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IMPLICATIONS OF CLIMATE CHANGE INDUCED COPING AND ADAPTATION STRATEGIES ON SEAWEED PRODUCTION IN TANZANIA: A CASE OF JAMBIANI VILLAGE, UNGUJA ISLAND

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Abstract

Climate change remains to be the biggest challenge of 21st century threatening to negatively impacts seaweed production levels in Tanzania. Seaweed farmers have coped and adapted to the impacts of the changes for several years but the implication of their efforts measured by the level of seaweed production is still not documented. The study investigated implications of various coping and adaptation strategies employed by farmers on seaweed production. A cross sectional study was adopted to collection information's September-November, 2016. Primary data collection tools includes Questionnaires and Focus Group Discussion from 100 seaweed farmers and analyzed by means of descriptive statistics, measures of central tendency and variation, and liner regression model at 5% confidence level. The results indicated that, seaweed farmers continued to employ documented and have recently developed new undocumented coping and adaptation strategies, documented for the first time by this study which include, setting seaweed plot in partially drilled area and tying of big sized seedling as well as planting plenty of seaweeds during cooler months. Nevertheless, production level declined from 80 to 130 sacks per harvest before notable environmental changes to 20 sacks per harvest in a situation of weather and climate changes. It was shown that only planting plenty of seaweeds during cooler months slightly improved seaweed production and others, none at all. The study recommends initiation of ceased extension services to offer technical education and services to seaweed farmers on the best ways to integrate available coping and adaptation strategies on seaweed production as well as developing the best alternative coping and adaptation strategies.

Keywords: Climate Change; Seaweed Farming; Seaweed Production; Jambiani Village; Zanzibar.

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1. Introduction

Seaweed farming industry remains to be second most dominant sector of economy in Zanzibar after tourism industry (Msuya, 2012). Commercial seaweed farming in Tanzania commenced about 25 years ago through cultivation of imported species of seaweed Kappaphycus alvarezii and Eucheuma denticulatum from Philippines (ICMZ, 2009), and it started in Jambiani village in Unguja island (Erika, 2011). It is acknowledged to employ about 21,000 people in Zanzibar (Hamad and Mtae, 2012).

Population statistics on coastal natural resources suggests that, approximately 30 million people live in the coastal region of the western part of the Indian Ocean, with eight million in Tanzania coastal regions (Obura *et al*. 2000) including major islands of Zanzibar and Mafia.

Zanzibar's economic base depends on coastal and marine ecosystems distributed along and within the Indian Ocean, that offer enormous number of livelihood opportunities, as well as social and economic benefits through ecosystem services (Mustelin *et al*., 2009). Coastal resources based socio-economic activities of fishing, crop farming, seaweed farming and tourism provide over 30% of Zanzibar's Growth Domestic Product (GDP) (Mustelin *et al*., 2009, 2010). Three percent of Zanzibar's population participate in seaweed cultivation whose product contributes 20% to Zanzibar's export earnings due to annual exportation of more than 30,000 tonnes of dried seaweed (Msuya, 2012).

However, there has been tremendous decrease in seaweed production especially *Kappaphycus* species which is most preferred in the market, triggered by elevated seawater temperature and increased intensity of ocean waves as the result of climate change and variability. Moreover, the industry is threatened by elevated seawater temperature that induce seaweed disease as well as strong ocean waves that cut and wash away seaweeds resulting to loose of approximately 1000 kg of seaweed (dry weight) per single harvest per farmer (ICMZ, 2009). To worsen the situation, these impacts of climate change and variability particularly those associated with elevated seawater temperature mostly affects Kappaphycus species that is commonly preferred and fetch higher price in the world market, leaving farmers on the crossroad (Msuya et al., 2014).

Due to decline in production, seaweed farmers in Zanzibar especially Jambiani village have adopted various on-farm coping and adaptation strategies meant to safeguard the seaweed industry against the impacts of climate change and variability. Most importantly, documentation of coping and adaptation strategies to adverse impacts spearheaded by stronger and powerful ocean wave is very scarce compared to that of elevated seawater temperature. Moreover, the implication of these coping and adaptation strategies to the level of seaweed production before this work was not known and documented.

2. Materials and Methods

Geographical location and weather of the Study Area.

The present study was conducted in Jambiani village Unguja island Zanzibar. Jambiani is the small village located in South region, East coast of Unguja Island, Zanzaibar-Tanzania (Figure 1). The village has an extended shore of approximately 7-10 km along the shoreline Erika, (2011) covering

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S06°19.263' E039°32.936'. Tropical climate characterized by bimodal rainfall; dominates the area, receiving 1300 and 1700 mm of rainfall per year. The long rains fall between March and May estimated to range between 900 mm and 1200 mm, and short rains fall between October and December, estimated to 400 mm and 500 mm while the dry season dominates between June to September. The mean annual maximum and minimum temperature is 29^{0}C and 21^{0}C respectively, characterized by fairly constant average temperatures across the year (MANRLF, 2016).

Figure 1: A map of Unguja Island showing location of study area.

Source: Cartographic Unit- University of Dar es Salaam.

Research Design and Approach

A cross sectional research design was used in this study in which data from seaweed farmers were collected only once in study area for three months September to November, 2016 (Kothari, 2004)

Sampling Procedures

Purposive sampling was employed to identify and select Jambiani village as the study area. Random and purposive sampling techniques were used to determine appropriate sample. The village register was employed to select respondents intended for questionnaires while seaweed farmers who aged more than 30 years were selected to form groups for FGD with help of local leaders.

