ASSESSMENT OF THE COLLABORATION AND COMMITMENTS AMONG MINING COMMUNITIES, MINING COMPANIES AND THE GOVERNMENTAL INSTITUTIONS TOWARDS THE REALISATION OF RECLAMATION GOAL

(A CASE STUDY OF THE RECLAIMED KUBI MINED SITE)

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DECLARATION

I do declare that except for references made to other people's work which have been duly cited, this work submitted as a thesis to the Department of Material Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi for the degree of Master of Science in Environmental Resources Management is the result of my own investigation.

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DEDICATION

This work is dedicated to my family.

ABSTRACT

Mining is an age old activity in Ghana and dates back to several decades. Starting as a simple alluvial activity it has transformed to the present day industrial level characterized by massive underground drills and heavy surface excavations which come with numerous environmental problems such as land degradation, thus, necessitating the reclamation of affected lands to ensure that society retains multiple use opportunities of such sites.

This study which is a case study of Anglogold Ashanti's reclamation of the their Kubi concession, was to determine the level of involvement of the Kubi communities in reclamation planning and decision making and their overall understanding of the reclamation process, the commitment of the company to reclamation activity in terms of management and hence the general performance of the established trees, species diversity and site conditions of the reclaimed site. Questionnaires were administered to community members while tree height and diameter measurements, species numbers and types and soil samples were taken from repeated sample plots that were laid on the reclaimed site.

The study revealed that communities were not involved in the reclamation decision making contrary to provisions under the Environmental Assessment Regulation. Secondly, the communities could not foresee how the reclaimed site could be useful to them in the future as their expectations were clearly different from that of the company. While the exotic species such as *Senna seamia* and *Acacia mangium* performed well on the site, almost all the indigenous species such as *Ceiba pentandra*, *Entandophragma angolense* and *Terminalia ivorensis* were stunted because of poor management and accounted for only 3.6% of the

reclamation species on the site instead of the 40% indigenous species recommended by the EPA. The soil chemical condition with a mean pH of 5.5 was good with most of the soil nutrients tested within the average range for most standard soil classifications.

It is recommended that further studies be conducted to find out the heavy metal levels on the reclaimed site because of their potential to contaminate underground water and streams since the communities depend solely on such streams.

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1.0 INTRODUCTION

1.1 Background

Mining in Ghana dates back to several decades in the past, using simple methods to extract the ore and subsequent treatment to obtain the metal. For example gold mining before the mid-nineteenth century was mainly alluvial, (miners recovering the ore from streams). Modern gold mining that plumbs the rich ore below the earth's surface began in about 1860. Since then, heavy machinery have been employed to excavate massive land tracts for mineral extraction and processing (Ghana Minerals Commission, 2005).

As a result of mineral extraction massive landscapes have been altered with uncovered pits and shafts with consequential land slides which normally have become death traps. There is also pollution of surface water by sediments or heavy metals, air pollution, loss of soil fertility due to loss of top soil and changes in vegetation resulting in loss of productive land.

Subsequently, it became necessary to introduce several environmental policies and regulations. Although from a different perspective, Cap 157 of 1929, which gave the colonial masters the mandate to designate certain areas as forest reserves in which activities such as mining, hunting, fishing etc. were prohibited without permission, was one of the first major steps to safeguard Ghana's environment.

Section 72 of the Minerals and Mining Law of 1986, (PNDCL 153), mentions environmental protection and prevention of pollution as part of operational requirements for mining companies, The Parliamentary Act 490 of 1994, which established the

Environmental Protection Agency (EPA) gave it the mandate to manage Ghana's environment in ways it deemed appropriate, while the Environmental Assessment Regulation 1999 (LI 1652) required undertakings listed under schedule 1 of that regulation among others to seek registration with the EPA and obtain environmental permit for any new development and subsequent operations. Others included The 1999 National Land Policy. All these are geared towards overall management and protection of the environment.

According to the EPAs guidelines for reclamation, and the Environmental Assessment Regulation, 1999 (LI 1652), companies are expected to undertake Environmental Impact Assessment and submit their reclamation plans including cost for any particular land use after the surrounding communities' opinion or interest and the previous land use have been considered unless the nature and extent of transformation is so severe that it cannot be returned to the previous land use.

