THE QUARRY LIFE AWARD

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Final Project Report **(to be submitted by 20th September 2018)**

Instructions:

- Document length: maximum 10 pages, excluding this cover page and the last page on project tags.
- We welcome the submission of Annexes (i.e. bachelor or master thesis, references, species lists, maps, drawings, pictures) to further HeidelbergCement's understanding and future use of your findings, however they will not be reviewed by the Jury, and we kindly ask for these to be sent separately to the National Coordinators.
- Please use the attached template for species data collected during the project and submit with the project report.
- Word/PDF Final Report files must be less than 10 MB.
- If you choose to submit your final report in your local language, you are required to also upload your final report in English if you wish to take part in the international competition.
- To be validated, your file must be uploaded to the Quarry Life Award website before **20th September** 2018 (midnight, Central European Time). To do so, please log in, click on 'My account'/ 'My Final report'.
- In case of questions, please liaise with your national coordinator.
- You should not publish additional private information in your final report (e.g.: address, day of birth, email-address, phone number), just complete the categories we ask for below under "Contestant profile".

The final reports should comprise the following elements:

For research stream projects:

1. Abstract (0,5 page)
2. Introduction :
    1. For projects that are building upon a previous project, write a summary of actions that were already completed in the previous project.
    2. Project objectives
3. Methods: a detailed description of the methods used during the project is required.
4. Results: the results of the project should be outlined and distinguished from the discussion.
5. Discussion:
    1. Results should be analysed and discussed with reference to region/country taking into account other publications.
    2. Outline the added value of the project for science and for the quarry / company.
    3. Recommendations and guidance for future project implementation and development on site is requested. Where possible, please mention the ideal timing and estimated costs of implementation.
6. Final conclusions: a short summary of results and discussion.

For community stream projects:

7. Abstract (0,5 page)
8. Introduction

1. For projects that are building upon a previous project, write a summary of actions that were already completed in the previous project.
2. Project objectives
3. A short description of the site and the team members and the targeted audience of the project.

9. Actions and activities: a detailed description of planned or implemented actions and outreach activities done to elaborate the project, list of stakeholders involved.
10. Discussion:
    1. Project teams should discuss the pros and contra and illustrate experiences.
    2. Outline the added value of the project for biodiversity, the society and the quarry / company.
11. Deliverables: practical implementation and development recommendations of the project are required. Where possible, please mention the ideal timing and estimated costs of implementation.
12. Final conclusions: a short summary of the project findings and discussion.

1. Contestant profile

1. Contestant name:	**Samuel Mtoka**
2. Contestant occupation:	Wildlife Researcher
3. University / Organisation	Tanzania Wildlife Research Institute
4. Number of people in your team:	**2**

2. Project overview

Title:	Potential of Wazo Hill Quarry in Stocking Carbon for Mitigating Global Climate Change
Contest: (Research/Community)	Research
Quarry name:	Wazo Hill

Abstract (max 0.5 page)

Global climatic change is understood to be caused by increase in atmospheric temperature resulted from emission of greenhouse gases mostly by human activities. As a result there are unpleasant events such as change in precipitation patterns and organisms migration among others. One of the important actions in mitigating climate change is to reduce carbon emissions and promote carbon sinks. In this study we determined the potential of Wazo hill quarry at latitude 6°34'S to 39°23'E, Northwest of Dar es salaam city, Tanzania in stocking carbon for mitigating global climate change. Specifically we described land cover/land use types, identified potential carbon stocking areas estimated biomass and carbon stock. Using remote sensing and survey techniques, we designated land use/cover and estimated Above Ground Carbon (AGC) stock. Twenty four 20x20meters plots were systematically placed for woody vegetation measurements in rehabilitated, self regenerating and un-quarried areas. Heights and diameters were measured and calculations of biomass and eventually estimation of AGC stock done on 557stems of 25 species in 11 families. Because of extractive mining industry, the quarry had several land use/cover types and had AGC stock of 3.6 tonnes per hectare which varied significantly among three areas ($P \leq 0.05$). The Generalized Linear Model showed restoration and biomass had a positive influence on the carbon stocking, although it was not significant ($P \geq 0.05$). Conclusively the quarry has potential for carbon stocking while being boosted with human effort through rehabilitation. We recommended rehabilitation to proceed in other quarried areas to increase the potentiality of the quarry in carbon stocking and extending more studies on below ground carbon, dead biomass, litter, soils and ponds. We also recommend exploration of carbon markets participations.

