Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

Master´s Thesis, 30 credits
Sustainable Enterprising Master´s programme 2008/09, 60 credits

Livelihood and diversification in Rural Coastal Communities

Dependence on Ecosystems Services and possibilities for Sustainable Enterprising in Zanzibar, Tanzania

Indramani Jayaweera

A centre with: SEI STOCKHOLM ENVIRONMENT INSTITUTE

The BEIJER INSTITUTE OF ECOLOGICAL ECONOMICS

Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

Livelihood and diversification in Rural Coastal Communities:

Dependence on Ecosystems Services and possibilities for Sustainable Enterprising in Zanzibar, Tanzania

Indramani Jayaweera

January 2010

Supervisor: Maricela de la Torre-Castro

A Dissertation submitted to the
Stockholm University
in partial fulfillment of the requirements for the degree of
Master of Science

Stockholm Resilience Center
Stockholm University
Stockholm
Sweden

Abstract

Poverty and degradation of ecosystem services are prevalent features of the livelihood insecurity of coastal communities in Zanzibar, Tanzania. Livelihood diversification is typical in coastal rural areas and it is increasingly important to identify opportunities for income generation and ways to alleviate poverty. Sustainable enterprises provide a strong tool for livelihood development, but are still unable to find pathway towards development of ecosystem services and sustainable enterprises in coastal communities in Zanzibar.

The aim of this study is to understand the existing livelihood diversification and income generating patterns in order to introduce sustainable enterprises in the future. Also, we aim to identify the conditions of the present dominant livelihood activities in terms of sustainability. During the study a household survey was conducted using a sample of 200 households from five coastal villages in Zanzibar. The data was collected by maintaining a daily diary and conducting comprehensive interviews. The statistical techniques, Analysis of Variance (ANOVA), linear regression and other statistical measures were used to analyze the results. The ANOVA technique is used to test the differences in income generated by different livelihood sectors. The regression analysis techniques are employed to find out whether there is a correlation between numbers of livelihood activities and income.

The results show that livelihood diversification is very high in coastal households in Zanzibar. With respect to ecosystem-based livelihoods, there is more household participation in fishing and seaweed farming, but it varies from village to village. Furthermore, fisheries and tourism are the most important sectors, and offer more opportunities to generate higher income for households. The findings suggest that there is space to improve the current dominant livelihood sectors in a sustainable way in the future. Livelihood management strategies are needed to take into account the market opportunities and their roles in livelihood development. Also, there is a need to identify possibilities to enhance livelihood opportunities in sectors with low household participation as an important way to reduce pressure on ecosystems. Finally, we outline the possible future impact of unsustainable development and of sustainable enterprises, and highlight the importance of a collaborative sustainable enterprise system to ensure livelihood security.

Acknowledgements

First of all I would like to offer many sincere thanks to my supervisor, Dr. Maricela de la Torre-Castro for her excellent supervising and assistance given to me in gaining knowledge during my thesis work. She always been available to look at my thesis work and has helped me to restructure my thoughts whenever necessary.

Special thanks go to Dr Miriam Huitric who helps me providing feed back to the thesis work during seminar sessions and gaining knowledge during course work. I also would like to give many thanks to Saman Muthukumara for assisting me in generating outputs of statistical software tools. Also, gratitude goes to Joel Forsberg for giving feed back during the seminar series. Many thanks go to the staff of the Resilience center, Stockholm University for providing me the necessary thoughts in acquire knowledge to carry out my master's studies.

Finally, my gratitude goes to my husband Ananda Edirisuriya and Wijayananda Jayaweera in assisting me to structure the thesis by proof reading, daughter Lumini and son Charindu for their patience and support during my stay in Sweden.

Table of content

List of figures

List of tables

Abbreviations

DFID	Department for International Development
ERB	Economic Research Bureau
FAO	Food and Agriculture Organization of the United Nations
ICMA	Integrated Coastal Area Management
MEA	Millennium Ecosystem Assessment
NBS	National Bureau of Statistics
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WCED	World Commission on Environment and Development
WRI	World Resource Institute
ZPRP	Zanzibar Poverty Reduction Plan

1 Introduction

1.1 Background and current situation

1.1.1 Poverty and coastal livelihood in Zanzibar

There are more than 35 million people living in the coastal zone of East Africa (Shah et al., 1997). They have a diversified livelihood economy that is dependent on the ecosystem services obtained from the surrounding natural resources. These natural resources support these local people's everyday survival. Most East African coastal and marine ecosystem services are severely undervalued, causing fewer investments for conservation (Lange and Jiddawi, 2009). As a result, marine and coastal ecosystems have been degraded critically, losing economic opportunities to the community. Understanding the critical role played by the enhancement of the economic opportunity is a necessary pre-requisite towards the elimination of poverty in the developing world (Warren, 2002).

Zanzibar is an island in Tanzania, situated in the Western Indian Ocean. Many attempts have been made towards alleviating poverty in Zanzibar, but outcomes are disappointing and still, coastal communities are distressed by poverty (ZPRP, 2002). The majority of these coastal communities are categorized as living at or below the national poverty line. In Zanzibar, poverty appears to be prevalent in the coastal communities and in Tanzania about 85% of the coastal population lives on less than $1/day (Ruitenbeek et al., 2005). The Household Budget Survey (1991) shows the average annual income of a person in Zanzibar is $137. Also, the results of poverty reduction programme show that non-income poverty indicators are very low. For example, life expectancy is only 48 years, 40% of the population is illiterate and poor sanitation is widespread (ZPRP, 2002).

Rural coastal livelihoods in many areas of Zanzibar are complex, diversified, and undergoing change continuously. Historically, most coastal livelihood activities are related to fisheries and agriculture (i.e. clove, coconut) sectors (Anderson and Ngazi, 1998; Eklund and Pettersson, 1992). However, the traditional coastal livelihood portfolio has been rearranged due to material change, infrastructural developments and introduction of new occupational sectors,

such as seaweed farming, tourism and others (Eklund and Pettersson 1992; de la Torre-Castro and Lindstrom, 2010). Generally, men perform a wider range of livelihood activities than women do; women's livelihoods are limited to handicraft, petty business, crop cultivation, collecting seashells, sea cucumber and, more recently, seaweed farming in combination with housework. Comparatively, the male job market has more opportunities than does the female job market (Pettersson-Lofquist, 1995a).

Some current coastal livelihood activities are no longer economically, environmentally and socially viable and need to be replaced with alternatives (Ireland et al., 2004). For this reason, coastal communities are changing their livelihood activities at different time periods, which make their income uncertain. If a coastal rural household has different options, they choose the most cost-effective opportunity to ensure the maintenance of their living standards. In Zanzibar, coastal communities have less opportunity for cost-effective livelihood options and the present livelihood options are not satisfactory. For example, youth unemployment rate is more than 20% (Juma, 2007) and 61% of the population is living without basic livelihood needs (ERB, 2003). Also, ecosystem-based commodities, such as firewood, charcoal and crops, are often not captured with retail value, and hence, are not subject to market competition.

The coastal livelihoods have been studied in different research work. Some livelihood research demonstrates the vulnerability of communities to seasonal variations (Adger et al., 2001; Brogaard and Seaquis, 2005). Other studies demonstrate the relationship between coastal livelihood systems and marine resources (Adger, 2000; Samoilys and Kanyange, 2008) and current investigations concentrate on livelihood adaptation to climate variability (Iwasaki et al., 2009; Osbahr et al., 2008). While the majority of livelihood research is often combined with agricultural production in the countryside (Ellis and Mdoe, 2003), very little research has concentrated on developing opportunities for the coastal communities in Zanzibar to gain access to more diversified livelihood (using enterprises concepts).

1.1.2 The coastal livelihood dependence

Natural resources are very rich in the coastal and marine areas of Zanzibar. The marine and coastal habitat consists of coral reefs, seagrass beds, mangroves and sandy beaches. Almost, every seascape component is very diverse with high densities of flora and fauna. Furthermore, minerals and forest resources (Jozani Park) are abundant along the coastal lines. Thus, coastal

livelihoods have evolved to be very dependent on natural resources. For example, 47% of the population depends directly on the fishing in Chawaka Bay (Mohammed and Jiddawi, 1999). Furthermore, this dependence varies from village to village due to the variation in distribution of resources, family traditions, income efficiency and others (Ngazy, 1997). Natural resource management efforts have highlighted the need for better understanding of the ecosystem dynamics (Folke, 1998). However, poverty reduction programs often fail to take into account the dependency between poverty and natural resources that are supposed to enhance the livelihood strategies by unlocking the value of those ecosystems (Shackleton et al., 2008; de la Torre-Castro, 2006; WRI, 2005).

According to the Millennium Ecosystem Assessment (MEA), "*The Ecosystem services are the range of benefits that humans obtain from ecosystem, and they are produced by interactions within the ecosystems*" (MEA 2005).

The combination of terrestrial and marine ecosystem services contribute to people's livelihoods both directly and indirectly. The direct contribution of ecosystem services can be seen from resources such as fish, fuel wood, forest and biodiversity that create vast livelihood opportunities (de la Torre-Castro and Ronnback, 2004). The indirect contributions of ecosystem services are water regulation, biodiversity and the fertility of the soil. In addition, some ecosystem services contribute both directly and indirectly. Direct dependence on services from ecosystems is highest among coastal people in Zanzibar, where alternative livelihood options are very limited (Crona, 2006).

Thousands of coastal people struggle for daily survival and many of them are aware of the importance of ecosystem services to their everyday lives (de la Torre-Castro and Ronnback, 2004). This means that they have to make regular short-term trade-offs between the natural resources and their next-day survival. If this trend continues without considering the sustainable use of natural resources the future of coastal community might be at risk. Also, rapid growth of population is an escalating problem in Zanzibar that recorded a population about 984,625 in the census of 2002. The annual population growth rate of 3% will increase the population density close to 400 inhabitants per square kilometer. As a result, the population along the coast has constraints on accessing coastal natural resources, which might diminish the sustainable livelihood options (ICAM, 1996). The signs of environmental degradation, as well as a decline in natural resources and ecosystem services, are beginning to become more visible. This is evidence

of declining yields of fish in some localized areas (Crona, 2006; Jiddawi and Ohman, 2002; Tobisson et al., 1998), deteriorating conditions of coral reefs (Johnstone et al., 1998), and seagrass beds (de la Torre-Castro, 2006). The World Wide Fund for Nature's Global 200 conservation priority list identifies Tanzania as one of the 43 priority marine eco-regions (Olson and Dinerstein, 1998), as it is crucial to the conservation of the marine ecosystem.

Sustainable utilization of coastal natural resources is, therefore, an obligatory issue in increasing the livelihood opportunities and poverty alleviation (de la Torre-Castro, 2006; WRI, 2005). To this end, investigating the importance of ecosystem services to the livelihoods of the poor could lead to the identification of better options for livelihoods that avoid negative trade-offs.

1.1.3 Enterprises development for the coastal communities in Zanzibar

The term enterprise is a broad concept and has a diverse use (Schieffer and Lessem, 2008). In this study, we use the term enterprise to refer to any ecosystem-dependent organized (community/household) activity that creates a product or service of value and provides the basis of livelihood along with market success. The organized activities considered here are agriculture, fishing, seaweed farming, tourism, mining, service and manufacture related ecosystem services, which belong to different economic sectors. The term sustainable is defined as '*development that meets the needs of the present without compromising the ability of future generation to meet their own needs*' (WCED, 1987). So, we define sustainable enterprises as a community-organized activity that aims for sustainability and long-term economic prosperity with environmental quality and social equity. Currently, many enterprises are changing their traditional arrangements, reconfiguring towards collaborative enterprising (CE-NET, 2004). The basic idea of the collaborative enterprises is that all members have an equal say in decisions and equal networks of peers who accept full responsibility for the all members' interest (there are no hierarchical and limited contractual relationship within members) (CE-NET, 2004).

However, some enterprises operate informally in unregulated environments with lack of legal, institutional and contractual structures in many parts of the world (Mead and Liedholm, 1998). Thus, some enterprises are unable to succeed due to market failures, which create bottleneck problems for their products (Albu and Scott, 2001). In Zanzibar, enterprises of micro, small or

medium scale with little diversity are not exposed to export markets (World Bank, 2007). Some enterprises (e.g. charcoal making and selling) are not operating in a sustainable way, which has a negative impact on the environment (USAID, 2007). Other enterprises (e.g. coffee enterprises: Kahawa Shamba Moshi) are operating in a sustainable way and benefiting households (Goodwin and Santilli, 2009). Nevertheless, limited basic financial services, limited educational attainment, low labour productivity, lack of entrepreneurial skills, low infrastructure facilities and weak institutions further obstructs promotion of enterprises in Zanzibar (USAID, 2007; World Bank, 2007). Capabilities, skills and knowledge of people need, therefore, to be developed in order to eliminate obstacles and increase access to the markets in Zanzibar.

If some basic needs are met for the coastal household, sustainable enterprises are most promising due to their ability to promote more sustainable livelihoods (Warren, 2002). Thus, understanding existing livelihoods and the differences between the livelihoods of different groups are particularly important to in creating coastal ecosystem-based enterprises (WRI, 2008). The livelihood diversification provides information about challenges, opportunities and different stakeholder groups in coastal communities (Campbell, 2008; Ireland et al., 2004). In addition, ecosystem services provide new opportunities for sustainable enterprises. Without a full awareness of the extent of business dependence and impact on ecosystem, therefore, it is not possible to apply sustainability to enterprises (MEA, 2005). This implies a need for practical approaches to manage ecosystem services and development trade-offs that lead to livelihood options.

Recent research has addressed the development of small rural enterprises by analysing the livelihood framework of agricultural intensification comprehensively (Ellis, 2000; Ellis and Freeman 2004). Many researchers in other areas emphasize enterprise development as the way to enhance coastal peoples' livelihood resilience (Campbell, 2008; WRI, 2008). When summarizing these concerns collectively, the current livelihood strategies need to be managed in a more economically viable, equitable and sustainable way by introducing sustainable enterprises. Thus, it is important to identify the scope of sustainable enterprises in the coastal communities in Zanzibar. This study provides a fundamental platform by which to highlight the importance of ecosystem services as well as livelihood diversifications to the establishment of sustainable enterprises.

1.2 Research questions

This study focuses on the livelihood of coastal communities in Zanzibar. The research questions addressed are:

1. What are the different livelihoods and what is the degree of diversification in coastal villages in Zanzibar?
2. What is the relationship between coastal ecosystem services and livelihood activities?
3. Is there any relationship between income level and livelihood diversification?
4. Is there any relationship between diversification and higher resilience?
5. What is the scope for sustainable enterprises for the rural coastal community in Zanzibar given the livelihood situation?

1.3 General study goal

To address long-term ecosystem management effectively, it is necessary to analyse the current livelihood activities in a social-ecology context.

The goal of this case study is to *identify and emphasize the opportunities to introduce sustainable enterprises to enhance income in order to bring economic prosperity while maintaining sustainable ecosystem stewardship for the rural coastal community in Zanzibar*.

This study focused mainly on coastal dwellers, how they engage directly with the coastal ecosystems and other ecosystems to maintain their livelihood. It is important to recognize their livelihood diversification, as the majority of coastal inhabitants engage in multiple income sources that encompass their capabilities, skills and knowledge. The study is also concerned with how these livelihood activities connect with ecosystem services and which livelihood activities seem to be more sustainable while providing good economic revenues to enhance their lifestyle. The study also intends to compare livelihood diversification within different villages to clarify how livelihood resilience differs in a diversification context. The analysis is focused mainly on the relative importance of the ecosystem services and income of coastal communities.

.

1.4 Purpose of the study

In order to alleviate poverty of the coastal communities of Zanzibar, an important first step is to enhance their income generation opportunities. Currently, there have been fewer institutional innovations proposed by the government to enhance their income opportunities (ERB, 2003). Furthermore, ecosystem degradation pressure increases due to poverty, institutional failures, lack of government policies, weak regulation and enforcement (de la Torre-Castro, 2006). Applying appropriate sustainable enterprises to enhance livelihood opportunities would help to alleviate poverty. Thus, the purpose of the study is to identify which of the current livelihood activities are providing more economic revenues to alleviate poverty within the framework of sustainable use of ecosystem.

1.5 Limitations of the study

Due to the fact that some households do not keep daily diary records constantly, we assume these households are doing the same activity and earning the same income when the data are not available for that day. The accuracy of recorded data depends on an individual's ability and reliability of daily diary records. However, it is assumed that the household daily diary provides accurate data, which provides a useful basis for collecting information about coastal livelihood activities and income (See methods section also).

The calculating revenues from one month for different livelihood sectors were measured in terms of the cash value of produce sold or gross revenue. The calculated gross incomes did not include unsold part retained for home consumption, cost for labor, purchasing or other input, since it was difficult to estimate.

In particular, this study does not address any assets or governance, institutional, political, policy, law and right issues related with livelihood activities extensively.

