A FINAL REPORT ON “THE POTENTIALS OF Pennisetum purpureum AS A BIOLOGICAL
GEOTEXTILE AND TOPSOIL APPLICATION TO PROMOTE BIODIVERSITY IN QUARRY SITE
RECLAMATION” AT YONGWA

SUBMITTED TO THE JURY OF THE QUARRY LIFE AWARD GLOBAL CONTEST

BY

PAUL K. NSIAH (TEAM LEADER) & HIS TEAM MEMBERS:
DAVID QUARTEY, EDWIN SEGLA, MAWUSI AMENUVOR & RICHARD ADOFO

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ABSTRACT

The study with the title “The potentials of *Pennisetum purpureum* as a biological geotextile and topsoil application to promote biodiversity in quarry site reclamation” was conducted at the Yongwa Limestone Quarry Site (YLQS) as part of competing for the maiden edition of the Quarry Life Award global contest organized by HeidelbergCement Group. The main goals of the research were: (a) To investigate the potentials of using the Elephant grass, *Pennisetum purpureum*, as biological geotextile in reducing the erosive forces of rain and runoff under natural rainfall during the reclamation of disturbed mine sites in Ghana. (b) To explore the effects of topsoil and organic manure, such as poultry manure, and mine-spoil in promoting the emergence and growth of native species in the reclamation of disturbed mine sites. The aim was to evaluate the potentials of each plant-growth media in promoting biodiversity during reclamation of disturbed mine sites. (c) To evaluate the combined effects of the three-selected growth media and the biological geotextiles on the rate of nutrient accumulation and the growth of some selected tree/fruit-crops using an Agroforestry Technology (AFT). The experimental set-up on erosion control mimicked the method of the BORASSUS-project funded by the European Commission (Smets et. al 2011). To establish the effectiveness of the biological geotextiles and plant-growth media, the experimental site was divided into an appropriate number of blocks and the Randomised Complete Block Design was used to allocate the biological geotextile, plant growth media, Agricultural fruit-crops and Forest tree-crops to the experimental blocks. Average total sediment yield from the Esonosre mat was far lower (29.1 kg) than that from the Bare soil (106.2 kg). In terms of biodiversity promotion using the Shannon-Wiener Index topsoil was the highest (1.32) followed by poultry manure with minesoil recording the least (0.89). This study has made it possible, for the first time, to develop a biological geotextile called the Esonosre mat, from the common Elephant grass, and that the Esonosre mat has proven to possess the ability to protect the topsoil and its living organisms, seeds and seedling of diverse plant species thereby conserving biodiversity in both the terrestrial and the aquatic ecosystem through sediment retention. This project has, again, demonstrated that topsoil and its substitute, poultry manure, have both great potentials in promoting biodiversity in newly reclaimed quarry/mine site. It has also been revealed that amending minesoil with either topsoil or organic manure, such as poultry manure, better help promote the survival and growth of fruit and tree crops than planting the same crops in minesoils without any amendments, during reclamation of disturbed quarry/mine sites. In addition, the project has provided a practical mine-site reclamation guideline to be adopted in order to achieve a safe and stable land, as well as a final land-use that is compatible with the proposed end-land uses, which will further help release Ghacem from the Reclamation Security Bond and also ensure that the Company is free from any future liabilities at the YLQS.

1.0 INTRODUCTION, BACKGROUNG INFORMATION AND PROBLEM STATEMENTS

Most of the mining companies in Ghana fail to stabilize slopes during the initial stages of revegetating their disturbed sites (Nsiah, 2008; Donkor, 2011; Aborgeh, 2012, Siaw, 2011). At this initial stage, rills and gullies are often created leading to the loss of topsoil and its living organisms, seeds and seedlings of diverse plant species (Picture 2). Eventually, the land owners, who are mainly peasant Ghanaian farmers, are left with infertile lands incapable of supporting the growth of their food crops.

