**Effects of Limestone Mining on Deforestation and Land Degradation in Mbeya Region, Tanzania**

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**Abstract:** This paper focuses on the effects of limestone mining on deforestation and land degradation in Usongwe Division, Mbeya Region. The study involved 120 people from three villages (Songwe, Majimoto, and Ikumbi) surrounding Mbeya Cement Company Limited and 10 key informants. Data were collected through household’s questionnaire survey, key informants interviews, focus group discussions, resource assessment, archive information, and field site visits. Findings revealed that 38.3 ha of forests were cleared out of the 1000 ha leased to Mbeya Cement Company Limited. Similarly, soil erosion, loss of vegetation, and air pollution were the main effects exacerbated by limestone mining. Measures to the restore ecological function in the areas surrounding limestone mining sites included steep slope levelling, afforestation, and flood control. To mitigate deforestation and land degradation; rehabilitation, reclamation, and restoration measures to the best land use for future generation were suggested to be in place.
Keywords: Deforestation, Land degradation, Limestone mining, Mbeya Cement Company

1. Introduction

Mineral resources have been used by man since time immemorial and represent an important economic activity which has substantial contributions to the socio-economic development (Saxena, et al., 2005). Socio-economic benefits have been generated from mining though there have been adverse effects of mining to the ecosystem due to massive excavation and removal of soil and rock layers (Joseph & Yeboah, 2008). Throughout the world, limestone mining activities have marked negative environmental impacts in view of the fact that limestone mining involves extraction of limestone from the earth’s crust by removing vegetation cover, top soil, and rocks that lie above the required limestone hence exacerbate deforestation and land degradation (William, 2001).

The scale of operations which are involved in limestone mining processes determines the extent of deforestation and land degradation (Aigbedion, 2007). Limestone has been mined through surface and underground methods (Fred, 2006). Underground limestone mining is commonly used when a specific rock layer is desired or in areas where there is thick material overlying the desired rock (Mengistu et al., 2000). Conversely, surface limestone mining involves removal of limestone “rooms” leaving regularly spaced “pillars” in place to support the overlying roof. These operations can be extensive and often covers hundreds acres of land. Surface quarrying method cause or escalates deforestation and land degradation (Kumar & Jamaluddin, 2010). Most of the surface operations are hillside cuts or open pit type quarries (Fatusin & Fagbohunka, 2012). On the other hand, controlled blasting at the quarry face is used to break the rocks into pieces.

The development of cement factories in the world has been escalating due to high demand of limestone, sandstone, and clay stone that have created a new set of issues including soil erosion, displacement of the people, pollution, and migration of wild animals (Fred, 2006; Nidhi & Manshi 2009). Most of the limestone sites are in or around the natural vegetation areas. A number of negative impacts associated with limestone mining activities have been noted to include; alteration of land structure due to excavation, interference with natural drainage, ground water depletion, stacking of mine waste, soil infertility, degradation of forest land, and adverse effect on aquatic biodiversity and public health.

In Tanzania, limestone mining has been restricted to areas surrounding cement factories including Wazo Hill in Dar es Salaam (Twiga Cement Company), Pongwe in Tanga (Simba Cement Company), and Songwe in Mbeya (Tembo Cement Company). Limestone mining in Mbeya Region started way back in early 1930’s (URT, 1997). Currently, limestone mining in Mbeya Region is under
the Tembo Cement Company Limited in Usongwe Division. The extent of environmental devastations particularly deforestation and land degradation due to limestone mining is currently less known. This paper sets to assess the current extent of deforestation due to limestone mining, examine impacts of limestone mining on land degradation, and assess the available ecological restoration measures against limestone mining.

2. Materials and Methods

2.1. The Study Area

This research was carried in Mbeya Rural District at Usongwe Division. Mbeya Rural District is among the districts of Mbeya Region in Tanzania. The district lies between latitude 7° and 9° South of equator and between longitudes 33° and 35° East of Greenwich. Mbeya Rural District lies at an altitude ranging from 1000-2400 meters above sea level. It is bordered to the north by Mbarali District and Chunya District, to the south by the Mbeya City Council and Rungwe District, to the east by Iringa region and to the west by Mbozi District (URT, 1997).