Sample Size and Sampling Frame

Both random and non-random sampling techniques were employed to determine the sample. Simple random sampling was employed to randomly pick 100 seaweed farmers using the latest village register. Purposive sampling was used to form two plenary groups of discussion comprised of seven and five women leaders of seaweed farmer groups respectively.

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Data Collection Techniques

A mixed approach including quantitative and qualitative methods was used in data collection. Quantitative data were collected through questionnaires that comprised of both closed and open ended questions; and qualitative data collected through Focus group discussions (FGD). Zanzibar seaweed yield (1990-2015) were obtained from Ministry of Agriculture, Natural Resources, Livestock and Fisheries, 2016.

Data Analysis

Content analysis was employed to analyse qualitative data from open-ended questions and FGDs dialogue. Quantitative data analysis was done using Statistical Package for Social Sciences (SPSS) version 20 and Microsoft excel software version 2013 to generate both descriptive and inferential analysis. Relationship between seaweed production level against on farm coping and adaptation strategies were statistically tested using regression model. Prior to the analysis, data were subjected to normality, linearity of the variables and heterogeneity of variance tests, where assumptions for parametric test were met. Regression analysis model was used with Pearson correlation test.

3. Results and Discussion

Socio-Economic Characteristics of Respondents

Results revealed that, seaweed farming activities are predominantly performed by women 100%, majority being married 63 % and without formal education 89% (Table 1). Age of respondents varied from 15 years to over 60 years. Age group of 31-45 years was dominant in the area with 51% (Table 1). Full involvement of female in the industry is explained by the facts that, this form of mariculture is simple and convenient source of income to female compared to fishing that requires physical strength due to its intensiveness in practices. Moreover, disassociations of male from seaweed farming is due to low profit, thus left opportunity for female to dominate the sector since this group has limited options for income generation. The result conform those of Msuya (2006) and Eklof *et al*. (2012) who reported that, more than 90% of seaweed farmers in Zanzibar were female.

Majority of farmers being married with no formal education is attributed by domination of Islamic culture in the area that discourage formal education to women but rather attending *madrassa* involving reading and memorizing the Holy Quran receive great attention (Msuya, 2006). This also confirm high rate of illiterate being common among seaweed farmers in Jambiani, Paje and Bwejuu villages (Msuya, 2006).

Majority of surveyed seaweed famers were born in the study village 94% and have lived in the area for at least more than two decades (Table 1). Most of the famers being natives of the village, suggests higher experience with the seaweed industry that commenced in the village more than 25 years ago (Msuya, 2006: Erika, 2011). The study further reveals, over generations' seaweed farming remains to be constant source of livelihood among local natives at Jambiani village as both older and active age groups of farmer engage fully. Partially due to lack of alternative source of livelihood (Hamad and Mtae, 2012).

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Table 1: Characteristics of seaweed farmers in the study area (n=100)

Socio-economic attributes	Response category	Response (%)
Age groups	Between 15-30 years old	22
	Between 31-45 years old	51
	Between 46-60 years old	20
	Above 60 years old	7
Education level	No formal education	89
	Primary education	10
	Secondary education	1
	College education	0
	University education	0
Marital status	Unmarried/Single	27
	Married	63
	Separated	1
	Divorced	2
	Widow	7
Place of birth	Born in Jambiani	94
	Born outside Jambiani	6
Duration lived in Jambiani	Between 1-20 years	44
	Between 21-40 years	38
	Between 41-60 years	12
	More than 60 years	6

Coping and Adaptation Strategies Employed by Seaweed Farmers and Their Implications on Seaweed Production Level

Seaweed farmers were interviewed on their on-farm based coping and adaptation strategies against devastating impacts of elevated seawater temperature and increased strength of ocean waves, the latter having very minimal attention in the scientific writings in the study area.

Findings of the study revealed that seaweed farmers have carried and are still carrying several on-farm coping and adaptation strategies to manage the impacts of climate change in seaweed cultivation (Table 2).

The study established that, majority of seaweed farmers employed more than one coping and adaptation strategies to manage the impacts of both, elevated seawater temperature and increased intensity of ocean waves (Table 2). This stands out to verify that seaweed farmers in Jambiani village were taking some actionable steps by changing some of their farming practises to protect their livelihood source against changes in weather and climate. The efforts which are invested in coping and adaptation clearly show that, degree of seaweed farmers' dependency in seaweed cultivation is extremely high despite existence of frustrating and discouraging environmental challenges among other challenges. This should be taken as a catalyst by different actors to provide a helping hand to the illiterate and poor community to work out their future by providing alternative livelihood earning activities including farmers assistance to move their farms in deeper water where temperature is relatively cooler hence *Kappaphycus* which retain high price can grow well (Msuya *et al.*, 2014).

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Table 2: Seaweed farmers coping and adaptation strategies against elevated seawater temperature and strong ocean waves.

Adaptation strategies against elevated temperature	Frequencies	Percentage
Planting plenty of seaweeds during cooler months	69	33
Increasing size of the seaweed farm	57	27.3
Fast removal of infected seaweed plants	48	23
Adopting shifting cultivation	35	16.7
Total	**209**	**100**
Adaptation strategies against strong ocean waves		
Increase the number of and placing pegs closer to one another	37	21.1
Frequent reattaching of loosened and uprooted pegs	56	32
Fixing very hard and long wooden pegs deep into the ground	42	24
Tying seaweed seedlings firmly on the rope using long tie-tie	27	15.4
Planting plenty of seaweeds during weaker ocean waves	13	7.4
Total	**175**	**100**

Note: These are multiple responses from 100 seaweed farmers.

