The Potential Use of Aquatic Ecosystem for Enhancement of Rehabilitation of Mining Site: A Case of Wazo Hill, Tanzania.

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Abstract

Rehabilitation programme of Wazo Hill quarry was focused on planting terrestrial plants, where three hectors in the former quarry have been re-cultivated for trees nurseries. The restoration of aquatic ecosystems was not considered in this programme; despite the fact that, quarries life are heterogeneous ecosystems, involving both terrestrial and aquatic ecosystems. The present study therefore was intended to restore aquatic ecosystems and investigating their potentialities in rehabilitation of quarries.

To achieve the study, an abandon pit was filled with water, fertilized with wastewater and 20 Nile tilapia (*Oreochromis nilotius*) were stocked. The water quality parameters (temperature, DO, Salinity, conductivity, pH, NH_4-N and NO_3-N) were monitored twice per month while the weight and length of Nile tilapia were monitored in monthly basis (From May to September). The digital camera was set for daily recording terrestrial and aquatic species attracted by the presence of aquatic environment. To investigate the potentiality of aquatic ecosystem, two set of *S. Siamea* nurseries were prepared; the first was irrigated with water from the aquatic pond and the second set was irrigated with tape water. The length and diameter of *S.Siamea* were monitored in monthly basis.

The results indicated that, the pH was increased linearly (R^2 = 0.86) with the average of 8.23 $\pm$ 0.56. The DO was decreased gradually (R^2=0.68) while salinity and conductivity was higher in dry season compared to rainy season. The variation of temperature within the ecosystem was not significant. The temperature recorded was ranged from 26.3^{o}C to 27.8^{o}C; which was within the standard of aquatic environment. NH_4-N recorded was increased exponentially (R^2=0.99) due to the increase of reproduction of Nile tilapia. NO_3-N was increasing; forming the parabolic curve with a peak value in July. The average of weight and length were 34.14 $\pm$ 2.88g and 14.38 $\pm$ 0.317cm respectively. The growth of Nile tilapia was increased from June to July and became stagnant from July to August. The stagnant growth of Nile tilapia was contributed by the increase of NH_4-N and NO_3-N. Despite to the negative impact on the growth of Nile tilapia, the increase of NH_4-N and NO_3-N in the aquatic pond were potential to the growth of *S.Siamea*. In comparison, the growth rate of *S. siamea* irrigated with pond water was higher than *S.siamea* irrigated with tape water. The difference observed was significant (P=0.002) at 95% the confidence interval.

In total 21 species attracted to the restored aquatic ecosystem was recorded and identified. These species was including dragonflies (*Anax mauricianus*, *Sympetrum flaveolum*, *Plathemic lydia* and *Orthetrum Cancellatum*), bees and wasp (*Anthophila*, *Sphex pensylavanius* and *Bembix oculata*); butterflies (*Charaxes brutus natallnsis*, *Junonia Coenia* and *Danaus plexippus*), mammals (*Atherrus Africanus and Chlorocebus pygerythrus*), amphibian (*Amietophynus gulturaliss and Amietophynus garmani*), reptilian (*Atractaspis engaddensis*) Whirligig beetle (*Gyrinidae*), *Musca domestica* and Water scorpions (*Nepidae*). Most of these species required aquatic environment to complete their life cycle. The mammals were used aquatic environment as a source of drinking water while most of aquatic species were used the pond for their habitat.

The present study have discovered the potentialities of using aquatic ecosystems for enhancement of rehabilitation of quarries. Converting the abandoned pits into aquatic ponds could enhance biodiversity at Wazo Hill while the stocking Nile tilapia in ponds could add values to the abandon pit by forming aquaculture projects.

1.0 Introduction

Tanzania Portland Cement Company Limited (TPCC) is a large company which is in the business of manufacturing, selling and distribution of high quality construction cement in Tanzania (Gastory, 2012). To produce high production of cements, TPCC requires raw materials including limestone, clay and mudstone or shale. The excavation of limestone, involves the removal of top soils and blasting of underlying limestone rock. This process left a desert with less or no fauna and flora, which in turn, bring the challenges in conservation of the environment (Hardouin, 1985, Oke and Ibhanesebar, 2013).

In cooperation with Germany Technical Cooperation (GTZ), TPCC have a programme of restoring, rehabilitation and conserving the natural environment (Gastory, 2012). The rehabilitation programme is basically focused on planting terrestrial plants, where three hectors in the former quarry have been re-cultivated for trees nursery (Gastory, 2012). The restoration of aquatic ecosystems is not considered in this programme despite the fact that, quarries life are heterogeneous ecosystems, involving both terrestrial and aquatic ecosystems (Khater and Arnaud, 2007; Oke and Ibhanesebor, 2013).

Aquatic ecosystems should not undermined during the rehabilitation processes of the quarries, because they are hot spots of most terrestrial biodiversity. Through the food web and habitat resources, aquatic ecosystems interact with their surrounding terrestrial area (Liken and Bormann, 1974). If they will be effectively implemented, aquatic ecosystems have ability to attract a wide range of other fauna including wading and migrating birds, amphibians, riparian mammals and insects. Aquatic ecosystems provide the feeding ground of many terrestrial birds, breeding site of fishes, frogs and other aquatic invertebrates in quarries (Grasman, 1996). Aquatic ecosystem provide sources of water from many migrant animals like lizard, rabbit and birds (Oke and Ibhanesebor, 2013). Furthermore the aquatic ecosystems recycle nutrients of wastewater.

The present study was intended to provide a better understanding of converting abandon pits of Wazo Hill into aquatic ecosystems. The abandon pits were filling with water, fertilizing using wastewater and Nile Tilapia (*Oreochromis nilotius*) were stocked into the pond. The study was also aimed to document terrestrial and aquatic species found in the quarry. This information will be used as a baseline for assessing the potential of aquatic ecosystem in rehabilitation program of Wazo Hill quarry.