Moreover, mining companies in Ghana are enjoined to post a reclamation bond which binds them to reclaim mined sites to reverse the negative impacts caused to the environment after mining operations have ended LI 1652 (1999).

1.2 Problem Statement

The current observation is that for land reclamation, mining companies frequently use trees which have little or no benefits to local communities. Such trees have little or no ability to restore degraded mined sites. Moreover, forest communities are not consulted as the law prescribes on the end use to which sites will be put after reclamation.

In some mined out areas, tree species like *Tectona grandis* (Teak) and *Terminalia catapa* (Indian almond) have been used for reclamation without considering species like *Leucaena leucocephala* and *Albizia lebbeck*, which have nitrogen fixing and soil binding abilities.

In view of the above, reclaimed sites do not meet the expectations of local communities due to the non involvement of such communities during the reclamation process in terms of decisions on species planted and more importantly the end use after reclamation. Consequently, most reclaimed sites are abandoned making the exercise ineffective and not beneficial to local communities as expected.

This raises a lot of questions, especially when about two percent of our productive forest reserves such as the Subri River Forest Reserve, a Globally Significant Biodiversity Area (GSBA) and Opon Manso Forest Reserve are being contemplated to be given out as mining concessions to mining companies for mineral prospecting and extraction.

It is neither realistic for Ghana to abandon its quest for economic development and growth while large quantities of minerals lie unexploited beneath our soils nor to imagine the mining companies removing the minerals without some damage to the environment occurring.

The bottom line however, is to produce as much of these minerals as possible with a minimum impact on the environment. What is seriously needed therefore is a realistic set of guidelines which will give the mining companies freedom to remove the resources but with enough control to ensure proper reclamation so that mined lands could be reused by local communities.

The need for conservation of environmental resources especially land and forest resources has never become greater than at present. This has been fuelled by rapid population growth, urban expansion and industrialisation and thus making these environmental resources relatively scarce commodities.

This study is therefore timely and significant in three ways;

- Firstly, that it is going to be carried out at a time when a number of Ghana's forest reserves are being contemplated to be given out as mining concessions to mining companies for mineral extraction.
- Secondly, that it will provide baseline data for comparison and reference for other assessments.
- Finally, it will provide information which will serve in enriching the existing modalities for reclamation in both forest reserves and off-reserve areas in Ghana.

1.3 objectives

The objectives of this study were therefore to assess;

- The condition of the selected reclaimed site, tree species suitability, growth performance, diversity and richness.
- The collaboration among communities, EPA, FSD, Minerals Commission and mining companies in the reclamation of mined forest sites and the general commitment of stakeholders to reclamation prescriptions.

2.0 LITERATURE REVIEW

2.1 Mining in Ghana

Ghana is endowed with substantial mineral resources. The mining sector is the largest foreign exchange earner having overtaken cocoa in 1991 with gold being the highest contributor. Generally, the mining sector has grown considerably since the initiation of the economic recovery programme in the 1980s. For example, gold production increased progressively from 299,615 ounces in 1985 to 541,406 ounces in 1990 and soared to 1,708,531 ounces in 1995 (Adade and Boakye, 1997). Gold production increased to a peak production level of 80,000 kg of gold in 1999 (Coakley, 2003). The weak gold price and drop in risk exploration capital saw production drop to approximately 69,000 kg/yr from 2001 through 2003 (Coakley, 2003)

Mineral exports thus have accounted for about 40% of the countries total gross foreign exchange earnings since 1992 compared to about 20% in the 1980s. Foreign exchange earnings from minerals increased from $107.9 million in 1995 to $682.2 million in 1995 (Adade and Boakye, 1997). The gold industry continues to lead the minerals sector in Ghana. On the other hand, in 2002, about 363,000 tonnes of manganese ore and 684,000 tonnes of bauxite were also produced. Production of diamonds included about 193,000 carats of industrial quality and 770,493 carats of gem quality (Encarta Encyclopedia, 2005)

In 2003, formal mining and quarrying accounted for approximately 25% of the GDP, about 10% of Government revenues and employed about 14,000 workers. Artisanal miners, who are locally known as "galamsey," may have accounted for an additional 100,000 people involved in diamond, gold, and industrial mineral exploitation, some of which was illegal. Ghana is among the leading gold producers in Africa, the third leading African producer of aluminum metal and manganese ore, and a significant producer of bauxite and diamond (Coakley, 2003).

