost/benefit (C/B) ratio were estimated using DREAM software. In addition, the market chain analysis was performed in order to get a better understanding of connections between actors and processes in a value chain. The analysis involved market mapping core processes, actors, flow of products, as well as and services providers. Analyzing cost and margins along the market chain also provided measure of how pro-poor/equitable the chain was.

Results of simulated computations of the IRR and the NPV show that the investment in biological control of coconut mites will be beneficial in Benin and Tanzania. The benefits in are more substantive in Tanzania where the coconut sub-sector has been more devastated from pests and diseases attacks. The results also suggest a positive relationship between programme-effectiveness measured in terms of NPV, IRR and net-gains which was expressed as producer and consumer surplus. Simulation analysis for Benin shows that producers will capture all the benefit from the research while in Tanzania producers will capture 76% compared to 24% for consumers. In the least optimistic scenario, the economy in Tanzania is expected to get a net-gain of US$ 3347 006, while Benin is expected to get net-gain of US$155 213. In Benin, which is analysed as a small open economy, increased coconut production is not expected to benefit consumers because the prices of coconut are not expected to decrease enough to be felt by consumers? Additional production following biological control of mites will go to export markets, maintaining a stable real price in the domestic market. The NPV of US$ 207 721 for Benin and 235 611 for Tanzania are positive demonstrating that investment is worthwhile. Apart from levels of devastation, differences in factors such as study area, land cultivated and number of farmers involved in coconut cultivation resulted into different distribution of benefits between Benin and Tanzania.

with other crops, renovation of these farms will also imply better farm hygiene and more output from the other crops as well.

For biological control to be successful there needs to be concerted effort to encourage collaboration between researchers, and extension systems (Hoffmann *et al.*, 1998). In North America, for example successful case studies have generally been projects where there has been external funding, researchers have studied the biology of the natural enemies, developed laboratory rearing protocols, transferred this technology to a producer for commercial scale production, and had small scale farmers willing to volunteer their farms for large scale trials (Glenister, 1991). This means, a successful area-wide biological control programme will require close partnerships among representatives from agricultural research and extension systems as well as the private sector. Benefits from Biological control may be of less important if farmers continue to grow low yielding coconut varieties. Thus, as initial gains of coconut control begin to be felt by farmers, research and extension services should have plans to support farmers to replant with higher coconut yielding varieties. Plans for area expansion as is already happening in Benin should also be planned and supported accordingly.

In addition to the consumer surplus model, this study also applied market chain analysis in order to understand how coconut marketing currently operates in both countries. These analyses determined the distribution of profit margins along the chains and identified points of inefficiency. The value chain maps showed that a wide range of stakeholders (actors, enabling environment and policies) are involved in activities from production, de-husking, assembling, packaging, transport, retailing to processing. However there is little coordination between these stakeholders both in Benin and Tanzania. The linkage between value chain actors is weak and informal. The actors simply meet at the market place to transact. There is no platform or responsible body that is working to foster effective and efficient linkage among chain actors as well as between them and service providers. The actors also lack any collective platform for leveraging their position with the institutional and policy framework. In Tanzania, there is some linkage among some actors. For instance market traders collaborate through their associations, and through credit and saving cooperatives. Out of 40 traders who were interviewed in Tanzania all belonged to such associations. Therefore such collaboration is often informal, therefore lacking legal basis for bargaining and leveraging. Sometimes these market traders collude and work as a cartel.

Results of this study have also established that while farmers constitute the largest number and proportion of actors, they hold the lowest market power as they get a small shares of the prices paid by consumers. In Benin a farmer receives only 17% of the consumer's price for one kilogram of coconut while traders share between them the remaining 83%. In Tanzania coconut farmers get only 8% of the prices paid by the consumers while traders, transporters and brokers capture the remaining 92%. All these findings demonstrate that farmers are at a disadvantage compared to other actors in the chain. Hence, addressing production problems alone may not benefit farmers since they will continue to receive lower prices for their produces. The existing marketing system wherein farmers sell raw materials and often to village-based traders indicates their inability to provide greater value for their products and seek higher-level markets.