Final report (max 9 pages)

INTRODUCTION

Global climatic change is currently understood to be mainly caused by increase in average atmospheric temperature for the past century (Gillis, 2015). According to the Intergovernmental Panel on Climate Change (IPCC) (2013[a]), the influence of human is the main reason for the global warming observed since middle of 20[th] century. The prime human influence has been on emission of greenhouse gases, among them carbon dioxide, methane and nitrous oxide (IPCC, 2013[b]). These gases are factors in increase in the average earth surface temperature which causes unpleasant effects such as change in precipitation patterns, change in organisms migration and life cycles, decrease in quantity of snow and ice, increase in ocean warming, rising of sea levels, increase in damaged corals, increase in strong storms, increase in high temperatures and heat waves. One of the important efforts in mitigating climate change is to reduce carbon emissions and promote carbon sinks and sequestration (IPCC, 2013[b]). The carbon sink is the place where carbon is trapped and stored, and the major natural carbon sinks are plants, soils and oceans. Carbon sequestration is the process of removing carbon dioxide gas from the atmosphere. A good example of sequestration is when plants grip carbon dioxide from the atmosphere and use it in photosynthesis. Some of this captured carbon by plants is transferred to soil as plants die and decay. Water bodies like oceans, seas, lakes and ponds are known to have potential for absorbing carbon (ISU, 2008). For example the oceans are known to be major carbon dioxide store. Carbon dioxide from the atmosphere dissolves in the surface waters of the ocean where some will stay as dissolved gas and other is turned into organic and inorganic compounds by some process such as photosynthesis.

Carbon stock is the quantity of carbon contained in a pool (FAO, 2004; IPCC, 2003). A pool is a reservoir or system which has the capacity to accumulate or release carbon. Examples of carbon pools are living biomass (including above and below-ground biomass), dead organic matter (including dead wood and litter), soils (soils organic matter) (IPCC, 2003).The forests sequester and store carbon than any other terrestrial ecosystem because of huge biomass of woody and perennial vegetation (Gibbs, *et al*., 2007; Sharp *et al*., 2016; Vashum and Jayakumar, 2012). The Wazo Hill quarry is potential area in carbon stocking because of the presence of pools such as biomass (both above and below ground, also dead and living), litter and soil. The vegetation especially woody is a remarkable carbon pool in the quarry. Moreover Wazo hill potential is in its capacity to accumulate or release carbon. The quarry has vegetation communities (naturally and planted), ponds and the soils that can sequence and stock carbon and contributes in mitigation for global warming. The vegetation of Wazo hill quarry that are of importance in carbon stocking are the woodlands and shrubs in rehabilitated areas after quarrying, after quarrying self-regenerating areas and the areas that haven’t been quarried. Thus, this study focused on the vegetation as among important factor for carbon sink in the area.

In estimation carbon stock, methods developed fall in the two types. The first one is the complete analysis of the whole tree which is destructive, the whole tree needs to be destroyed to get its biomass that will yield the carbon content. The second method is none destructive and gives the estimated of the carbon by measuring the trees to get its biomass and eventually calculating the amount of carbon. In none destructive method of measuring trees, the above ground biomass (AGB) is used to calculate the amount of above ground carbon (AGC).

Nevertheless calculating carbon stocks in key carbon pools involves summation of above ground live biomass (live trees, non-tree woody, non-tree non-woody); dead wood (standing and lying deadwoods); litter and below ground live biomass (roots). In this work the none destructive method was preferred that involved the measurements of trees and shrubs only, there was no involvement of dead woods and litters as the study was planned to deal with trees and shrubs only for logistical and time limits. In this report we give the insights of the status of the Wazo hill quarry potentials for stocking and sequestering carbon. This information is expected to raise awareness on the importance of the quarry and perhaps other quarries in carbon issues and promote programmes for improve carbon stocking in the quarries.

Objective of the study

The main objective was to determine the potential of Wazo hill quarry in stocking and sequestering carbon for mitigating global climate change.

Specifically the study:

1. Described land cover/land use types in Wazo hill quarry
2. Identified potential carbon stocking areas in the quarry
3. Estimate biomass and carbon pool in the quarry
3. Estimated and compare the Above Ground Carbon stock among three delineated areas
4. Determine the influence of restoration effort and biomass on the carbon stocking

MATERIALS AND METHODS

Study area

The study area was at Wazo hill quarry that is located at 25kilometers Northwest of Dar es salaam city centre in Tanzania, East Africa. The studied area lies at latitude 6°34' South and longitudes 39°23' East (Figure1).