1) Implications of Coping and Adaptation Strategies Against Elevated Seawater Temperature on Seaweed Production Level.

Percentage distribution of seaweed farmers preferences on using on-farm coping and adaptation strategies against elevated seawater temperature are presented in Table 2. These strategies are discussed in conjunction with results on their implications to seaweed production levels as presented in Table 3 and 4.

Table 3: Seaweed production level under various coping and adaptation strategies against elevated temperature.

	Number of sacks produced/harvest (in range)	Mean (Sacks)	Number of seaweed farmers responded
Before increase in temperature	45-80	72.4	83
After the increase in temperature	20-45	21.5	88
Current Production when adopting shifting cultivation	2-15	14	29
Current Production when adopting increased farm size	5-20	18	47
Current Production when planting plenty of seaweeds during cooler months	13-29	23	61

NOTE; The production level was presented in dried form of seaweed using a 25-kilogram sack locally known as Polo. Given the wide range of responses produced, results of seaweed production level were presented in average (Mean) in which, total of all indicated production level was computed then, divided by the number of seaweed farmers responded to the question.

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Planting Plenty of Seaweeds During Cooler Months

33.0 % of interviewed farmers plant plenty of seaweeds during cooler months from May to August (Table 2). It was remarked for the first time in this study that, planting plenty of seaweeds during cooler months was an outstanding adaptation mechanism against pronounced effects of elevated seawater temperature.

This was adopted from farming experiences gained over many years, longer time of stay within the same village that equipped farmers with knowledge and understanding on weather conditions of the village which enabled them to identify cooler season as the best time to plant bulk seaweeds. On interview one respondent said
"………*During cool (Masika) season, many seaweed farmers plants plenty of seaweeds and maximize size of their farms because, seaweed grows well and the harvests becomes satisfactory compared to hot (Kiangazi) season*".

This quotation suggests that, cool season (May to August) characterized by high cloud cover and moderate rainfall, lowers the temperature of the seawater creating cooler environment in the ocean that supports growth of seaweeds (Makame, 2013: Msuya, 2007).

Results from Table 3 on the implications of this strategy on seaweed production level shows that, production loss with average of 50.9 sacks per harvest was encountered after the increase in seawater temperature. This is more than 50% decline in production when compared to production before temperature increase. When farmers integrated this strategy in seaweed cultivation, production gain with average of 1.5 sacks per harvest was encountered. This is approximately 7% gain in harvest despite using this strategy in a condition of elevated temperature. This denotes that, planting plenty of seaweeds during cooler season slightly improves production level as compared to other interventions.

On the other hand, low production levels than would have been expected during cooler months when seaweed farmers plant plenty of seaweed in a single plot can be attributed to effects of shading and competition as the result of higher stocking density as reported by Msuya (2013) . Moreover, low production level is aggravated by the negative impacts of stronger ocean waves whose period coincide with cooler months when farmers plant plenty of seaweed.

Increasing Seaweed Farms

Findings from Table 2 shows that, 27.3 % of seaweed farmers adapted by increasing size of their seaweed farms, performed by adding more number of pegs during plot set-up that intended to compensate for the loss. The same is also reported by Makame (2013) that, farmers in Kiuyu Mbuyuni and Matemwe villages adapted to warm ocean water by increasing size of their seaweed farm. However this finding contradicts that of Msuya *et al*. (2007a) and Msuya (2012) who reported that, female are restricted to increase size of their farm due to inadequate physical power to handle big sized farms, as well as enormous family responsibilities. This may mean, seaweed farmers either have no choice other than coping and adapting due to seaweed loss beyond their comfort zone or the farm size increase is not significant to cause much trouble to female farmers. Alternatively this may suggest that, farmers (female) in study area have changed their mind set of "*I can't manage large sized farm*" hence are now capable to manage large sized farms despite many family responsibilities and other compounding challenges.

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On the aspect of the strategy's implication to seaweed production level, a production loss averaged 3.5 sacks per harvest was reported when farmers increased size of their farm to counteract impacts of elevated temperature (Table 3). This accounts for 16.3 % loss in seaweed yield even when big sized farm are set in warm water. Relatively low production loss after integration of the strategy as compared to the performance of other interventions suggests that, big sized farms in a changing environment compensate for the loss due to small sized farms and should be prioritized.

Adoption of Shifting Cultivation

16.7 % of seaweed farmers practiced shifting cultivation within intertidal shallow water that meant to explore a spot on the shallow water where seawater temperature was a bit cooler to support seaweed growth (Table 2). This is because, majority of seaweed farmers in the area are women who do not locate their plots in deep cool water, constrained by lack of skills, boats and other farming materials (Msuya, 2012). This was further supported by the following testimony during FGD that,

"……….many seaweed farmers do not locate seaweed plot in deep water due to lack of boats and tedious work of deep water based seaweed cultivation, but some years back, male seaweed farmers used to locate their farms in deep water".