Nevertheless, there are opportunities which these countries can use to springboard the sub-sector's revival. For example in Benin's primary competitive have advantage in cross-border coconut trade lies in its ability to supply large quantities of coconut. In Tanzania, the coconut offers a wide range of processing possibilities. In addition to copra for oil production, there are market and technological options for producing coir fibre, shell, and charcoal, alcohol, copra cake (livestock feed) and timber. Expansion of both domestic and regional markets for coconut products presents future opportunities for investment in the coconut sub-sector. However, processing activities and investment remain very limited and predominantly small scale due to low supply of coconuts and poor processing equipments. Future plans for reviving the coconut sub-sector should also aim at coconut product diversification, with plans of coordinated value chain development for each product that commands substantive market within the local and regional market.

5.2 Recommendations

Based on the findings as presented in the main text and summarized under conclusions, a number of recommendations are as follows;

(i) Simulation analysis of the technology (biological control of coconut mite using natural predators) has demonstrated significant net gains. Following the initial release of predators of Coconut Mite is expected to spread and attain equilibrium within six years, by which time farmers and other actors along the chain will begin to realize increased net returns. Since natural ecosystem are dynamic and constantly changing, expected benefits can only be maintained if other negative factors which may arise to undermine the positive impacts of this technology will be addressed through well planned, financed and evaluated extension services. This should work closely with research stations which will provide maintenance research required by technology.

It is therefore recommended that contemporaneous with the release of natural predators of coconut mite plans should be underway for improving research and extension services to coconut farmers in Benin and Tanzania. It is further recommended that research and extension services should be adequately financed to provide these services.

(ii) This technology has proved to be economically viable in Benin and Tanzania even when key variables such as the discount rate and the probability of research success are varied over a wide range. It is therefore recommended that plans should be made to use this technology in other countries such as Kenya, Mozambique, Ghana, Ivory Coast and Nigeria which have suffered considerable loss of coconuts due to coconut mite.

(iii) The analysis has shown that currently farmers in Benin and Tanzania receive only 17% and 8% of the net gains from coconut sales respectively. If no changes are made to realign market power within the chain, gains from producing improvement will remain skewed in favour of traders and brokers.

It is therefore recommended that government authorities work closely with NGOs and should have road maps for value chain development to foster efficiency and equity along the chain. In Tanzania such plans can be developed as part of the District Agricultural Development Plans (DADPS) where resources are available for such initiatives. District Agricultural and Livestock Development Officers (DALDOs) should ensure that such plans are included in their annual budgets, and processes should be inclusive, accommodating all actors and service providers.

(iv) The analysis revealed several opportunities for value addition, including developing new products so that utilization of the coconut plant is maximized. Some of the new products require investment by the private sector. Previous experiences such nationalization led to massive withdrawal of investors from coconut industry. The analysis shows that most of the processing enterprises are currently very small with inadequate capacity to absorb increasing production. It is therefore recommended that the government should work closely with subsector stakeholders and review the policy and institutional arrangement so that disabling policies are amended and inhibiting institutions are removed or realigned to provide a conducive environment for value chain development.

(v) The analysis showed that farmers in both countries are poorly coordinated, lacking a common platform for bargaining with other actors in the chain. None of the any respondents for this study at the farm level belonged to any agriculture cooperative or association. In order to ensure that farmers benefit from the productivity gains arising from this technology, there should be deliberate efforts to empower them through organization and support the evolution of stakeholders platform for coordinated value chain development.

5.3 Areas for Further Research

This study considered economic surplus approach in estimating the benefits due to biological control and integrated the approach using market chain approach. The study estimated the benefits of research from the data on cost incurred by the donors and government. The analysis did not consider the cost incurred by farmers in estimating consumer surplus model. There is a need for independent research that will capture the cost incurred by farmers in estimating the benefit of biological control.