In addition, a number of industrial minerals, which included clays (kaolin), dimension stone, limestone, salt, sand and gravel, and silica sand, are produced on a small scale (Barning, 1997).

Other beneficial roles of the mining sector to the economy includes employment, development of the mining communities by providing them with social amenities like good drinking water, electricity, constructing of roads and school buildings. The mining companies also contribute to the internal economy through the payment of taxes.

With Anglo Gold investing $1.4 billion to acquire Ashanti during 2003 and 2004 and actual or planned capital investment by the top five gold companies active in Ghana of nearly $1.7 billion, gold production is expected to increase to between the 100,000 to 103,000 kg/yr from 2007 to 2010. Recent reinvestment and rehabilitation of bauxite and manganese mining operations and the proposed privatization of the state diamond mining company suggested that the mining sector would be a significant component of the economy for at least the next decade (Coakley, 2003).

2.2 Mining

Mining is a process that begins with exploration and continues through ore extraction and processing to the closure and rehabilitation or reclamation of worked-out site (UNEP, 2000).

2.2.1 Mining methods in Ghana

According to Gregory (1983), there are four main types of mining operations namely;

- Underground mining.
- Surface mining.
- Alluvial mining (Placer mining). This relates to the recovery of heavy (high specific gravity) minerals that have become concentrated in secondary deposits following their separation by weathering agents from primary higher up watersheds.
- Non-entry mining; e.g., Frasch process for sulfur and Solution mining.

Tagoe (1999) stated that the mining method employed to extract a particular mineral is determined by a number of factors, the most important being the depth, configuration, grade and mineral characteristics of the ore body, the geology of the host rock and also economic factors.

2.2.1.1 Underground mining

Underground mining takes place when minerals lie deep beneath the surface. It is only economical for high grade ore bodies (UNEP, 2000). In this method, shafts are sunk vertically until the minerals are reached (Gregory, 1983). An inclined passage way (winze) must be drilled for ore and waste removal as well as to provide ventilation (UNEP 2000).

2.2.1.2 Surface mining

This is the removal of soil and rock or the overburden material above the mineral seam and extraction of the exposed mineral. The method is usually dominated by large operations of stripping, loading and hauling which involves the use of heavy earth moving machines (Tagoe, 1999).

There are several forms of Surface mining, including, Strip mining, Open pit mining and Dredging.

Strip mining requires removing a large amount of overlying materials to expose the desired ore. Most Strip mining is done for the extraction of coal (Vasilind and Weiner, 1990). Open pit mining on the other hand is done for a range of minerals that is, metals and non-metals where little over burden material is removed (Gregory, 1983).

2.2.2 Impact of surface mining on vegetation

Mineral extraction could result in the destruction of forests, which might not be under threat from any other human activity (UNEP, 2000).

Duncan and Sayer (1991), identified that cutting of new paths during exploration can provide access to poachers, settlers and illegal loggers. Risk of forest fires may increase during extraction and also the mine camp may become the focus for new settlement and colonisation leading to further clearing of forests for housing, farming etc.

2.2.3 Impact of surface mining on soil

The negative impacts of surface mining on land are many. According to UNEP (2000), the removal of the top soil and its subsequent mixing with the overburden changes soil catena. These activities deprive soil organisms and other wild animals their habitat.

Erosion becomes a serious menace under any form of mining activity that scraps off the vegetation and the valuable fertile soil. Erosion has the effect of carrying the physical and chemical constituents of soil away and makes it impossible to support agriculture.

There may also be changes in the land form which involves the removal and deposition of rocks and other over burden materials that do not contain the mineral on the surface of the land. This heap of mine waste occupies a large amount of land and disfigures the landscape. In most cases, trenches and excavations are also uncovered at surface mining sites. These therefore cause serious problems for development of the areas since it impedes construction work and make the cost extremely high (UNEP, 2000).

Mine soils are most often deficient in nitrogen. Nitrogen is deficient largely because of the absence or reduction of soils with an organic base, especially whenever topsoil has been removed (Hossner, 1988).