2.0 General Objective

The general objective of the present study was to restore aquatic ecosystems at Wazo Hill quarry by converting the abandon pits and to investigate the potentialities of aquatic ecosystems on the rehabilitation of quarries.

2.1 Specific Objectives

The following were the specific objectives of this study

- Monitoring, recording and identifying terrestrial and aquatic species attracted by aquatic ecosystem.
- Monitoring of growth rate Nile tilapia (*Oreochromis nilotius*) stocked into aquatic ecosystem
- Monitoring water quality after stocked Nile tilapia into aquatic ecosystem
- Optimizing the reuse of water from aquatic ecosystem for irrigation of plants nurseries.

3.0 Methodology

3.1 Site Description

Wazo Hill quarry is located approximately 25 km from Dar es Salaam city centre (Annex 1; Fig. 1.1). The quarry is placed between latitude -6^{o} 34’ south and longitudes 39^{o} 23’ and 39^{o} 25’ East, which is approximately 100m above the sea level. The quarry comprises the highest fossil reef and the largest carbonate both occurred on the coast of Tanzania. The climate condition in Wazo Hill (Dar es Salaam) is characterized by hot and humid weather condition with average temperature ranging from 24-32^{o}C (UNEP, 1998). The lowest temperature occur during May to September while December to March are the hottest months. Like other coastal areas of East Africa, the Dar es Salaam coast is under influence of reversing monsoon winds, which blows from NE direction between November and March and SE direction between May and September. The area receives bimodal rainfall occurring from March to June and from November to December (Kabanda and Jurry, 1999; Kijazi and Reason, 2009 and Francis *et al*, 2001).

The quarry is comprising more than five manmade water ponds. The retention of water in these ponds varies with seasons. In the dry season most of the ponds are dried. However, during the rainy season all ponds are flooded. Apart from water ponds, the quarries comprises the nurseries of trees which is a part of the ongoing programme under UKIVIUTA. As a part of rehabilitation of Wazo Hill quarry life, through quarry life award, one of the abandoned water ponds have been transformed to fish pond as the first initiative to restore aquatic ecosystem in Wazo Hill.

3.2 Methods and Statistical Analysis

3.2.1 Identification of Pond for Experiment setup

Before transforming any abandoned water ponds into aquatic ecosystems the feasibility study was carried out in the Wazo Hill quarry. The purpose of the study was to gather the baseline information of the existing ponds, particularly water quality parameter, pond’s size and the ability of ponds to retain water in both seasons; dry and rainy. In total, five ponds were visited (Annex 2: Figs.2.1-2.6). In each of the visited pond, the water quality parameters (pH, DO, salinity, conductivity, and temperature, ammonia, nitrate and nitrite) were examined. The diameter and depth of each pond were recorded in order to determine the capacity of the pond. Based on result of the feasibility study, the water pond located at latitude 06^{o} 39.354 South and 039^{o} 09.922 east were selected (Annex 2; Fig.2.3). The pond is round with a diameter of 9 meters and mean depth approximated to 2.5 meters. The pond has a capacity of holding water approximate to 70 meters cubic; with a capacity of retaining water. The water quality in this pond was good compared to other ponds found at Wazo Hill. Therefore the pond was suitable for fish stocking.

3.2.2 Stocking Nile Tilapia (*Oreochromis nilotius*)

In total 20 fingerlings of Nile Tilapia (*Oreochromis nilotus*) were stocked into the selected pond (Annex 3: Figs. 3.1 and 3.2). The length and weight of the fingerlings were measured before stocked into the pond. The Nile tilapia had an average weight of 30.15g and length of 10 cm. The Nile tilapia (*Oreochroms niloticus)* were used in the present study due to the following reasons: (1) it is mostly cultured fish and hard species which can sustain in both season; dry and rain season, (2) the species feed on the natural food particularly phytoplankton which can be easily developed by using wastewater and (3) the species has a capacity of attracting amphibians, birds and frogs through food web.

3.2.3 Monitoring of Growth rate of Nile Tilapia (*Oreochromis nilotius)*

To monitor the Nile tilapia growth rate, a sensitive balance was used for determination of fish weight while a ruler was used to determine the length of fish. The measurements of weight and length of the tilapia was carried out in monthly basis; from May to August 2014. To convert the pond into aquatic ecosystem, 20 litres of wastewater was discharged into the fish pond in weekly basis; to enhance the production of algae.

3.2.4 Monitoring of Water quality Parameters

Physical and chemical water quality parameters were conducted twice per months. The physical parameters: temperature, pH, salinity and conductivity was determined using the pH meter while DO was determined using the DO meter. Nitrate Nitrogen (NO_3-N) and Ammonia Nitrogen (NH_4-N) were analysed in accordance with standard methods for examination of water and wastewater, APHA (1998).

3.2.5 Reuse of water from Aquatic Pond for the Growth of Trees (*Senna Siamea*)

Two set of *Senna siamea* nurseries were prepared for the purpose of comparison their growth rate after subjected to tape water and water from the aquatic pond. Each set of *Senna siamea* nursery was comprised 14 plants as indicated in (Annex 4: Figs. 4.1-4.6). At the beginning of the experiment, the initial length and diameter of each plant was measured and recorded using tape measure and callipers. The *Senna sianne* species was preferably used in this experiment because of its ability to persist drought and preventing erosion (UKIVIUTA, 2014).

3.2.6 Assessing and Identifying Aquatic and terrestrial species

After transforming water pond into aquatic ecosystem and introducing Nile tilapia in it; it was a great significance to assess and identify aquatic and terrestrial species attracted with the presence of aquatic environment. To achieve this objective, aquatic species were sampled by scooping net. Butterflies, dragonflies, monkeys, frogs, snakes, porcupine and other terrestrial animals were collected mainly by direct observation and photos were used for additional determination.