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APPENDICES

Appendix 1: Framers questionnaire

PART A: INTERVIEWRER'S DETAILS

A1 Name of interviewer		
A2 Name of respondent		
A3 Name of head of household		
A4 Date of interview (IDATE)		
A5 Country name		
A6 Region/Sub-country name		
A7 District name		
A8 Village name		
GPS READING	Way point number	
	N/S	
	E/S	
	Attitude (Meters)	
Time	Start	End
Rating (To be checked by the leader)	Good Fair Good	Signature

APPENDICES

Appendix 1: Framers questionnaire

PART A: INTERVIEWRER'S DETAILS

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A6 Region/Sub-country name		
A7 District name		
A8 Village name		
GPS READING	Way point number	
	N/S	
	E/S	
	Attitude (Meters)	
Time	Start	End
Rating (To be checked by the leader)	Good Fair Good	Signature

PART B: SOCIO-DEMOGRAPHIC AND ECONOMIC CHARACTERISTICS

B1. Household[13] socio-demographic characteristics

ID	Name of household member	Sex 1=Male 2=Female	Age (In years)	Relationship with household head 1=Head 2=Spouse 3=Son/Daughter 4=Relative 5=Un-related	Formal schooling 1=Attended before 2=Attending now 3=Never attended 4=Too young to attend	Off school training 1=None 2=Vocational training 3= Short term training on best agriculture practice (non-extension services)	Working on the farm 1=Full time 2=Part time	Working off-farm 1=Yes 2=No	Major livelihood occupation*
01									
02									
03									
04									
05									
06									
07									
08									
09									
10									
11									
12									

[13] *(Note to interviewer: A household consist of all people who live under the same roof, eat from the same pot and share expenditures. A person is not considered as a member if she spent more than 3 month away in the past 12months)*

13									
14									
15									

*Major occupation: 0=None, 1=Crop production, 2=Livestock keeping, 3=Business, 4=Salaried employment, 5= Wage work, 6=Technician, 7=Artisan/handcraft, 8=Natural resources (wood, charcoal etc), 9=Traditional healing/medicine, 10=Rent income, 11= Others (Specify)

PART C: LAND TENURE AND USE STRUCTURE

C1: Please provide the information on land use and tenure.

Land tenure structure	Size (Acres)	Size of land (Acres) under different land uses					
		Coconut	Other perennial crops	Annual crops	Grazing land	Fallow	Rented/given out
Private (titled) land							
Land with use right only							
Share cropped land							
Borrowed land							
Rented in							

D: PRODUCTIVE ASSETS

D1: Please provide information on the following key productive assets

Asset	Number owned	**Working status**:**1**=It is/are most of the working properly, **2**=It is one/most of them working moderately, It is/most of them working properly, **3**=Most of them working improperly (Obsolete)	Total value (Total current value if liquidated)
Hand hoe			
Machete			
Axe			
Ox-plough, weeder, riper etc			
Ox-cart			
Wheel barrow			
Oxen			
Donkeys			
Horses			
Sprayer			
Watering cane			
Irrigation pump			
Tractor			
Pick-up, Lorry etc			
Others (Specify)			

E.FARM SIZE AND LABOURE1.Please provide the information on the crops cultivated and the farm size in the years 2008/2009

SN	Crop	Area under cultivation (acre)	Area under fallow/grazing (acre)

E2. What is the labour input used in the first season in 2008

SN			Land preparation		Planting		Fertilizer/chemical application		Weeding		Harvesting and transporting	Storage (Shelling + storage equipments	
	Crop	Land rent cost	Family labour* cost	Hired labour cost	Family labour cost	Hired labour cost	Family labour cost	Hired labour cost	Family labour cost	Hired labour cost	Family labour cost	Hired labour cost	Family labour cost

Family Labour: People (A.E)*Effective days*Effective Hours
A.E=Equivalents (1 Adult = A person of 15 and above of years of age; A child of 10-14 years of age will be equated to 0.5 of an adult equivalent)

F: COCONUT CROPPING SYSTEM(S) AND PRODUCTION

F1: What are the common crop mixture do you practice? **Circle one**

1= Intercropping in coconut gardens[14]

2= Mixed cropping in coconut gardens[15]

3= Coconut based multistoried cropping system[16]

4= High-density multispecies cropping systems[17]

F2: Please list the crop mixture for the coconut based cropping system and corresponding yields for last two seasons mentioned in F1 above

SN	Crop Name	Area (acres)	Yield in 2008		Yield in 2009	
			Season 1	Season 2	Season 1	Season 2
1	Coconut					
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