2 Theoretical framework

2.1 Livelihood diversification

Human beings have always set off to earn some income in order to meet their basic needs. The income generation activities are constrained in some part of the world due to population growth, land shrinking and environmental degradation (Warren, 2002). Thus, people are continuously engaged in different activities to overcome these constrains. For this reason diversification of the livelihoods in most rural areas of the developing worlds is unavoidable.

The concept livelihood can be used in many different ways due to the fact that livelihood is a complex and changing process (Chamber and Conway, 1991; Ellis, 2000). The concept of livelihood is commonly used to describe different ways of people obtaining an income for their survival. The Advisory Panel of the World Commission on Environment and Development proposed "*livelihood as adequate stocks and flows of food and cash to meet basic needs*" (WCED, 1987). They argued adequate stocks provide opportunity to equity in assets and access that enable gaining the livelihood. Modifying the WCED panel definition, Chambers and Conway 1991, proposed "*A livelihood comprises the capabilities, assets, (stores, resources, claims and access) and activities required for a means of living*". According to Chamber and Convey definition, capability is an important component in livelihood concept, as personal or household livelihood strategies change in different time and manipulate on own capability. However, Ellis (2000) argued that 'asset' in this livelihood definition included different number of component and might be confusing. This is because, human and physical capital acceptance depends on the economic capital. For example, quality of education, health services and infra structural development vary among states that depend on economic capital of the state. Also, the basic livelihood framework highlighted; a livelihood is not just people doing some activities in order for survival, but encompasses vulnerability context (risk factors), policy and institutional context (government structure, authority, laws and right, democracy and participation) which conduct livelihood efforts (Ellis and Allison, 2004).

A main concern is when the livelihood activities of many coastal households do not provide a sufficient income for their survival. For this reason most coastal households depend on

heterogeneous livelihood activities and income sources make livelihood diverse and additional support for survival. Livelihoods are diverse at many levels including location, activities, time scale, household members and others (DFID, 2001). Ellis (2000) defines livelihood diversification as "*the process by which rural households construct an increasingly diverse portfolio of activities and assets in order to survival and improve their standards of living*". Livelihood diversification can be achieved by increasing people's livelihood options, developing income circulation in rural or urban areas, improving human capital and reducing dependence, especially on natural resources (Ellis and Allison, 2004).

In this study, livelihood diversification refers to coastal communities. This implicates attempts by individuals or households involved in diverse livelihood strategies (including income generating activity and non income generating activity) to improve their living standards and survival for the future. The livelihood strategies include full time, temporary or seasonal courses of actions. Income comprises of cash which is a measurable outcome of the livelihood process, but non income activities also valuable contribution to their survival. Most of the non income activities provide materials (e.g. foods, fire wood), for household consumption.

The individual or household livelihood activities vary over time and relative mix of activities is tempered by context-specific limitation and opportunities (i.e. market development or prices, infrastructure, natural resource base etc.). For the coastal poverty community, livelihood diversifications are significantly related with what extent to access resources, irrespective of whether these uses are sustainable or not (Ellis, 2000). Therefore, certain activities are more common in a specific environment. This indicates that access to livelihood resources are an important part of livelihood concept applying for the coastal households. The livelihood resources access is shaped by a wide set of issues including assets or different type of capitals. These capitals are a useful component of the assets involved in the livelihood strategies in individuals or households (Ellis, 2000). Also, it is the basic building block of household production, market availability, mutual exchange with other households and flow of livelihood outcomes (Ellis, 2000). Scoones (1998) identified five different types of capital in livelihood context (See Table 1).

Table 1. People's livelihood assets

- Natural capital: The natural resources and stocks (land, water, biological resources, water regulation etc...) that are utilized by people.
- Human capital: The skill, knowledge, ability and health which are important for the succession of own livelihood strategies.
- Social capital: These are the social resources people can utilize to support their livelihood (network, associations, social relation etc.)
- Economic capital: Cash, savings, loans and other economic assets which households can have access.
- Physical capital: These are the assets created by a certain economic production process such as, buildings, tools, machines, land.

Source: Scoones (1998)

The access to different types of assets depends on the household composition comprising of household size, age of household members and gender within household (Winters et al., 2001).

2.2 Resilience

The concept of resilience can be defined in many ways and is widely applied in different fields, including engineering, ecology, sociology, and economy (Folke, 2006). The human is an important component in all of these fields and there are the proactive strategizing agents who are responsible for changing social, ecological and economic systems. They, also have a potential ability to change the way to enhance or reduce the system resilience. The livelihood approach is human centered and it is historically proven that the livelihood can be changed in different ways

(Ellis, 2000). For example, after the Industrial Revolution in 19th century, the livelihood activities in agricultural sector have declined and transformed into non-farm livelihood activities.

In terms of social aspect resilience can be derived from combination of sustainability, opportunity and equity (Folke et al., 2002). According to Chamber and Conway (1991), "*A livelihood is sustainable when it can cope with and recover from stress and shocks maintain or enhance its capabilities and assets, while not undermining the natural resource*". The de Haan and Zoomers (2003) define livelihood resilience as the *"ability of an individual or household to recover from or to withstand changes in the social or physical environment coping with uncertainties and the ability to adapt to changing circumstances and thus ensure security of livelihood"*.

Livelihood resilience varies with the people's ability to cope with disturbances and the capacity to deal with future changes (Folke et al., 2003). The new opportunities, novelty, innovation (de Haan and Zoomers, 2003) and flexibility are the important characters required to cope with livelihood uncertainty. A significant number of literature demonstrates clearly livelihood diversification is the strategy of enhance resilience (Bryceson, 2002a; Campbell et al., 2002; Ellis, 2000; Ellis and Allison, 2004). Marschke and Berkes (2006) show livelihood diversification as a coping strategy and adaptive strategy which leads to self organization and eliminating household uncertainty. Moreover, livelihoods depend on varying ecosystem services that are more flexible as they have the capacity to cope with shocks due to alternative resource use (Adger, 2000; Bailey and Pomeroy, 1996). In particularly, livelihood depends on ecosystem services which coastal livelihood resilience might foster or enhance the way the local people use and value of ecosystem services in different time scale (Shackleton et al., 2008). An ecosystem with low resilience may still provide ecosystem services. But, if it exceeds a certain threshold level the ecosystem may shift to an undesirable irreversible state. When the ecosystem health and the flow of goods and services are decreased the change of ecosystem state may significantly constrain the livelihood options available to the community (Folke et al., 2002).

However, there are many global and local contexts that contribute to livelihood disturbances (de Haan and Zoomers, 2003). At the same time economic drivers create conditions that bring stresses and shocks on the livelihood (MEA, 2005). The income and wealth are very effective factors to escape shocks (Adger, 2006; Grootaert et al., 1995; Warren, 2002). The income of people depends on the market availability and they tend to save much money when the income is

high. The high savings will increase livelihood resilience (WRI, 2008). Thus, market availability and other forms that secure savings are the key issues in the livelihood resilience context. Therefore, resource dependent livelihoods are partially buffered from market availability (Bayliss- Smith, 1991). Rural people are not aware of market opportunities and of coping with unforeseen difficult situations in the future. Therefore, properly design community/households level enterprises can enhance economic stability and livelihood resilience.

3 Methods

3.1 The Study areas and villages

Zanzibar is an archipelago (official name Unguja) located 40km from the central coast of mainland Tanzania. Zanzibar is located at 6 degrees south Latitude and 39 degrees east Longitude of Africa in the Western Indian Ocean. It is 85km in length, 39km in width (at its broadest point) with an area approximately of 1530km^2. The current population of Zanzibar is approximately about 984,625 and with high population growth rate. The population growth rate had risen from 1.8% in 1988 to 3.1% in 2002 (National Bureau of Statistics (NBS), Tanzania). A vast majority of the total population is Muslim, 60% of population living in rural areas and a large portion is established in the coastal zone.

This study focuses on five villages Kizimikazi, Mkokotoni, Paje, Marumbi and Uroa/Chawaka. Kizimikazi is located on the southwest coast of Zanzibar. The 2003 census in Tanzania reported a population about 3,208 in Kizimikazi. The Kizimikazi coastal and marine area is a well-known region in the Western Indian Ocean made up of coral, mangrove and seagrass complexes (Berggren et al., 2007). This area has traditional fishing grounds and fishing efforts have been largely expanded during the last decade. Furthermore, dolphin tourism is a popular livelihood activity in Kizimikazi village. Mkokotoni village is situated in North–West coastal area with a population of approximately 2500-3000. This is a large traditional fishing village. Paje village is located in south-east coast, 45 kilometers away from the Zanzibar town. It is the oldest fishing village and population is around 1200. Tourism is the most popular livelihood activity here and there is no access to sound fishing market. Marumbi village is situated in the East part of Zanzibar coast having about 1,000 inhabitants. This is a very small fishing village. Uroa village is situated north of Marumbi with approximately 2250 inhabitants. Chawaka village is directly connected with Zanzibar town and therefore easy to access. The population is about 2750. Inhabitants' habitants of these villages contribute to multiple livelihood activities such as fisheries, seaweed farming, agriculture, small scale business and tourism. The location of all these villages can be found in the map shown in Figure 1.

Figure 1. The map of Zanzibar archipelago

(Source: www.zanzibar-paradise.com/contact.html)

3.2 Data sources

The data collection on rural costal livelihood diversification is a complicated task, as livelihood means almost any aspect of the way people gaining their daily needs for survival. In order to potentially identify livelihood events in Zanzibar, we chose to investigate both qualitative and quantitative data sources. Booth et al. (2003) argued a combination of qualitative and quantitative data provides more credibility to research findings. In this research work, we collect qualitative data through appropriate literature reviews (sustainable livelihood options and resilience), open end questionnaires, personal observations and informal dialogues with people. The quantitative data were collected through a household survey (household income and number of livelihood activities).

These data were collected in five rural coastal villages in Zanzibar during one month period ranging from August to September in 2008[1]. This period is a stable season in Zanzibar (i.e. without heavy rain or light rain) which helps to minimize the disturbances for data collection. From each village forty households were randomly selected giving a sample of 200 households. The selected villages cover north, east and south coastal area in Zanzibar. The west coast was not considered as it is an urban area. The selected five villages contribute to different socio-economic and environmental conditions attached with varying livelihood activities. For example, Mkokotoni is a traditional fishing village. In Kizimikazi, there is a marine protected area where tourism is popular. In the past Paje was popular for fishing activities. But the trend has now changed to seaweed farming and tourism. The environmental condition of the coast area of Paje has deteriorated in the recent past. Marumbi is a small village compared to others having low development rate. Chawaka and Uroa are fishing villages with a sound fish market and also with some tourism. In this study these two villages are considered as a one unit due to the similar characteristics in activities, size and population.

The 40 households from each village were chosen in a completely randomized manner with help of the Bwana Diko (local monitoring agent). The household residents in the sample are permanent residents and performing varying livelihood activities. Both these factors were used as household selection criterion.

The data were collected using two methods (i) maintaining a daily diary (ii) comprehensive interview. The selected households were trained and required to record their data in a daily diary provided for that purpose. These data includes different livelihood activities performed during the day and the income obtained from each livelihood activity. A set of guidelines were provided in their mother language on how to maintain the daily diary. The research team visited the villages at least once a week to check on how the diary was maintained and gave feedback to the Bwana Diko. Furthermore, to improve the reliability of income data, personal income are compared with related literature (gross income per week) to identify whether the given income are in the range. The comprehensive interviews were conducted with each household head. A semi structured questionnaire was used during the interviews. The data gathered through the questionnaire included households' demographic characteristics, such as household size (number

[1] The data was collected by de la Torre-Castro.M. as part of the larger research project: 'Opening windows and closing doors'

of family members), main profession (main livelihood activity) of the household head, extra livelihood activities, gender and educational level.

In this study we use these raw data as a primary data source. They are recorded in an EXCEL workbook in order to make manipulation easy and transfer to other data analysis tools for advanced statistical analysis. The collected data were analyzed using statistical tools available in EXCEL and JMP statistical package.

3.3 Statistical analysis

3.3.1 Univariate analysis: One-way analysis of variance (ANOVA)

To test for differences in income of different livelihood sectors, we employ Univariate one-way analysis of variance (ANOVA). The details of the method can be found in Appendix III (A). The treatments are the livelihood sectors, Fishing, Seaweed, Agriculture, Coconut Agriculture, Forestry, Tourism, Mining, Service and Manufacture related with ecosystem services, Service and Manufacture not related with ecosystem services and Wage employment. The response variable (Y_{ij}) is the total monthly income of each household for each livelihood sector.

Our null hypothesis is:

$\boldsymbol{H_o}$*: Mean income from all livelihood sectors are the same*

Alternative hypothesis is:

$\boldsymbol{H_1}$*: At least mean income from two livelihood sectors are different*

The assumption of Normal distribution of the response variable is tested using the Qui-squire test. As this assumption is violated data are transformed into Log base 10 (Log_{10} (Y_{ij}). If the ANOVA showed overall significance at ($\alpha = 0.05$) the Tukey method for pair-wise comparison is used to test which of the livelihood sectors differed significantly.

3.3.2 Bivariate analysis: Simple Linear Regression

To find out if there is a correlation between number of livelihood activities performed by each household and the total monthly mean income we employ a simple linear regression. The details

of the method can be found in Appendix III (B). The independent variable (X_i) is the *Number of Livelihood Activities* and dependent variable (Y_i) is the *Mean Income*.

The relation between the dependent and independent variable can be expressed using the simple linear regression model.

Mean Income = α + β *Number of Livelihood Activities* + *Error* (ε)

Our null hypothesis is:

$\boldsymbol{H_o}$*:* $\alpha = \beta = 0$

Alternative hypothesis is:

$\boldsymbol{H_1}$*: At least one of them not equal to zero*

To test the significance of the relation between '*Number of Livelihood Activities*' and '*Mean Income*' we use the coefficient of determination (r^2). If the correlation between number of livelihood activities and mean income is high the value of r^2 is close to one.

3.3.3 Bivariate analysis: Polynomial Linear Regression

To examine whether there is a higher degree of relation between number of livelihood activities performed by each household and the mean income we employ a polynomial regression. The independent variable (X_i) is the *Number of Livelihood Activities* and dependent variable (Y_i) is the *Mean Income*.

The relation between the dependent and independent variable can be expressed using an order two polynomial regression model.

Mean Income = α + β *Number of Livelihood Activities* + γ *Number of Livelihood Activities*^{2} + *Error* (ε)

Our null hypothesis is:

$\boldsymbol{H_o}$*:* $\alpha = \beta = \gamma = 0$

Alternative hypothesis is:

$\boldsymbol{H_1}$*: At least one of them not equal to zero*

The significance of the relation between '*Number of Livelihood Activities*' and '*Mean Income*' is tested using the coefficient of determination (r^2).

4 Analysis of the Results

4.1 Household characteristics in the sampled villages

A household is described here as people living together and sharing everyday needs such as meals, shelter etc. There are several factors that can affect the livelihood diversification. These include household size, gender differences and educational level. The data relevant to these household characteristics are gathered for the sample villages and presented in Table 2. (The figures are calculated as average values.)

Table 2. Household characteristics by villages

Household characteristic	Kizimikazi	Paje	Mkokotoni	Marumbi	Chawaka/Uroa
Average household size	5.2	5.6	6.8	5.5	6.1
Proportion household head (male)	0.98	0.63	0.93	1.00	0.85
Proportion household head (female)	0.02	0.37	0.07	0.00	0.15
Head main profession					
Fishing	0.80	0.30	0.53	0.93	0.58
Seaweed farming	0.00	0.33	0.00	0.00	0.12
Tourism	0.10	0.10	0.00	0.05	0.00
Farming	0.04	0.13	0.35	0.02	0.08
Employment	0.03	0.11	0.02	0.00	0.15
Small business	0.00	0.00	0.05	0.00	0.02
Other work	0.03	0.03	0.05	0.00	0.05
Educational level (household head)					
No formal Education	0.03	0.10	0.14	0.16	0.08
Low primary education (1-3)	0.00	0.04	0.16	0.09	0.00
Higher primary (4-8)	0.31	0.25	0.30	0.34	0.22
Secondary (form (1-1V)	0.66	0.58	0.40	0.41	0.70
Advance K level	0.00	0.03	0.00	0.00	0.00

The household characteristics gender of the household head, educational level and profession of the household head are varying from household to household in the five villages. The average household size is varying from 5.2 (in Kizimikazi) to 6.8 (in Mkokotoni). The overall average of the mean household size of the sample is 5.8. This value can be used as estimator for the household size of Zanzibar.

The Household head in all villages is significantly dominated by males (mean 0.88). But, compared to other villages in Paje more household heads were females.

The main profession of the household head of all villages is fishing except in Paje, where seaweed farming is the main profession of the household head. Other activities do not

significantly contribute to the main profession of the household head in all villages. With regard to the educational background of the household head, majority of the respondents have secondary educational level and very few have acquired advance K level.

4.2 Coastal livelihood strategies and diversity

To answer the Question 1, What are the different livelihoods and what is the degree of diversification in coastal villages in Zanzibar? we tried to identify different livelihood activities and their diversity. This is done in two steps, (1) Identifying different livelihood activities of each household and number of livelihood activities carried out by each household in each village. The data were obtained directly from the diaries' with no data processing. (2) Studying livelihood diversification index by sector and village; studying how livelihood sectors are varying across the different coastal villages. The categorized data were used during this step.