3.3 Statistical Analysis

Descriptive stastic was used to summaries the data obtained from this study. For statistical test, the linear regression analysis was used to determine correlation of water quality parameters with time. T-test was used to compare the means values of data of *S.siamea* subjected with tape water (control) and *S. siamea* subjected to water from aquatic pond. Both descriptive and inferential statistic was performed by using Origin Pro and Microsoft excel 2013.

4.0 Results

4.1 Water Quality parameters

Water quality parameters (pH, Dissolved Oxygen, temperature, salinity, conductivity, ammonium nitrogen and nitrate nitrogen) recorded from May to September are represented from Fig. 5.1 to Fig. 5.7 (Annex 5). The pH value in the aquatic pond ranged from 6.84 to 9.82 with a mean of 8.23 ± 0.56. The minimum pH was observed in the beginning of the experiment. From May to September, the pH in the aquatic ecosystem was increased linearly (R^2= 0.86) where the maximum pH of 9.86 were observed (Fig. 5.1; Annex 5). In contrast, the Dissolved Oxygen (DO) was decreased gradually from May to September. The average DO observed in the aquatic ecosystem was 8.24 ± 0.56 mg/l with the maximum DO of 6.83 mg/l observed in May and the minimum 2.69 mg/l on September (Fig. 5.2; Annex 5). The trend of salinity and conductivity were similar; forming the parabolic curve with the maximum value on July and the minimum value on May and September (Figs. 5.4 and 5.5: Annex 5). The average salinity and conductivity was 1.5 ± 0.01 and 0.32 ± 0.07 S/cm respectively. The mean temperature of water was slightly decreased linearly from May to September (R^2 = 0.91). The variation of temperature in the aquatic ecosystem was not significant. The temperature within the ecosystem was ranged from 26.3 to 27.2ºC with mean of (Fig. 5.3; Annex 5).

Ammonium Nitrogen (NH_4-N) was increased parabolic from May to September (R^2=0.99). Although from May to July the increase of NH_4-N was slightly low. Generally the NH_4-N within aquatic ecosystem was ranged from 0.32 mg/l to 1.2 mg/l with average of 0.61 ± 0.16 mg/l (Fig.5.6; Annex 5). Nitrate Nitrogen (NO_3-N) recorded from May to September was initially increased, particularly from May to June; which was the beginning of experiment. From June to September the NO_3-N was slightly varied however the general trend showed the parabolic curve with optimal value in July (Fig. 5.7; Annex 5).

4.2 The weight and length of Nile Tilapia *(Oreochromis nilotius)*

In the beginning of the experiment, the average weight and length of Nile Tilapia (*Oreochromis nilotius*) were 34.16 ± 2.88g and 14.38 ± 0.317cm respectively. After Nile tilapia introduced into the ponds followed by wastewater, the weight and length of Nile tilapia were increased particularly from June to July, then from July to August, the weight of the Nile tilapia was seemed to decrease while the length remained constant (Figs. 6.1 and 6.2; Annex 6).

4.3 Growth rate of *Senna Siamea*

The growth rate of *Senna Siamea* is reported in terms of increase in height and diameter as shown in Figs. 7.1 and 7.2 (Annex 7). The increase in height of *Senna siamea* subjected to pond water was higher than the *S. Siamea* subjected to tape water (Fig. 7.1). *S.Siamea* (subjected to pond water) were increased with time from May to September while the *S. Siamea* (Subjected to tape water) were slightly increased from May to June, and remained constant from July to September. From the t-test at the confidence interval of 95%, the difference in increase in height between *S.Siamea* subjected to water pond and *S.Siamea* subjected to tape water was extremely significant (P= 0.0008). Likewise in the increase in diameter of *S.Siamea* for *S. Siamea* subjected to was higher than *S. Siamea* subjected to tap water (Fig. 7.2). The different was significant at 95% confidence interval (P=0.0002).

4.4 Aquatic and Terrestrial species Identified

In total 21 species of terrestrial and aquatic animals were recorded and identified within and around the aquatic ecosystem. Of which, 4 species were dragonflies (*Anax mauricianus, Sympetrum flaveolum, Plathemic lydia* and *Orthetrum Cancellatum)*, 3 species of bees and wasp (*Anthophila, Sphex pensylavanius* and *Bembix oculata)* and 3 species of butterflies

(*Charaxes brutus natallnsis, Junonia Coenia and Danaus plexippus).* Furthermore, 2 species of mammals (*Atherrus Africanus* and *Chlorocebus pygerythrus)* were recorded, including 2 species of amphibian (*Amietophynus gulturaliss* and *Amietophynus garmani)* reptilian (*Atractaspis engaddensis)* 1 species of Whirligig beetle *(Gyrinidae),* one species of *Musca domestica* and 1 species of catfish (*Clarias gariepinus)* and water scorpions (*Nepidae*) (Figs. 9.1-9.18; Annex 9).

5.0 **Discussion**

Water quality

Rehabilitation of Wazo Hill quarry was enhanced by introducing aquatic ecosystem. Apart from its role of providing the habitat to many aquatic animals, the ecosystem was providing a source of water supply to terrestrial animals and for irrigating plants nursery. In addition, the aquatic ecosystem was supporting life cycles of many amphibian and insect such as frogs and dragonflies. Due to this fact, it was great significance to monitor the water quality within the ecosystem. Referring to a results of water quality parameters (Annex 5) the pH was fluctuating between 6.5 to 9.0 (Fig. 5.1). The high level of pH observed was attributed to the increase of ammonium nitrogen in the system (Fig. 5.6; Annex 5). The ammonium nitrogen, initially was low in the pond and tended to increase with time (Fig. 5.6). The increase of ammonium nitrogen with time was attributed to the increase of Nile tilapia after the increase of reproduction. Another factor contributing to the rise of pH and ammonium nitrogen was low frequency of water exchange in the aquatic pond. This is because of the sewage which was added to fertilize the pond.

pH in most aquatic ecosystem ranged from 6 to 9, however it can fluctuate daily or seasonally. Despite of the fluctuation of pH observed in Wazo Hill pond, water beetles, Nile tilapia and catfish were tolerable. The range of pH within this pond, suggested that, the pond can support biological diversity, increasing reproduction and increasing the growth of many aquatic organisms. The value of ammonium nitrogen in many aquatic ecosystems are recommended to be less than 1mg/l. However, in the present study the ammonium value observed in September was 1.2 mg/l; which was 0.2 mg/l above the standard.