Apart from farmers shifting cultivation practices on shallow water that meant to exploring regions with cooler seawater, seaweed farmers in Kiuyu Mbuyuni and Matemwe village reported to shift their plot in various spots to cope with decline in fertility levels (Makame, 2013). The same strategy also reported by Campos (2010) in Philiphines that, seaweed farmers kept moving their plot to various spot where ocean water moves freely to abate the impacts of poor seaweed growth attributed by locating seaweed plot in crowded zone. This is because nutrients especially nitrogen is known to improve seaweed ability to withstand pigment loss which is vital for photosynthesis (Lobban and Harrison 1994). Also, artificial nutrient supplements have shown to improve seaweed growth and hence production (Msuya *et al*., 2007: Msuya, 2013). Nonetheless it is not practical in natural environment (in the ocean) where farms are set.

Strategy implication to production level denotes, a production loss averaged 7.5 sacks per harvest was encountered when farmers strategized through shifting cultivation. This is 34.8 % production decline due to increased temperature despite of integrating shifting cultivation strategy.

This suggests that, shifting cultivation within the intertidal shallow water was not an effective strategy against effects of warm water on seaweed growth, and further reflects that cooler zone on shallow water is difficult to locate. Low number of respondents who complimented this idea suggests that, this is no longer a feasible coping strategy despite its widespread use in Unguja island (Msuya, 2006, 2012: Makame, 2013). Seaweed farming in shallow intertidal water also proves failure in Songosongo Island and Tanzania mainland (Hayashi *et al*. 2010), the root-cause being elevated seawater temperature (Msuya, 2009).

No improvements in seaweed production entail that, farming in shallow water is no longer a feasible mechanism to counteract elevated temperature. On the other hand, study by Mmochi *et al*. (2005) on placing farms in deep waters has shown promising results against increasing temperature. Since shifting cultivation in intertidal water does not provide promising production results, and since artificial fertilization which would improves seaweed growth and production is

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not feasible in the outdoor farming (Msuya *et al*. 2007; Msuya 2013), the latest and only promising technique remains to be moving farms into deep waters.

From these facts, it's high time for the government and private sector like NGOs to support farmers to move their farms to into deep water. Furthermore, it is a time for sensitizing men to engage themselves in seaweed farming as the proposed technique needs male power, meanwhile alternative livelihood earning activities should be created for female farmers who are already and will continue to be affected by the changing environment.

Fast Removal of Infected Seaweed Plants

23% of seaweed farmers reported to minimize the effect of epiphytes through fast removal of infected seaweed plants from the plot (Table 2). This was indicated to be a good and effective strategy as suggested by seaweed farmers that,

"………*fast removal of infected plant delays the possibility of diseases prevalence and thus does not compromise growth and survival of seaweed in the plot*".

Furthermore, the problem of ice-ice disease is widespread in Western Indian Ocean (WIO) region, mostly during the period of high seawater temperature (hot season) (ICMZ, 2009); Erika 2011) when water motion is low due to calm weather induced by weaker waves. Infected seaweed portion of the plant appears whitish due to microbial colonization, become soft and decompose away resulting to breakage of branches (Trono *et al.*, 1994) thus results to loss in seaweed production Also, elevated seawater temperature is ideal for growth and dominance of algal epiphytes (locally known as *ushava*), that invade and tangle seaweed plant creating competition for nutrient (Erika, 2011). Similar containment measure against seaweed diseases is common in Philippines (Campos, 2010).

The implication of this strategy on seaweed production levels highlights that, production level declined to approximately 41 sacks per harvest after emergencies of seaweed diseases (Table 4). This is more than 50% production decline when compared to production levels before emergencies of diseases. When farmers adopted fast removal of all diseased seaweed plants, a production decline to approximately 28 sacks per harvest was encountered compared to before removal of infected seaweed plants. This is equivalent to 62 % decline in production even with integrated of this strategy in seaweed cultivation.

This implies that, level of production still worsen even with removal of infected seaweed. This is probably caused by reduced quantity of matured and harvested seaweed after discard of all infected seaweeds. Also, poor timing for removal of infected seaweeds may results to plentiful seaweed infection that in turn will be discarded. Higher incidences of ice-ice diseases during hot season induced by higher temperature and weaker waves (ICMZ, 2009; Erika 2011) suggests the idea of farmers' poor timing for removal of infected seaweed due to unknowing rate of diseases prevalence in such conditions as it is speculated that, farmers' awareness and understanding on seaweed diseases is marginal. This is further enhanced by tidal cycles which at certain period hinders farmers to access their farms and quickly removes infested seaweeds. Furthermore, other compounding factors such as strong waves that cut and washes away seaweeds and elevated

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temperature that facilitate seaweed softening, fragmentation and detachment from their rope (Makame, 2013) acts synergistically with diseases to worsen the situation.

Table 4: Seaweed production level at elevated temperature coupled by quick removal of infected seaweeds as coping strategy.

	Number of sacks produced per harvest (in range)	**Mean (sacks)**	**Number of seaweed farmers responded**
Production level before emergencies of diseases	80-100	86	91
Production during existence of diseases before adapting removal of infected seaweeds	38-55	45	84
Level of production after quick removal of infected seaweeds adopted	10-25	17	37

NOTE; The production level was presented in dried form of seaweed using a 25-kilogram sack locally known as Polo. Given the wide range of responses produced, results of seaweed production level were presented in average (Mean) in which, total of all indicated production level was computed then, divided by the number of seaweed farmers responded to the question.