4.2.1 Coastal livelihood strategies

The Figure 2 depicts fraction of the graph that describes how total number of households participation are varying with the different coastal livelihoods. The total number of livelihood activities (strategies) is 129. These livelihood strategies consist of cash crops, small scale business, fishing, collection bivalves, bait, sea cucumbers, stone or keeping livestock, gathering of forest product, seaweed farming, mason, driver and many others.

The Figure 2 shows that a significant number of households are performing the fishing activities. The second most participated activity is seaweed farming and small scale farming, followed by firewood collection and small scale business. A small number of households conducted other activities such as teaching, mason, making hats, dress making etc.

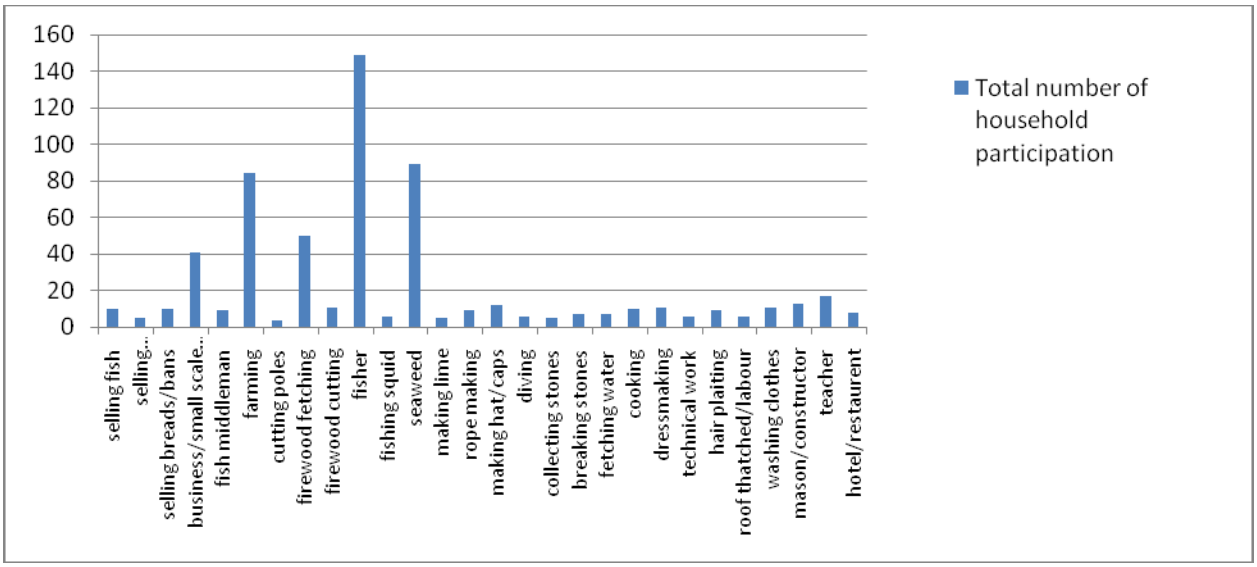


Figure 2. Livelihood activities portfolio, all villages

4.2.1.1 Number of livelihood activities performed by households

In Section 4.2.1, we identified livelihood activities in Zanzibar. This section is dedicated to study the number of livelihood activities performed by each household. The results are captured and presented in Figure 3.

According to Figure 3 majority of the households performed more than one activity (88.5%). The number of household activities performed by each household is ranging from 1-30. Most households (80.5%) participates activities ranging from 1-6. Significant number of households (23%) performed 2 activities and very limited number (8%) of households performed activities less than 10.

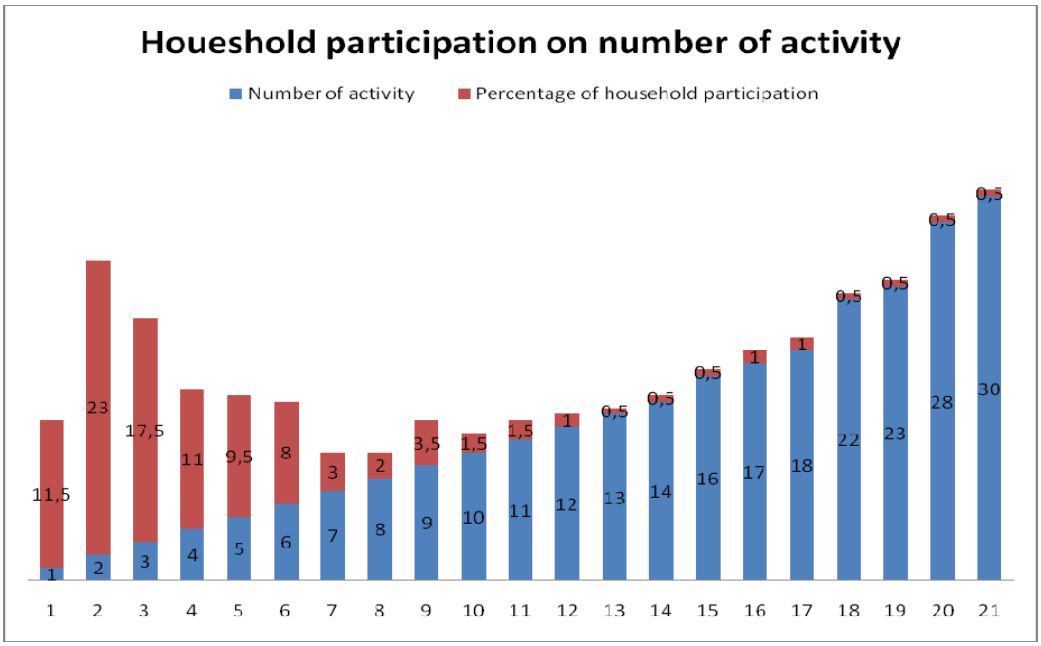


Figure 3. Household percentage against number of livelihood activities

4.2.1.2 Number of livelihood activities performed by villages

In Section 4.2.1.1, we studied the number of livelihood activities performed by each household. This section is devoted to study how livelihood activities are varying across the coastal location. The Table 3 shows average number of livelihood activities per household in different coastal villages.

Table 3. Average number of livelihood activities per household in different coastal villages

Village	**Average number of livelihood activities per household**
Kizimikazi	5.00
Paje	6.00
Mkokotoni	4.00
Marumbi	3.00
Chawaka/Uroa	4.00

According to Table 3, Paje village has highest average number of livelihood activities per household; Mkokotoni and Marumbi have relatively low average numbers compared to other villages. These observations verify in each village there are different livelihood activities

available for its coastal communities. The mean of the average number of household livelihood activities in sampled villages is 4.89 (5.00).

4.2.2 Coastal livelihood diversification

In Section 4.2.1, we identified there are 129 different livelihood activities. To reduce the complexity and have a better grouping, by considering the nature of the livelihood activities, we divide all these into 10 livelihood sectors, namely fishing, seaweed framing, forestry, agriculture, agro-coconut, tourism, mining, services and manufacture (directly related with ecosystem services), services and manufacture sector (directly not related with ecosystem services) and wage employment (government and private sector). See the Appendix I for detail categorization. In our overall analysis, we used these livelihood sectors as the basis for classification of livelihood activities.

4.2.2.1 Coastal livelihood diversification index by sector

We define livelihood index as the ratio between numbers of households performing a particular livelihood sector to the total number of households (200) in the sample. Figure 4 shows the livelihood diversification index across the sample of five villages.

It is observed that participating in the fishing sector in each of the village is proportionately almost similar, where as in other sectors the participation is disproportional. The majority (82%) of the households in the sample are participating in the fishing sector. Also, relatively higher contributions can be identified with agricultural sector (55%), seaweed (47%), services not directly related with ecosystem services (48%) and forestry (24%). Tourism is an important livelihood activity in coastal Zanzibar; however only 22 households (11%) are participating in the tourism sector. Mining sector in most villages is negligible except Paje. Paje villagers are participating in almost every sector in high proportion compared to other villages. There are no any reported coconut related activities in Chawaka and Marumbi.

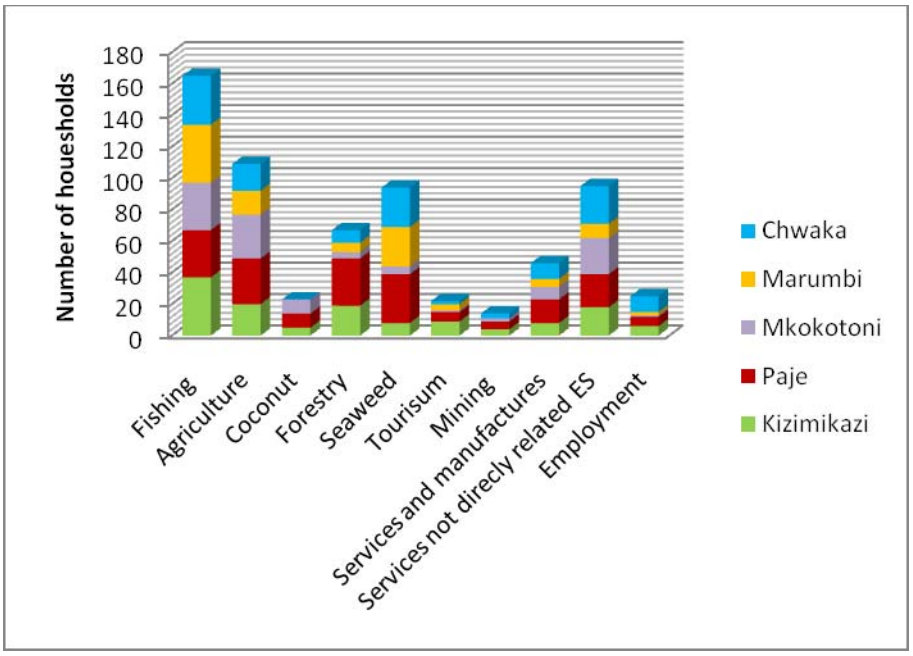


Figure 4. Livelihood index per sector

4.2.2.2 Coastal livelihood diversification by village

The Figure 5 illustrates the number of livelihood activities within a sector for different villages. It can be seen that all livelihood activities within a particular sector are disproportionately varying across the villages.

In every village there are more than one sector having high values for number of activities participated by households. This would mean that in every village there is more than one popular sector where inhabitants can perform functions to generate some source of income. Villagers in Kizimikazi are participating more on services not related with ecosystem services and fishing sector, Paje villagers are participating more on forestry sector and services not related with ecosystem services, Mkokotoni has high values for agriculture and fishing sectors, Marumbi and Chawaka have high values for fishing sector and seaweed sector. Mining is not widespread in Marumbi and there is no participation in agro coconut sector both in Marumbi and Chawaka. In Kizimikazi and Paje there is a considerable participation in every sector compared to all others.

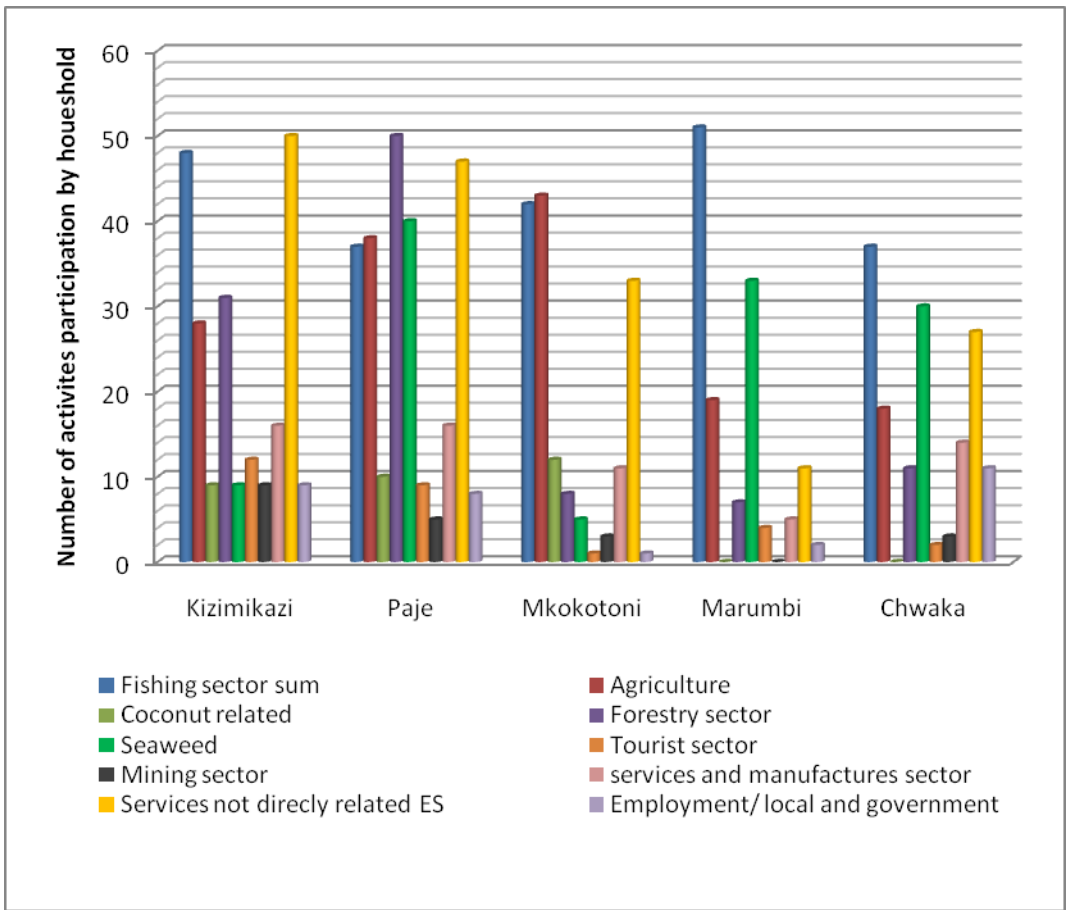


Figure 5. Livelihood sectors divergence by villages

The information shown in Figure 4 and Figure 5 illustrates what sectors are considerably important in different villages and as a whole in Zanzibar Island. According to these figures fishing, agriculture, forestry, seaweed farming, services not related with ecosystem services are widespread sectors among the coastal communities.

4.3 Livelihood dependence of the coastal communities on ecosystem services

To answer the Question 2, '*What is the relationship between coastal ecosystem services and livelihood activities?*', we tried to study how the number of different household livelihood activities are depending on provisioning services in the sample of villages.

Coastal communities depend on ecosystem services for their subsistence needs, especially on livelihood activities and income. The degree of dependence is varying across the communities and households. The Figure 6 illustrates how number of household livelihood activities is varying with provisioning services (See Appendix II to the definition of Provisioning Service).

According to Figure 6 a majority of household livelihood activities are depending on fishing and related services. Also, aquaculture, crops and biomass fuel provisioning services have a significant contribution to their livelihoods.

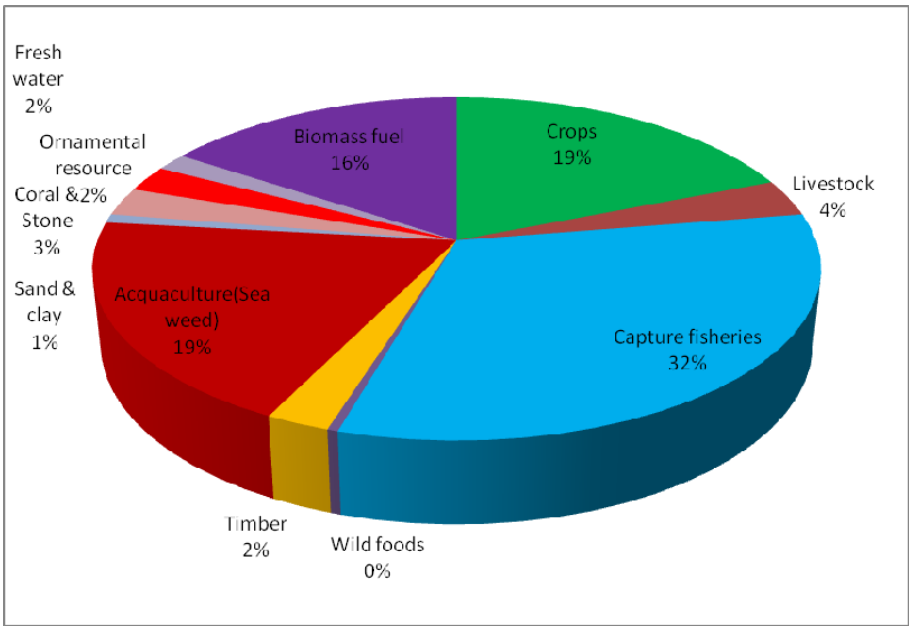


Figure 6. Percentage of household dependence on provisioning services

4.4 Relationships between income and livelihood strategies

In Section 4.2 we identified that all villages are engaged in multiple activities demonstrating diverse livelihood in households and villages.