---

[14] Growing annuals/biennials in the interspaces of coconut

[15] Growing of perennial crops in association with matured coconut palm, like cocoa, clove, nutmeg, coffee, pepper, mulberry, jack, breadfruit, mango, papaya and timber yielding trees

[16] Three or more crops having different morphological characteristics in the interspaces of coconut so as to intercept solar radiation at different levels and exploit different soil zones

[17] A large number of crop species with very high plant density, including annuals, biennials and perennials

F3: Please rank the reasons for crop mixtures in your farm mentioned in F1 above, from 1 to 13, with one being the most important and 13 being the least important

SN	Reasons	Rank
1	Household food security	
2	Soil conservation	
3	Crop compatibility	
4	Reduced cultural practices	
5	Crop insurance	
6	Taste and preference	
7	Cultural reasons	
8	Harvesting at different times	
9	Nutrient enhancement	
10	Adapted agroforestry practices	
11	Measures against crop failure	
12	Incorporation of women crops	
13	Ecological reasons	

G.COCONUT ESTABLISHMENT

G1. What planting materials do you use? **(Circle one)** 1=Seed nuts, 2=Seedlings

G3. Where do you get coconut planting materials? **(Circle one)** 1=Own farm (Nurseries), 2=Fellow farmers, 3= Others (Specify)

G4. Please provide information on the coconut varieties in your farm

Variety ID	Variety name	Acreage	Number of coconut palms	Average nuts/palm/year

H: MITES EXTENT AND SEVERITY, AND CROP PROTECTION PRACTICES

H1: In the last five years has the production of coconut in your farm **(Circle one)**

1=Increased
2=Remained the same
3=Decreased

H2. What are the most important coconut production and post-harvest constraints? **Circle one**

Production constraints	A constraint? 1=Yes 2=No	If yes, what is the level of severity 1=Highly severe 2=Severe 3=Less severe	If yes what is the level of severity compared to other constraints (Comparative ranking, 1st being most severe)	If yes to coconut mite, which year did it start to be a major constraint in your farm
Coconut mite				
Lethal disease				

H3. Do you consider coconut mite a problem in you farm? **(Circle one)** 1=Yes, 2=No

H4. If yes, do you think coconut mite causes any loses in your farm? **(Circle one)** 1= Yes, 2=No

H5. Do you consider rainfall a limiting factor for coconut yield **(Circle one)** 1=Yes, 2=No

H6. What is your opinion on last rainfall[18] **(Circle one)** 1=adequate, 2=moderate, 3=Not adequate

H7. Please report the losses due coconut mite in the in the last five years

Year	Size of nuts*	Average nuts per palm	Average nuts per acre
2004			
2005			
2006			
2007			
2008			
2009			

*Code for size: 1=Large, 2=Medium, 3=Small

H8. What is the extent of and severity and coconut mite problem in your farm?

Plot (SN)	Acreage	Proportion of land infected by coconut mite (%)			Perceived level of severity (impact on coconut production) Codes; 1=more severe, 2=severe, 3=less severe, 4=not yet a problem		
		Now	Five years ago	Control measures used	1st season 2008 (most recent)	Five years ago	

Codes for coconut control: 1=Biological control, 2=Pesticides, 3=Using resistant varieties, 4= Others (Specify)……….

[18] Data on rainfall will supplemented by data from meteorological stations (Adequate……, Moderate…………, Not adequate)

H3. Do you consider coconut mite a problem in you farm? **(Circle one)** 1=Yes, 2=No

H4. If yes, do you think coconut mite causes any loses in your farm? **(Circle one)** 1= Yes, 2=No

H5. Do you consider rainfall a limiting factor for coconut yield **(Circle one)** 1=Yes, 2=No

H6. What is your opinion on last rainfall[18] **(Circle one)** 1=adequate, 2=moderate, 3=Not adequate

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2006			
2007			
2008			
2009			

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		Now	Five years ago	Control measures used	1st season 2008 (most recent)	Five years ago	

Codes for coconut control: 1=Biological control, 2=Pesticides, 3=Using resistant varieties, 4= Others (Specify)..........

[18] Data on rainfall will supplemented by data from meteorological stations (Adequate......, Moderate............, Not adequate)

H9. Which of the following coconut mite control technologies are you aware of and what is your current use status? If you are currently using coconut mite control method what is the associated yield of coconut?