Three villages were involved in this study namely Songwe, Majimoto, and Ikumbi which were proximity to the limestone mining sites under the Mbeya Cement Company Limited in Usongwe Division. Mbeya Rural District has a tropical climate with an average temperature ranging between 6°C in the highlands and 26°C on the lowlands. Mean annual rainfall ranges from 650 mm and 2700 mm (URT, 1997; Barnabas, 2010). The study area is characterized by sparse, *Acacia/cambretum* woodland. Dominant tree species include *Acacia spp*, *Faidhebia albida* and *Combretum spp* and the local name trees include *Mpogoro, Mtiangasale, Nahumba* and *Itonto* (URT, 1997). Soils are moderate fertile, course or medium textured and varying from sandy loams, alluvial solids to cracking rocks (URT, 1997).

Majority of the people in Mbeya Rural District are farmers cultivating maize, cabbages, carrots, green beans, tomato, and onions, cucumber, Irish potatoes coffee, pyrethrum, sunflowers, avocado, passions, and mangoes crops. Furthermore, some people keep livestock as their main source of income. The common livestock kept in larger numbers include cattle, sheep, goats, and poultry (Barnabas, 2010). Additionally, Mbeya Rural District has high potentials for minerals including gold, granite, limestone, diamond, platinum, uranium, cobalt, and nickel (URT, 1999).

2.2. Data Collection and Analysis

Data for this research were collected through households questionnaire survey, key informants interviews, focus group discussions, resource assessment, archive information, and field site observation as detailed below.
2.2.1. Household questionnaire survey

Researchers administered structured questionnaires to 120 respondents selected from 120 households in the three villages. In each of the three villages, forty (40) households were selected from the village register using a systematic random sampling technique. Only one respondent was picked in each household to represent the entire household’s members. Training of research assistants and questionnaire pre-testing were done. Aspects covered in the questionnaires were socio-economic characteristics of the respondents, plant species affected by limestone mining, effects of limestone mining on vegetation and land degradation, and types of restoration measures and their effectiveness in ameliorating environmental devastations caused by limestone mining. Other aspects were the presence of the stakeholders dealing with environmental conservation practices as well as suggestions for the measures to reduce deforestation and land degradation due to limestone mining.

2.2.2. Focus group discussions

Focus group discussions were held based on the fact that the method reveals in-depth information on issues, perception, and ideas of various community groups. For a proper group management, two sessions (morning and evening) of six people were conducted. Two sessions were preferred because some villagers were rarely found in the morning due to farming practices. One day was used for each village. Purposive selection was used to select various category of the respondents in terms of age to include youths and elders; sex to include males and females, and working experience in limestone mining to include people who worked in limestone mining and those who are not working. These groups were included in order to diversify information on the subject matter. Topics which were discussed involved the extent of deforestation and land degradation due to limestone mining, legal frameworks on mining, and conservation practices used to restore the environment against impacts of limestone mining.

2.2.3. Key informants interview

Structured interviews were organized and administered to the key informants who were the Mbeya Cement Company Environmental and Safety Officer, District Land and Forest Officers, District Mining Officer, Ward Executive Officer, Village Heads, and Village Executive Officers. Checklist guide was used to guide the interviews. Topics included in the checklist were the impacts of limestone mining on deforestation and land degradation, restoration measures attempted to overcome environmental devastations exacerbated by limestone mining, as well as policy and legal frameworks governing the limestone mining in the study area.
2.2.4. Resource assessment

Resource assessment was used to collect information on the types of plant species and land uses available in the study area. Furthermore, it involved the identification of plant species found in the area and their relative abundance. The counting was done in the established site in the study area. A total of 3 transects with 200 plots were established in the study site each with a radius of 12.5 meters as described by Sharma et al., (2013). This was done so as to formulate the area similar to the quarry area that amounts 1000 ha. In each plot tree species were identified in common names, scientific names, and local names. Trees abundance of each plot was obtained by counting the number of each tree species.

2.2.5. Field site visits

Field site observations were used to authenticate different activities which were practiced by the Mbeya Cement Company Limited in extracting limestone and the way they affect vegetation and land within the study area. Field site visits were organized in collaboration with the local leaders and the mining officers in the study area. Camera and tape measures were used to record information and measuring the quantitative data to include depth and width of the gullies and pits left after excavation.

2.2.6. Archive data

Secondary data were collected through review of the related documents from different sources including books, journals, and local government documents. Archive information obtained from these reports complemented information collected from primary data.