2.2.4 Impact of surface mining on air quality

Law (1984), stated that the main air pollutants from mining are suspended particulates, solids and liquid particles arising into the atmosphere from combustion, abrasion or disturbance. Nemerow (1978) noted that 7000 acres of forests immediately surrounding the Tennessee upper basin are completely denuded as a result of Sulfur Dioxide damage and a further 17,000 acres forest was replace by grasses. Again, the commonly used untarred roads for mining activities generate thick dusts which tend to block stomatal pores in plants and subsequently affect their physiological processes such as photosynthesis (Nemerow, 1978). Besides, dusts may cause respiratory diseases such as bronchitis and pneumonia.

2.2.5 Impact of surface mining on water quality

The dangerous reagents used in the treatment of mineral ore may cause problems. One of such reagents commonly used is Cyanide, which is extremely toxic to man, animal and aquatic life (Nemerow, 1978). According to Law (1984), water can also be polluted by altering its state by other means than chemical and these are mostly process related. Law (1984) further noted that processes such as increasing sediment load which results in increased turbidity, raising water temperature through discharges into streams, ground water interception and water course diversion may all result in the destruction of aquatic habitats and increase in endemic diseases among users of water that has been contaminated by the mining operations.

2.2.6 Social impact of surface mining

Mineral extraction can cause the displacement of forest dwelling communities, distortion of land economy, chronic pollution and noise from crushing and transport (Duncan and Sayer, 1991). According to Gormey (1997), also, all dust from mining whether toxic or otherwise, present a serious nuisance for nearby communities. Furthermore, full time farming activities become very difficult in most mining areas. This is because farming activities are not allowed in the concessions. In several cases agricultural crops are destroyed during the exploration causing production loss resulting in huge financial cost and social disorientation of such communities.

2.3 Mined sites reclamation

Reclamation, according to Law (1984), implies that the reclaimed site is inhabited by the organisms that were originally present or by others that are similar to the original inhabitants. In short, reclamation strives to rebuild entire properly functioning ecosystems on disturbed lands (Depuit, 1988). Such ecosystems provide the widest range of options for changing land uses in the future and for diversity in physical, chemical and biological resources (Laycook, 1980; Law, 1984).

2.3.1 Objectives of reclamation

In the past, reclamation programmes for lands which had been drastically disturbed (by mining, construction, overgrazing, severely eroded croplands, etc.) usually consisted of attempting to establish suitable and adapted vegetation for the sole purpose of erosion control. This according to Hossner (1988), was certainly a worthy objective and for most part, various reclamation programmes adhering to this objective have been successful.

According to Law (1984), reclamation primarily depends on the goals set by society which in turn are determined by what society wants and needs from its natural resources by the physical and ecological conditions of the site and the economic and social trade offs.

Three broad reclamation goals according to Depuit (1988), are therefore appropriate;

- To ensure that society retains multiple use opportunities of the site.
- To obtain desired environmental quality through rapid stabilisation of soils against erosion and pollution, and
- To develop into diverse and self sustaining vegetation ecosystems through plant succession.

Therefore, reclamation planners now must formulate restoration plans which must fulfill these major objectives (Hossner, 1988):

1. Newly reclaimed lands must be stabilised against accelerated wind and water erosion.
2. Revegetation programmes must target specific landuses

2.3.2 Considerations for successful reclamation

For a successful reclamation to take place there should be a carefully laid down plan (Singer and Munn, 1999). Planning must include consideration of the proposed Landuse Plan and the Mining Operation Plan. Because of their interrelationship, these plans should be developed simultaneously prior to disturbances of the site as part of a comprehensive programme (Law, 1984). The Reclamation Plan ensures that the site is reclaimed after mine operations cease (Singer and Munn, 1999). In the first instance, this requires a full appraisal of the physical and chemical characteristics of the waste and the scope for ameliorating the unfavourable characteristics of the site (Beeny, 1993).

Restoration usually includes demolition of structures, sealing of mine openings, regarding to approximate pre-development profile, revegetation for stabilisation, water treatment among others. Cost for the restoration is projected and the financial plan designed to be implemented throughout the life of the project is prepared (Singer and Munn, 1999).

Local participation in all the stages above has been identified as a crucial factor for reclamation success. For example, in Ghana, the Ministry of Lands, Forestry and Mines, through the Minerals Commission, after carrying out pilot reclamation schemes to rehabilitate three areas in the Western, Greater Accra and the Eastern region identified stakeholder participation as very paramount to ensure the sustainability of the project. Consequently, the participation of communities through the planning, design and implementation stages was ensured (Ghana Minerals Commission, 2005).