Dissolved oxygen (DO) is another parameter of the importance in aquatic ecosystem. The results have showed the decrease of DO with time. This decrease of DO observed was probably attributed by several processes occurring in the pond such as respiration, nitrification and the increase of algae. In the beginning of an experiment, the DO was high (above 6.5 mg/l) due to small number of Nile tilapia as well as low amount of algae. As the reproduction of Nile tilapia increases, the respiration also was increased which in turn lowering a level of DO in the aquatic ecosystem (Oke and Ibhanesebor, 2013.

The increase of nitrate nitrogen in the pond (Fig. 5.7; Annex 5) was related to the increase of sewage and high level of ammonium nitrogen. The excess in nitrate nitrogen in aquatic ecosystem can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warmed blooded animal at higher concentration. It is recommended that the level of nitrate nitrogen in aquatic ecosystem to be less than 1 mg/l. The level of nitrate nitrogen was relatively higher (1.5 mg/l) than the recommended value.

Growth of Nile Tilapia (Oreochromis nilotius)

The increase of height and weight of Nile tilapia observed in Figs.6.1 and 6.2 (Annex 6) was contributed by both water quality, few number of Nile tilapia and the availability of few species of organisms. At the beginning of the experiment (May) the water quality for all parameters were within standard of aquatic ecosystem. During this period the number of fish was minimal as well as frogs, water scorpions, water beetles and other aquatic organisms. As the reproduction of Nile tilapia was increased, more organisms like frogs were doubled; resulting into high competition of dissolved oxygen as well as food. The increase of population of both Nile tilapia and other organisms was a reason of stagnant growth of Nile tilapia observed from July to August. This result implies that, the aquatic pond for aquatic was overwhelmed with aquatic species which changed the water quality into the ecosystem.

Growth rate of Senna Siamea

Refering to Figs. 7.1 and 7.2 (Annex 7), the *S.siamea* subjected to water pond water were increased compared to tape water. This is because the pond water was comprised NO_3-N and NH_4-N which is essential to plants. It was revealed at the beginning of the experiment, when the NO_3-N and NH_4-N were low in the pond water; there was no significant difference between tape and pond water observed. However, with the increase of NH_4-N and NO_3-N the difference between tape water and pond water was significant. This is due to the efficiency of Nitrogen available in the pond. Low availability nitrogen and NH_4-N in water tape probably was a factor of limiting *S.Sianea* growth (Penning de Vries *et al*. 1980).

Aquatic and Terrestrial species

Dragonflies (Odonata) were found in abundance after restoration of aquatic ecosystem. This is because the provision of aquatic pond seemed to provide the environment for female dragonflies to lay eggs (Dunkle, 2000). Most of a dragonfly's life is spent in the naiad form, beneath the water's surface, using extendable jaws to catch other invertebrates (often mosquito larvae) or even vertebrates such as tadpoles and fish (Dunkle, 2000). This agreed with the observation in CEP II quarry where few small water pool were not very suitable for the dragon flies (Rehounkova, 2012). The results implies that the provision of aquatic ecosystems including fishes and frogs, can attract remarkable number of dragonflies in quarries.

In total three species of **bees and wasps** were found within the ecosystem throughout, from the beginning of experiment (May) to the end (September). Bees were mostly widespread around the pond because they need water supply for the operation of a honeybee colony, particular the hive and thinning processes. Bees use water for cooling the hive by evaporation, and for thinning honey to be fed to larva. Apart from bees and wasp, domestic **flies** (*Musca domestica*) were found in plenty around the ponds particular during the rainy season. The availability could contributed to wastewater used for fertilization of the ecosystems.

Availability of **butterflies** species observed in the quarry probably have been contributed by ongoing rehabilitation activity, including plantation of trees, glasses and flowers. Tree protects butterflies from strong winds while flower was attracted them. The relationship between the aquatic ecosystem and availability of the butterflies in Wazo hill is not well established. However some literatures have highlighted that certain types of butterflies congregate around the aquatic ponds to absorb salts and other minerals that have been dissolved in water (Murray, 2003; Beaulieu, 2014). In a case of **mammals**, a provision of aquatic ecosystems provided of water supply. Vervet monkeys (*Chlorocebus pygerythrus)* for instance, were observed daily drinking water from the pond during the afternoon hours especially in dry season. African porcupine *(Atherrus Africanus)* were also found however they were not mostly widespread in Wazo Hill. The African porcupine was observed once in a while; drinking water in the pond. This is because, African porcupine is mostly found in night time, however they rarely forage for food in day time (National Graphic, 2014).

Two species of **African common toad** (*Amietophynus gulturaliss* and *Amietophynus garmani)* were mostly found in the aquatic pond. The aquatic ecosystems was able to provide a conducive environments for *A. gulturaliss* life cycle. Like other toads, the *A. gulturaliss* life has observed beginning in aquatic pond. *A gulturaliss* typically laid their eggs in the pond. The eggs were laid in double strings which sometimes where wound around submerged vegetation around the pond. The eggs was then hatched into tadpoles. This stage of life of *A.gulturaliss* also depends on the availability of water (Stuart *et al.,* 2004). This is because the tadpole develop lungs which normally are used as an accessory breathing organ in aquatic environment. The dependency of tadpole on water shade light on the provition of aquatic ecosystem in Wazo Hill. In contrast to the pond filled with water only, aquatic ecosystem provide algae which are eaten by tadpole. The second species; *A. garmani* were not mostly distributed in Wazo Hill. However their life cycles depends on the aquatic pond, following the same stages as *A. gulturaliss.*

Reptilian is not common in Wazo hill particularly in a rehabilitated area. Only one species of snake; **mole viper or stiletto snake** (*Atractaspis engaddensis*) was identified. This is because *A. engaddensis* are rarely seen on the surface except after heavy rains. Generally, *A. engaddensis* feed upon burrowing reptiles, rodents, and frogs. The restoration of aquatic ecosystem can therefore provide a source of food to mole viper and reptilian in general. The aquatic ecosystems provided also a conducive environment to **whirligig beetle** (*Gyrinidae*). The whirligig beetle use the surface tension of the water pond to stay afloat. They more likely live in both moving and standing water, but are most commonly found in smaller bodies of water such as ponds and streams (Weaving *et al.,* 2003).