2.3. Data Analysis

Data were analyzed using of Statistical Package for Social Science (SPSS) version 16.0 for windows. Statistical Analytical System (SAS) was also used to compute data into means, standard errors by using SAS version 10.1 for Windows Statistical Package based on the following statistical model:

\[ Y_i = \mu + T_i + e_i \]

Where \( Y \) is general response (excavated soil, tree stocking density)
\( \mu \) is the general mean particular for each observation.
\( T_i \) is the treatment effect due to location.
\( e_i \) is the random error terms common for all observations.
Means were separated using Least Significant difference as executed by SAS.
3. Results and Discussion

3.1. Extent of Deforestation due to Limestone Mining

The extent of deforestation due to limestone mining was explored. Results from the established three transects with 200 plots disclosed that Usongwe Division had more than 250 different tree species. The dominance species were *Faidherbia albida* (1248 stem/ha) and Mtangasale (1001 stem/ha). The non-dominance specie was *Dichrostachys spp.*, 14 stem/ha (Table 1 & Figure 1).

**Table 1:** List of some tree species found in study area

<table>
<thead>
<tr>
<th>S/n</th>
<th>Common name</th>
<th>Local name in Nyiha and Nyakyusa local languages</th>
<th>Stem/plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Faidherbia albida</em></td>
<td>Mpogoro</td>
<td>1248</td>
</tr>
<tr>
<td>2</td>
<td><em>Acacia drepanolobium</em></td>
<td></td>
<td>399</td>
</tr>
<tr>
<td>3</td>
<td><em>Acacia gerrerdii</em></td>
<td></td>
<td>89</td>
</tr>
<tr>
<td>4</td>
<td><em>Acacia mearnsii</em></td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>5</td>
<td><em>Acacia nilotica</em></td>
<td></td>
<td>198</td>
</tr>
<tr>
<td>6</td>
<td><em>Albizia adiantifolia</em></td>
<td></td>
<td>269</td>
</tr>
<tr>
<td>7</td>
<td><em>Boscia mozambiensis</em></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td><em>Commiphora spp.</em></td>
<td></td>
<td>156</td>
</tr>
<tr>
<td>9</td>
<td><em>Dichrostachys spp.</em></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td><em>Ximenia americana</em></td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>11</td>
<td><em>Grewia similis</em></td>
<td></td>
<td>310</td>
</tr>
<tr>
<td>12</td>
<td><em>Isongore</em></td>
<td></td>
<td>711</td>
</tr>
<tr>
<td>13</td>
<td><em>Itonto</em></td>
<td></td>
<td>397</td>
</tr>
<tr>
<td>14</td>
<td><em>Ivumuu</em></td>
<td></td>
<td>193</td>
</tr>
<tr>
<td>15</td>
<td><em>Litukutu</em></td>
<td></td>
<td>283</td>
</tr>
<tr>
<td>16</td>
<td><em>Mtangasale</em></td>
<td></td>
<td>1001</td>
</tr>
<tr>
<td>17</td>
<td><em>Nahumba</em></td>
<td></td>
<td>512</td>
</tr>
<tr>
<td>18</td>
<td><em>Senna singuena</em></td>
<td></td>
<td>164</td>
</tr>
<tr>
<td>19</td>
<td><em>Zyziphus spp.</em></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>20</td>
<td><em>Mtoo</em></td>
<td></td>
<td>619</td>
</tr>
<tr>
<td>21</td>
<td>Unidentified-1</td>
<td></td>
<td>428</td>
</tr>
<tr>
<td>22</td>
<td>Unidentified-2</td>
<td></td>
<td>401</td>
</tr>
<tr>
<td>23</td>
<td>Unidentified-3</td>
<td></td>
<td>313</td>
</tr>
<tr>
<td>24</td>
<td>Unidentified-4</td>
<td></td>
<td>177</td>
</tr>
<tr>
<td>25</td>
<td>Unidentified-5</td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

(Source: Field data, 2015.)