Apart from the above on-site effects, there are also associated off-site effects such as the siltation of rivers and streams by sediments being washed from the rills and gullies of the bare soils, which in turn lead to pollution and flooding of the rivers and streams during the rainy season and drying-up of the water bodies even with minor drought. Thus, biodiversity in the aquatic ecosystem together with their environment is, again, jeopardized.

Secondly, there is lack of an assessment of the initial ground conditions, either for contaminant concentrations or for soil nutrient level before vegetation establishment on disturbed mine sites in Ghana (Nsiah, 2008; Donkor, 2011; Aborgeh, 2012, Siaw, 2011). This initial ground assessment is always needed in order to determine the level of remediation required for successful plant growth and also serves as an effective means of identifying site risks and liabilities which can seriously affect the fulfillment of site aspirations and the overall
success and sustainability of a site restoration (Hutchings et al, 2006). The assessment further provides the baseline data upon which the overall success of reclamation can be measured.

Another issue of concern to the researcher is the lack of application of topsoil and the non-amendment of minesoils by most mining companies in Ghana during reclamation of disturbed mine sites in Ghana (Nsiah, 2008; Donkor, 2011; Aborgeh, 2012, Siaw, 2011). The application of topsoil is a key element in any successful reclamation project (Stoupe, 1998) especially if the objective is to promote native plant species, whiles minesoils with amendments have shown good potentials for horticultural crop production in the United States of America (Ballard et al, 2000). Topsoil is perceived to contain majority of the seeds and other plant propagules, soil micro- and macro-organisms, organic matter and much of the more labile plant nutrients that aid in promoting the emergence and growth of pioneer and other planted species on newly reclaimed lands. Norman et al (1997) maintain that since quarry sites generally lack topsoil, reject fines, scalplings, or other fine-grained materials can be used to replace topsoil, provided they are amended with organic matter.

1.1 Objectives of the Study
The specific objectives were:

1) To innovate, design and construct a biological geotextile from the Elephant grass, *Pennisetum purpureum*, to be known as “Esonosre mat” using simple technology.

2) To evaluate the effectiveness of the newly developed Esonosre mat and that of York mat in reducing runoff and soil loss to promote biodiversity when reclaiming the Yongwa Limestone quarry site.

3) To determine soil metal concentrations and nutrient conditions prior to revegetation at the YLQS.

4) To demonstrate the potentials of topsoil and that of poultry manure as growth media in promoting the emergence and growth of more diverse native plant species compared with minesoil during the initial stages of revegetating disturbed mine sites at YLQS; and

5) To assess the effects of the amendments of minesoils with topsoil and poultry manure on the survival and early growth performance of some selected agricultural fruit-crops and forest tree-crops using Agroforestry Technology at the YLQS.

2.0 METHODOLOGY

2.1 Description of the study area
The project was carried out at the Yongwa Limestone Quarry Site (YLQS) belonging to Ghacem Limited, a subsidiary of HeidelbergCement Group. The YLQS is owned by Ghacem Limited a subsidiary of HeidelbergCement Group. It was established in May 2004 to deliver local limestone material to the Tema and Takoradi cement factories and to the sister company in Togo in response to curbing costly imports. The quarry is located at Klo-Begoro in the Yilo Krobo District of the Eastern Region of Ghana, 92 km north of the Tema factory. The quarry site can be accessed by the main Somanya-Asesewa road and a dirt track linking the Bueyonye and the quarry site at Klo-Begoro, the nearest settlement. The coordinates are: (N6°33'00" - W0°04'40"). Currently there are two pits in operation, a third one lies about 300 m north of the current pits and will deliver further raw-material. The concession covers an area of about 81.45 ha, while the present project site occupies an area of about 46 ha.
The project area lies in the high temperature and rainfall zone, within the forest zone of Ghana. It is characterized by two main raining seasons, notably the wet and dry seasons. The annual rainfall mean is ranging between 1500mm and 1700mm. The mean temperature ranges between 22°C (minimum) and 30°C (maximum). The state of flora within the Klo-Begoro concession area has undergone tremendous change over the years due to human activities. Generally the vegetation consists of elephant grass, shrubs and scattered trees such as Acacia spp., Neem-tree (*Azadirachta indica*), *Ceiba pentandra*. Also widely spread is the castor oil plant (*Ricinus communis*) which develops very well on the exposed soil.