To answer the Question 3, '*Is there any relationship between income level and livelihood diversification?*' in this section we investigate the relationship between livelihood diversification and income. This is done in two steps, (1) Investigate the correlation between mean income and total number of household performed activities (2) Investigate the revenue relation among livelihood sectors.

4.4.1 Correlation between income and total number of performed activities

To investigate the correlation between mean income and number of household activities, we employ the Bivariate simple linear regression technique. We consider the independent variable (X_i) as the number of activities. Each household in the sample participated in one or more livelihood activities and there would be one or more households doing the same number of activities. This would mean there are multiple income values for a particular number of livelihood activity. Thus, we consider mean income as our dependent variable in the analysis.

X_i : Number of activities

Y_i: Mean Income

The Figure 7 depicts the relationship between 'Mean income' and 'Number of livelihood activities' for the sample of 200 households in the coastal community. The results of the regression analysis are presented in the Appendix IV (B).

The relation between the two variables can be expressed by the linear regression model:

Mean income = 140277.12 + 3590.2567 ***Number of livelihood activities***

These results reveal that there is a very weak correlation (correlation coefficient (r^2) = 0.1244) between mean income and number of livelihood activities. This would mean the *Number of livelihood activities* (independent variable) does not explain the *Mean income* (dependent variable).

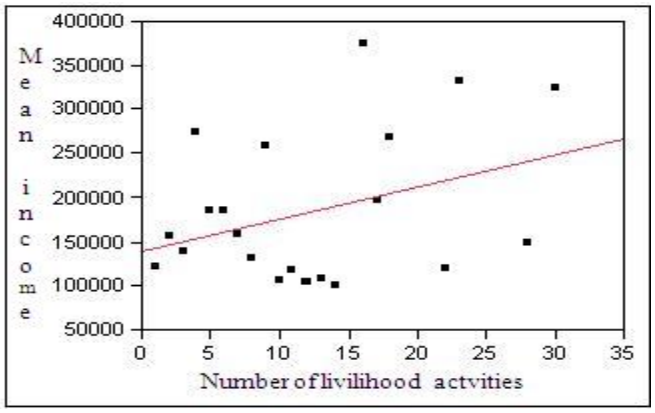


Figure 7. Linear regression fit for mean income and number of livelihood activities

In order to find the unexplained portion we analyzed the data and try to fit polynomial regression of order 2, 3 and 4. Also, according to Figure 7, we can see that the variation takes a polynomial form between number of activities 0 to 14. The variation beyond that, is highly random. The results revealed that using a polynomial regression of order 2 the correlation can be improved significantly. The Figure 8 depicts the polynomial relationship (order = 2) between *Mean income* and *Number of livelihood activities* for the sample of 200 households in the coastal community. The results of the polynomial regression analysis are presented in the Appendix IV (C). According to the results we can see that there is an improvement in the correlation coefficient (r^2 = 0.3508) observed between mean income and number of livelihood activities. From the Figure 8, we can see that mean income level tends to increase up to number of livelihood activities 6, and beyond that it tends to decrease.

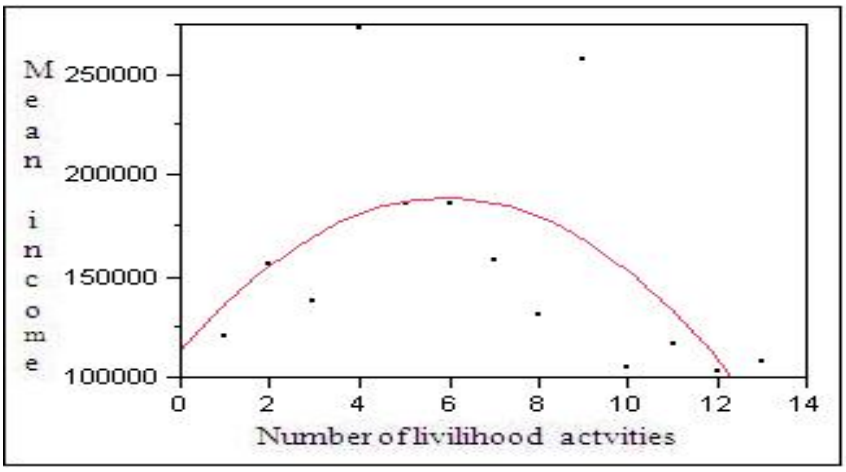


Figure 8. Polynomial regression fit for mean income and number of livelihood activities

4.4.2 Diversification of income of livelihood sectors

4.4.2.1 Income disparities by sectors

The Figure 9 illustrates total household monthly income percentage per sector in all villages. According to Figure 9, more than 50% income is earned from the fishing sector. Second income generation is the service not directly related with ecosystem services (18%) and contributions from other sectors are less than 6%. Also, income from mining sectors in all villages is negligible.

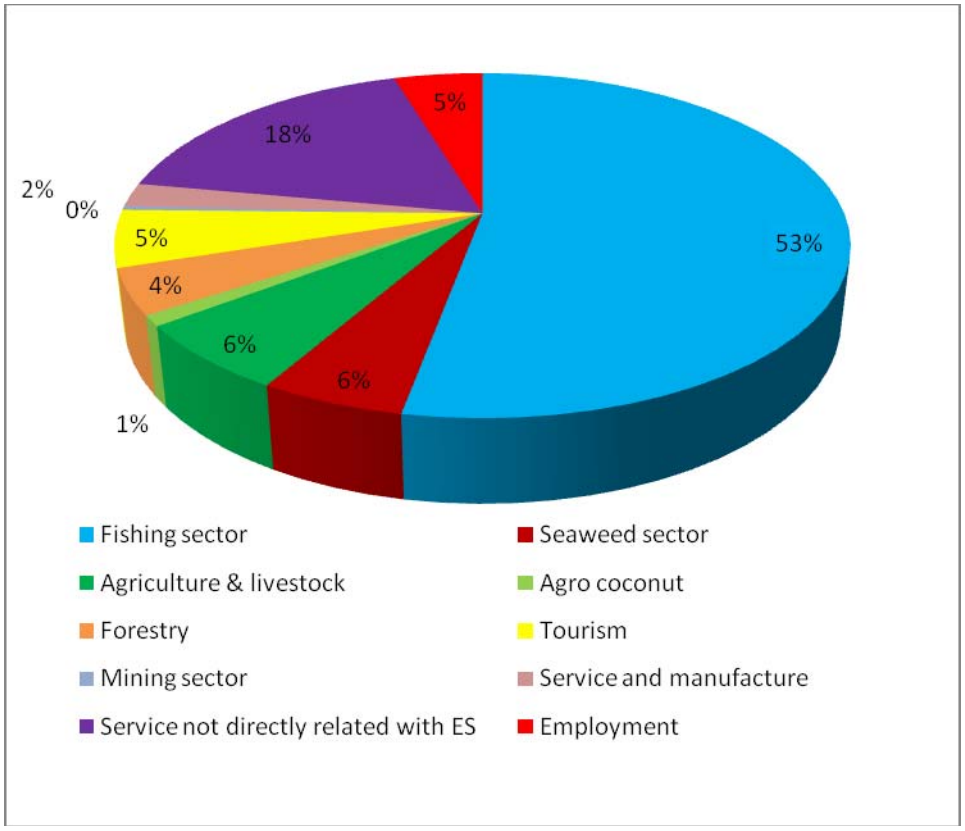


Figure 9. Income percentage contribution by livelihood sectors

The Figure 9 provides subjective judgements. Therefore, we performed a statistical analysis to objectively looking into the research findings.

4.4.2.2 Significant income of livelihood sectors

In order to test the significance differences of income of different livelihood sectors, we used one-way ANOVA. The results of the analysis are presented in Appendix IV (A) and ANOVA is

given in Table 4. The Figure 10 shows the mean income of different livelihood sectors. It can be seen from the figure that the highest income is obtained from the fishing sector followed by tourism, employment and service and manufacture not related with ecosystem services. The lowest income is obtaining from mining.

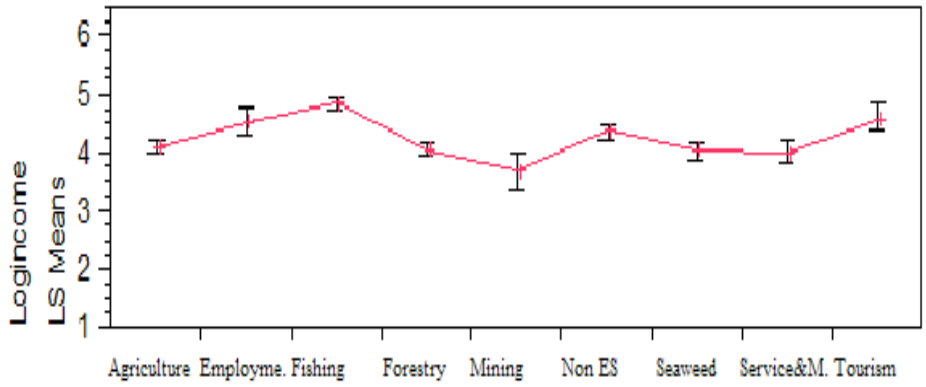


Figure 10. Least square means plot for mean income vs. livelihood sectors

Table 4. Analysis of Variance (ANOVA)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	8	72.16349	9.02044	28.3168
Error	568	180.93901	0.31855	**P-value**
C. Total	576	253.10251		0.0001

Since the P value 0.0001 is less than α (0.05) we can reject our H_0. That means we can conclude that average income levels of different livelihood sectors differs at 0.05 level of highly significance. This means there is a difference in mean income levels of different livelihood sectors.

Table 5. Summary of the mean income level comparison of different livelihood sectors

Level					**Least Sq Mean**
Fishing	A				4.8421262
Tourism	A	B			4.5825866
Employment	A	B			4.5493762
non ES service		B	C		4.3586802
Agriculture			C	D	4.1074561
Forestry				D	4.0399375
seaweed				D	4.0220346
service & manufacture			C	D	4.0091710
mining				D	3.6674385

Note: Levels not connected by same letter are significantly different

Since the ANOVA showed overall significance ($\alpha = 0.05$), we employed the Tukey method to pair-wise comparison when livelihood sectors differed significantly. The details of the pair-wise comparison are presented in the Appendix IV (A). Summary of the ANOVA results of mean income level comparison of different livelihood sectors are presented in Table 5.

Even though Figure 10 shows fishing has the highest mean income level followed by tourism and employment, Tukey test shows (summarized in Table 5) that there is no significant different between (fishing, employment), (fishing, tourism) and (tourism, employment). Therefore, we can statistically conclude that there is no such significant difference between mean income levels of fishing, tourism and employment.

5 Discussion

5.1 Livelihood diversify patterns

5.1.1 General patterns

A large and disparate body of literature illustrates that rural livelihood diversification is a pervasive phenomenon (Ellis, 2000; Ellis and Freeman, 2004). This is true for all the sample villages in Zanzibar; our study shows that participation in multiple livelihood activities is a common factor among these households. Similar results were also recognized in rural Africa (Barret et al., 2001) and in particular in coastal communities in Kiwengwa (Zanzibar) (Gossling, 2002). The average number of livelihood activities in which households participate (ranging from 3 to 6) is high for all these coastal villages (Table 3) compared with studies carried out in other African countries. For example, in nine coastal communities in Kenya, the average number of different livelihoods per household ranged from 1 to 3(Cinner et al., 2005).

Our results reveal that livelihood strategies are dynamic and show a high degree of diversification. This raises the question: *why do coastal communities in Zanzibar show such a high degree of livelihood diversification*? This might be due to several factors. The people in our study are responding to pressures and opportunities, and they adapt according to the availability of resources. Seasonal variations, market demand or market failures, and different skills can also affect livelihood diversification. In responding to the above factors, household members are "doing something" that may result in completely different livelihood activities which may not be relevant to their competence or desires. Furthermore, livelihood diversification varies with the household characteristics, (Table 2) such as number of family members, age, education level and gender.

According to the results given in Figure 5, it is clear that household participation in the service and manufacture not related with ecosystem services is high. However, other studies carried out during 1990s reveal that household participation in service and manufacture not related with ecosystem services is occasional and very low (Pettersson-Lofquist, 1995a). We observe this situation as a new trend among the coastal households in Zanzibar. This might be

due to the increase of tourism at the local level and it provides opportunities for other sectors to grow. For example, Kizimikazi and Paje villages have high household participation in the tourism sector and also high participation in the service and manufacture not related with ecosystem services (Figure 5).

It is argued that a higher income can be earned when there is livelihood diversification than when household income depends on a single livelihood activity (Ellis, 2000). Higher income can be used to develop skills, to invest, or to make better use of available resources. However, the results of this study raise the question whether a higher degree of diversification always provides a higher income? We have seen, in a large proportion of households, that there is no strong correlation (correlation coefficient=0.124) between income and livelihood diversification (Figure 7). We can observe from Figure 8 that six activities provide the maximum income, and beyond six activities, household incomes tend to decrease. Even though households are participating in different numbers of livelihood activities, their income is usually concentrated on just one or two specialized activities. This might be due to the fact that the skills of household members are limited to a number of activities (Table 2). The other livelihood activities recorded do not provide sufficient income and might reflect households "doing something" in the short term to cope with livelihood stresses. Often the members of poor households lack the skills or access to resources to engage in higher income activities. In particular, better-off families have access to stable high income activities compared with the poor families as they have more assets than the poor (Ellis, 2000; Davis et al., 2009). This raises the issue of the poverty trap and how assets are an important component when discussing household livelihood conditions.

Our findings show that higher greater diversification does not always provide higher income, as income is volatile and depends on a number of external factors. The dependence of livelihood on ecosystem services can be uncertain for many reasons, including commercialization, technological innovation and environmental variability (Adger, 2000). Particularly, in Zanzibar there are limited opportunities for new technological innovations and competition with global markets. For this reason, coastal communities have to depend on traditional local markets with very low-level facilities. This hinders economic growth. Markets are critical to household livelihood, but there is a considerable gap between the two factors. The role played by the market in developing livelihoods needs to be changed in the future.

5.1.2 Livelihood diversification and Resilience

Diversification within and among livelihood sectors is a widely recognized strategy for reducing risk (Scoones, 1998; Ellis, 2000; Ellis and Allison, 2004). Diversification contributes to livelihood resilience (ability of households to recover from or to withstand changes caused by external shocks). In our study, there was an average of five livelihood activities per household (Table 3). This diverse portfolio helps to promotes flexibility, as when one substitute livelihood option declines, alternative options will be expanding. Our findings illustrate that, in livelihoods based on ecosystem services, the fisheries sector has a high degree diversification (26 activities) and the tourism sector has a low degree of diversification (5 activities) (see Appendix 1). Therefore, understanding the multiple livelihood activities and the external drivers of the fishing sector is an important means to enhance resilience. However, Thyresson (2009) discusses coral reef fisheries trade in Zanzibar leads to less ecological resilience. If the ecological resilience is reduced it will affect the livelihood resilience. Thus, to protect ecological resilience there is a need to evaluate the impact on the ecosystem from fishing and to adapt the necessary legal frameworks, and increase public awareness and enforcement.

However, the livelihoods of poor households are under stress from lack of income and wealth. Their income mainly depends on access to markets for their products. For example, the seaweed farmers' income depends on the market price of seaweed. The present market segments and their exploitative attitudes are not helping to enhance the livelihood resilience of households. However, livelihood diversification leads to reduced stress in the short term by household members selling different products when the market price of seaweed is reduced.

Livelihood diversification is also a coping strategy (Ellis, 2000). A high level of diversification provides opportunities to change livelihood activities from one to another. Our experience from collected data is that some of the livelihood activities do not provide sufficient income to the household. People are performing these activities as there are no other livelihood options available. Income is a very effective factor in enhancing livelihood resilience. Therefore, investigation of present high income livelihood activities, as well as other alternatives and sustainable marketing requirements, is necessary. Regarding livelihood sustainability, new opportunities, novelty and innovation are vital aspects (de Hanna and Zoomers, 2003). Thus, households need to adapt in order to participate in high income activities, and structural changes

are needed that are implemented in a sustainable, novel way. The sustainable enterprises can be used to enhance the livelihood in a novel way.

5.2 Are the dominant livelihood sectors sustainable?

All the various livelihood sectors contribute to the survival of coastal households. The major contributors are; fishing, seaweed harvesting, agriculture, and service and manufacture not related with ecosystem services (Figure 4). The results of our income analysis show that fishing, tourism and employment sectors provide relatively high incomes to the households (Table 5). The seaweed farming and fishing sectors are based on the coastal ecosystem. Therefore, in order to identify sustainable livelihood sectors based on the coastal ecosystem, in the next section, we discuss the socio-economic and environmental aspects of seaweed farming, tourism and fishing.

5.2.1 Seaweed farming

Zanzibar's coastal areas offer a favourable environment for seaweed cultivation. Industrial seaweed farming was established in 1989 due to high international market demand at that time (Pettersson and Lofquist, 1995b). Seaweed farming is often considered to be more sustainable than other aquacultures, such as shrimp farming or salmon farming (Bryceson, 2002b; Johnstone and Olafsson, 1995).