The presence of many indigenous tree species in Usongwe Division (Table 1) implies that the area might be rich in terms of flora. *Faidherbia albida* being the dominant specie could be attributed by soil fertility and the climate that favor its adaptation. However, being a dominant specie imply that the particular specie has been affected by limestone mining since there were no any tree in the limestone mined plot.
Results portray that the number of stem per ha in the study area within the three transects ranged between 727 ±28 to 1009 ± 40 (Table 2). The three transects recorded highly variable (P< 0.05) tree stocking ranging from 727 to 1009 stems/ha. Results indicate that “Transect Two” had the highest stocking density (P<0.05) compared with the rest of the two transects. The plausible reason for this variation could be that, plots for other transects (one and three) were arbitrarily positioned in the areas rich in sand stone hence not favorable for the nurture of many tree species. Effect of limestone mining on tree density is demonstrated by the absence of any tree stem in the mined site (Table 2).

Table 2: Number of stem per ha in three transects in non-mined area

<table>
<thead>
<tr>
<th>Transect</th>
<th>Plot (N)</th>
<th>Stems/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65</td>
<td>727 ± 28&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>86</td>
<td>1009 ± 40&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>49</td>
<td>875 ± 22&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>67</td>
<td>870 ± 30</td>
</tr>
</tbody>
</table>

<sup>a, b, c</sup> means with different superscript in same column differ significantly (P < 0.05).
Source: Field data, 2014.
Furthermore, results unveil that deforestation in the study area was caused by land clearing prior drilling and blasting processes. An observation during transect walk disclosed a big open pit pentagon in shape of about 850 m long, 450 m width, and 27 m depth which equals to 382500 m$^2$ in area (Figure 3). Limestone has been excavated up to 27 m depth making a volume of 1,032,750 m$^3$. The situation, however, could be worse as more than half of the respondents (61.7%, n=120) reported that there was an increase in cutting of vegetation due to limestone mining in the study area (Figure 4).
Arvind & Biswajit, (2011) ascertain that deterioration in physical, chemical, and biological quality of the environment affects both flora and fauna resources. Limestone mining in the study area revealed to devastate natural vegetation. This was revealed by the existence of the large mining pit found in the study area covering about 38.25 ha of the forest cleared for limestone mining. This had also substantiated by 61.7% of the respondents who noticed an increase in deforestation in Usongwe Division (Figure 4). The total area expected to be used for the limestone mining was 1000 ha. This area was covered with various indigenous tree species (Table 1). Therefore, this justifies the high deforestation in the study area. Despite that greenery bears a pivotal role in protecting the quality of all aspects of environment, there have been reported result on effect of limestone mining concern with other scholarly work that mining activity has been reflected through decrease in green cover or water resource or both (Sahu & Dash, 2011; Fatusin & Fagbohunka 2012; Sharma et al., 2013).

Figure 4: Respondents views on the extent of deforestation due to limestone mining. (Source: Field data, 2015.)

3.2. Impacts of Limestone Mining on Land Degradation

Impacts of limestone mining on land degradation were assessed in the study area. Results revealed that limestone mining in the study area had exerted impacts on the landscape and eco-system at large. Limestone mining extraction activities (Figure 5 and 6) influenced negative impacts of limestone mining on land degradation. These mining extraction practices were land clearing, blasting, drilling, storage of the overburden dump materials, and the movement of heavy trucks.
Figure 5: Limestone materials collected by a digger. Photo by Hancelem Haule, 2015.

Figure 6: Eroded land due to limestone mining. Photo by Hancelem Haule, 2015.

Table 3 pinpoints that respondents had mentioned soil erosion as a major negative effect exacerbated by limestone mining in the study area. Other impacts include loss of vegetation cover, air pollution, drainage/hydrological interference, and disturbance of soil micro-organisms.

Table 3: Impacts of limestone mining on land degradation

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Songwe</th>
<th>Maji Moto</th>
<th>Ikumbi</th>
<th>Total</th>
<th>Average (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil erosion</td>
<td>21</td>
<td>22</td>
<td>11</td>
<td>54</td>
<td>45</td>
</tr>
<tr>
<td>Loss of vegetation/ground cover</td>
<td>12</td>
<td>9</td>
<td>18</td>
<td>39</td>
<td>32.5</td>
</tr>
<tr>
<td>Disturbance of soil micro-organism</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>Air pollution</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>14</td>
<td>11.6</td>
</tr>
<tr>
<td>Drainage &amp; hydrological interference</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Source: Field data, 2015.