Water-scorpions (*Napidae*) was found distributed mostly in the water column in aquatic ecosystems. The advantage of the aquatic environment to water scorpions was clear. This is because the water scorpions feed primarily on invertebrates found into aquatic ecosystem. The development of fish and tadpole was also used by water scorpions as a food, although it was rarely occurred. The life cycle of water scorpions utterly depends on availability of water. The water scorpion laid their above the waterline in mud.

6.0 **Involvement of Stakeholders to the Project**

The present project has involved different people of different expertise, ages, nationality and education. The first group was technicians from University of Dar es Salaam (Fig.10.7; Annex 10). Their main role was to provide advices on water quality management in aquatic ecosystems and then proposed a proper fish species to be introduced into aquatic ecosystem. During a period of data collection, two students from a department of aquatic sciences and fisheries, University of Dar es Salaam were involved. The students were used this ecosystem as a part of their practical training. They were able to practice in sampling procedures and analysis of water quality parameters. In additional to that, the students got an opportunity to conduct fish stock assessment in the pond which is not easily to be conducted in natural water bodies (Figs. 10.4-10.6; Annex 10). Within Wazo Hill community, workers who visited to the pond acquired a knowledge on benefits of aquatic ecosystem. Most of the workers were impressed with a survival of Nile Tilapia (*Oreochromis nilotius*) in Wazo Hill. As a consequences, the workers bring more possibilities concerning an investment of aquaculture projects using abandon pits of Wazo hill quarry. Apart from workers, another group involved in this project was pupils from Boko primary school. The pupils was engaged in preparation of tree nurseries as a part of rehabilitation programme. The pupils had an opportunity to learn on aquatic life and the benefits of aquatic ecosystem in the rehabilitation of Wazo Hill quarry (Figs. 10.8-10.10; Annex 10).

Furthermore, the International Youth Volunteers (IYV), including youths from Italy, Brazil, Spain, Europe, Uganda, Kenya and Tanzania, were visited on the project. The purpose of their visit was to investigate the possibilities of using the project outputs for mitigation measures of climate change (Figs. 10.1-10.3; Annex 10). The IYV suggested that, the projects can be extended further to the communities with water scarcity particularly in developing countries. Using the output of this project, the ponds can be constructed and retained water during the rainy season. The Nile tilapia can be introduced into the ponds to initiate aquaculture businesses. IYV also proposed that the project can create opportunities for employments to many youths in developing countries.

7.0 **Conclusion**

Restoration of aquatic ecosystem in quarries is not just a hole with water in it. The aquatic ecosystems is always contains water and essential elements such as plants, snails and fish; each one recycling the other's waste products. The aquatic ecosystem have magically attracted a sorts of creatures such as frogs, birds, dragonflies, butterflies, snakes, monkeys, bees and Wasps in Wazo Hill quarry. Apart from attracting creatures, the present study have discovered the potentials of using aquatic ecosystems for enhancement of rehabilitation of quarries. Converting the abandoned pits into aquatic ponds and introducing Nile tilapia can enhance aquaculture by reproduction and supplying Nile tilapia fingering to neighbourhood. The factory can also benefit by increasing a profit as a result of selling fish products and fingerlings.

The water quality from the aquatic ecosystems containing significance amount of NH_4-N and NO_3-N. These nutrients are very essential to the growth of plants. Therefore the availability of these nutrients in Wazo Hill quarry can add value to ongoing activities of rehabilitation of quarry, where the water from the pond can be used for watering tree's nurseries. Despite of the fluctuation of pH, salinity and conductivity, the water from the aquatic ecosystem can still being used as source of water supply to mammals like vervet monkeys; support life cycles of frogs, snails and dragonflies.

The results from this small scale experiment has positively indicating successfully how the integration of both aquatic and terrestrial ecosystems can be used to restoration of biodiversity in quarries. Therefore, the methodology can be up scaled to the extent of providing aquatic mammals such as crocodiles and hippopotamus and other species of fishes such as catfishes.

8.0 **Recommendations**

For the management practice; Wazo Hill quarry are recommended to:

1. Convert the abandon pits into either fish ponds or aquatic ecosystem. Wazo Hill factory must first use the cement dust from the factory to lining pits in order to prevent water seepage from the pit. The filling of water to ponds should be done during the rainy season to avoid high bills of using tape water to fill water into pits.
2. Upscale the production of Nile tilapia (*Oreochromis nilotius)* which is already introduced into one of the abandon pit. This can be achieved by distributing Nile Tilapia to other ponds including a big pit located at 06^o 39.167' South and 039^o 09.706' East. This will continue to attract terrestrial and aquatic species in both areas; rehabilitated and non-rehabilitated.
3. Use wastewater generated in the factory for fertilizing ponds in order to enhance development of algae in the ponds, which in turn can be used to be feed fish and frogs. The reuse of wastewater will also reduce the volume of water to be disposed.