### 2.2 Research approach: Inputs (Activities)

#### 2.2.1 The design and construction of the Esonosre mat for slope stabilization

The stems of the elephant grass were cut into one meter sizes. Each one-meter stick was then divided into four small sticks and used in the design and construction of the Esonosre geotextile in grid mats using a simple technology as shown in Picture 1.

![Picture 1: Construction of the Esonosre mat at Yongwa](image)

#### 2.2.2 Evaluation of the effectiveness of the Esonosre mat in erosion control

In order to evaluate the effectiveness of the newly developed Esonosre mat and that of the York mat in reducing runoff and soil loss to promote biodiversity at the Yongwa Limestone quarry site, field experimental plots were prepared at a degraded waste-dump site of the quarry area (Picture 2). The experimental set-up mimicked that of the BORASSUS-project (Smets et. al 2011). Six (6) experimental field blocks (B1, B2, B3, B4, B5 and B6) measuring 11m × 1m was designed with the help of wooden boards (Picture 3). The design and construction of Blocks were based on the method adapted by Davies *et al.* (2006), though with major modifications in this current project. Concrete gutters were constructed at the lower end of each Block to collect sediment yield with the help of a silt fence, whiles run-off was collected through a PVC pipe connected to a container placed at the mouth of each Block. The Randomized Complete Block Design was used to allocate each of the three treatments; Esonosre mat, York mat, and Bare soil (control) on their respective plots, with a replicate treatment as shown in Picture 3.

![Picture 2: The waste-dump site to be reclaimed](image)

After each substantial storm, data on sediment yield was collected by weighing separately, sediments collected from each of the six Blocks with the help of a scale whilst runoff volume was determined using the graduation on the container. The data were then displayed in tables and charts.
2.2.3 Assessment of contaminant status and nutrient levels in soil prior to revegetation

In order to guarantee that the Yongwa quarry site is free from any potential contaminants that could pose health and ecological risks to biodiversity after the reclamation process and again to ascertain the level of soil nutrients for plant growth and any subsequent need of fertilizer applications, soil samples were collected at the site to be reclaimed prior to revegetation and sent to the KNUST Soil Science Laboratory for subsequent analyses of contaminant concentrations and nutrients levels. All samples were analysed for the major plant nutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S): as well as organic matter content (OMC), and pH. Sub-samples samples were also analysed for potentially toxic elements such as Lead (Pb), Zinc (Zn), Copper (Cu), Cadmium (Cd), Arsenic (As), Nickel (Ni). The results were displayed in tables and charts.

2.2.4 Establishment of a Demonstration Plot as part of community involvement in Reclamation

Stakeholder consultation meeting (Picture 5) was organized during the study with the aim of sensitizing and educating the various stakeholders, especially the affected communities, about the benefits of the QLA and also to solicit their views and interests on how the Yongwa quarry site should be reclaimed after the operation. Regarding final land-use options, the stakeholders propose agricultural land-use, with commercial fruit-crops being the preferred crops to be established during the final post-project reclamation. They were, however, educated on the importance of biodiversity in maintaining not ecosystem but also on their livelihoods as human beings depend on biodiversity to survive. It was agreed after the education that some indigenous tree-crops should be planted alongside the commercial fruit-crops in the form of Agroforestry.

![Picture 4: Stakeholder consultation meeting](image1)

![Picture 5: School children being educated on biodiversity & rehabiliation](image2)

![Picture 6: The Demonstration Plot as at June 21, 2012](image3)

In order to acknowledge and respond to stakeholders’ concerns and prerogatives during the meeting, the researcher and his team established a reclamation demonstration/trial plot at the project area in Yongwa as shown in Picture 6 above.