Results in Table 3 disclose that 45% of the respondents cited soil erosion as a major negative effect on land. Soil erosion was caused by the excavation of limestone practices (land clearing, blasting, and drilling) as well as the frequent movement of heavy trucks in the mining sites. Discussion with Mbeya Cement Company Environmental and Safety Officer revealed that the ratio of the overburden excavated to the amount of mineral removed (stripping ratio) estimated in the study area was 8:1. This means that for every tone of limestone ore being produced, eight tones of waste are generated. The direct impacts of mining disturbance to the soil are usually severe with the destruction of natural ecosystems, either through the removal of all previous soils, plants, and animals or their burial beneath waste disposal facilities.

The overburden removal from the mining area was also reported by 32.5% of the respondents to cause the loss of vegetation in the study area (Table 3). In the study area, the overburden removal
was normally done by the process of blasting or using excavators, which produced large volume of waste (soil, debris, and other material). The removed overburden was useless to the mining industry hence was stored in big heaps within the mine lease area and to the public land. Saxena et al. (2005) argue that the bigger the scale of the mining, the greater is the quantum of the wastes generated.

It is estimated that open-pit mines produce 8 to 10 times as much waste compared to underground mines. The noted high ratio of overburden excavated to the amount of mineral removed (stripping ratio) in the study area (8:1) could be associated with the low mining technology applied in the study area. This ratio is almost as twice as ratio of 4:1 reported by Mengistu & Fentaw (2000) in Ethiopia. Results indicated that Mbeya Cement Company was producing twice as much amount of the wastes compared to Chronicle Cement Company in Ethiopia. The higher stripping ratio noted for Mbeya Cement Company could be associated with high extent of land degradation. Stripping ratio varies with the area under mining and the generation of overburden varies from mine to mine (Anon, 2006). According to the Indian Bureau of Mines, average stripping ratio for limestone mines in India is 1:1.05. For large-scale cement sector with captive mines, the average stripping ratio is only 1:05. This is quite good to be adopted by Mbeya Cement Company to ensure sustainability of the land resources.

Furthermore, results revealed that 11.6% of the respondents unveiled that limestone mining exacerbated air pollution (Table 3). Air pollution was caused by the excavators, movements of diggers, bulldozers, and other trucks in the mining sites. In addition, discussion with the Village Heads and Village Executive Officers revealed that watering was not done to avoid dusts. Similarly, trucks which were carrying debris/soils were not covered hence escalate the spreading of air pollution. Furthermore, discussion with Mbeya Cement Company Environmental and Safety officer disclosed that air pollution was principally caused by the use of open cast mining method. This is in line by the argument by Sharma et al., (2013) that open cast mining cause excessive air pollution as they generate huge quantities of wastes than underground mining.

3.3. Measures for Ecological Restoration Against Limestone Mining

Measures to control the adverse effects of limestone mining on the environment in the study area were probed. Results in Table 4 portray that 55% of the respondents reported an absence of the measures to restore the degraded environment in the study area. However, few of the respondents mentioned the existence of restoration measures on the degraded land due to limestone mining. The reported measures to be in place include reforestation, flood control, and steep slope control (Table 4).

Results in Table 4 indicate that respondents traced the presence of reforestation in the areas surrounding limestone mining sites. Respondent’s views concurred by the views aired out by the Village Heads and the Village Executive Officers during discussion that Mbeya Cement Company
have been providing seedlings to the villagers to be planted in their surroundings. Nonetheless, Focus Group Discussions disclosed that local people were planting the provided trees but no follow-up from the Mbeya Cement Company was been made to assess the nurture of the planted trees. Consequently, most of the planted trees left without care hence died. However, discussion with District Land Officer revealed that most of the trees were also dying because they were not indigenous to the area. In practice, Mbeya Cement Company is the polluter and it should have been made responsible to ameliorate the impacts of the limestone mining. They should have paid for all the negative impacts on the environment.

Table 4: Applied ecological restoration measures

<table>
<thead>
<tr>
<th>Measures</th>
<th>Songwe</th>
<th>Maji Moto</th>
<th>Ikumbi</th>
<th>Total</th>
<th>Average (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steep slope control</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>Flood control</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Reforestation</td>
<td>11</td>
<td>6</td>
<td>8</td>
<td>25</td>
<td>20.8</td>
</tr>
<tr>
<td>No measure at all</td>
<td>23</td>
<td>18</td>
<td>25</td>
<td>66</td>
<td>55</td>
</tr>
<tr>
<td>Do not know</td>
<td>7</td>
<td>3</td>
<td>9</td>
<td>19</td>
<td>15.8</td>
</tr>
</tbody>
</table>

(Source: Field data, 2015.)