2) Implications of Coping and Adaptation Strategies Against Strong Ocean Waves on Seaweed Production Level

Results on the on-farm coping and adaptation strategies against increased strength of ocean waves are presented in Table 2. Each strategy will be discussed in conjunction with results of its implications on seaweed production level as presented in Table 5.

Table 5: Seaweed production level under various coping and adaptation strategies against stronger ocean waves

		Number of sacks produced (in range)	**Mean (sacks)**	**Number of seaweed farmers responded**
Production level before stronger ocean waves		95-128	99	85
Production level during stronger ocean waves but before employing adaptation strategies		75-93	89	73
	a) Increasing the number of and placing wooden pegs closer to one another	33	20-35	37
	b) Frequently reattaching of loosened and uprooted pegs	29	15-33	58

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Various coping and adaptations Measures during stronger waves	c) Fixing very hard and long wooden pegs with deep rooting	27	25-40	55
	d) Tying seaweed seedlings firmly on nylon rope using long tie-tie	21	10-25	35
	e) Planting plenty of seaweeds during months with weaker ocean waves	5	2-5	33

NOTE; The production level was presented in dried form of seaweed using a 25 kilogram sack locally known as Polo. Given the wide range of responses produced, results of seaweed production level were presented in average (Mean) in which, total of all indicated production level was computed then, divided by the number of seaweed farmers responded to the question.

Frequent Reattaching of Loosened and Uprooted Pegs

32 % of interviewed farmers preferred to integrate this strategy during seaweed cultivation against stronger waves (Table 2). Higher percentage of seaweed farmers who reported to frequently reattach loosed and uprooted pegs suggests that, the strategy is considered to be the most effective as a short term response against stronger ocean waves.

When its effectiveness was assessed in terms of seaweed production level, a decline in production estimated to 56 sacks per harvest was recorded (Table 5). It accounts for 62.9 % loss in seaweed yield. This is because Off-bottom farming technique which is the main technique practiced in Tanzania is vulnerable to stronger waves (Makame, 2013). Although the strategy of reattaching loosed seaweeds to ropes and re-rooting uprooted pegs is easy in the intertidal water and off-bottom technique however it cannot be effective mainly due to tidal cycles. This work is done during spring low tide during which farmers access their farms mainly by foot. This occurs approximately after every 10 to 12 days in Tanzania (as it can be observed from tide chart). It means in between this period, i.e during neap tide if strong waves uproots pegs or detach seaweeds the effects cannot be intervened. Reports from some farmers show that, if strong waves occur during neap tide when they cannot access their farms, big losses occur. They only visit the beach to collect seaweeds that have been detached and brought to the beach by storm for drying. In this case the farmer who goes to the beach first collects everything that she/he finds while others do not get anything and no allegations against her/him since the seaweeds found on the beach have no farmers' identity. This may imply that during the period of strong waves the farmer who visit the beach on regular basis is likely to have high seaweed production level than her/his colleagues regardless of his/her farm size and vice versa. This suggests that, maintenance of shallow water based seaweed farms are currently challenging as it involves frequent survey to oversee integrity of seaweed plots in this unstable environment. This also notifies that, seaweed farming in recent era of climate change is more laborious and time consuming compared to farming in climate change free era.

Fixing Very Hard and Long Wooden Pegs Deep into The Sand

24.2% of seaweed farmers strategically fixed very hard and long pegs to stabilize seaweed against strong ocean waves (Table 2). Big stones and tack hummers were reported to be used to ensure

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maximum penetration of pegs into the sediment and assure their firmness against stronger waves. This is given by the testimony below,

"*……………….I abandoned the use of mere hands to push down pegs because it was not working, and decided to use big stones and tack hummer to hit on the pegs to assure maximum penetration into the sediments to avoid impacts of strong ocean waves*"

Seaweed farmers' opting for this strategy shows its potential for being useful solution against stronger waves induced uproot of pegs.

On the other hands, when its implications to production level was assessed, production level still showed downward trend even with fixing very hard and long pegs. Average production decline estimated to 62 sacks per harvest, accounting for 69.7 % losses in seaweed yield was reported under this strategy (Table 5). That means, the strategy was not effective against stronger waves. Relatively higher number of farmers, who employed the strategy, entailed their perception that it would help to offer positive containment of pegs against strong waves. Nonetheless higher percentage loss in seaweed production from tightly fixed pegs can be explained by loss of seaweeds due to stronger waves induced disruption of pegs (seaweed plot) resulting to washing away of freely suspended seaweeds.

Given that, mangrove forest are commonly used as the source of pegs (Msuya, 2011: 2012), it means the use of this strategy of hard and long pegs may accelerate pace for mangrove harvesting resulting to coastal forest degradation. Notwithstanding that, mangrove forest plays vital roles in carbon sequestration which is crucial for climate change mitigation, prevention of coastal erosion and provision of fish breeding grounds (Mbwambo *et al.*, 2013). Thus changes in marine environment where seaweed farming is performed, jeopardizes nearby land based coastal resources (mangrove forest) whereas loosing mangrove forest in favour of seaweed farming will bring more problems including but not limited to coastal erosion, loss of seagrasses due to heavy land based sediment/mud loading, compromised water quality due to lack of filters (mangroves), loss of corals and associated fisheries etc.