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ANNEX 1: Location of Experiment set up

Figure 1.1: Location experiment set up in Wazo Hill quarry

ANNEX 2: List of Figures involving the visit of ponds at Wazo Hill and the procedures of a Pond for experiment

Figure 2. 1: The pond with high turbidity

Figure 2.2: Concrete pond

Figure 2.3: selected pond for experiment set up

Figure 2.4: measuring a diameter of the pond

Figure 2.5: Recording pH, salinity, Temperature

Figure 2.6: Recording water quality parameters

ANNEX 3: List of Figures: introducing Nile Tilapia into the Fish ponds and monitoring of water quality.

Figure 3.1: Nile Tilapia (*O. niloticus*)

Figure 3.2: Measurements of weight

Figure 3.3: Introducing Nile Tilapia

Figure 3.4: Water sampling

Figure 3.5: Determination of NH_4-N

Figure 3.6: Determination of NO_3-N

ANNEX 4: List of Figures showing a selected species of plant (*S.Siamea*) and experiment set of plants nursery.


Figure 4.1: Selecting a required species of tree


Figure 4.2: Selecting of tree species


Figure 4.3: Preparation of *S.Siamea* species


Figure 4.4: A complete set up Experiment


Figure 4.5: Taking initial measurements


Figure 4.6 : Recording initial measurements

ANNEX 5: List of Figures showing a water quality parameters in the aquatic ecosystem

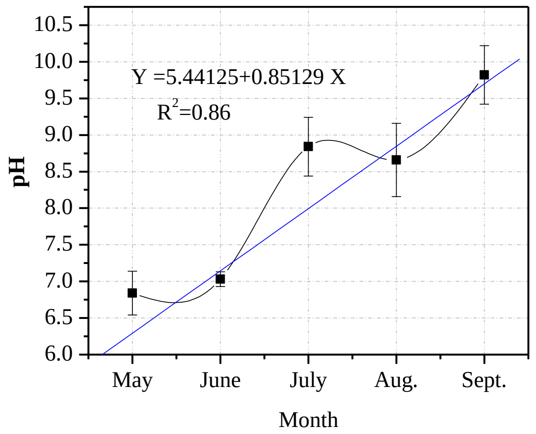

Figure 5.1: The pH measurements from May to September

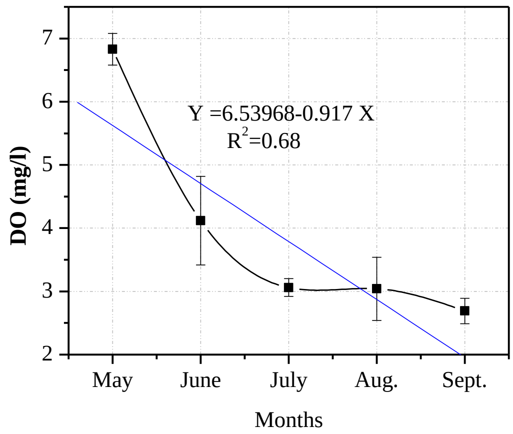

Figure 5.2: The DO measurements from May to September

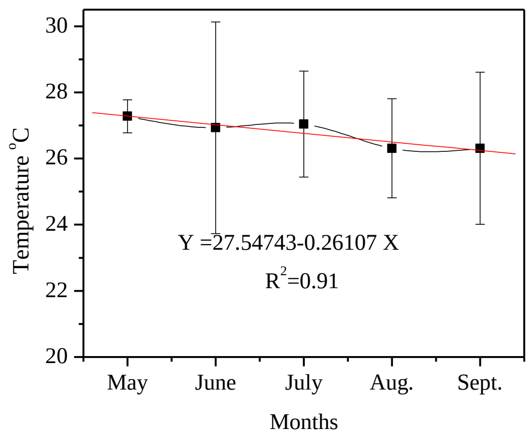

Figure 5.3: A trend of temperature in the aquatic system from May to September

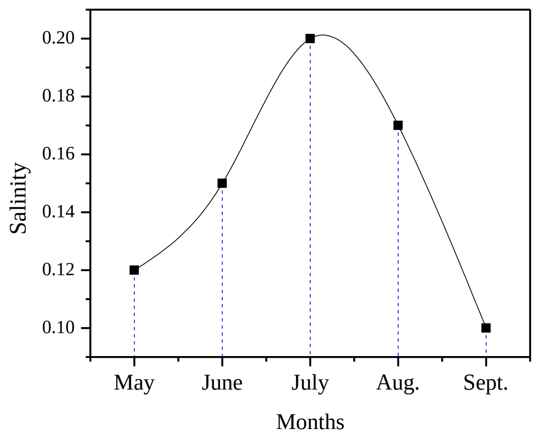

Figure 5.4: A trend of salinity in the ecosystem measured from May to September

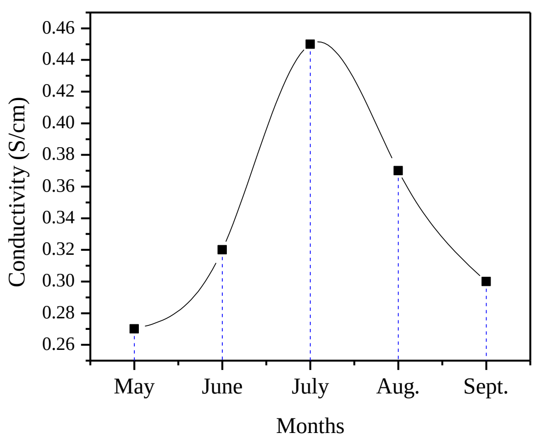

Figure 5.5: A trend of conductivity in the ecosystem measured from May to September