Technology ID	Coconut mite control	Aware of the technology? 1=Yes 2=No	If aware, current use status 1=Currently using 2=Abandoned 3=Never adopted 4=No coconut mite on the farm	When did you know the existence of this technology?	Since when did you start to use it for the first time? (Year)	If you are aware from whom did you receive information?*

Codes for source of information: 1=Farmers in the village; 2=Mass media (Radio, News papers etc), 3=Extension workers, 4=Local NGO, Research institutes, 5=Farmers' Community Based Organization (CBOs), 6=others (Specify)

H10. If you aware of any coconut mite control technology but have not adopted any, what are the most important reasons for non-adoption? (Multiple answers possible)

S/N	Reasons for no-adoption	Reason status	Ranking (1st being the most important)
1			
2			
3			
4			

H11. If you aware of any coconut mite control technology in H4 how would you rank various coconut mite control technologies you have been introduced to?

Technology ID	Coconut mite control technology	Ranked based on				
		Yield enhancing 1=Most yield enhancing 2=Moderately yield enhancing 3=Last yield enhancing	Technical simplicity (Simplicity to most complex) 1=Simplest 2=Simpler 3=Complex	Labor demand (Least demanding to the most demanding) 1=Least demanding 2=Moderately demanding 3=Most demanding	reason 4	
1						
2						
3						

I. COCONUT UTILIZATION

I1. Do you grow coconut for the following use? Code (1=Yes, 2=No) in the box

1. Coconut water ☐☐

2. Roofing (Coconut fronds) ☐☐

3. Coconut oil ☐☐

4. Fuel wood ☐☐

5. Palm wine ☐☐

6. Others (Specify)

I2. Rank the following coconut use according to the importance of growing coconut

1-------------first choice	a. Part of diet
2---------------second choice	b. coconut
3---------------third choice	c. Roofing
4---------------fourth choice	d. Oil processing
	f. Others (Specify)

I.COCONUT PROCESSING

1	Do you process coconut to any form? **Circle one**	1=Yes (go to 2) 2=No (go to 5)
2	What is/are the product(s) you produce from raw coconut?	--- --- --- -------------
3	What are the methods/equipments you use in processing coconut?	--- --- --- --------------------------
4	What are the facilities you use in storing coconut products?	--- --- --- ---------------
5	What are the reasons for not processing the crop produce? Rank ----------- ----------- ----------- ----------- ----------- -----------	1=Expensive, 2=Time consuming, 3=Lack of technology, 4=No market for products, 5=Other problems (Specify)--------

6	What are the constraints in processing coconut? Rank ----------- ----------- ----------- ----------- ----------- -----------	1=Marketing, 2=Capital/credit availability, 3=Equipment & installations, 4=Product quality training, 5=Product price stabilization, 6=Lack of policies, 7= Others (Specify)

Appendix 2: Questionnaire coconut traders

A: INTERVIEWRER'S DETAILS

A1 Name of interviewer			
A2 Name of respondent			
A3 Date of interview			
A4 Country name			
A5 Region/Sub-country name			
A6 Market/Village name			
A7 Time	Start	End	

B: INFORMATION ON COCONUT MARKETING;

B1: Type of trader **(Circle one)** 1=Whole saler, 2= Retailer

B2. How long have you been in this business as a wholesaler (years)...?

B3. How many products do you trade in (number)..?

B4. Where do you get coconut for sale? **(Circle one)**

1= from farmers 3= Open auction sale, 5= Secret bidding
2= from collectors. 4=Contract sale, 6=others (Specify)............

B5. Why do you prefer this source(s)? **(Circle one)**

1=Cheaper buying prices
2=Proximity to the market
3=Homeland
4=Any other reason (specify) ....

B6. What are the terms of payment to the above sources? **(Circle one)**

1=Cash terms only 3=Both of the above terms
2=Credit terms 4=Other (Specify).............................

B7. What is the average amount of fresh coconuts do you buy on weekly basis? ....

B8. Do you have any information pertaining to selling prices in other markets? **(Circle one)**

1= YES 2 = NO

B9. If Yes, how far from those markets? **(Circle one)**

1=Rural markets 2=Urban markets

B10. How do you obtain such pieces of information? **(Circle one)**

1=Through agents
2=Through own investigation / visits
3=Any other sources (specify) ....