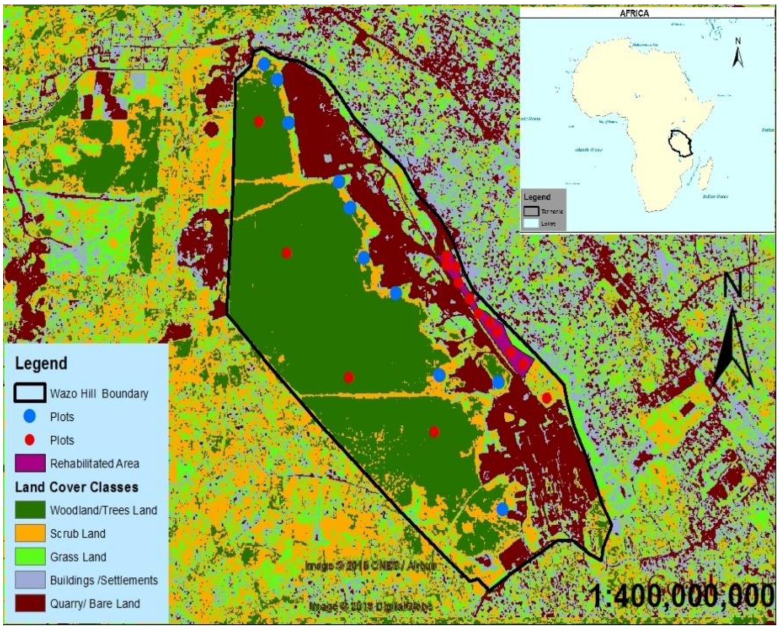

Figure1. Wazo hill quarry, red and blue cycles are location of plots (Source: Google image of 21st June 2017).

The climate is influenced by the Indian Ocean where the average daily temperature is between 24 and 32°C. Cool season is in May to September and the hot season is December to March. The rainfall is high ranging from 1,000 to 1,900 mm per year (Climatesmps, 2009). The natural vegetation is of East African Coast, but there is extensive destruction and modification because of human activities.

Methods

This study was conducted from January to September, 2018. Several activities were planned and implemented included induction on safety in working in the quarry, participants visiting the quarry, preliminary survey and logistical preparation, updating information on the website, public voting, visitation by both international and national jury, data collection and organisation, data analysis, report writing and submission (Annex 1).

The method involved remote sensing and survey techniques. Remote sensing involved acquisition of Google image (dated 21st June 2017) for designation of the land cover/use and production of maps. The description of the carbon stocking areas was given based on the type or nature of the area. Surveys were for identifying potential carbon stocking areas in the quarry, ground-truthing and estimation of carbon stock. Three areas were identified for sampling namely re-habilitated, self-regenerating and un-quarried. Rehabilitated area is the one that quarrying was done, which means removing vegetation and top soils, blasting to extract the substratum. Rehabilitation involved refilling of the areas and planting of vegetation. In this particular location the rehabilitation started in 2010. Self-regenerating area is the one where quarrying had taken place as explained above and rehabilitation hasnt been done. There are few places with top soil dunes remained after quarrying and some plants have started to grow presumably seeds from nearby rehabilitated area. The un-quarried area is the one which no quarrying has taken place, therefore the topsoil is intact, but the vegetation appears to have some human disturbances in the past. This area has the biggest trees example the Baobabs (*Adansonia digitata*).

A total of 24 plots each with size of 20x20meters were systematically placed for woody vegetation measurements, where 10 were in each of rehabilitated and self-regenerating areas and 4 were in un-quarried area. The coordinates of the plots were taken using a Global Positioning System (GPS) unit Garmin GPSmap60CSx for references and mapping. Marker tape was used to demarcate the boundary of the plot. Measurement of heights and diameters (at a height of 1.3 Meters) involved trees and shrubs with at least 10cm circumference. Some of the trees had more than one measurable stems, therefore measurements involved other stems in additional to the main one (that is stem1, stem2 and stem3, see table 1). Little stems were not measured because, according to Lewis *et al*., (2009), little steams contain about 5% of AGC.The measured tree circumferences were used to calculate the diameters using the following formula:

$D=C/\pi$

Where: D-Diameter (in cm)

C-Circumference (in cm)

π- Pie (3.14)

Tree heights were measured by calculating the distance of the tree to the observer and the angle of the tree then using the trigonometric calculations (Tanθ=Opposite/Adjacent) to obtain the height. This is the tedious procedure to be done to each tree, instead the measurement was done to one tree in a plot and was used as reference for other trees. Tree identification was done in the field with the assistance of field guides up to the genus and species levels. In the rehabilitated area the society 'UVIKIUTA' that is working on rehabilitation has labelled some planted trees and some society staffs assisted in identification of the trees.

Estimation of the carbon pool in the quarry was done to live perennial wood vegetation (that is trees and shrubs), that gave the estimate of AGB and AGC. This was chosen to avoid destructive method such as Biomass Expansion Factor (Giri *et al*., 2014). Tree measurements were used to calculate the tree biomass and carbon stock using the method based on above ground tree biomass (Chave, *et al.*, 2005). This method gives underestimation of carbon stock because only AGC is calculated. In estimating above ground biomass in the tree Chave, *et al*., (2005) proposed the following formula that was used:

$$AGB=0.112x\ (\rho D^2H)^{0.916}$$

Where: AGB-Above Ground Biomass
ρ-wood specific gravity
D-diameter (in cm)
H-height (in m)

The wood specific gravity for each species was searched from the literature. After calculating the biomass, the AGC was estimated for each stem by taking 50% of biomass (Chave *et al*., 2005). The overall carbon stock calculations in the quarry was done for all stems measured, but density calculations didn't not involve other stems because they were not standing on their own but joined to single stem to ground. For comparison purpose each of the three areas (rehabilitated, self-regenerating and un-quarried) was further calculated separately.