Many research reports have discussed the economic value of seaweed farming in terms of foreign exchange earnings and its value as a profitable livelihood (Pettersson and Lofquist, 1995b; Ronnback et al., 2002). Seaweed farming in Zanzibar has reportedly enhanced living standards (Bryceson, 2002b), particularly benefiting the women (Bryceson 2002b; Msuya, 1993) engaged in this sector. However, present global market values, the monopoly of seaweed prices and exploitative attitudes of the multinational companies, render the future of seaweed farming uncertain (de la Torre- Castro and Lindstrom, 2010). Most women are disappointed over the fluctuating prices for seaweed products, but they continue with seaweed farming as they lack alternative livelihood options (Eklund and Pettersson, 1992), ignoring the health problems that seaweed farming can cause (de la Torre- Castro and Lindstrom, 2010).

Seaweed farming changes the traditional gender roles and women's autonomy in economic and social terms (Pettersson and Lofquist, 1995b). The expansion of seaweed farming in tidal areas introduces problems related to land tenure and property rights (ICAM, 1996; Mohammed and Jiddawi, 1999). There are also other various problems associated with seaweed farming, such as lack of equipments (e.g. nylon string), access to bank loans, inadequate seaweed drying places, and loss of harvests due to theft (Eklund and Pettersson, 1992).

Seaweed farming affects the environment to an extent that varies with the coastal area, the intensity of farming and the nature of the substratum (Bergman et al., 2001). The expansion of seaweed farming in coastal areas leads to different environmental impacts, e.g., monoculture-related diseases (Ronnback et al., 2002), benthic microbial processes and meiofauna population (Johnstone and Olaffon, 1995). It damages the nearby environment (Collen et al., 1995) and fish populations(Bergman et al., 2001) reducing catches and catch composition(Eklof et al., 2006), damages seagrass beds (de la Torre-Castro., 2006) and decreases the biomass primary production of macrophytes (Eklöf et al., 2005).

Our results show (Figure 4) that the seaweed farming sector is an important source of livelihoods for most villages in the sample. The diversification of activities within the seaweed farming sector and the rate of participation varies with the village; Paje inhabitants have the highest participation, followed by Marumbi and Chawaka/Uroa (Figure 5). Figure 9 and Table 5 reveal that seaweed farming is not a profitable sector (providing only 6% of income and mean income is 4.0) compared with the other livelihood activities. This means seaweed at present is not sustainable, due to low diversification within this sector, low prices and negative environmental impact. In addition, some other countries are also farming seaweed, which provides market competition for Zanzibar (Feidi, 2005). The quality of seaweed produced in Zanzibar has deteriorated (Feidi, 2005). Therefore, the skills of the seaweed farmers and technology needed required to be improved in order to enhance the quality of the seaweed produced, reduce the environmental impact and capture global markets. Also, it is necessary to reorganize the present seaweed market chain, to enhance benefits to the farmers rather than the multinational companies.

5.2.2 Tourism

Its diverse coastal resources, cultural heritage and climate all make Zanzibar an attractive destination for foreign visitors. Tourism began to increase in the 1980s and expanded rapidly. The recorded number of tourist arrivals was 42,141 in 1990 (Makame and Boon, 2008) and it increased to 219,047 in 2007 (Lange and Jiddawi, 2009). Tourism has grown rapidly and contributes as a major source of income to Zanzibar's foreign exchange earnings. In 2007, the tourist sector earned US$ 184.9 million in foreign exchange, and its contribution to the GDP is 25%, but economic benefits to the local people are very low (20%) (Lange and Jiddawi, 2009). However, the target of the Tanzanian government is to receive one million tourists by 2010 and for tourism to be the leading foreign exchange earning sector by 2015(Makame and Boon, 2008). This rapid expansion generates additional livelihood opportunities. Currently, about 45,000 people are employed in this sector and it is anticipated that the number will increase in the future (Makame and Boon, 2008). Also, tourism creates new market opportunities for locally produced goods and services, for infrastructural development and new skills for the community. In this context, tourism offers a good prospect to improve the livelihood and standard of living of the coastal communities.

Many researchers have pointed out not only the positive but also the negative consequences of tourism in different coastal areas in Zanzibar (Gossling, 2003; ICAM, 1996; Makame and Boon, 2008; Pettersson-Lofquist, 1995a; Wallevik and Jiddawi, 1999). The most significant negative consequences are due to lack of awareness and long-term planning (i.e., The ICAM, 1996), for example, absence of proper waste management systems and sewage disposal methods. Furthermore, tourism has a negative impact on coral reef fisheries (Thyresson, 2009) and coral reefs, and sand mining for hotel construction leads to shoreline erosion (Wallevik and Jiddawi, 1999). Water scarcity is an escalating problem in Zanzibar (ICAM, 1996). Often, tourists use more water than they would at home (Gossling, 2002), but half of the local people are experiencing water shortages in everyday life (ERB, 2003). Moreover, tourism expansion will cause increased demand for natural resources (Gossling, 2003; Muhando and Jiddawi, 1998; Pettersson-Lofquist, 1995a; Thyresson, 2009). The increased demand for fish could raise fish prices, triggering low protein consumption in the diet and ultimately creating health problems for the local population (Gossling, 2003).

The establishment of coastal holiday resorts could cause a negative social impact for the local women (Wallevik and Jiddawi, 1999). This is because both the women's livelihoods (such as seaweed harvesting, collecting seashells, sea cucumber etc.) and tourist-related activities all depend on the same shallow and sandy beaches (ICAM, 1996; Wallevik and Jiddawi, 1999). This creates a problem of conflict for space. Additionally, according to Gossling (2003), local people are turning their livelihoods to tourism and abandoning their traditional livelihoods, threatening traditional ways of life.

The case study carried out by Gossling (2003) shows that, in the Kiwengwa area, 50% of the households are participating in tourism-related activities. The results presented in Section 4.2.2 show that tourism has a lower participation rate (11%) in our study areas (Figure 4), where much of the contribution is coming from the village of Kizimikazi (Figure 5). This is due to the fact that participation in tourism-related livelihood activities is limited by lack of language proficiency, low literacy rates and low skills of the people (Gossling, 2003., ICMA, 1996; Lange and Jiddawi, 2009; Wallevik and Jiddawi, 1999). However, Section 4.4.2.2 shows that the tourism sector offers the second highest mean income and there is no significant income differential between the fisheries and tourist sectors (Table 5). This indicates that the tourism sector is very important to enhance the income of coastal communities and there is a need to enhance the language proficiency, literacy and skills of the people to enable them to participate. Also, tourism management is needed in order to improve tourism in an innovative way by reducing impacts on the environment while maintaining long-term sustainability of livelihood for local communities.

5.2.3 Fisheries

Marine fisheries provide an important source of protein in the diet, and significant revenue, to the local households. There are approximately 34,269 fishermen (the majority of them small-scale artisanal fishers) active in the territorial waters in Zanzibar (Lange and Jiddawi, 2009). Total fish catches are estimated at approximately 23,000 tons per year (Jiddawi and Khatib, 2007), of which 99% is consumed locally (ERB, 2003). The majority of fishing activities take place within 5 miles of shore using simple, traditional fishing gear and vessels (Feidi, 2005; Jiddawi and Ohman 2002).

Fisheries resources contribute between 2.2% and 10.4% of the country's GDP (Jiddawi and Ohman, 2002). The major export products are invertebrates; shrimp, octopus, lobster bring US$ 0.6 million in foreign exchange for Zanzibar (Jiddawi and Ohman, 2002). Even though the majority of households contribute, and the fisheries sector provides relatively high incomes, there is strong evidence that the artisanal inshore fishery in Zanzibar is severely overfished (Jiddawi and Ohman, 2002; Mkenda and Folmer, 2001; Muhando and Jiddawi, 1998). Furthermore, fishing particular functional groups (Thyresson, 2009), beach seine and drag-net fishing, could lead to undesirable consequences for the fisheries resource and the marine ecosystem (Jiddawi and Ohman, 2002). Muhando (1998) pointed out that the fishery sector is experiencing the following unresolved problems; lack of access to fishing boats, sustainable fishing gear and new technology, which forces fisherman to fish in inshore areas and leads to overexploitation of the inshore resources. This implies that the development of fishing-related livelihoods is hindered by economic constraints. Therefore, fishermen tend to use destructive fishing gear, easy to access but harmful for the environment, leading to resource overexploitation. The lack of fish handling and storage (freezer) facilities affects the price fluctuations and causes losses of the product after it is caught and landed. Furthermore, marine resources are uncoordinated and improperly exploited for different uses, causing conflict among different stakeholders and sometimes causing destructive environmental results.

The Figure 9 shows that the fisheries sector is an important source of income (53%) for the coastal households. Similar results are reported (52%) in two other coastal villages in Zanzibar, Nyamanzi and Mlingotini (Sesabo and Tol, 2005). This emphasizes the importance of sustainable fisheries management to protect their livelihood. If the fisheries resources are destroyed, the fishing livelihood will collapse. Currently, there are no alternative resources available to fill the place of the fisheries sector as a source of livelihood activities. Our study suggests that there is a need to develop livelihood programs that currently have low household participation (e.g. mining) together with fisheries management, to enhance livelihood opportunities. Moreover, the distribution of fisheries income among households is not equal. We estimate that middlemen represent the major income earning activity in the fisheries sector. There were eight middlemen in the sample villages and they contributed 20% of the fisheries income. Thus it appears that the fisheries sector is not providing the most equal benefits to the local community. According to our findings, the fisheries sector is more promising for livelihood security, due to its relatively low

environmental impact, high income and high sector diversification than are the seaweed farming and tourism sectors. Our study suggests there is more space to develop the fisheries sector in a sustainable way by enhancing market opportunities and eliminating the present obstacles to its development.

5.3 Future of livelihoods and diversification in coastal communities

Our study provides information about current livelihood and diversification in coastal communities in Zanzibar. These livelihoods and their diversification have changed in the past and may change in the near future. The literature contains numerous diagnoses of the widespread current management failures in Zanzibar (de la Torre- Castro, 2006; de la Torre- Castro and Lindstrom, 2010; Gossling, 2003; Lange and Jiddawi, 2009; Muhando and Jiddawi ,1998), and shows how present livelihoods are experiencing a number of stresses. However, we are still uncertain about the extent to which the existing livelihoods should be expanded and their impact in terms of livelihood resilience. Table 6 illustrates some actual factors (conditions) affecting major livelihood activities (see Section 5.2). A snapshot of these factors would help to throw further light on these issues.

Table 6. Factors (conditions) affecting dominant livelihood activities

Physical context	Social context	Natural context	Personal context
Lack of infrastructural facilities	Institution failure	Biodiversity threat	Lack of assets
Low technology	Conflicts among stakeholders	Ecosystem conditions deteriorating	Poverty
Lack of equipment	Lack of legal framework	Stock declining	Low skills and capability
	Weak organizations/associations	Toxic substances	Low labour productivity
	Gender roles	Pollutant	Lack of credit
	Less market availability		Health problems
	Monopoly in price control		

5.3.1 Scenarios

It is difficult to forecast the future of the major livelihood sectors and livelihood diversification. This is because they are dynamic in nature and interlinked stresses affect livelihoods at different levels. For example, poverty affects households' access to assets and also affects human resource management at the institutional level which influences the households' livelihoods.

In the following, we discuss the best case and worst case scenarios by applying the concept of sustainable enterprises and livelihood resilience to the fisheries, tourism and seaweed farming sectors. The scenarios show possible trajectories of evolution of major livelihoods in the ecological, social and economic context at the local level.

5.3.1.1 Worst case scenario: Unsustainable development

The majority of coastal households depend on fisheries and this will expand in the future due to high population growth. According to Table 7, there has also been a trend of expansion in the tourism and seaweed harvesting sectors in the future.

Table 7. Seaweed production and tourist arrivals in Zanzibar

Year	Seaweed production (Tons)	Number of tourist arrivals
1995	4287	56,415
1996	4768	69,159
1997	3667	86,495
1998	4305	86,455
1999	6606	86,918
2000	4990	97,165
2001	8116	-
2005	7362	-
2007	8485	219,047

(Source: Economic Research Bureau, 2003; Lange and Jiddawi, 2009)

If these three sectors expand without considering sustainability, it might have an effect on the livelihood security of the coastal people. Fish stocks are on the decline (Mekenda, 2001) and the present artisanal fisheries are overfished in Zanzibar (Jiddawi and Ohman, 2002; Muhando and Jiddawi, 1998. Also, in general, world fisheries resources are depleting significantly (Garcia and Grainger, 2005). Tourism leads to a selective fishing harvest, specially focusing on the top

predators (i.e. tuna, shark) (Gossling, 2003), which increases the top-down effect and alters the marine ecosystem (Jackson et al., 2001).

Inadequately planned tourism activities introduce a number of problems including local water scarcity (Gossling, 2002), exhausting natural resources and degrading the ecosystem (Gossling, 2003). Tourism and the livelihoods it offers are basically dependent on ecosystem-based services. If the ecosystem becomes degraded the tourists will probably leave to go elsewhere and villagers will be left without either the ecosystem services or the tourism. This puts livelihood related to tourism in danger and also other livelihoods, as most livelihoods depend on ecosystem services (i.e. fisheries, forestry). Furthermore, expansion in tourism leads to conflict between local communities and other stakeholders (ICAM 1996; Mohammed and Jiddawi 1999). These conflicts mainly affect the seaweed farming sector as they restrict the space available for seaweed farming activities.

The expansion of seaweed farming in limited areas paves the way for monoculture diseases (Ronnback et al., 2002), structural changes in biodiversity (Bergman et al., 2001; de la Torre-Castro, 2006; Johnstone and Olaffon, 1995; Msuya et al., 1995) and key functional groups which leads to change in the ecosystem function. Also, in Zanzibar monopoly control of seaweed prices (US$ 0.09 per kg) (Bryceson, 2002b) by several multinational companies provide undesirable light to the future. Research on monoculture production in prawn farming provides evidence for the serious ecological problems that might caused (Ronnback et al., 2002), yet not much research has been conducted on seaweed farming. The current epiphyte problems in seaweed farming (*E. cottonii*) provide some hints of lower productivity (Pettersson and Lofquist, 1995b) in the future. Thus, seaweed diseases and deteriorating environment influence the reduction in market demand due to low quality of seaweed. Also, monopoly control of seaweed prices in Zanzibar does not offer good prospects for the future. Multinational companies now pay a very low price to the farmers and these companies might cease to operate in Zanzibar in the future, due to high market competition. Finally, the women whose livelihoods include seaweed farming activities could be left with health problems and no market for seaweed, as Zanzibar only exports raw seaweed and does not process seaweed.

The expansion of these three sectors leads to environmental degradation which is overlapping. Therefore, expansion of the unsustainable seaweed farming, tourism and fisheries sectors would lead to an undesirable state of future livelihoods for coastal communities in Zanzibar.

5.3.1.2 Best case scenario: Sustainable enterprises

One way to enhance livelihood security in the future is to introduce collaborative sustainable enterprises which reduce conflict between different sectors (Evans et al., 2008). The collaborative enterprises are a sharing process which ultimately touches all areas of livelihood sectors. We define *collaborative enterprises* as *where people from different enterprises work together in different levels to gain some value which is important to improve community livelihood security.* Collaborative sustainable enterprises help to fulfil livelihood necessities, with groups acting together in managing enterprises. Also, they can provide efficient mechanisms for exchanging, coordinating and allocating various resources. The vision and benefits that can be gained from collaborative enterprises are summarized and captured in Table 8.

Table 8. Vision and benefits of collaborative enterprises

Vision of development of collaborative enterprises	**Benefits to households**
Strong commitment to ecosystem protection, environmentally-friendly technologies and products (e.g. 'eco' label).	Long-term livelihood maintenance without damage to the ecosystem.
Creating necessary knowledge and skills, improving public awareness and providing technology and equipment.	Improve quality and productivity of the manufactured goods or services that can capture global markets. Also increase livelihood opportunities (e.g. tourism).
Create market network with other enterprises, market opportunities and access to global market.	Eradicate poverty by increasing household income.
Active participation in decision making and create social safety net.	Enhance livelihood security to eliminate conflicts between livelihood sectors and develop social stability.