B11. How do you take advantage of such of information? ....

C. INFORMATION ON PRICING AND COST

C1. On average how long do you store coconuts before you sell? **(Circle one)**
1=1-7 days
2=Two weeks
3= More than two weeks

C2. If a wholesaler stores for long periods, why does he do so? **(Circle one)**
1=To make profit
2=Low supply from farmers
3= Marketing Problems such as low prices

C3. Please provide the average quantity of coconut brought per week and the buying price at the supply source(s) during and off-seasons in 2009.

SN	Source	During the season			Off-seasons		
		Quantity*/week	Price (USD/Local currency**)		Quantity/week	Price (USD/Local currency	
			Buying	Selling		Buying	Selling
1	Farmers						
2	Others retailers						
3	Wholesalers						
4	Brokers						
4	Any other sources (Specify)						

C4. What kind of marketing cost did you incur?

SN	Activity	Cost (USD/Local Currency)/week
	Assembly	
	Grading	
	Packaging	
	Gunny bags	
	Twine	

	Transport (Lorry, bicycle etc)	
	Loading	
	Offloading	
	Meals	
	Levy/Taxes	
	Wastage (proportion............)	
	Miscellaneous marketing services	

C5. To whom do you sell the produce? **(Circle one)**

1. Home Consumers
2. Hotels and restaurants
3. Other traders
4. Oil Processors
5. All of the above
6. Any other customers (specify).......................................

C6. Where do you sell coconut? Name the places/centres/regions...
....
....
....
....

C7. Do you sell coconut in different grades (e.g. small and big sized nuts)? **(Circle one)**
1=Yes, 2=No

C8. Do you charge different prices to different buyers? Give reasons...
....
....
....

C9. Are you aware of any of the wholesalers who export coconut to neighbouring countries?
1=Yes, 2=No

C10. Which are those countries other wholesalers export coconut? Name them
....
....
....
....
....

C11. Are you aware of any of the wholesalers who import coconut from neighbouring countries? **(Circle one)** 1=Yes, 2=No

C11. Which are those countries other wholesalers import coconut from? Name the countries

....
....
....
....

D. CONSTRAINTS AND OPPORTUNITIES

D1. How does the action of the government/local authorities/trade associations affect your business?...
....
....
....
....
....

D2. What are your major marketing problems / challenges facing your business?
....
....
....
....
....
....

D3. What should be done to improve marketing of coconut?
....
....
....

D4. What do you think are the opportunities for both production and marketing coconut?

Appendix 3: Questionnaire for coconut processor

A: INTERVIEWER DETAILS

A1 Name of interviewer	
A2 Name of respondent and Position	
A3 Country name	
A4 Region/Sub-country name	
A5 District name	
A6 Name of the enterprise	
A7 Date	
Full postal address	
Email	
Mobile	
Fax	

B: BACKGROUND INFORMATION:

B1. Type of business..

B2. How long has your business been operating?..

B3. What is your product range? Mention please

1. --
2. --
3. --
4. --
5. --
6. --

B4. Which of your products is most important to you? (Rank them in term of sales)..
....
....
....
....

B5. Do you experience fluctuations in demand for your products during the year? **(Circle one)**

1=Yes, 2=No

B6. Are there seasonal high or lows? **(Circle one)**

1=Yes, 2=No

B7. Do you experience unpredictable changes in demand for your products? **(Circle one)**

1= Yes, 2=No

B8. What is the causes?

B8. What has been your annual output over recent years? (Tonnage or value, whichever is most appropriate, for a large factory tonnage is best, for a small processor an estimate of value would be more appropriate):

Years	Production (tonnage/Kg/value)

B15. For the industry as whole, is demand[19] for your main products static/increasing or decreasing: **(Circle one)**
1=Yes, 2=No

B16. What are your markets (local / export / both, if both then what are the proportions for each market eg local 60% export 40%):