Data Management and Analysis

Data collected in the field were recorded in the note books and then entered in the computer software (Microsoft Excel®). The data were summarised in excel and then analysed using R and SPSS softwares. Kruskal-Wallis Test was used to determine the variation among three areas and the Generalized Linear Model (GLM) was used to test the influence of restoration and biomass on the carbon stocking. The Google image was examined for descriptions of the land cover/use types.

RESULTS

Land cover/use

The Wazo hill quarry is an area set for extractive utilisation of natural resources where subsurface materials are extracted for cement production. The land use type/cover consist of built infrastructures which are buildings, roads and other tracks; rehabilitated area after quarrying, quarried area, on-going quarrying active area and un-quarried area (Figure 2a).

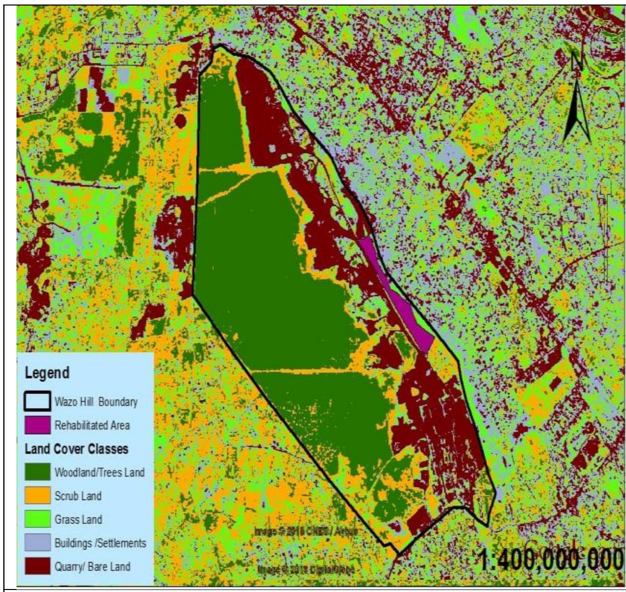

Figure 2a. Land use/cover map of Wazo hill quarry (Source: Google image of 21st June 2017).

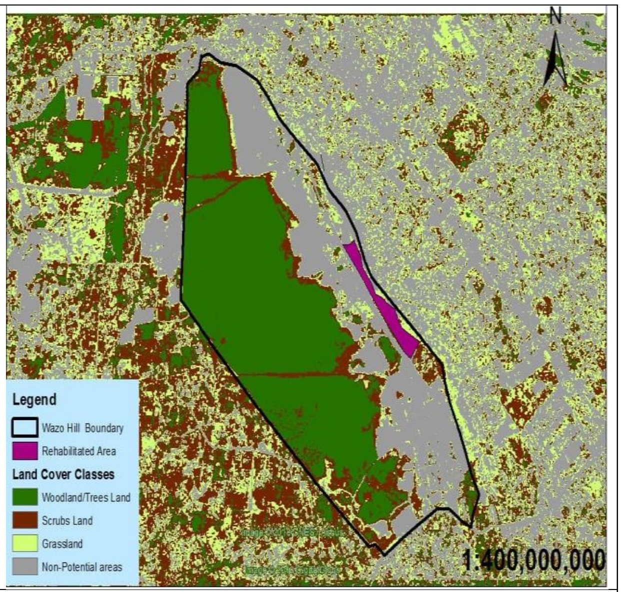

Figure 2b. Potential carbon stocking areas in Wazo hill quarry (Source: Google image of 21stJune 2017).

The activities in the quarry have created features such as water ponds, soil and other subsurface material heaps. The active (on going) quarrying area is generally bare, the top soils have been removed. The vegetation cover is in the rehabilitated and the un-quarried areas. There are also few plants that are self-regenerating to the areas where quarrying took place and no rehabilitation has been done. The un-quarried area can be described as a bush land because human influence has modified the original forest to scattered trees (the big one like Baobabs provide remarkable landscape feature), shrubs, bushes, grasses and herbs. The soil is intact and the condition for plant growth is good. The self regenerating area can be described as scrub land. This area has low shrubs, grasses and herbs that are found on heaps of soil, small area that top soil remained during quarrying and shallow substratum. Because of quarrying the condition for plant growth is not good. The rehabilitated area can be described as wooded grassland as there are planted trees, grasses and herbs. The trees have been planted in consideration of good space use and the seedlings are cared by watering in dry season, mulching and pruning. The conditions for plant growth have been improved following rehabilitation efforts. With this observation the potential areas for carbon stocking in the Wazo hill quarry are Rehabilitated area and Un-quarried area (Figure 2b).