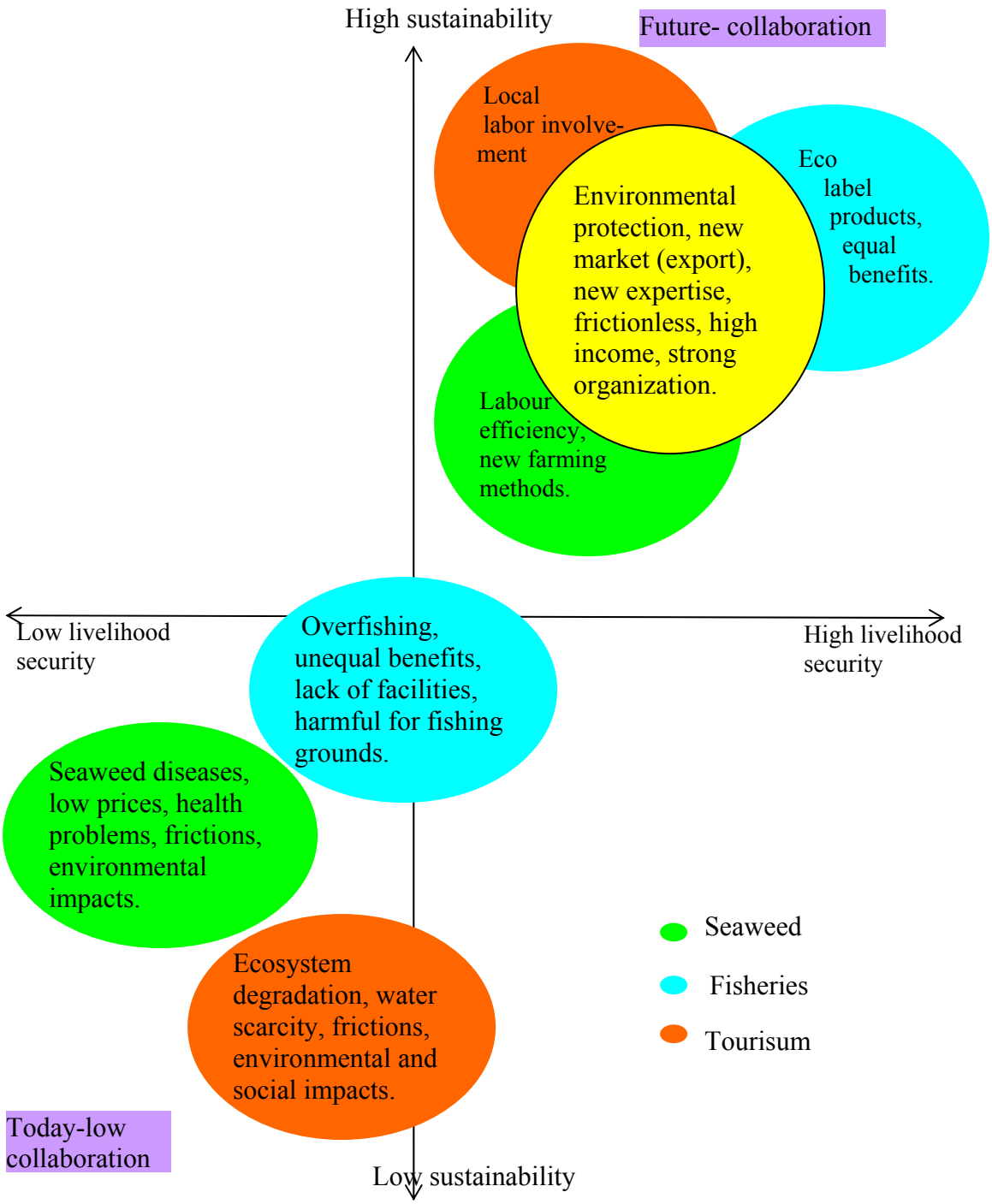


Figure 11. Future possibilities with collaborative enterprises

Therefore, in the future, a possible approach is collaboration between enterprises in the seaweed, fisheries and tourism sectors. This would provide opportunities for people with diverse interests who can come together to anticipate, discuss, and solve current problems for the future. Furthermore, collaborative enterprises can easily create the preliminary conditions that facilitate

livelihood adaptability and acceptance of the concept of livelihood resilience management among the stakeholders whenever necessary. The method stimulates reflection and dialogues among stakeholders and creates interest in continued involvement in livelihood security processes. It can facilitate the identification of mechanisms and options that allow the livelihoods to move away from undesirable states. The Figure 11 shows future possibilities with collaborative enterprises.

6 Conclusions

Our findings reveal that livelihood diversification is very high in Zanzibar and it varies with location. Fisheries are a highly diversified sector in terms of the number of households participating and the number of activities performed. Also, the fisheries sector provides higher income and is considered to be the most important source of livelihood for the coastal communities. Therefore, coastal resource management needs to emphasize the importance of sustainable use of fisheries resources and alleviate present problems in order to protect livelihoods in coastal communities. Also, it is important to consider the introduction of sustainable fisheries enterprises as a novel way to capture local and global markets which enhances incomes and protects marine resources.

Tourism is also an important sector with the potential to generate more income for coastal communities. However, the household participation in this sector is very low in our study areas. Therefore, it is necessary to enhance the necessary skills of individual workers and raise their awareness to improve community participation. Furthermore, the present unplanned tourism raises several environmental problems. To develop long-term, sustainable tourism in Zanzibar there is a need to consider social, economic and environmental issues and enhance ways to benefit the local community.

Seaweed farming is also an additional source of household livelihood, but the income derived from it is very low and it is less sustainable than the other sectors. In particular, there is a need to rearrange the market chain to enhance the income of the local community (not only multinational companies). Coastal households and communities find it difficult to reap the benefits of their hard work without proper institutions, law and governmental policy changes which are more appropriate to Zanzibar.

Identifying possibilities to enhance livelihood opportunities in sectors that currently have low household participation is also an important way to reduce pressure on ecosystem services. The results show how livelihoods are depending on different ecosystem (provisioning) services. Households depend more on some ecosystem services and less on others. Thus, ecosystem services are fundamental assets in coastal livelihoods. It is necessary to access ecosystem services in such a way as to generate economic value and increasing opportunities to the

community while maintaining sustainability. Particularly, in Zanzibar, the ways to enhance livelihood opportunities and thus to increase income have not been recognized. Better understanding of micro- and medium-scale economic approaches, and the roles of government and institutions within the current livelihood framework can lead to access to new economic opportunities. It is necessary to conduct more research to address ways to increase the skills, knowledge and other facilities in the rural coastal communities to introduce new livelihoods and thus to enhance income.

Livelihood diversification allows households to change and adapt structurally to unstable situations, it provides flexibility and adaptability to aid daily survival. Therefore, livelihood diversification is very important in the context of livelihood resilience. These issues remind us that livelihood diversification is more than just income generation and it contains global, national and local drivers. However, current livelihoods seem not sufficient to provide security to coastal communities. Thus, there is a need to identify the drivers behind the livelihoods to ensure livelihood security. Even though major livelihood activities depend on natural resources, to date natural resource management is a delicate issue in Zanzibar (de la Torre- Castro and Lindstrom 2010).

Many studies have attempted to show the importance of expansion in the seaweed farming and tourism sectors as livelihood opportunities (Bryceson, 2002b; Msuya, 1993; Wallevik and Jiddawi, 1999; Makame and Boon, 2008). However, by depending on a single enterprise, households will still have insoluble problems of declining sustainability. Thus to reduce threats to current livelihoods there is a need for a collaborative approach to enhance the livelihood security. This is because the collaborative approach provides environmental protection, new market chains for enhancing income and a social safety net for households.

References

Adger, W.N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography* **24** (3):347-364.

Adger, W.N., P.M. Kelly, and N.H. Ninh. 2001. Living with environmental change: Social vulnerability, adaptation and resilience in Vietnam. Routledge, London,UK.

Adger, W.N. 2006. Vulnerability. *Global Environmental Change* **16** (3): 268-281.

Albu M. and A. Scott. 2001. Understanding livelihoods involving micro-enterprise. Markets and technological capabilities in the SL framework. Intermediate Technology Development Group (ITDG).
http://practicalaction.org/advocacy/docs/advocacy/micro-enterprise-livelihoods.pdf [online] available 2009/11/21

Andersson J. and Z. Ngazi. 1998. Coastal communities production choices, risk diversification and subsistence behavior, responses in periods of transition. *Ambio* **27** (8): 686-693.

Bailey,C. and C. Pomeroy.1996. Resource dependency and development options in coastal south east Asia. *Society and Natural Resources* **9**: 191-99.

Barret C.B., T.Reardon and P. Webb. 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. *Food Policy* **26**:315-331.

Bayliss- Smith, T. 1991: Food security and agricultural sustainability in the New Guinea Highlands: vulnerable people, Vulnerable places. *IDS Bulletin* **22**:5-11.

Berggren,P., O.A. Amir., A.Guissamulo., N.S Jiddawi., Z.Ngazy., E.Stensland., A.Samblad, and V.G. Cockroft. 2007. Sustainable Dolphin Tourism in East Africa. Page 2 in Marine Mammal basic biology and ecology research. MASMA Technical Report. WIOMSA Book Series No.7,ix+72pp.

Bergman, K.C., S. Svensson, and M.C. Ohman. 2001. Influences of algal farming on fish assemblages. *Marine Pollution Bulletin* **42** (12): 1379-1389.
Booth,W.C., G.G.Colomb, and J.M.Williams. 2003. The Craft of Research. The University of Chicago Press, Chicago.

Brogaard, S. and J. Seaquist. 2005. An assessment of rural livelihood vulnerability in relation to climate - a case study in agro pastoral northern China. Human Security and Climate Change.An International Workshop.
http://www.gechs.org/downloads/holmen/Brogaard_Seaquist.pdf [online] available 2009/09/01

Bryceson, D. 2002a. The scramble in Africa: Reorienting rural livelihoods. *World Development* **30**(5): 72-739.

Bryceson, I. 2002b. Coastal Aquaculture Developments in Tanzania: Sustainable and non sustainable experiences. *Western Indian Ocean Journal Marine Science* **1**:1-10.

Campbell, B.M., S. Jeffery., W. Kozanayi., M.K. Luckert., M.Mutamba, and C. Zindi. 2002.Household livelihoods in semi-arid regions: options and constraints. CIFOR. *Bogor,* **153**.

CE-NET. 2004. (Concurrent Enterprising Network of Excellent). A Roadmap towards the Collaborative Enterprise – CE Vision 2010. Centre for Concurrent Enterprising, University of Nottingham.
http://www.esoce.net/Roadmap%20Summary%20v17.pdf [online] available 2009/11/28

Chambers. R and G.R. Conway. 1991 sustainable rural livelihood: practical concepts for the 21st century, *IDS Discussion paper* **296**. Institute of Development Studies. Brighton, Sussex, UK.

Cinner. J., C. Abunge., A. Wamukota., J. Kawaka., J. Mariara, and C. Hicks. 2005. A baseline Socioeconomic Assessment of Fishing communities along the north coast of Kenya. Draft report. The Wildlife Conservation Society's Coral reef Conservation Project.

Collen J., M. Mtolera., K.Abrahamsson., A.Semesi, and M. Pedersén.1995. Farming and Physiology of the Red Alga Eucheuma: Growing Commercial Importance in East Africa. *Ambio* **24** (7-8): 497-501.

Crona, B. 2006. Of Mangroves and Middlemen. A study of social and ecological linkages in a coastal community. Doctoral thesis in Marine Eco-toxicology. Stockholm University.

Davis, B., P. Winters, and G. Carletto. 2009. A cross country comparison of rural income generating activities. *World Development* **38** (1):48-63.

de Haan, L., and A. Zoomers. 2003. Development geography at the crossroads of livelihood and globalization. *Tijdschrift voor Economische en Sociale Geografie* **94**(3):350–362.

de la Torre-Castro, M., and. P Ronnback. 2004. Links between humans and seagrass- an example from tropical East Africa. *Ocean and Coastal Management* **47**:361-387.

de la Torre-Castro, M.2006. Human and seagrasses in East Africa. A social ecological systems approach. Doctoral thesis in natural resource management. Stockholm University.

de la Torre-Castro, M., and L. Lindstrom. 2010. Fishing institutions: Addressing regulative, normative and cultural-cognitive elements to enhance fisheries management. *Marine Policy* **34**:77-84.

DFID (Department for International Development). 2001. *Sustainable Livelihoods Guidance Sheets.* Electronic edition.

ERB (Economic Research Bureau), 2003. Zanzibar country analysis final report, Ministry of Finance and economic affairs, Revolutionary Government of Zanzibar. http://www.tzdac.or.tz/Znz/Country%20Analysis.doc[online] available 2009/10/12

Eklund S., and P. Pettersson. 1992. Mwani is Money. The development of seaweed farming on Zanzibar and its Socio economic Effects in the Village of Paje. Report from a Minor Field Study. *Working paper* **24**. Development studies unit, Department of Social Anthropology, Stockholm University, Sweden, 26pp.

Eklöf,J.S., M. de la Torre-Castro.,l.Adelsköld, N.S,Jiddawi and N.Kautsky. 2005. Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms.*Estuarine,Coastal and Shelf Science* **63**:385-396.

Eklöf,J.S., M. de la Torre-Castro., C. Nilsson, and P.Rönnbäck.2006. How do seaweed farms influence local fishery catches in a seagrass-dominated setting in Chawaka Bay, Zanzibar. *Aquatic Living Resource* **19**:137-147.

Ellis, F. 2000. *Rural Livelihoods and Diversity in Developing Countries.* Oxford: Oxford University Press.

Ellis, F., and N. Mdoe**.** 2003. Livelihoods and Rural Poverty Reduction in Tanzania *World Development* **31**(8): 1367-1384.

Ellis, F., and E. Allison, 2004. Livelihood diversification and natural resource access. Access to Natural Resources Sub-Programme. Livelihood Support Programme, LSP Working Paper **9**, FAO.

Ellis, F., and H.A. Freeman. 2004. Rural livelihoods and poverty Reduction strategies in Four African Countries .*The Journal of Development Studies*.**40** (4):1 – 30.

Evans.K., W. de Jong, and P. Cronkleton. 2008. Future scenarios as a tool for collaboration in forest communities. *Institute Veolia Environnement Surv. Perspect. Integr. Environ. Soc*., **1**, 97–103.

Feidi. I.H. 2005. The fisheries of Zanzibar: potential for new investments. NAGA, *World Fish Center Quarterly* **28** : 3-4.

Folke, C. 1998. Ecosystem approaches to the management and allocation of critical resources. Pages 313-345*in* M. Pace and P. Groffman, editors. *Successes, limitations and frontiers in ecosystem science.* Springer, New York, New York, USA.

Folke, C., J. Colding, and F. Berkes. 2003. Synthesis: building resilience and adaptive capacity in social–ecological systems. Pages 352–387 *in* F. Berkes, J. Colding, and C. Folke, editors. *Navigating social–ecological systems: building resilience for complexity and change.* Cambridge University Press, Cambridge, UK.

Folke,C., S.Carpenter., T.Elmqvist., L.Gunderson., C.S.Holling., B.Walker., J.Bengtsson., F.Berkes., J.Colding., K.Danell., M.Falkenmark., L.Gordon., R.Kasperson., N.Kautsky., A.Kinzig., S.Levin., K.Mäler., F.Moberg., L.Ohlsson., P.Olsson., E.Ostrom., W.Reid., J.Rockström., H.Savenije, and U. Svedin. 2002. Resilience and Sustainable Development:Building Adaptive Capacity in a World of Transformations. Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Development. http://www.sou.gov.se/mvb/pdf/resiliens.pdf[online] available 2009/10/02

Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological system analyses. *Global Environmental Change* **16**, 253-267.

Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *Ambio* **22**(2-3) 151-156.

Garcia.S.M., and R.J.R. Grainger. 2005. Gloom and doom? The future of marine capture fisheries. *Philos Trans R Soc Lond B Biol Sci.*; **360**(1453): 21–46.

Goodwin, H., and R. Santilli. 2009. Community-based tourism: a success? International Centre for Responsible Tourism. *ICRT Occasional Paper* **11**. http://www.icrtourism.org/documents/OP11merged.pdf [online] available 2009/11/22

Gossling, S. 2002. Global environmental consequences of tourism. *Global Environmental Change* **12**: 283-302.

Gossling, S. 2003.Market integration and ecosystem degradation: is sustainable tourism development in rural communities a contradiction in terms? *Environment, Development and Sustainability* **5**: 383-400.

Grootaert, C., R. Kanbur, and G.T. Oh. 1995. The dynamics of poverty: why some people escape from poverty and others don't- an African case study. World Bank, *WPS* **199**.

ICAM,1996. Towards Integrated Management and Sustainable Development of Zanzibar's Coast. Finding and recommendations for an action strategy in the Chawaka Bay-Paje Area. Department of environment institute of Marine Science.

Ireland., D.Malleret, and L. Baker. 2004. Alternative Sustainable Livelihoods for Coastal Communities: A review of experience and guide to best practice. The Western Indian Ocean Marine Biodiversity Conservation project. IUCN.

Iwasaki, S., B.H.N Razafindrabe, and R. Shaw. 2009. Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India. Mitigation and Adaptation strategies for Global Change. *Earth and Environmental Science*. **14**: 4.

Jackson. J. B. C., X. M. Kirby., W. H. Berger., K. A. Bjorndal., L. W. Botsford., B. J. Bourque., R. H. Bradbury., R. Cooke., J. Erlandson., J. A. Estes., T. P. Hughes.,S. Kidwell., C. B. Lange., H. S. Lenihan., J. M. PandolÞ., C. H. Peterson., R. S. Steneck., M. J. Tegner, and R. R. Warner. 2001 . Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* **293**.

http://www.palomar.edu/oceanography/www_resources/jacksonetal.pdf [online] available 2009/11/22

Jiddawi, N.S., and M.C.Ohman. 2002. Marine fisheries in Tanzania. *Ambio* **31** :7-8.