Similarly, topographic leveling was also done to control the steep slope in the mining sites. Steep slopes were due to slope cuts and piling of soil/debris heaps. Steep slope leveling was done by the Mbeya Cement Company so as to reduce soil erosion, soil creeps, and mud flows during rainfall. Meanwhile, steep slope control was also done so as to enhance visibility within limestone quarrying sites due to high heights of the soil/debris heaps. An observation during field site visits disclosed that topographic leveling was decisive to control sloping in the mining sites, but was not effective at the boundaries between the mining sites and to the villagers partly because efforts were made to level inside the mining sites than outside where there was huge accumulation of soil/debris heaps.

Respondent’s responses on the existence of the measures to enhance ecological restoration against the impacts of limestone mining on the environment revealed the existence of the little efforts. However, for the sustainability of the environment in the study area, 53% of the respondents had suggested rehabilitation as an ecological restoration measure to be in place (Figure 7). Rehabilitation involves returning the land to the original form and allows productivity in conformity with a prior land-use plan including a stable ecological state that does not contribute substantially to the environmental deterioration and is consistent with surrounding aesthetic values (Oral & Rohan, 2008).

The study revealed that even Mbeya Cement Company favors rehabilitation as it was unveiled by the company Environmental and Safety Officer that they expect to develop designs for appropriate landforms for the mining site according to the design principles established and establishing appropriate sustainable ecosystems. Therefore, in order to encourage environmental sustainability and
maintain current levels of natural assets including land, rehabilitation of environment normally through tree planting is necessary to be included in the planning and decision making as an important tool. Cooney & Dickson, (2006) put forward that rehabilitation mechanisms aims at preventing adverse impacts from happening and keeping those that do occur within acceptable levels.

![Restoration Measures (In frequency & %)](image)

**Figure 7:** Suggested restoration measures against limestone mining. (Source: Field data, 2015.)

Reclamation was also suggested by 30% of the respondents to ameliorate negative environmental impacts exacerbated by limestone mining (Figure 7). Reclamation in the context of the study area involves top-soil that be removed with a dozer prior to blasting. It can be mixed with other materials, even in small quantities, to provide organic matter, beneficial micro-organisms, fungi, and nutrient pools. Thus, reclamation considerations should be incorporated into the mining planning such that it becomes a major governing factor in the mining operations, waste disposal, and site closure. In this scenario, reclamation in the study area should not be confined necessarily towards the decommissioning phase of the mining activities. Rather site reclamation should be progressive such that the rate of restoration is more or less similar to the rate of mining. In the study area, site reclamation can be achieved through rehabilitation to blend the mined area to the surrounding area. Large bulldozers can shape the mining pits to a slope that is similar to the surrounding terrain so as to encourage water infiltration as quickly as possible to prepare the land for replanting. Thereafter, tree planting at a density of 625 trees per ha-1 can be done after 3 and 9 weeks (Hangi, 1996; Seiser, 2001; Mihayo, 2003). All tree species to be planted can be native to the area and selected based on several characteristics such as tree form, growth rate, wood quality, and resistance to diseases.
Restoration on the other hand was also recommended to enhance environmental conservation around limestone mining sites (Figure 7). Restoration operation allows no land use flexibility and incurs the greatest cost (Cooke & Johnson, 2002; EBI, 2007). In restoration, the central issue often is future land use requirements and whether returning to the pre-disturbance use constitutes the best use of land. To extract better results on restoration, Kitula (2005) stresses that ecological variables must be considered while selecting plant species for restoration. These include their capacity to stabilize soil, soil organic matter and available soil nutrients, and under storey development. Therefore, restoration of land to the best land use for future generation by using modern technologies is decisive in the study area.

4. Conclusions

Results unveiled that limestone mining had exacerbated negative effects on the landscape and ecosystem at large in the study area. In conservation and development trade-offs, there are winers and losers. Similarly, striking a win-win balance between conservation and development has never been an easy endeavor. A way forward is to balance conservation and development. The study recommends rehabilitation, reclamation, and restoration measures to be in place to mitigate deforestation and land degradation that have been exacerbated by open cast limestone mining method and the frequent movement of heavy trucks in the limestone mining sites.

Potential Conflicts of Interest

"The authors declare no conflict of interest."

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