Overall Measurements

Total 557 trees and shrubs measured belonged to 25 species in 11 families. The species composed of both exotic and indigenous origins, with values such as timber, firewood, fruits (food), medicine (herbs), and animal feeds (fodder). The family Fabaceae had the largest number of species (See Annex 2). In additional to the main stem, about 79 plants (14.3%) had more than one measurable stems where 25 plants had two more stems and 2 had three more stems. The big variance on diameters was because of the big trees baobabs found in the unquarried area. Table 1, shows the summary of all trees and shrubs measured. In overall, Wazo hill was calculated to have AGC stock of 3.6tonnes per hectare and the density was 117individuals per hectare.

Table 1.The statistical summary for the measurements of diameters and heights of the trees and shrubs.

Description	N	Range	Min.	Max.	Mean	Std. Error	Std. Deviation	Variance
Main stem diameter(cm)	557	222.0	0.9	222.9	3.4	0.4	9.6	91.4
Main steam height(m)	557	23.0	2.0	25.0	6.9	0.1	3.1	9.9
Stem1 diameter(cm)	79	19.5	2.9	22.4	6.6	0.4	3.8	14.7
Stem1 height(m)	79	16.0	1.0	17.0	6.2	0.4	3.3	10.8
Stem2 Diameter(cm)	25	8.0	3.0	11.0	5.2	0.4	1.9	3.7
Stem2 height(m)	25	16.0	2.0	18.0	6.1	0.8	3.9	15.2
Stem3 diameter(cm)	2	5.0	1.0	6.0	3.5	2.5	3.5	12.5
Stem3 height(m)	2	12.3	5.0	17.3	11.2	6.2	8.7	75.6

Comparison Among the three Areas

For each of the three areas namely re-habilitated, self-regenerating and un-quarried, summary and calculations were done for density, AGC carbon stock, number of species, number of families, number of individuals measured, number of measured main stems, stems1, stems2, and stems3 (Table 2).

Table 2. Measurements of Trees and Shrubs in the three areas.

SN	Description	Rehabilitated area	Self regenerating areas	Un-quarried area
1	Number of Species	14	3	15
2	Number of Families	6	2	8
3	Density (individuals per hectare)	162	41	149
4	AGC stock (tonnes per hectare)	149	82	342
5	Measured main stems	325	83	149
6	Measured stems1	30	9	40
7	Measured stems2	7	2	15
8	Measured stems3	1	0	1

Unquarried area had the highest number of species, families and AGC stock. The rehabilitated area had the highest density and measured main stems. Distribution of species varied significantly among the areas (Chi-square test statistical, X =654.7, df=40 $P \leq 0.001$), like wise the density (Chi-square test statistical, X=30.8, df =10, $P \leq 0.001$).

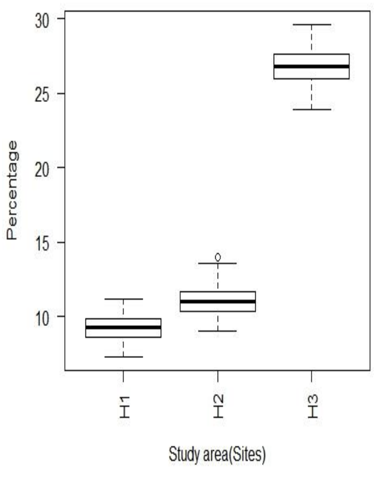

Figure 3a. Multiple stems compared among study areas (H1=Rehabilitated, H2=Self-regenerating, H3=Un-quarried).

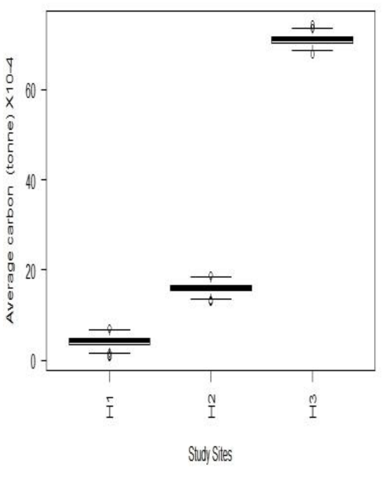

Figure 3b. AGC stock among the three areas (H1=Self-regenerating, H2=Rehabilitated, H3=Un-quarried).