Jiddawi,N.S., and H. Khatib. 2007. Zanzibar marine fisheries frame survey 2007. Census report. Department and fisheries and marine resource. Ministry of Agriculture, Livestock and Environment.61pp.

Johnstone, W., and E. Olafsson. 1995. Some Environmental Aspects of Open Water Algal Cultivation: Zanzibar, Tanzania. *Ambio* **24**:7-8.

Johnstone, R.W., C.A. Muhando, and J.Francis. 1998. The status of the coral reefs of Zanzibar: one example of a regional predicament . *Ambio* **27** (8): 700-707.

Juma, A. 2007. Promoting Livelihood Opportunities For Rural Youth: Some lessons from Tanzania. IFAD governing council roundtable generating remunerative livelihood opportunities for rural youth.
http://www.ifad.org/events/gc/30/roundtable/youth/rural_youth.pdf [online] available 2009/10/05

Lange, G M., and N. Jiddawi. 2009. Economic value of marine ecosystem services in Zanzibar: Implication for marine conservation and sustainable development. *Ocean and coastal management* **52** (10): 521-532.

Makame, K.M., and E. K. Boon. 2008. Sustainable Tourism and Benefit-Sharing in Zanzibar: The Case of Kiwengwa-Pongwe Forest Reserve. *Journal Human Ecology* **24**(2): 93-109.

Marschke, M.J., and F. Berkes, 2006. Exploring strategies that build livelihood resilience: a case from Cambodia. *Ecology and Society* **11**(1):42.

MEA (Millennium Ecosystem Assessment), 2005. Ecosystem and Human Well-being : Opportunities and Challengers for Business and Institute World Resources Institute, Washington, DC.

Mead, D.C., and C. Liedholm.1998. The dynamics of micro and small enterprises in developing countries. *World development* **26** (1): 61-74.

Mkenda, A. 2001. Fishery resources and welfare in Zanzibar. Doctoral thesis at Goteborg University. Department of economics. Goteborg University. Sweden.

Mkenda, A., and H. Folmer. 2001. The maximum sustainable yield of artisanal fishery in Zanzibar: A co integration approach. *Environmental and Resource Economics* **19**: 311-328.

Mohammed,S.M., and N.S. Jiddawi. 1999. The Ecology and Socio economy of Chawaka bay, Zanzibar. Reported prepared for Jozani-Chawaka bay conservation project, CARE, Tanzania.

Msuya, F. 1993. Seaweed farming in Zanzibar: An amazing story. *ALCOM News* **11**: 11–15.

Msuya, F.E., M. A.K. Ngolie M, and J.P. Shunula. 1995. The impact of Seaweed farming on the Macro-Fauna and Macro- Flora of the East coast of Unguja Island, Zanzibar, Tanzania. pp 42.

Muhando,C.A., and N.S Jiddawi. 1998. Fisheries resources of Zanzibar, Problems and Recommendation. page 247-254 *in* K. Sherman., E. Okemwa., and M. Ntiba. Blackwell Science.USA.

Ngazy, R.M.1997. Economic valuation of marine resources conservation and sustainable use: The case of Menai Bay, Zanzibar.

Olson, D.M. and E. Dinerstein. 1998. The global 200: A Representation approach to Conserving the Earth's Most Biologically Valuable Ecoregion. *Conservation biology* **12** (3): 502-515.

Osbahr ,H., C. Twyman., W.N. Adger, and D.S.G. Thomas. 2008. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique, *Science Director* **39** (6): 1951-1964.

Pettersson, P., Lofquist. 1995a. Social &Economic change in Zanzibar: Seaweed farming, Tourism, and Livelihood in a Coastal Community. Social Aspects of Coastal Zone Management Series Paper No. 2 Development studies unit, Department of Social Anthropology, Stockholm University, Sweden.

Pettersson P., Lofquist. 1995b. The development of open-water Algae framing in Zanzibar: Reflections on the socioeconomic impact. *Ambio* **24** :7-8.

Ronnback P.,I. Bryceson, and N. Kautsky. 2002. Coastal Aquaculture Developments in Eastern Africa and the Western Indian Ocean: Prospects and Problems for Food Security and Local Economies. *Ambio* **31**: 7-8.

Ruitenbeek, J., I. Hewawasam, and M. Ngoile. 2005. Blueprint 2050: sustaining the marine environment in mainland Tanzania and Zanzibar. The International Bank for Reconstruction and Development, The World Bank, Washington, D.C., USA.

Samoilys, M.A. and N.W. Kanyange. 2008. Natural resource dependence, livelihoods and development: Perceptions from Kiunga, Kenya.IUCN ESARO. ISBN: 978-2-8317-1118-8.

Schieffer, A. and E. R.e Lessem.2008. Beyond Social and Private Enterprise: Towards the Integrated Enterprise. Entrepreneurship and International Management. Transit Stud Rev **15**:713–725

Scoones,I., 1998. Sustainable rural livelihoods: A Framework for analysis, Institute of Development studies, *IDS working paper* **72**.

Sesabo,J. K. and R. S. J. Tol. 2005. Factors affecting Income Strategies among households in Tanzanian Coastal Villages: Implications for Development-conservation initiatives. *Working paper FNU*-**70**.

Shackleton,C, S.Shackleton., J. Gambiza.,E. Nel., K.Rowntree, and P.Urquhare., 2008,Link between ecosystem Services and Poverty Alleviation, Ecosystem and poverty reduction research programme: DFID, NERC, ESRC.
http://www.unpei.org/PDF/preliminaryassessments/Links-Ecosystem-Services-and-Poverty-Alleviation.pdf [online] available 2009/10/15

Shah,N.J., O. Linden., C.G.Lundin, and R.Jhonstone.1997. Coastal management in Eastern Africa: Status and Future. *Ambio* **26** (4) :227-234.

Tobisson, E., J. Anderson .,Z.M. Ngazi., L.Rydberg, and U. Cederlof.,1998. Tides, monsoons and seabed: local knowledge and practice in Chawaka Bay Zanzibar. *Ambio* **27** (8) :677-685.

Thyresson,M.2009. Analyzing key-ecosystem processes in coral reefs and socio-economic drivers behing their exploitation. Licentiate in Philosophy Thesis in Natural Resource Management. Department of System Ecology. Stockholm University. Sweden.

(USAID) 2007. Torell E., B. Kalangahe., R. Munubi .,S. Mwanahija, and B. Crawford B. Integrated Coastal Management, Livelihood Development and Micro-Loan Strategies: The Case of the TCMP-FINCA Partnership in the Bagamoyo District of Tanzania. The Sustainable Coastal Communities and Ecosystems Program (SUCCESS) .In Association with The Tanzania Coastal Management Partnership (TCMP). http://pdf.usaid.gov/pdf_docs/PNADO946.pdf[online] available 2009/11/10

Wallevik, H.B. and N. Jiddawi. 1999. Impacts of tourism on the activities of the women of the southeast coast of Unguja, Zanzibar. Proceeding of the 20th conference on advances in marine science in Tanzania, 535-550.

Warren, P.2002. Livelihood diversification and Enterprise Development: An Initial Exploration of concepts and Issues. LSP working paper 4. Livelihood diversification and Enterprises Development Sub-Programme. Food and Agriculture Organization of the united nations (FAO).

WCED,1987, Food 2000: Global policies for sustainable Agriculture, a report of the Advisory Panel on Food security, Agriculture, Forestry, and Environment to the World Commission on Environment and Development, Zed Books Ltd, London and New Jersey.

Winters, P., B. Davis, and L. Corral. 2001. Assets, activities and income generation in rural Mexico; Factoring in social capital and public capital. *Agricultural Economics* **27**:139-156.

WRI (World Resource Institute). 2005. The Wealth of the Poor: Managing Ecosystems to Fight Poverty.
http://www.wri.org/publication/world-resources-2005-wealth-poor-managing-ecosystems-fight-poverty [online] available 2009/09/12

WRI (World Resource Institute). 2008. Roots of Resilience: Growing the wealth of the poor. http://www.wri.org/publication/world-resources-2008-roots-of-resilience [online] available 2009/08/12

The World Bank. 2007. Africa Now; Building a better future.
www.worldbank.org/africa[online] available 2009/11/12

ZPRP, 2002. A plain language guide to the Revolutionary Government of Zanzibar's Zanzibar Poverty Reduction Plan (ZPRP) of January 2002.
http://www.hakikazi.org/zwp/priorities.htm [online] available 2009/10/12

Appendices

Appendix I: Categorization of livelihood sectors

The Table 11 shows categorization of different livelihood activities. The categorization is based on nature of the activity and includes main ten sectors fishing, seaweed, forestry, agriculture, agro coconut, tourism, service and manufacture directly related with ecosystem services, mining, service and manufacture not directly related with ecosystem services and wage employment (government and private). Livelihood activities related with Ecosystem goods and services are included in Service and manufacture related with Ecosystem Services sector which are not related with the main sectors (Fishing, Seaweed etc).

Table 11. Categorization of livelihood sectors

Fishing sector	**Seaweed sector**	**Forestry sector**	**Agriculture**	**Agro-coconut related**	**Tourist sector**	**Service & manufacture related with ES**	**Mining sector**	**Service & Manufacture not related with ES**	**Employment**
Trap fish	Seaweed farming	Cutting pole	Farming	Planting coconut tree	Diving	Mats making	Fetching sand	Shopkeeper	Nurse
Fisher	Planting seaweed	Cutting forest	Keeping animal	Cutting coconut tree	Tourist guide	Basket making	Stone collecting	Making shoes	Teacher
Hand line fish	Collecting seaweed	Firewood cutting	Selling eggs	Curving coconut tree leaves	Restaurant or hotel work	Hat making	Breaking stone	Transporting	Doctor
Net fishing	Tying seaweed	Firewood collection	Selling vegetable	Taking off coconut leaves	Renting diving items	Fetching water	Making bricks	Luggage carrying	Watchman
Fishing squid	Cleaning seaweed	Carrying pole	Selling fruits	Coconut tree climber	Selling tourist items	Selling water	Stone transport	Drawing picture	Driver
Diving for octopus	Drying seaweed	Making charcoal	Selling milk	Removing coconut cover		Cooking traditional bed	Grinding stone	Henna painting	Conductor
Octopus collection	Selling seaweed	Selling charcoal	Selling cassava	Rope making		Selling foods	Making lime	Burials	Garment
Selling octopus		Selling firewood	Selling sugar cane	Selling rope		Preparing flour	Selling lime	Technical work	
Bivalve collection			Selling yam	Tying ropes		Cooking chapatti		Bicycle repairing	
Anadara collection			Cleaning ground nuts	Selling coconut		Selling breads		Tape engineer	
Sea cucumber collection			Cleaning weeds	Selling coconut residue		Cooking kachori		Dress making	
Tiger cowries collection			Helper in farm	Roof thatching		Selling pour age		Painting lime on stone	
Bait collection			Picking mango	Coconut harvesting				Picok painting	
Frying fish			Planting					Cleaning house	
Selling			Working					Selling	

cutlets of fish			with cow carriage					kitchen vessel	
Making traps								Selling clothes	
Boat painting								Small scale business	
Cooking sea cucumber								Carpenter	
Fish auctioneer								Constructor	
Fish middleman								Sweeping	
Data recorder(fish)								Tailor	
Training								Hair plating	
Selling seashells								Cow carriage	
Humpbacked collection								Washing clothes	
Income collector								Road sweeping	
								Curving bed	
								Lumbering	
								Singing	
								Working with carriage	

Appendix II: Definition of ecosystem services (provisioning services)

Service	Sub category	Definition	Example
Food	Crops	Cultivated plants or agriculture Fruits, Products harvested by people	Fruits, Vegetables, Grains, Yam
	Livestock	Animals and animals' products raised for domestic of commercial consumption or use	Chicken meat/egg, Cattle meat/ milk
	Capture fisheries	Wild fish and other marine resources captured and collected through traps, nets, lines & hooks and other non-farming methods	Parrot fish, Snapper, Octopus, Sa cucumber
	Aquaculture	Fish, shellfish, and/or plants that are bred and reared in freshwater or saltwater confinement for purposes of harvesting	Seaweed
	Wild food	Edible plant and animal species gathered or captured in the wild	Fruits and nuts, Bush meat
Biological material	Timber	Products made from trees harvested from natural forest ecosystems, plantations, or non-forested lands	Industrial wood, Pole wood
	Sand and Clay	Sand and clay gathered or extract in the earth	White sand from coral brick clay
	Coral and Stone	Coral and stone gathered or collect from the nature	Coral Stone
	Ornamental Resources	Ecosystem-derived products that serve aesthetic purposes	Wild flower, Mat & basket , materials (grass, reeds, leaves)
Fresh water		Inland bodies of water, groundwater, rainwater, and surface waters for household, industrial, and agricultural uses	Freshwater for drinking, cleaning and industrial work
Biomass fuel		Biological material derived from living or recently living organisms- plant and parts of plant serves as a source of energy	Fuel wood, Charcoal

Source: Adapted from the reports of the definition of ecosystem services version 1.1, more information can be obtained from http://pdf.wri.org/esr_definitions_of_ecosystem_services.pdf

Appendix III: Statistical theory

A. Completely randomized design: One-way Analysis of Variance (ANOVA)

A completely randomized design or one-way Analysis of Variance (ANOVA) is used when it is necessary to see there is any difference between groups (treatment) on some variable. In this design treatments are assigned to experimental units in a completely randomized manner. The complete randomization provides that every experimental unit as an equal chance to receive any one of the treatments.

Data layout

Treatments					
1	**2**	**……**	**i**	**……**	**r**
Y_{11}	Y_{21}		Y_{i1}		Y_{r1}
Y_{12}	Y_{22}		Y_{i2}		Y_{r2}
Y_{13}	Y_{23}		Y_{i3}		Y_{r3}
$Y_1 n_1$	$Y_2 n_2$		$Y_i n_i$		$Y_r n_r$

n_i is the number of observations for the i[th] treatment.

$n = \sum_{i=1}^{r} n_i$ is the total number of observations in the study.

Y_{ij} is the j[th] the response (dependent) variable for the i[th] treatment.

$\bar{Y}_{i.} = \frac{Y_{i.}}{n_i} = \frac{\sum_{j=1}^{n_i} Y_{ij}}{n_i}$ is the sample mean for the i[th] treatment.

$\bar{Y}_{..} = \frac{Y_{..}}{n} = \frac{\sum_{i=1}^{r}\sum_{j=1}^{n_i} Y_{ij}}{n}$ is the overall or grand mean.

Treatment mean model

The one-way ANOVA model can be stated as $Y_{ij} = \mu_i + \varepsilon_{ij}$

where, Y_{ij} is the value of the response variable in the j[th] trail for the i[th] treatment.

μ_i is the population mean for the i[th] treatment.

ε_{ij} is the random error of the j[th] trail for the i[th] treatment, which has a Normal distribution with mean 0 (zero) and variance (σ^2). i.e. $\varepsilon_{ij} \sim N(0, \sigma^2)$

$i = 1, 2, \ldots\ldots, n, \quad j = 1, 2 \ldots\ldots\ldots n_i$

Important features of the model

1. The observed value of the response variable in the j[th] trail for the i[th] treatment is the sum of the two components μ_i and ε_{ij}.
2. Since E (ε_{ij}) = 0, E (Y_{ij}) = μ_i.
3. Since μ_i is a constant, Var(Y_{ij})= σ^2.
4. Since ε_{ij} is normally distributed, Y_{ij} also has a normal distribution. i.e. $Y_{ij} \sim N(\mu_i, \sigma^2)$
5. The error terms (ε_{ij}) are assuming to be independent. Hence, the error terms of any one trail has no effect on the error on the error term for the outcome of any other trail for the same treatment.
6. Since ε_{ij}'s are independent Y_{ij}'s are also independent.

Least square estimators

An estimated value for the population mean (μ_i) for the i[th] treatment can be estimated using the sample mean ($\bar{Y}_{i.}$) using least square method. i.e. $\hat{\mu}_i = \bar{Y}_{i.}$

The estimated value for the observation Y_{ij} is denoted by $\hat{Y}_{ij}$ and can be estimated from $\bar{Y}_{i.}$, i.e. $\hat{Y}_{ij} = \bar{Y}_{i.}$ and estimated value of ε_{ij} is denoted by $\hat{\varepsilon}_{ij}$ can be estimated from $(Y_{ij} - \bar{Y}_{i.})$, i.e. $\hat{\varepsilon}_{ij} = (Y_{ij} - \bar{Y}_{i.})$.

Hypothesis to be tested

In a one-way ANOVA a single factor is subject to the experimentation and the objective is to check whether the treatment means are the same. So, the hypothesis interested to be tested can be formulated as follows.