Trial field plots were prepared at a waste dump site at the YLQS adjacent to the Experimental Blocks. The entire area was divided into 3 Plots (P1, P2, and P3) of equal size (14m × 6m). Three treatments; minesoil amended with topsoil (MAT), minesoil amended with poultry manure (MAP) and minesoil without amendment (MWA) as a control; were used in the study. Each of the 3 plots was further divided into 3 sub-plots giving a total of 9 sub-plots (P1a, P1b, P1c, P2a, P2b, P2c, P3a, P3b and P3c). The Esonosre mat and York mat (2m wide each) were each randomly laid on each of the 3 sub-plots in P1 leaving the 3rd sub-plot as a control. The same procedure was repeated for P2 and P3 as shown in Picture 4 above.

Five selected agricultural fruit-crops (Mango, Cashew, Cocoa, Oil Palm and Citrus) were planted on each of the nine sub-plots. In addition, six different indigenous forest tree species (*Terminalia ivorensis, Terminalia*...
superba, Khaya anthotica, Pycnanthus angolenses, Cordia spp Triplochiton sclerezylon) as well as two other species of nitrogen-fixing plants (Cassia siamea and Leuceania spp.) were planted in the different substrates. The percentage survival of each species was determined ten (10) weeks after planting whereas the different plant (pioneer) species emerged (regenerated) were identified through the assistance of one Mr. Owusu-Ansah de-Graft, who is a Forester and a Botanist at the RMSC, Kumasi. The Shannon-Wiener Diversity Index was employed to determine the biodiversity index whereas bar charts were used to display the percentage cover of the various treatments.

3.0 RESULTS

3.1 The design and construction of the Esonosre mat for slope stabilization
The design and construction of a one-meter square biological geotextile in grid mat from the Elephant grass, Pennisetum purpureum, called Esonosre mat has been born in Ghana through the innovation the researcher, Paul K. Nsiah. A stack of the newly born Esonosre mat in Picture 7.

3.2 Average sediment yield from the various treatments
Total sediment yield (average for the two plots of each treatment) for the period May 19, 2012 to September 1, 2012 (total precipitation= 235mm) is presented in Figure 1. Total sediment yield (soil loss) from the Esonosre mat was far lower (29.1 kg) than that from the Bare soil (Control) (106.2 kg, Picture 6.) with the York mat yielding the least (9.6 Kg).

3.3 Assessment of contaminant status and nutrient levels in soil prior to revegetation
Results on the nutrient status, heavy metal concentrations, pH, organic matter and organic carbon at the Trial Plot prior to revegetation have been presented in appendixes 1, 2, and 3 respectively. With the exception of arsenic, all the other heavy metal concentrations were within the acceptable range.

3.4 Biodiversity promotion
The following results, in terms of biodiversity promotion, survival and growth of agricultural fruit-crops and forest tree-crops were obtained 10 weeks after creating Trial plot.
Topsoil was able to promote the regeneration of 19 different species of about 90% plant cover followed by the poultry manure 9 different species with 52% plant cover while the control (minesoil) recorded only 5 species with 18% plant cover as depicted in Appendix 1 and Figure 2.

The Esonosre mat did not only promote floral diversity but also fauna as there was a new revelation. These snails as depicted in picture below were found to be so associated with the Esonosre mat, but the other treatments were not found so. In addition, fauna like butterflies, beetles, grasshoppers and bees were captured on the newly reclaimed site.

The diversity of plant species by Shannon-Wiener’s Diversity Index yielded 1.32 on Topsoil followed by 1.05 by Poultry manure, whereas the Control (minesoil) recorded the least 0.89 as shown in figure 3.
3.5 Survival and growth of agricultural fruit-crops

Percentage survival of each of the five fruit-crops 10 weeks after planting gave the following results: Mango and oil palm showed 100% survival in all three substrates, while Citrus, gave 100% survival in both MAP and MAT, but failed to do so in MWA with 67% survival. Whereas cashew recorded 0% survival in all the tree treatments, cocoa was only able to produce 33% survival in MWA failing in the other two treatments with 0% as illustrated in Figure 4.