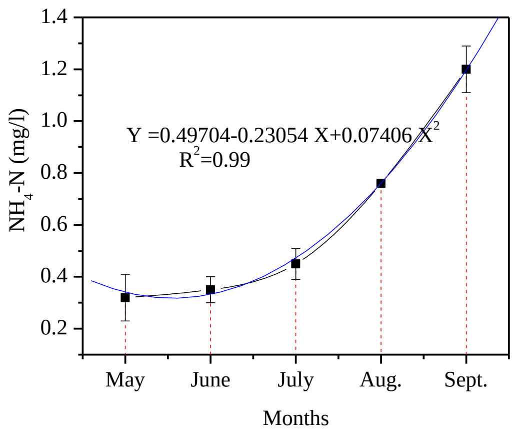

Figure 5.6: A trend of NH_4-N in the ecosystem from May to September

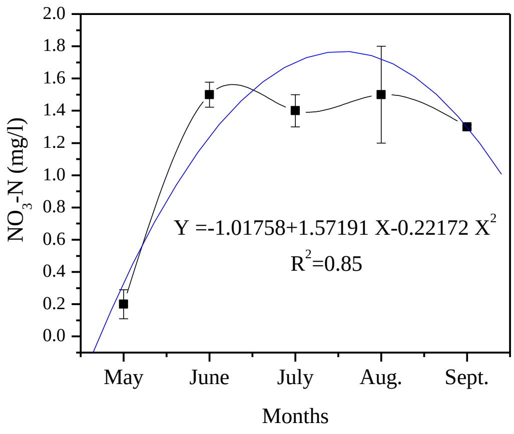

Figure 5.7: A trend of NO_3-N in the ecosystem from May to September

ANNEX 6: List of Figures showing an increase of length and Weight of Nile Tilapia (***Oreochromis nilotius)***

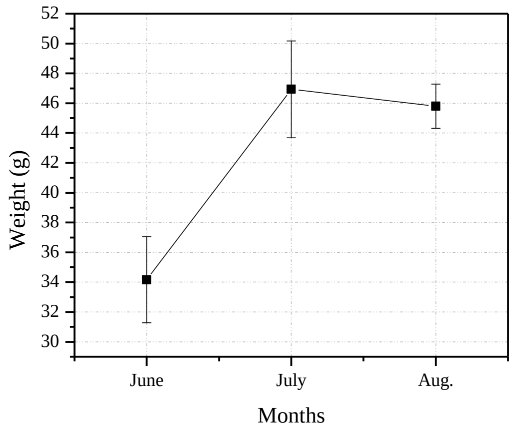

Figure 6.1: An increase of weight of Nile Tilapia

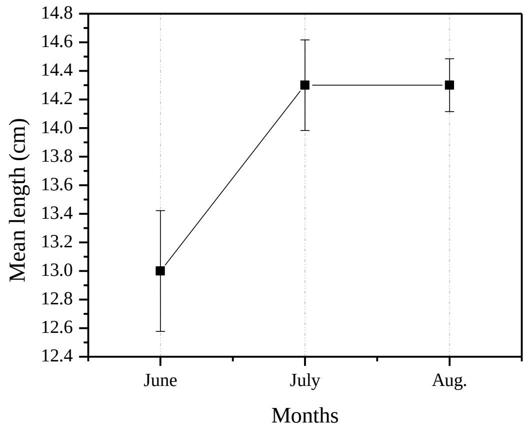

Figure 6.2: An increase of length of Nile Tilapia

ANNEX 7: List of Figures showing an increase of length and diameter of *S. Siamea*

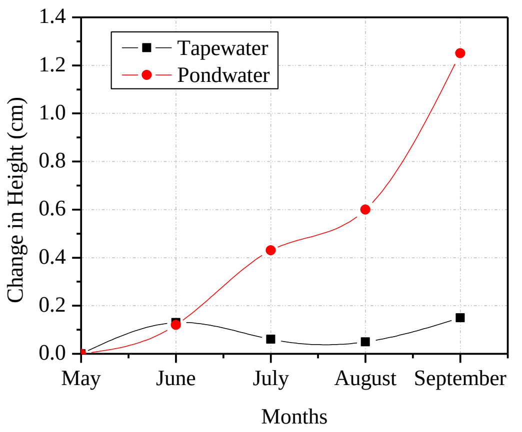

Figure 7.1: An increase of height of *Senna Siamea* measured from May to September

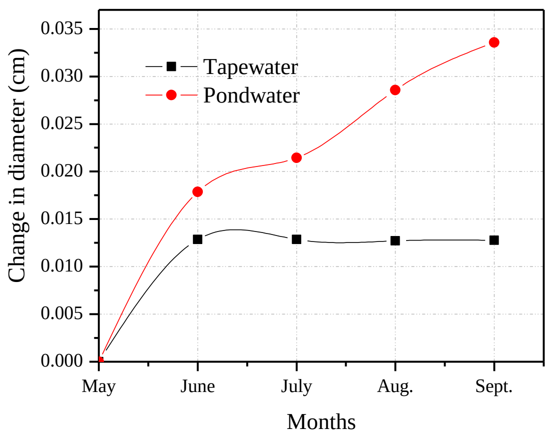

Figure 7.2: An increase of diameter of *Senna Siamea* measured from May to September

ANNEX 8: List of Aquatic and Terrestrial Species identified within Aquatic Ecosystem

1. **Amphibia**
   Amietophynus gulturaliss
   Amietophynus garmani

2. **Mammalia**
   Atherrus Africanus
   Chlorocebus pygerythrus

3. **Aetnopterggii (Cat Fish)**
   Clarias gariepinus

4. **Water Beetles**
   Whirligig beetle (Gyrinidae)

5. **Dragon Flies**
   Anax mauricianus
   Sympetrum flaveolum
   Plathemic lydia
   Orthetrum Cancellatum

6. **Bees and Wasps**
   Anthophila
   Sphex pensylavanius
   Bembix oculata

7. **Flies**
   Musca domestica

8. **Butterflies**
   Charaxes brutus natallnsis
   Junonia Coenia
   Danaus plexippus

9. **Reptilia**
   Atractaspis engaddensis

10. **Birds**
    Dove

11. **Water-Scorpions**
    Napidae

12. **Millipede**

ANNEX 9: Photo of aquatic and terrestrial species found in Wazo Hill quarry after restoration of aquatic ecosystem.