Increasing the Number of and Placing Wooden Pegs Closer to One Another

21.1 % of seaweed farmers contained their farming by increasing the number of pegs and placing seaweed seedlings closer to one another (Table 2). This was intended to enhance stocking density of seaweed plants per unit plot, thus overcomes stronger waves from cutting and washing away seaweed plants. With this intervention, seaweed farmers need to retain relatively high biomass of seaweed seedlings for the next planting cycle. This may introduce negative consequences in the quantity of harvest, since large quantity of seaweeds is retained as seed stock thus lowers seaweed farmer's income gain. However, this strategy in a long run has pronounced effects on mangrove ecosystems due to its high demand in numbers of pegs per cultivation plot.

Moreover, implications of this strategy on seaweed production level showed decline in production level estimated to 56 sacks per harvest occurred when this strategy employed, that is equivalent to 62.9 % losses in seaweed yield (Table 5). This means even with integration of this strategy, production level still exhibited downward trend. But, relatively higher production average (33 sacks per harvest), suggest that, satisfactory amount of seaweeds was harvested although relatively

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few farmers employed the strategy. This is probably because placing many pegs closer, made high stocking density on the plot that in turn minimized wave strength hence reduced breakage of growing seaweeds. On the other hand high stocking density perhaps caused shading and competition effects, thus reduced production that would have been attained in a normal planting settings (Msuya, 2013).

Tying Seaweed Seedlings Firmly on Nylon Rope Using Long Tie-Tie

15.4 % of seaweed farmers protected their growing seaweeds from stronger waves induced breakage by tying seaweed seedlings firmly using long tie-ties locally produced by famers (Table 2). It was reported by Makame (2013) that formers do not receive farming material such as ropes, tie-ties, from seaweed buyers anymore. From farmers reporting perspective there is a concealed advantage that, apart from being deprived of seaweed farming materials they managed to purchase and modify their tie-tie to produce long tie-ties that believed to be good and effective for tying firmly seaweed seedlings. Nonetheless seaweed farmers buy farming materials including tie-tie (Makame, 2013: Msuya, 2011, 2013a). Integration of this strategy in seaweed cultivation introduces additional investment cost since, to locally produce long tie-tie, farmers need purchase many tie-tie that are locally modified to end up with long ones. Therefore, high investment cost due to local production of long tie-tie, farmers will be forced to leave the enterprise.

On production level implications, average production loss estimated to 68 sacks per harvest encountered that accounts for approximately 76.4 losses in seaweed yield per harvest (Table 5). It should be noted that, slippery and softness nature of seaweeds due to warm seawater (Trono 1994; Msuya 2012), induces detachment of tightly fixed seaweed, hence together with stronger ocean waves, jeopardize seaweed growth resulting to failure of the intervention as demonstrated by huge production losses.

Planting Plenty of Seaweeds During Months with Weaker Ocean Waves

7.4 % of interviewed seaweed farmers adjusted to changes by planting plenty of seaweeds during months with weaker ocean waves (Table 2). Low percentage of farmers who complemented for this strategy suggests this to be the least effective measure. When reflected to its potential to safeguard seaweed production level in changing environment (Table 5), decline in production averaged to 84 sacks per harvest. This accounts for approximately 94.4% loss in seaweed yield compared to production before the emergence of persisting strong waves. Extremely higher production loss even after adoption of this strategy implies that, seaweeds do not grow well during months with weaker waves because, seasons with weaker waves coincide with period for extreme higher surface seawater temperature (hot seasons) persisting from January to March/April. Moreover, weaker waves delay possibilities for rough water movement that creates smooth water motion (Trono, 1994: Makame, 2013). The effects of high seawater temperature on growing seaweeds compounded by slow moving water is extremely higher, therefore altogether acts synergistically to compromise seaweed growth resulting to higher production loss. Also in Tanzania March and April are months of peak heavy rains (*masika*) which may cause low salinity and negatively affect seaweed cultivated in the intertidal shallow waters. Seaweed cultivated in intertidal areas are exposed to relatively low salinity (direct rains) during spring low tides for almost two to four hours per day for at least ten days a month (two spring tide cycles). Some studies conducted in natural stocks in Tanzania show decline in seaweed biomass and canopy

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cover in months of heavy rains Buriyo *et al.* (2001) and some famers have reported to stop farming during heavy rains due to poor seaweed growth (de la Torre Castro and Jiddawi, 2005).

In overall, the study established that, all coping and adaptation strategies against strong ocean waves turned seaweed farming more energy intensive enterprise due to the need in farmers' physical fitness to implement the strategies. On the contrary seaweed industry is dominated by female who can't withstand physical power demanding work for a longer period of time. This means, the activity may be unbearable to them and may discourage their participation resulting to possible collapse of the industry if immediate efforts are not taken.

3) Statistical Justification Using Liner Regression Model

Regression analysis was categorized into two groups based on the two different categories of independent variables (coping and adaptation strategies used under elevated seawater temperature and stronger ocean waves) tested on the dependent variable (seaweed production level). Results on regression model analysis were grouped as follows

Result group 1: The analysis of model strength through Inference on Beta Values

The relationship between seaweed production levels and various coping and adaptation strategies under condition of elevated seawater temperature and stronger ocean waves was analyzed. If the beta coefficient is significant (p-value less than 0.05), an examination of the sign of the beta is carried. If the regression beta coefficient is positive, the interpretation is that for every 1-unit increase in the predictor variable, the dependent variable will increase by the unstandardized beta coefficient value.