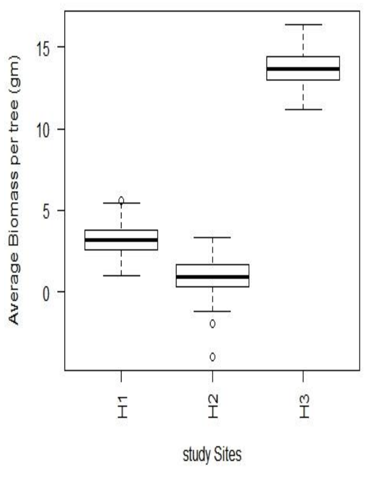

Figure 3: Biomass among the three areas (H1=Rehabilitated, H2= Self-regenerating, H3=Un-quarried).

The highest AGC stock was in the un-quarried area (Table 2 and Figure 3b). Kruskal-Wallis Statistical Test revealed a strong significant variation in AGC stock among three types of area (KWS= 244.736, df=2, P<0.0001). When biomass was compared, the un-quarried area had the highest average biomass followed by the rehabilitated area while the least biomass was observed in the self-regenerating area (Figure 3c), and this variation was statistically significant (KWS = 245.138, df=2, P<0.0001). When multiple stems were compared among the three areas, un-quarried area showed the highest abundance of trees with multiple stems (Figure 3a), however this variation was not significant (X=0, df=2, P=1).

The GLM revealed significant positive influence of biomass on the carbon stocking while areas didn't have significant influence on the carbon stocking. Table 3 shows summary of GLM test on influence of biomass and types of area on the carbon stocking in Wazo hill quarry, the intercept represent the self-regenerating area.

Table 3. A result of GLM test on influence of biomass and area types on the carbon stocking.

Coefficients:	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	-1.256e-06	1.590e-06	-7.900e-01	0.430
Biomass	5.000e-04	3.604e-10	1.387e+06	<2e-16 ***
Restored	9.116e-07	1.782e-06	5.120e-01	0.609
Un-quarried	1.078e-06	1.984e-06	5.430e-01	0.587

DISCUSSION

The Wazo hill quarry is an extractive industry, therefore the land use is mainly based for extracting materials for factory production. Main potentials areas for carbon stocking in the quarry are un-quarried and the rehabilitated areas. The un-quarried area is large than all remained land use/cover types combined in the quarry hence giving

the quarry its potential in for carbon stocking. Because quarrying is advancing at a rate that give enough time for rehabilitating the quarried area, the carbon stock in the un-quarried area can be slowly shifted into the rehabilitated areas. This is speed is seen as the since the factory started its operation the quarried area hasn't reached half of the potential area that quarrying can take place something that is good for gradual moving the carbon stock around and gives the quarry its potential in stocking carbon for global climate change mitigation.
The 557 individuals plants measured belonging to 25 species in 11 families that were dominated by the family Fabaceae is not uncommon because Fabaceae is the third largest land plant family with wide distribution and diversity of the species (EB, 2018). As per EB (2018) and Armstrong (2005), Fabaceae, is the third largest family among the angiosperms after Orchidaceae and Asteraceae has more than 700 genera and 20,000 species of trees, shrubs, vines, and herbs. With this regard the possibility of this family to surpass other families in the Wazo hill quarry is apparent.

About 14.3% (79 individuals) of measured vegetation had more than one stem that met the criteria set for measurements, this small percent indicates the sivilicultural practices (especially in rehabilitated areas) that are done to allow fast re-vegetation during the rehabilitation of the quarried areas. Also, the fact that multiple stems are commonly observed in shrubs that bear several stems to extent of lacking well-defined main stem (Lawrence and Hawthorne, 2006), it is expected with few shrubs in the area and presence of sivilicultural practices, observation of multiple stems will be few.

The overall Wazo hill quarry amount of above ground carbon stock 3.6 tonnes per hectare is very small compare to amount that are found in natural forests example 174.6 tonnes per hectare was found in the Eastern Arc Mountains forests of Eastern Africa (Marshall *et al*., 2012). The reason for this difference is the purpose set for the land, where the natural forest is set for conservation. In contrast the Wazo hill is set for extractive utilisation. The densities of the stems between the quarry and natural forest add more explanation of this. While the natural forest had high density of 400 stems per hectare (Marshall et al., 2012), the Wazo hill quarry has 117stems per hectare. As the carbon stock is mainly in the plants this means the lower biomass translates to low carbon stock. However the amount of carbon stock in the quarry is not to be ignored, bearing in the mind that on-going efforts of rehabilitation will continue to be planted with vegetation that will hold carbon.

The rehabilitated area had the highest density of vegetation (162individuals per hectare). This is because of the human influence on space use where trees and shrubs are planted with consideration of proper space use contrast to other areas. In addition, the rehabilitated area is filled with soil for preparation of the environment for plant growth and the saplings are cared, this is contrary to other two areas.