3.6 Survival and growth of forest tree-crops

The results on the above heading were as follows: MAP showed 100% survival for *Triplochiton scleroxylon*, 50% for both *Terminalia superba* and *Cordia milleni* whiles MAT yielded 50% for each for all the three species. MWA, on the other hand, gave 50% each for both *Terminalia superba* and *Triplochiton scleroxylon*. All the remaining three species *Terminalia ivorensis*, *Pycnanthus angolensis* and *Khaya anthotheca* failed to survive in any of the treatments as depicted in Figure 5.

4.0 DISCUSSIONS

4.1 The design and construction of the Esonosre mat for slope stabilization and site protection

Through this Quarry Life Award competition, a one-meter square grid biological geotextiles mat, called the Esonosre Mat, has been designed and constructed from the stems of the Elephant grass, *Pennisetum purpureum* in Ghana (Picture 5). *P. purpureum* (with some common names as the Elephant grass, the Napier grass) is a species of grass native to the tropical grasslands of Africa. The feasibility of employing *P. purpureum* in the construction of biological geotextiles in the erosion control industry which this current study has achieved is the first of its kind making this this research an unprecedented one.

Results from an initial 3-month field investigation has shown average total sediment yield from the Esonosre mat covered plot to be far lower (29.2 kg) than that of the bare plot (106.0 kg) which is about 363% greater. These results agree with the pilot study by Davies et al 2006. The study has revealed the mat to be an effective biotechnical method of slope stabilization and soil conservation by providing the time necessary for vegetation to establish and grow especially on graded slopes during reclamation of disturbed mine sites such as Yongwa.

4.2 Assessment of contaminant status and nutrient levels in soil prior to revegetation

In order to guarantee that the Yongwa quarry is free from any potential soil-metal contaminants that could pose human health and other ecological risks to biodiversity after the reclamation process and again to ascertain the level of soil nutrients for plant growth and any subsequent needs for fertilizer applications, soil samples were collected at the site to be reclaimed at Yongwa prior to revegetation and sent to the KNUST Soil Science
Laboratory for subsequent analyses of contaminant concentrations and nutrients levels. The results show that with the exception of arsenic which exceeded (150mg/kg) the recommended threshold of 75mg/kg by the USEPA, all the other heavy metals were within the acceptable limit. Research has shown that arsenic contamination could result from either the parent material, as the element is a natural constituent in lead, zinc, gold, and copper ores, or from various human activities including combustion, wood preservation, and pesticide application and mining.

The significance of topsoil for biodiversity promotion and plant growth, which has been observed to be lacking in most reclaimed areas in Ghana (Nsiah, 2008; Donkor, 2011; Aborgeh, 2012, Siaw, 2011), was investigated by testing minesoil without topsoil (MWT) and minesoil amended with topsoil (MAT). One of the major reasons cited by most mining companies for their failure in applying topsoil on reclaimed areas Ghana is that the topsoils at those sites are too thin to be salvaged at the time of mining, meaning the topsoils are not available. This study, again, tried to find a solution to the unavailability of topsoil by investigating the feasibility of amending minesoils with organic manure, such as poultry manure, in promoting biodiversity as well as the survival and growth of different plant species at Yongwa. The findings after 10 weeks in terms of biodiversity promotion (species richness and abundance), percentage plant cover in addition to the survival and growth of some selected fruit- and tree-crops are depicted figures 3, 2, 4 and 5 respectively.