Table 6: Model Summary under Elevated Seawater Temperature

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	-.542	.294	.211	65.43

Table 7: Model Summary under Stronger Ocean Waves

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	-.657	.431	.399	43.87

Table 4 and Table 5 above showed that there is a mild relationship and fairly good relationship between seaweed production level against elevated seawater temperature and stronger ocean waves respectively (r = -0.542 and r = - .657 respectively). This implies that the two tested variables are inversely related in the sense that elevated seawater temperature and stronger ocean waves are not favorable for seaweed production. The $R^2 = 0.211$ and $R^2 = 0.431$ implies that the model accounts for 21.1% and 43.1% of the variations between elevated temperature and stronger ocean waves against seaweed production level respectively.

Result group 2: Effects of coefficients on Dependent variable

Regression model was used to identify and predicts the strength of the effect that the one or more independent variable(s) have on a dependent variable. Using Pearson's correlation test, the nature of the relationship between seaweed productions were assessed before and after existence of harsh

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climatic conditions and during when different coping and adaptation strategies employed as independent variables respectively (Table 8 and Table 9).

Table 8: Correlation Matrix under the condition of elevated seawater temperature

	Btemp	**Atemp**	**shifting cultivation**	**increased farm size**	**plant plenty**
Prod	0.456	-.436	-.875	-.348	-.176

Table 9: Correlation Matrix under the condition of stronger ocean waves

	Production level during stronger ocean waves but before employing adaptation strategies				
	Increasing the number of and placing wooden pegs closer to one another (M1)	Frequently reattaching of loosened and uprooted pegs (M2)	Fixing very hard and long wooden pegs with deep rooting (M3)	Tying seaweed seedlings firmly on nylon rope using long tie-tie (M4)	Planting plenty of seaweeds during months with weaker ocean waves (M5)
Before stronger ocean waves	-.446	-.635	-.173	-.534	-.694

Findings on Table 8 and Table 9 above indicate that Seaweed production is higher in the absence of elevated seawater temperature and weaker ocean waves. But decrease due to presence of elevated seawater temperature and stronger ocean waves. The negative value predicts further decrease in production level upon shifting cultivation, increased farm size or planting of seaweeds. But The less negative value on production during planting plenty seaweeds indicates, less production decline occurred compared to coping by shifting cultivation and increasing farms size. Moreover, stronger ocean waves have an inverse impact on the production of seaweeds (Table 9). In this case, there was a negative impact between stronger ocean waves and iincreasing the number of and placing wooden pegs closer to one another, frequently reattaching of loosened and uprooted pegs, fixing very hard and long wooden pegs with deep rooting, Tying seaweed seedlings firmly on nylon rope using long tie-tie and Planting plenty of seaweeds during months with weaker ocean waves. In all above studied cases the production of seaweeds decreased drastically with the largest decrease observed planting was done when there were weaker ocean waves.

Result group 4: The Interpretation of Coefficients

Interpretation coefficient on the model summarized in Table 10 below leads to the construction of the regression equation as

$$\text{Seaweed Production level} = 124.66 + 2.455\text{btempi} - 2.543\text{atempi} - 6.652\text{shifting cult} - 5.436\text{increased farm size} - 2.564\text{planting of seaweeds}$$

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Table 10: Interpretation Coefficients Table on elevated seawater temperature

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	124.66	37.44		3.435	.000
Shifting cult	-6.652	3.37	-.246	2.544	.022
Increased farm size	-5.436	5.43	-.434	2.224	.013
Planting of seaweeds	-2.564	2.53	-.848	1.544	.005

The above equation implies that in the absence of the three mentioned factors then seaweed production grow by an amount equal to 124.66. On the other hand with an increase in temperature, if shifting cultivation is changed while other factors are constant, then seaweed production is decreased by 6.652. It was also noted that if size of the farm is increased but temperatures still being high then seaweed production decreased by an amount equal to5.436. Finally, if planting of seaweeds takes place then seaweed production still decreased by an amount equal to 2.564 and this is the most important predictor of seaweed production since its absolute beta value is highest valued at 0.848.

Furthermore, results in Table 11 leads to the construction of the regression equation

$$\text{Seaweed Production} = 99.35 - 7.334\text{M1} - 6.445\text{M2} - 8.344\text{M3} - 6.232\text{M4} - 1.434\text{M5}$$

Table 11: Interpretation Coefficients Table on stronger ocean waves

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	99.35	34.55		2.224	.100
M1	-7.334	23.34	-0.334	4.234	.034
M2	-6.445	21.75	-0.233	2.348	.043
M3	-8.344	22.22	-0.637	4.234	.002
M4	-6.232	24.21	- 0.534	3.245	.021
M5	-1.434	2.282	-0.123	2.343	.435

The above equation implies that in the absence of stronger ocean waves, seaweed production grows by an amount equal to 99.35. On the other hand, using the absolute beta value it was observed that fixing very hard and long wooden pegs with deep rooting is the most important predictor of seaweed production in the presence of strong ocean waves.

In overall, Climate change have caused tremendous downfall in seaweed production level justified by downfall production trend existed in Zanzibar possibly due to seaweed die-off (Msuya *et al.*, 2014) triggered by elevated seawater temperature (Figure 3). Trend in seaweed production continued to worsen (downfall trend from 2008 to 2011 in Jambiani village) even with the

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integration of various on-farm coping and adaptation strategies (Figure 2). It was found that coping and adaptation strategies are not improving seaweed production at all. Only the strategy of planting plenty of seaweeds during cooler months fairly improved production level. Moreover, production level after the increase in seawater temperature is extremely poor (temperature attributed 50% decline) as compared to production after increased intensity ocean waves (strong waves attributed 10% decline). This means, elevated seawater temperature impairs heavily seaweed growth causing extreme decline in production Buriyo *et al*. (2001); Sheikh *et al*. (2012), and Msuya *et al*. (2014) as compared to the impacts of stronger ocean waves.