Despite human influences in un-quarried area but still led in the amount of carbon stored (Figure 3b). This is because presence of big trees like baobabs increase potentiality for carbon stocking. The rehabilitated area is the second area that contains carbon stocking potential. This signifies the efforts of rehabilitation activities in the quarry. The rehabilitation in this area started in 2010 therefore there is a significant time that has allowed the growth of the plants to attain the sizes that matter in carbon stocking. The self-regeneration areas are with poor conditions for plants growth hence small amount of carbon too.

The three areas had significantly difference amount of AGC stock. The amount of carbon is influenced by amount of biomass that in turn is affected or influenced by soil conditions, climate, species, age of the plants and human influence. The un-quarried areas had most of the amount of the carbon because of the presence of natural vegetation mostly by big tress such as Baobabs (*Adansonia digitata*). The rehabilitated area had been restored by refilling the soil and creating the conditions for plant growth hence enabling the re-vegetation and considering the lapse of more than five years since rehabilitation started. Also there is a good use of space (see Table 2 for the density of individuals in the area) however most of the trees planted are younger than the old tree in the un-quarried areas hence making that difference. The quarried areas that depend on natural regeneration have the least amount of carbon because of the poor conditions for the plant growth associated with removal of top soil that lead to poor health status and small amount of biomass accumulated, that translate to small amount of carbon stock. The highest number of species in unquarried area compared to other areas can be explained by difference in levels of human disturnance and influence. With the least level of human disturbance, the unquarried areas retain more species than rehabilitated and quarried areas.

Restoration activities and biomass have influence on carbon stocking as the GLM showed a positive influence (although was not significant). This is because carbon is common element in all form of life biomass inclusively (Odum, 1971). The relationship between carbon stock and biomass is directly, the high amounts of biomass correspond to high amount of carbon. Many authors assent that the carbon concentration of tree parts to be 50% or 45% of the dry biomass (Vashum and Jayakumar, 2012), this agrees with the positive influence of biomass on the carbon stock.

CONCLUSION AND RECOMMENDATION

From the results and discussion on the Wazo hill quarry potentiality in Carbon stocking, it is concluded that:

- The Wazo hill quarry is a potential area for carbon stocking because of presence of carbon pool that stores AGC stock of 3.6 tonnes per hectare, this amount can be raised with sustaining rehabilitation activities.
- The measurements underestimated the carbon stock of the area because of consideration of only AGC, this means the potentiality of the quarry in carbon stock is more when considering beyond AGC
- Rehabilitation of quarried area promotes carbon pools and facilitates the functioning of the ecosystem. Rehabilitated area had more density of trees than un-quarried area showing importance of rehabilitation not only in ecosystem functioning but also in carbon stocking .

Also this study recommends that:

- ✓ There is need for more work in the potential for the Wazo hill quarry in carbon stocking, more work can be done on the below ground carbon, dead biomass, litter, soils and ponds.
- ✓ Planting of trees should choose fast growing and proliferative species that accumulate biomass
- ✓ We need to continue with promotion of programmes and activities that keep up the potential of the Wazo hill quarry in carbon stocking, example continuing with rehabilitation of the quarried areas.
- ✓ Explore benefit of carbon market from the quarry Carbon stock and think possibility of replication in other quarries.

ACKNOWLEDGEMENTS

We thank the Almighty God forgiving us good health during the whole time of the study. We thank the organizers and funders of the International Quarry Life Award of the Heidelberg Cement Group for creating this good learning, sharing, growing and interactive opportunity at the international stage indeed it is wonderful and memorable experience.

We thank the management and staff at Tanzania Portland Cement Company Limited (TPCC) for their warmly welcome during the whole time of our study. We cannot give the whole list but we find the following individuals to be memorable to us Mr. Richard Magoda, for coordinating QLA business at TPCC. He always answered our phone calls, short message services and emails, and passed information to us. Mr Hamis, the safety and security officer at TPCC for series of his inductions talks on safety in working in the quarry that indeed made us safe for the whole time of our work. We thank UVIKIUTA staffs who are working on rehabilitation of the quarry and tree nursery, Mr Samuel and Abbas for their support.

We thank the jury members both national and international for visiting and advising us, special thanks goes to Dr. Henry Ndangalasi, Stephane Riviere and Leonard Gastory. We thank our fellow participants of QLW 2018 2018 from Tanzania Sylvia Ruambo, Japhet Mwang'ombe, Nancy Iraba, Fadhili Malesa and Mbonea Asery for sharing this opportunity. We also thank Mr Ezekiel Sigala for assisting us in the field data collection and lastly but not least we thank our institutes Tanzania Wildlife Research Institute and University of Dodoma for supporting us.