Topsoil gave the highest number of species (19) with the highest percentage cover (90%) followed by poultry manure (9 species, 52% plant cover) while the minesoil recorded least (5 species, 18% plant cover) after a period of 10 weeks. When employed to take into account both species richness and the relative abundance of species to quantify how well the species are represented within each treatment plot, the Shannon-Wiener’s Index revealed topsoil to be the highest (1.32) followed by poultry manure (1.05) with the control (minesoil) recorded the least (0.89) as shown in figure 3. This demonstrates the significance of topsoil in promoting biodiversity during reclamation of disturbed mine sites as topsoil is perceived to contain majority of the seeds and other plant propagules, soil micro- and macro- organisms, organic matter and much of the more labile plant nutrients that aid in promoting the emergence and growth of pioneer and other planted species on newly reclaimed lands.

The study has also proved that amending minesoil with poultry manure in the absence of topsoil, better helps promote biodiversity as well as the survival and growth of fruit- and tree- crops during the reclamation process. This means that in the absence of topsoil, as it is the case in most quarry sites, poultry manure could be used to amend the minesoil for the survival and growth of plants. This is in agreement with the statement by Norman et al (1997) that since quarry sites generally lack topsoil, reject fines, scalpings, or other fine-grained materials can be used to replace topsoil, provided they are amended with organic matter. The 100% survival of Mango and Oil-palm in all the 3 treatments (MAT, MAP and MWA) followed by Citrus with 100% in both MAP and MAT but 67% in MWA, with Cashew recording 0% in all 3 treatments, and cocoa scoring only 33% in MWA, as presented in figure 4 has, again, helped revealed the type of crops that could better grow at the Yongwa quarry site to be implemented during the final post-project reclamation.

5.0 ADDED VALUE OF THE PROJECT FOR BIODIVERSITY, THE SOCIETY AND THE COMPANY

This study has made it possible, for the first time, to develop a biological geotextile, called the Esonosre mat, from the common Elephant grass and that the Esonosre mat has proven to have the ability to protect the topsoil
and its living organisms, seeds and seedling of diverse plant species thereby conserving biodiversity in both the terrestrial and the aquatic ecosystem through sediment retention.

This project has, again, demonstrated that topsoil and its substitute, poultry manure, have both great potentials in promoting biodiversity in newly reclaimed quarry/mine site. It has also been revealed that amending minesoil with either topsoil or organic manure, such as poultry manure, better promote the survival and growth of fruit and tree crops than planting the same crops in minesoils without any amendments during reclamation of disturbed quarry/mine sites. Ghacem can now amend the minesoils at Yongwa with poultry manure during the final post-project reclamation since topsoil is not available at the quarry site.

The development of the Esonosre mat biological geotextile offers myriad benefits to the Ghanaians society, especially mine communities, in several ways. These benefits include employment generation as the communities in Yongwa are being trained to produce the Esonosre mat in commercial quantities to be sold to Ghacem and other interested mining companies for reclamation purposes. This will in turn result in poverty alleviation in developing countries endowed with mineral resources as the practice could be replicated in these countries. This commercial production of the geotextiles by the communities is seen to promote local community’s involvement in land reclamation that has the potentials of eliminating or reducing conflicts between mining communities and mining companies through enhanced cordial relationship between the two parties (Nsiah, 2008). The communities will also benefit from the reduction in the cost of farm inputs (e.g. fertilizer) due to the acquisition of soils with good nutrient levels from the stabilization of the slopes together with the total decomposition of the geotextiles leading eventually to better crop yield.

In addition, the project has provided a practical mine-site reclamation guideline to be adopted in order to ensured that the lands being handed over to their owners during closure and decommissioning is safe from all potential contaminants that could easily enter the food chain, stable from any threats of slope failure or gully formation, and at the same time, a fertile land capable of supporting the desired crops to be established. This practice will further help release Ghacem from the Reclamation Security Bond and also ensure that the company is free from any future liabilities at the YLQS.

Finally, the establishment of the demonstration plot has become a means through which Ghacem has acknowledged and responded to the community’s concerns regarding the types of agricultural fruit-crops and forest tree-crops that could be supported by the soils at the Yongwa quarry site. These concerns were raised during the stakeholders’ durbar held at Klo Beglo (Picture 4).