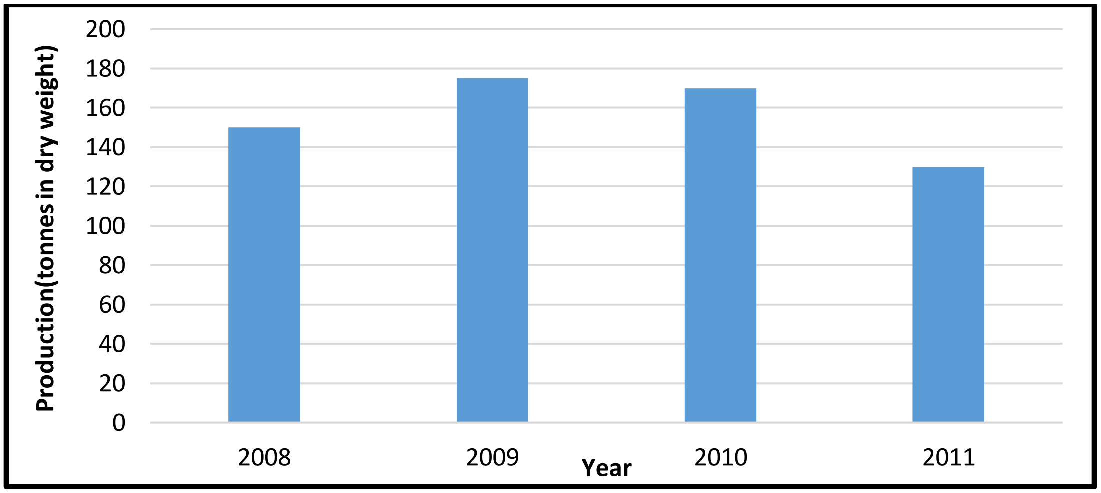

Figure 2: Jambiani seaweed production data from 2008-2011

Source: Erika, 2011.

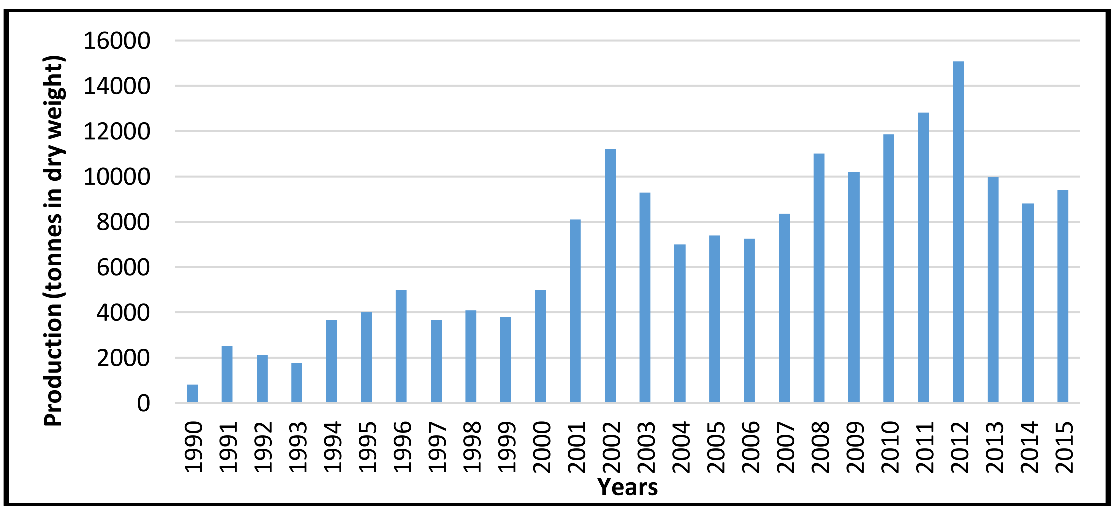

Figure 3: Seaweed production in Zanzibar (1990-2015).

Source: Seaweed division (MANRLF, 2016)

4. Conclusion and Recommendations

As a way of coping and adapting to observed changes, seaweed farmers, continued to employ previously documented and newly developed coping and adopting strategies, the latter being

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documented for the first time by this study. Newly developed adaptation strategies includes planting plenty of seaweeds during cooler season, increasing the number of and placing pegs closer to one another, increasing size of farm, tying firmly seaweed seedlings and fixing very hard and long pegs with deeper rooting. Nevertheless, seaweed production level under old and newly developed coping and adaption strategies still declining implying for failure in containment measures. Thus, calling for both development of new seaweed farming technology against climate and weather changes as well as new alternative activities for income generation to support the vulnerable community.

The study recommends that, it's time, for the government to venture into this industry and start offering extension services to seaweed farmers, and organizing seminars to educate farmers on the best farming practices in a changing environment. Seaweed farmers in Tanzania should be empowered to carry floating line and raft techniques that are taken in deep and cooler water. This is by provision of boats which is the major challenge and other farming material to facilitate set up of farms in deep water since, strategies against stronger ocean waves require physical power, thus men's participation must emphasized

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