H_0 : $\mu_1 = \mu_2 = \mu_3 = \ldots\ldots\ldots \mu_r$ Vs H_1 : Not all μ_i's are equal.

Partitioning the Total Variation

The deviation of the response variable (Y_{ij}) to the grand mean ($\bar{Y}_{..}$) can be split into deviation due to treatments and deviation due to uncertainty of data.

i.e. $(Y_{ij} - \bar{Y}_{..}) = (\bar{Y}_{i.} - \bar{Y}_{..}) + (Y_{ij} - \bar{Y}_{i.})$ and

$$\sum_{i=1}^{r}\sum_{j=1}^{n_i}(Y_{ij} - \bar{Y}_{..})^2 = \sum_{i=1}^{r}\sum_{j=1}^{n_i}(\bar{Y}_{i.} - \bar{Y}_{..})^2 + \sum_{i=1}^{r}\sum_{j=1}^{n_i}(Y_{ij} - \bar{Y}_{i.})^2$$

where,

$\sum_{i=1}^{r}\sum_{j=1}^{n_i}(Y_{ij} - \bar{Y}_{..})^2$ is the total sum of squares (SST). This measures the total variability of the response variable from the grand mean.

$\sum_{i=1}^{r}\sum_{j=1}^{n_i}(\bar{Y}_{i.} - \bar{Y}_{..})^2$ is the treatment sum of squares (SSR). This measure the difference between treatment means.

$\sum_{i=1}^{r}\sum_{j=1}^{n_i}(Y_{ij} - \bar{Y}_{i.})^2$ is the error sum of squares (SSE). This measures the total variation of the response variable from the treatment mean.

ANOVA Table

Source of Variation	Sum of squares (SS)	Degrees of freedom	Mean Squares	F-Value	P-Value
Treatments	SSR	(r-1)	MST= SSR/(r-1)	F_{cal} = MST/MSE	$P_{val} = Pr(F_{dist} > F_{cal})$
Error	SSE	(n-r)	MSE=SSE/(n-r)		
Total	SST	(n-1)			

The mean square error (MSE) can be used to estimate the population variance (σ^2). We obtain the F value ($F_{n-r,\alpha}^{r-1}$) at α level from the F-Distribution.

The null hypothesis can be rejected if $F_{cal} > F_{n-r,\alpha}^{r-1}$.

Comparison among Treatment means using Tukey multiple comparisons

Once the null hypothesis is (H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots\ldots\mu_n$) is rejected, we can compare each pair of treatment means to test whether ones are different from each other. The Tukey multiple comparison test involves comparing all treatment means pair-wise using studentized range distribution.

An estimated value for the Tukey multiple comparison confidence interval for the difference of treatment means μ_i and μ_j, i.e. $(\mu_i - \mu_j)$ at α significance level can be obtained from,

$$(\bar{Y}_i - \bar{Y}_j) \pm T \sqrt{MSE\left(\frac{1}{n_i} + \frac{1}{n_j}\right)},$$

where,

$\bar{Y}_i$, $\bar{Y}_j$ and MSE are the estimated values of μ_i, μ_j and σ^2 respectively and T is the table value at α significance level.

B. Bivariate analysis: Simple linear regression

A linear regression is an approach used to model relationship between a dependent variable (Y) and one or more independent variables (X). The two most common application of linear regression are (1) Forecasting: During forecasting a model is fitted using an observed set of X and Y values. The fitted model can be later used to forecast the value of Y variable given an additional value of X variable. (2) Measure strength: Here, the main focus is on quantifying the relationship between a dependent variable (Y) and number of independent variables $X_1, ..., X_n$.

In a simple linear regression model there is only one independent variable (X) and dependent variable (Y). The model takes the form:

$Y_i = \alpha + \beta X_i + \varepsilon$

where, Y is the dependent variable,

ε the error or residual,

i = 1,2 ….n and n is the number of observations.

The relation between the variables can be given by the equation:

$Y_i = \alpha + \beta X_i + \varepsilon_i$

where,

Y_i is the i^{th} observation of the dependent variable.

X_i is the i^{th} observation of the independent variable.

ε_i the error or residual at the i^{th} observation.

i = 1,2 ….n and n is the number of observations.

Assumptions

1. ε_i has a Normal distribution with mean 0 (zero) and variance (σ^2). i.e. $\varepsilon_i \sim N(0, \sigma^2)$

2. ε_i and ε_j are uncorrelated for all i, j; i not equal j

Least square estimators

The fitted model is given by the equation:

$\hat{Y}_i = \hat{\alpha} + \hat{\beta} X_i$

The $\hat{\alpha}$ and $\hat{\beta}$ are the estimated values of α and β. They can be obtained by the following equations using the method of least squares.

Let $\sum_{i=1}^{n} x_i y_i = \sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})$

$\sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} (X_i - \bar{X})^2$ and $\sum_{i=1}^{n} y_i^2 = \sum_{i=1}^{n} (Y_i - \bar{Y})^2$

Then,

$$\hat{\beta} = \frac{\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i^2}$$

$$\hat{\alpha} = \bar{Y} - \hat{\beta}\bar{X}$$

Hypothesis to be tested

The objective is to test whether there is a relation between the two variables X and Y. So, the hypothesis interested to be tested can be formulated as follows.

Our null hypothesis is:

$\boldsymbol{H_o}$: $\alpha = \beta = 0$

Alternative hypothesis is:

$\boldsymbol{H_1}$: *At least one of them not equal to zero*

ANOVA Table

Source of Variation	Sum of squares (SS)	Degrees of freedom	Mean Squares	F-Value	P-Value
Regression	SSR	1	MSR= SSR	F_{cal} = MST/MSE	P_{val} = $Pr(F_{dist} > F_{cal})$
Error	SSE	(n-2)	MSE=SSE/(n-2)		
Total	SST	(n-1)			

Where,

SST = $\sum_{i=1}^{n} y_i^2$

SSR = $\frac{(\sum_{i=1}^{n} x_i y_i)^2}{\sum_{i=1}^{n} x_i^2}$

SSE = $\sum_{i=1}^{n} y_i^2$ - SSR

The null hypothesis can be rejected if $F_{cal} > F_{n-r,\alpha}^{r-1}$.

The strength of the relation can be found using correlation coefficient (r^2).

$$r^2 = \frac{(\sum_{i=1}^{n} x_i y_i)^2}{(\sum_{i=1}^{n} x_i^2)(\sum_{i=1}^{n} y_i^2)}$$

Appendix IV - Statistical results

A. Results -ANOVA

Analysis of Variance

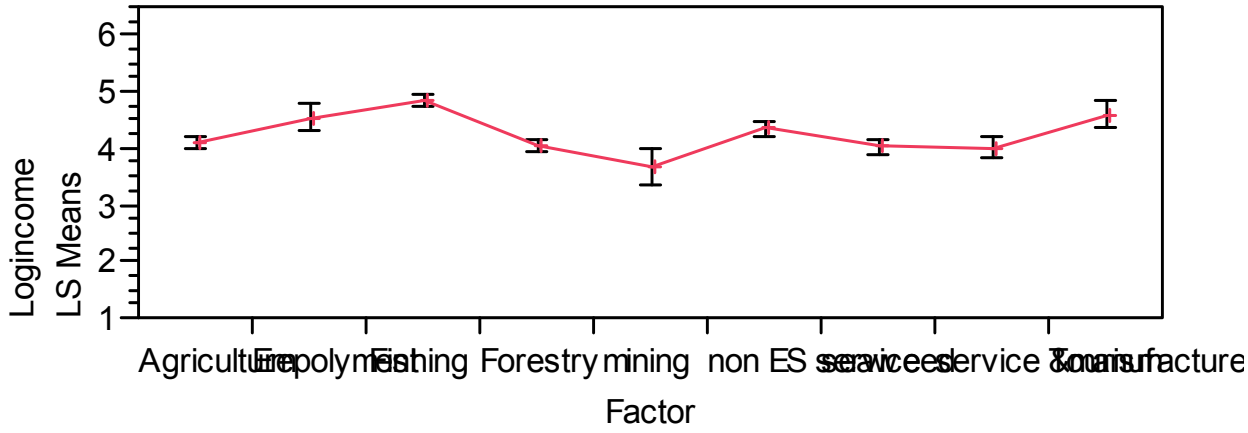
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	72.16349	9.02044	28.3168
Error	568	180.93901	0.31855	**P-value**
C. Total	576	253.10251		0.0001

Factor
Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Agriculture	4.1074561	0.05884344	4.10746
Empolyment	4.5493762	0.12316358	4.54938
Fishing	4.8421262	0.04434396	4.84213
Forestry	4.0399375	0.06432008	4.03994
mining	3.6674385	0.17017494	3.66744
non ES service	4.3586802	0.06561091	4.35868
seaweed	4.0220346	0.06121847	4.02203
service &manufacture	4.0091710	0.09825055	4.00917
Tourism	4.5825866	0.12033185	4.58259

LS Means Plot



LSMeans Differences Tukey HSD

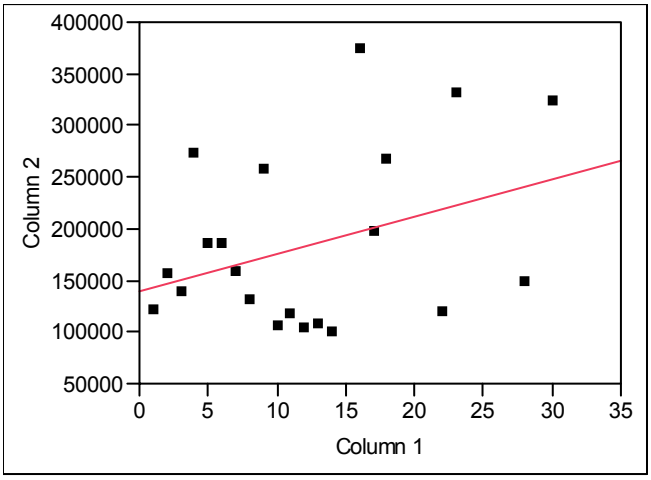
α=0.050 Q=3.11379
LSMean[i] By LSMean[j]

Mean[i]-Mean[j] Std Err Dif Lower CL Dif Upper CL Dif	Agriculture	Empolyment	Fishing	Forestry	mining	non ES service	seaweed	service &manufacture	Tourism
Agriculture	0	-0.4419	-0.7347	0.06752	0.44002	-0.2512	0.08542	0.09829	-0.4751
	0	0.1365	0.07368	0.08718	0.18006	0.08813	0.08491	0.11452	0.13395
	0	-0.8669	-0.9641	-0.2039	-0.1207	-0.5257	-0.179	-0.2583	-0.8922
	0	-0.0169	-0.5052	0.33897	1.00069	0.0232	0.34982	0.45489	-0.058
Empolyment	0.44192	0	-0.2927	0.50944	0.88194	0.1907	0.52734	0.54021	-0.0332
	0.1365	0	0.1309	0.13895	0.21007	0.13955	0.13754	0.15755	0.17219
	0.01689	0	-0.7004	0.07679	0.22783	-0.2438	0.09907	0.04962	-0.5694
	0.86695	0	0.11486	0.94209	1.53605	0.62522	0.95561	1.03079	0.50295
Fishing	0.73467	0.29275	0	0.80219	1.17469	0.48345	0.82009	0.83296	0.25954
	0.07368	0.1309	0	0.07812	0.17586	0.07919	0.07559	0.10779	0.12824
	0.50524	-0.1149	0	0.55892	0.6271	0.23686	0.58472	0.49731	-0.1398
	0.9641	0.70036	0	1.04545	1.72227	0.73003	1.05547	1.1686	0.65886
Forestry	-0.0675	-0.5094	-0.8022	0	0.3725	-0.3187	0.0179	0.03077	-0.5426
	0.08718	0.13895	0.07812	0	0.18192	0.09188	0.0888	0.11743	0.13644
	-0.339	-0.9421	-1.0455	0	-0.194	-0.6048	-0.2586	-0.3349	-0.9675
	0.20393	-0.0768	-0.5589	0	0.93897	-0.0326	0.2944	0.39642	-0.1178
mining	-0.44	-0.8819	-1.1747	-0.3725	0	-0.6912	-0.3546	-0.3417	-0.9151
	0.18006	0.21007	0.17586	0.18192	0	0.18239	0.18085	0.1965	0.20842
	-1.0007	-1.536	-1.7223	-0.939	0	-1.2592	-0.9177	-0.9536	-1.5641
	0.12066	-0.2278	-0.6271	0.19398	0	-0.1233	0.20854	0.27013	-0.2662
non ES service	0.25122	-0.1907	-0.4834	0.31874	0.69124	0	0.33665	0.34951	-0.2239
	0.08813	0.13955	0.07919	0.09188	0.18239	0	0.08974	0.11814	0.13706
	-0.0232	-0.6252	-0.73	0.03265	0.12333	0	0.05723	-0.0184	-0.6507
	0.52565	0.24383	-0.2369	0.60484	1.25915	0	0.61606	0.71738	0.20286
seaweed	-0.0854	-0.5273	-0.8201	-0.0179	0.3546	-0.3366	0	0.01286	-0.5606
	0.08491	0.13754	0.07559	0.0888	0.18085	0.08974	0	0.11576	0.13501
	-0.3498	-0.9556	-1.0555	-0.2944	-0.2085	-0.6161	0	-0.3476	-0.9809
	0.17898	-0.0991	-0.5847	0.25859	0.91773	-0.0572	0	0.37332	-0.1402
service &manufacture	-0.0983	-0.5402	-0.833	-0.0308	0.34173	-0.3495	-0.0129	0	-0.5734
	0.11452	0.15755	0.10779	0.11743	0.1965	0.11814	0.11576	0	0.15535
	-0.4549	-1.0308	-1.1686	-0.3964	-0.2701	-0.7174	-0.3733	0	-1.0571
	0.25832	-0.0496	-0.4973	0.33489	0.9536	0.01837	0.3476	0	-0.0897
Tourism	0.47513	0.03321	-0.2595	0.54265	0.91515	0.22391	0.56055	0.57342	0
	0.13395	0.17219	0.12824	0.13644	0.20842	0.13706	0.13501	0.15535	0
	0.05804	-0.5029	-0.6589	0.11779	0.26617	-0.2029	0.14016	0.0897	0
	0.89222	0.56937	0.13978	0.96751	1.56413	0.65067	0.98094	1.05714	0

Level					Least Sq Mean
Fishing	A				4.8421262
Tourism	A	B			4.5825866
Empolyment	A	B			4.5493762
non ES service		B	C		4.3586802
Agriculture			C	D	4.1074561
Forestry				D	4.0399375
seaweed				D	4.0220346
service &manufacture			C	D	4.0091710
mining				D	3.6674385

Appendix IV

B. Results- Simple linear regression



Linear Fit
Column 2 = 140277.12 + 3590.2567*Column 1

Summary of Fit

RSquare	0.124428
RSquare Adj	0.078345
Root Mean Square Error	81362.14
Mean of Response	184557
Observations (or Sum Wgts)	21

Analysis of Variance

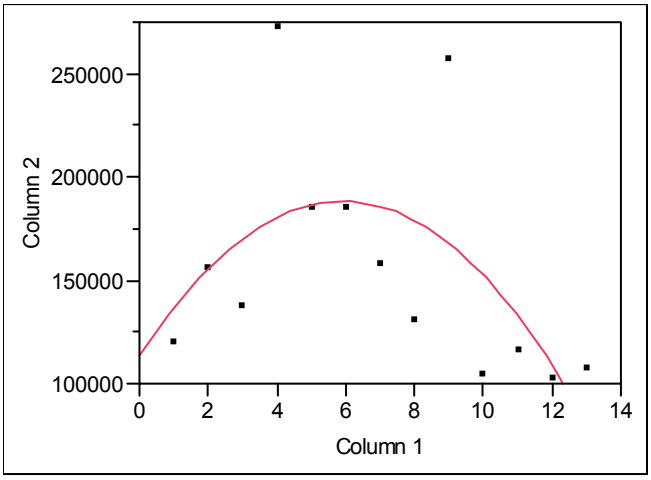
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.7874e+10	1.787e+10	2.7001
Error	19	1.2578e+11	6.6198e+9	**Prob > F**
C. Total	20	1.4365e+11		0.1168

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	140277.12	32270.58	4.35	0.0003
Column 1	3590.2567	2184.924	1.64	0.1168

Appendix IV

C. Results- Polynomial linear regression



Polynomial Fit Degree=2

Column 2 = 218254.6 - 4652.9011*Column 1 - 2135.6364*(Column 1-7)^2

Summary of Fit

RSquare	0.350871
RSquare Adj	0.221045
Root Mean Square Error	49175.58
Mean of Response	155785.4
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	1.3071e+10	6.5356e+9	2.7026
Error	10	2.4182e+10	2.4182e+9	**Prob > F**
C. Total	12	3.7254e+10		0.1153

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	218254.6	32769.39	6.66	<.0001
Column 1	-4652.901	3645.137	-1.28	0.2306
(Column 1-7)^2	-2135.636	1099.05	-1.94	0.0807