7.0 CONCLUSIONS: STATEMENT ON CHANCES OF SUCCESS AND OUTLOOK ON FUTURE IMPLEMENTATION

Though all the goals and objectives of this project set for the purpose of the maiden edition of the QLA have been achieved by now, there still remain a lot more to be done as my project has great potentials of going beyond QLA, all for the benefit of the company and the various stakeholders, especially during the post-project reclamation. Therefore, the following activities will be continuously carried out on the reclamation demonstration plot after the QLA.

First among all, is the continuous assessment of biodiversity (both flora and fauna) at the project site. This is necessary because the 3-month period used in assessing biodiversity was not enough to give all the potential
species at the site since some species may take more time than three months to emerge at newly reclaimed sites, especially the more energy-demanding and shade-tolerant species.

Assessment of arsenic concentration at the site will also be monitored. The initial results from the soil analyses for potential metal concentrations have shown arsenic concentration to be above the standard threshold. Subsequent analyses will be carried to confirm the actual concentration and the need for any corrections through phytoremediation technology.

Continuous Monitoring of nutrient status at the site. Results from soil analysis in determining nutrient status prior to revegetation have indicated low levels of plant nutrients at the site. Continuous soil sampling and analyses will be carried out to determine the rate of mineralization and any subsequent need for fertilizer application for the various planted crops.

Monitoring growth performance of the planted fruit – and tree- crops. The limited period of time as far as the QLA is concerned, did not allow for growth assessment of the planted-species. To be able to fully assess the growth performance of these crops in the different growth media requires continuous monitoring by taking data on diameter and height increments to determine growth rates.

It is, therefore, proposed that the above monitoring activities should continue for some time in order to evaluate the overall success of this pilot reclamation project to be implemented during the final post-project reclamation at the YLQS and other similar quarry sites.

8.0 REFERENCES


Hutchings T, Sinnet D, Doick K. 2006. Soil sampling derelict, underused and neglected land prior to greenspace establishment; Best Practice Guidance Note 1. The Land Regeneration and Urban Greening Research Group, United Kingdom.


**APPENDIX 1.** List of plants species visually identified on the various treatment plots.

<table>
<thead>
<tr>
<th>Growth Media</th>
<th>Plant Species</th>
<th>No. of individual species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOPSOIL</strong></td>
<td><em>Tridax procumbens</em></td>
<td>56</td>
</tr>
<tr>
<td></td>
<td><em>Lycoperiscum spp</em></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Chromolaena odorata</em></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><em>Aspilia africana</em></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>Mimosa spp</em></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>Solanum torvum</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><em>Sida acuta</em></td>
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</tr>
<tr>
<td></td>
<td><em>Physalis angulata</em></td>
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</tr>
<tr>
<td></td>
<td><em>Richardia brasiliensis</em></td>
<td>53</td>
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<tr>
<td></td>
<td><em>Setaria pallide</em></td>
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<tr>
<td></td>
<td><em>Cassia occidentalis</em></td>
<td>17</td>
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<tr>
<td></td>
<td><em>Talinum triangulate</em></td>
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</tr>
<tr>
<td></td>
<td><em>Creeping plant</em></td>
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<td></td>
<td><em>Wild garden eggs spp</em></td>
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</tr>
<tr>
<td></td>
<td><em>Ricinus communis</em></td>
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<tr>
<td></td>
<td><em>Cola gigantia</em></td>
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<tr>
<td></td>
<td><em>Centrocaema spp</em></td>
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</tr>
<tr>
<td></td>
<td><em>Oryza longistaminata</em></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><em>Canna indica</em></td>
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<td><strong>Poultry manure</strong></td>
<td><em>Tridax procumbens</em></td>
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<td><em>Chromolaena odorata</em></td>
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<td><em>Aspilia africana</em></td>
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<td></td>
<td><em>Ricinus communis</em></td>
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<td><em>Creeping plant</em></td>
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