Market	Proportion
Local	
Export	
Total	

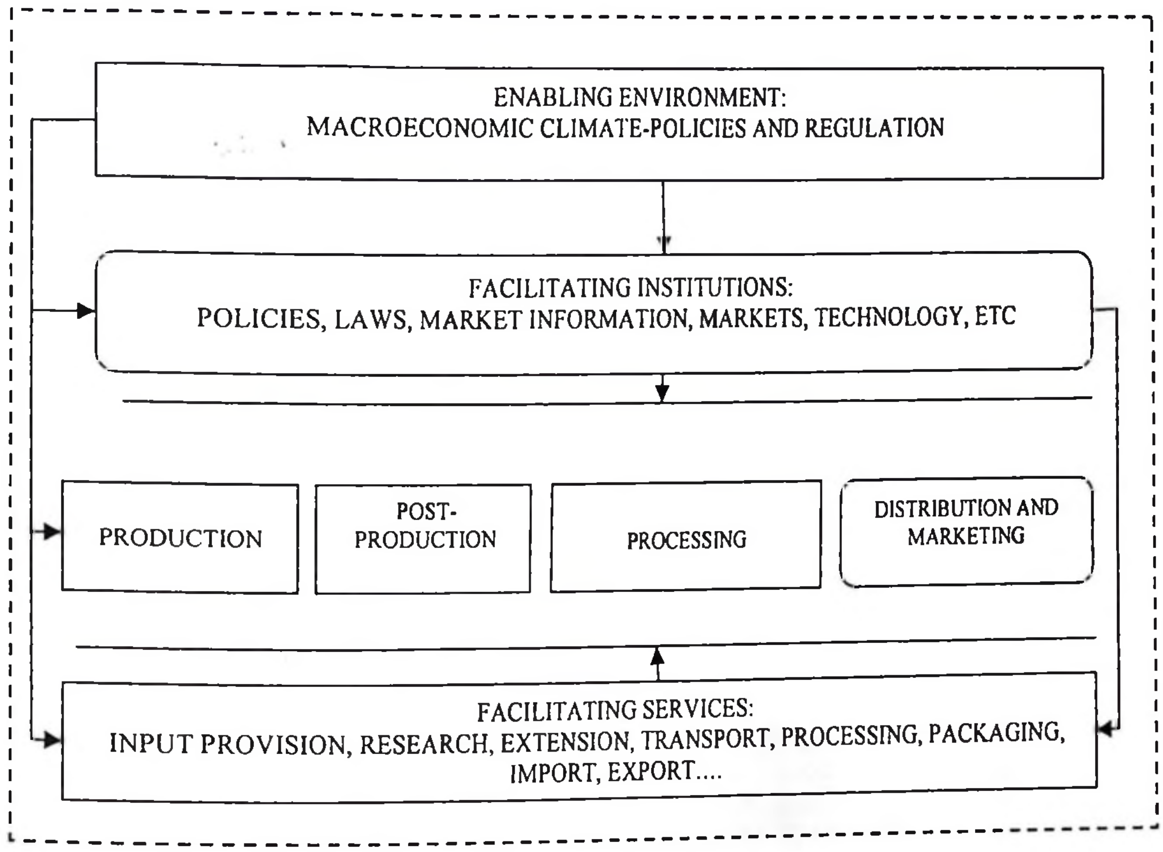
B17. How does government economic policy affect your business? (For instance interest rates, inflation, tax, import duties, privatization, infrastructural investment)..
....
....
....
....
....