Figure 9.1: African common toad (*Amietophrynus gutturalis*)

Figure 9.2: African catfish (*Clarias gariepinus*)

Figure 9.3: African common Toad **(***Amietophynus garmani)*

Figure 9.4: Tadpole

Figure 9.5: Porcupine (*Atherrus Africanus)*

Figure 9.6: Vervet monkey (*Chlorocebus pygerythrus)*

Figure 9.7: African common toad (*Amietophrynus gutturalis*)

Figure 9.8: Water-scorpions (*Napidae*)

Figure 9.9: Porcupine (*Atherrus Africanus)*

Figure 9.10: Dragonflies (*Sympetrum flaveolum)*

Figure 9.11 : Bees

Figure 9:12: Domestic flies (*Musca Domestica*)

Figure 9.13 : Wasp

Figure 9.14: stiletto snake (*Atractaspis engaddensis*)

Figure 9.15: Nile Tilapia and Fingerlings

Figure 9.16: Dragonflies (*Sympetrum flaveolum)*

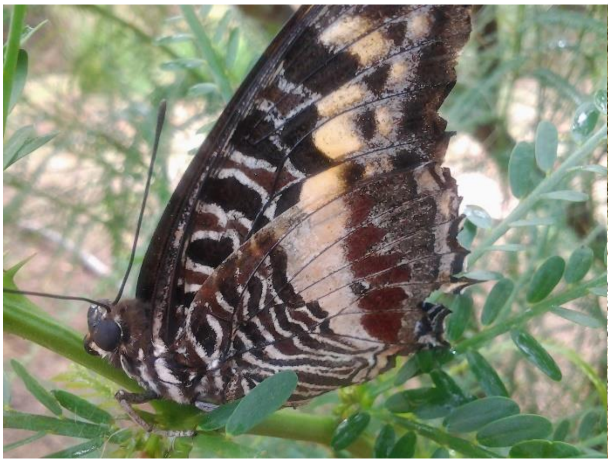

Figure 9.17: Butterfly (*Junonia Coenia*)

Figure 9.18: Whirligig beetle (*Gyrinidae*)

ANNEX 10: Photos of different stakeholders involved in the project

Figure 10.1: Demonstration of the project to International Youths Volunteers (IYV)

Figure 10.2: IYV watching Nile Tilapia in the pond

Figure 10.3: IYV participating in planting *S.Siamea*

Figure 10.4: UDSM students and technician preparing a net for fish stock assessment

Figure 10.5: Putting on safety aid before entering into the pond

Figure 10.6: Setting a net into the pond

Figure 10.7: Safety officer from Wazo Hill and Technician from University of Dar es Salaam watching Nile tilapia

Figure 10.8: Pupils from Boko Primary School; studying on aquatic life

Figure 10.9: Pupils from Boko Primary School; learning how to prepare nurseries for plants

Figure 10.10: Pupils from Boko Primary School; packing soil

References

"Porcupines, Porcupine Pictures, Porcupine Facts – National Geographic". Animals.nationalgeographic.com. Retrieved 2014-09-21.

APHA (American Public Health Association) (1998), *Standard Methods for Examination of*
Beaulieu D (2014). Providing a heathy environment for butterflies; http://landscaping.about.com/cs/forthebirds/a/butterfly_plant_4.htm

D.C

Dunkle S W (2000). *Dragonflies through Binoculars: a field guide to the dragonflies of North America*. Oxford University Press.

Francis J., Wagner GM., Mvungi A., Ngwale J and Sallema R (2001). Tanzania National Report, Phase I: Integrated Problem Analysis. GEF MSP Sub-Saharan Africa Project on "Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. 60 pp

Gastory, L (2012) Integrated constructed wetland for wastewater treatment, nutrient recovery and quarry re-naturalization. Project report submitted to quarry life award, Tanzania.

Grasman, KA, Scanlon PF, Fox, GA (1996). Reproductive and physiological effects of environmental contaminants in fish-eating birds of the Great Lakes: a review of historical trends. Environmental Monitoring and Assessment 53:117-145

Hardoum J (1985). A successful land rehabilitation programme in Kenya. *Tropicultura* 3: 65-67.

Kabanda TA and Jurry MR (1999). Inter-annual variability of short rains over northern Tanzania. Climate Research 13:231-241

Khater C and Arnaud M (2007) Application of Restoration Ecology principles to the practice of limestone quarry rehabilitation in Lebanon. *Lebasane Science Journal* 8: 19-28

Kijazi AL and Reason CJC (2009). Analysis of the 2006 floods over Northern Tanzania. *International Journal of climatology* 29:955-970

Liken GE and Bormann FH (1974) Linkage between terrestrial and aquatic ecosystems: *Biosciences* 24: 417-456.

Murray, John. *A Few Short Notes on Tropical Butterflies: Stories*. New York: HarperCollins, 2003, 112.

Oke OS and Ibhanesebor GAO (2003). Limestone quarrying: the impact on the vegetation and landform of Sagumu cement factory site, Sagumu, Southwestern Nigeria. *Int. J. Biol. Chem. Sci.* 7: 433-440.

Rehounkova K (2012), Sand pit for Biodiversity at Cep II quarry life award Report

Stuart S N, Chanson J S, Cox N A, Young BE, Rodrigues ASL, Fischman DL, Waller RW. (2004). Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783–1786

UKIVIUTA (2014) Oral lecture on different types of terrestrial species: Advantages and their disadvantages: Lecture provided in Wazo Hill quarry

UNEP 1998. Maziwi Island off Pangani (Tanzania) History of its destruction and possible causes: UNEP Regional Seas Report and Studies Number 139

Water and Wastewater, 20th edition, Water Environment Federation, Washington,

Weaving A, Picker M and Llewellyn C (2003). Field Guide to Insects of South Africa. New Holland Publishers, Ltd.