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ANNEXES

Annex 1. Working Plan and Time Frame for the Carbon Potential Work, Wazo Hill

Time	**Activities**	**Responsible part**
January	Visiting the Wazo Hill Quarry, Induction on Safety on Working in the Quarry and some explanations on the Quarry Life award competitions Updating on the website	Some TPCC staff and QLA 2018 participants
February	Logistical preparation and Preliminary survey of the field work Start Data collection Updating on the website	Researchers and Some TPCC staff
March	Setting vegetation plots for measuring trees Updating on the website	Researchers and Some TPCC staff
April	Start Data collection: measuring trees Updating on the website Visitation by International Jury member	Researchers and Some TPCC staff, International Jury member, National jury Member
May	Start Data collection: survey the quarry for recording carbon stock areas and land use/cover types. Continue Data collection: measuring trees Updating on the website	Researchers and Some TPCC staff
June	Start Data collection: working on aerial images and Geographical Information System Continue Data collection: measuring trees Updating on the website	Researchers and Some TPCC staff
July	Continue Data collection: working on aerial photographs/satellite image and Geographical Information System Continue Data collection: measuring trees Updating on the website	Researchers and Some TPCC staff
August	Presentation to National Jury Start Data organisation and analysis and writing final report Updating on the website	Researchers, QLA coordinator, National Jury
September	Completion and Submission of the Final Report Updating on the website	Researchers

Annex 2. Families and Species of the Trees Measured in the Wazo Hill Quarry

SN	Family	Tree species
1	Anacardiaceae	1.Sclerocarya birrea
2	Bignoniaceae	1.Markhamia lutea
3	Casuarinaceae	1.Casuarina equisetifolia
4	Cneoraceae	1.Harrisonia abyssinica
5	Dichapetalaceae	1.Dichapetalum stuhlmani
6	Ebenaceae	1.Diospyros sp 2.Diospyros usambarensis
7	Fabaceae	1.Acacia nigrescens 2.Acacia sp 3.Albizia lebbeck 4.Albizia sp 5.Cassia abbreviate 6.Faidherbia albida 7.Leucaena leucocephala 8.Peltophorum pterocarpum 9.Pongamia sp 10.Senna siamea 11.Tamarindus indica
8	Malvaceae	1.Adansonia digitata 2.Grewia bicolour 3.Grewia sp
9	Meliaceae	1.Azadirachta indica 2.Trichilia emetica
10	Myrtaceae	1.Psidium guajava
11	Rutaceae	1.Citrus limon

Annex 3. Families and species in each of the three areas of Rehabilitated, Quarried and Unquarried

SN	Area	Family	Species
1	Rehabilitated	Casuarinaceae	Casuarina equisetifolia
		Fabaceae	Senna siamea Pongamia sp Acacia sp Leucaena leucocephala Albizia sp Peltophorum pterocarpum Faidherbia albida Tamarindus indica
		Malvaceae	Grewia sp
		Meliaceae	Azadirachta indica Trichilia acuminata
		Myrtaceae	Psidium guajava
		Rutaceae	Citrus limon
2	Self re-generating	Fabaceae	Leucaena leucocephala Albizia sp Faidherbia albida
		Meliaceae	Azadirachta indica
3	Un-quarried	Anacardiaceae	Sclerocarya birrea
		Bignoniaceae	Markhamia lutea
		Cneoraceae	Harrisonia abyssinica
		Dichapetalaceae	Dichapetalum stuhlmani
		Ebenaceae	Diospyros usambarensis Diospyros sp
		Fabaceae	Leucaena leucocephala Albizia lebbeck Pongamia sp Acacia nigrescens Cassia abbreviata
		Malvaceae	Grewia bicolour Adansonia digitata
		Meliaceae	Azadirachta indica

To be kept and filled in at the end of your report

Project tags (select all appropriate): This will be use to classify your project in the project archive (that is also available online)	
Project focus: ☒Beyond quarry borders ☐Biodiversity management ☐Cooperation programmes ☐Connecting with local communities ☐Education and Raising awareness ☐Invasive species ☒Landscape management ☐Pollination ☐Rehabilitation & habitat research ☐Scientific research ☐Soil management ☐Species research ☐Student class project ☐Urban ecology ☐Water management Flora: ☒Trees & shrubs ☐Ferns ☐Flowering plants ☐Fungi ☐Mosses and liverworts Fauna: ☐Amphibians ☐Birds ☐Insects ☐Fish ☐Mammals ☐Reptiles ☐Other invertebrates ☐Other insects ☐Other species	Habitat: ☐Artificial / cultivated land ☐Cave ☐Coastal ☐Grassland ☐Human settlement ☐Open areas of rocky grounds ☐Recreational areas ☐Sandy and rocky habitat ☐Screes ☐Shrub & groves ☐Soil ☐Wander biotopes ☐Water bodies (flowing, standing) ☐Wetland ☒Woodland Stakeholders: ☒Authorities ☐Local community ☐NGOs ☐Schools ☐Universities