[19] *This question should help us to estimate market potential*

C. PROCESSING FACILITIES

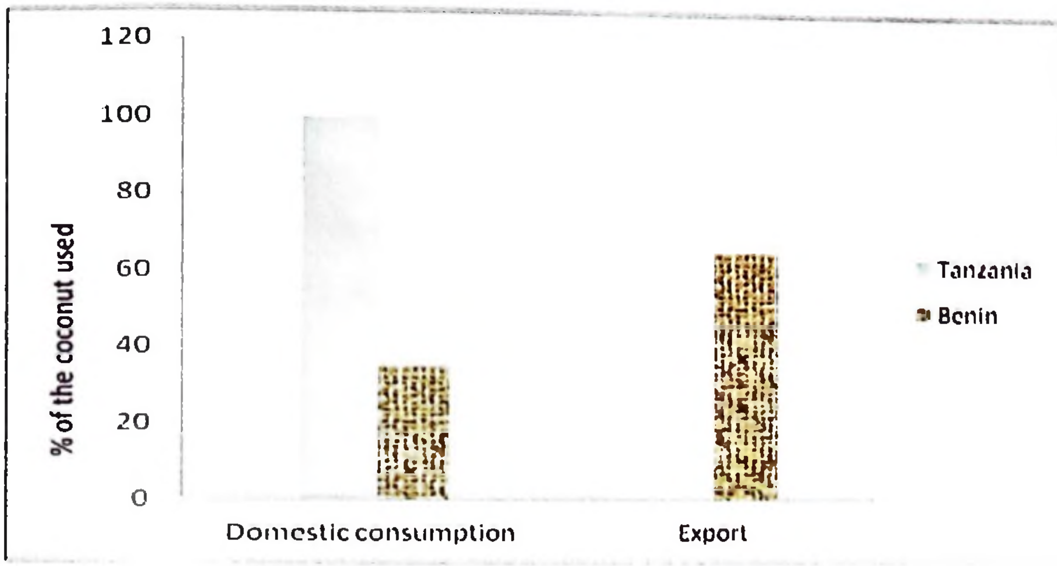
1	What are the methods/equipments you use in processing coconut?	-- -- -- -- -- -- -
2	What are the facilities you use in storing coconut products?	-- -- -- -- ---------------
3	What are the constraints in processing coconut? Rank ----------- ----------- ----------- ----------- ----------- -----------	1=Marketing, 2=Capital/credit availability, 3=Equipment & installations, 4=Product quality training, 5=Product price stabilization, 6=Lack of policies, 7= Others (Specify)
4.	What do you think are the opportunities for processing coconut? (Explain)	

Appendix 4: Market chain framework

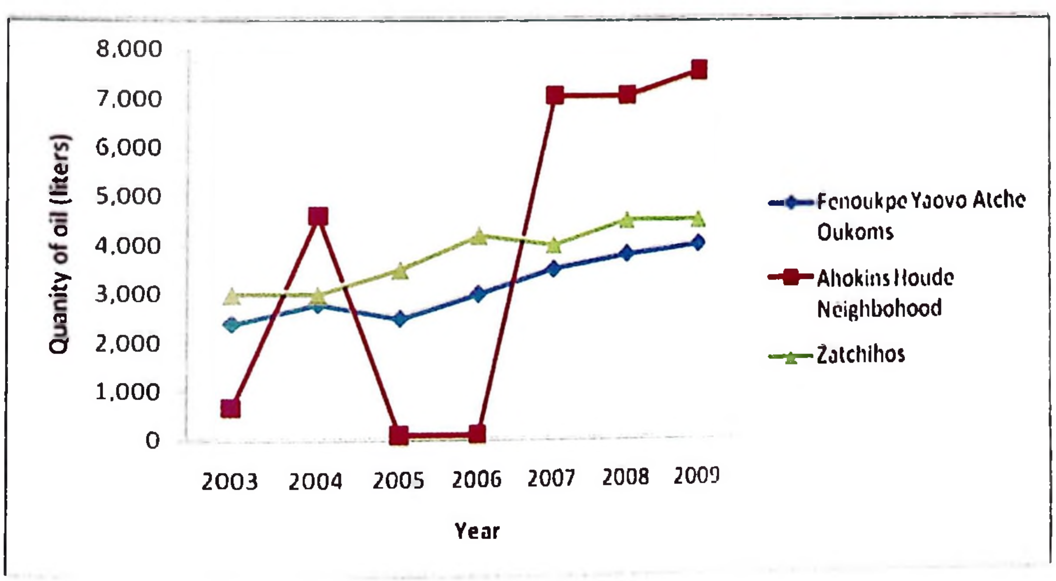


Source: UNIDO (2009)

Appendix 5: Coconut utilization



Appendix 6: Annual production of coconut oil (liters) for selected small scale oil processors in Benin



Appendix 7: Plate East African Tall coconut trees badly affected by drought conditions at Boza village, Pangani, Tanzania

Appendix 8: Coconut mite damage on mature coconut fruits

Appendix 9: Left, grading of coconuts in Temeke market, Dar es Salaam.

Right coconut market in Cotonou, Benin.