Reclamation programmes should take into consideration the following agronomic principles;

According to Hossner (1988), for any use, with any type of vegetation (native or introduced) for any region, the following must be satisfied.

- The proper plant material must be selected for the intended use.
- The intended use must be reasonable and feasible.
- Proper adjustment must be made to the growth medium in order to optimise the establishment and growth of the selected vegetation.
- The vegetation must be established at the appropriate time with the right methodology.
- If needed for the intended use, the established vegetation should be properly managed in order that one can reasonably obtain the planned use.
- One should set certain minimum standards so as to judge the relative success of the restoration programme

2.3.3 The reclamation process

The following are some of the processes that go on during reclamation of mined lands

2.3.3.1 Earth works

During reclamation of mined out sites, the following earthworks may be necessary;

- Backfilling
- Grading and leveling
- Ripping
- Handling and Replacing Top Soil

2.3.3.1.1 Backfilling

With few exceptions, backfilling must achieve the approximate original contour that existed before mining. This includes the elimination of high walls, spoil piles and depressions, stable post mining slopes and slopes which may not exceed the angle of repose or a lesser slope (Grim and Hill, 1974).

Three areas of major long term concern in backfilling are slope stability, ground water control and water quality maintenance.

2.3.3.1.2 Grading and leveling

Grading helps to remove steep slopes, reduce the problems of soil instability as a result of erosion and enables stripping of surrounding topsoils, which are available for re-spreading. However, minimising compaction on sites where trees are to be planted cannot be over emphasised. Simple leveling of the dump spoil material with small bulldozers is recommended. Areas or slopes where trees will be planted must not be track leveled and rough grading is recommended (Skousen, 2002).

2.3.3.1.3 Ripping

Ripping encourages infiltration, reduces erosion compaction and increases the volume of soil readily accessible to plants. In order to further mitigate the problems of compaction, tillage of the soil is required (Evans, 1982).

2.3.3.1.4 Handling and replacing top soil

Removal of top soil prior to mining and replacement of the top soil as the final cover following mining is a requirement in reclaiming mined sites (Grim and Hill, 1974). Top soil is used to top dress all reformed spoil piles and other disturbed areas. The main use of the top dressing with soil is to provide a better physical environment for the initial germination. However, top soil also serves to retain water or limit the movement of water, decrease the influx of atmospheric oxygen into the underlying mine spoil and increase neutralisation capacity. These help limit acid mine drainage generation (Down and Stock 1973).

Law (1984) noted that handling of top soil is crucial in the reclamation process. Top soil undergoes a marked deterioration and acidification whenever it is stored improperly for a long time as a result of anaerobic decay of organic matter in the stockpile. It is important to ensure that soils are not stripped or replaced when they are too dry or too wet as this can lead to compaction, loss of structure and loss of micorrhizal inoculums. Top soil should be replaced along contours where possible. Spreading of top soil is preferable in dry weather when it is friable and the machinery used has minimum effects (Down and Stock, 1973).

2.3.3.2 Revegetation

Revegetation is the process of replacing the original ground cover with grass following land disturbance and this is followed by the planting of trees (reforestation). Revegetation and reforestation are used to improve the appearance of the site and for useful purposes such as agriculture and reduction of erosion (Lima and Wathem, 1999; Mantey 2004).

When attempting to restore a native ecosystem, the initial revegetation is unlikely to provide vegetation that is identical to the original. The initial revegetation effort establishes the building blocks for a sustaining system so that successional processes lead to the desired vegetation complex (Arnon and Johnson, 1942).

Furthermore, revegetation of degraded areas is a means of improving land productivity. Burial of undesired materials during spoil replacement, reduction of slopes through dredging, replacement of topsoil, seeding, mulching and irrigation are all practices which may be use for revegetating mined land. The success of revegetation depends on precipitation pattern, physical and chemical characteristics of surface topography and revegetation species mixes (Arnon and Johnson, 1942).

2.3.3.2.1 Species selection for revegetation

The selection of plant species for revegetation of mined out sites is an important aspect of the reclamation process. The selection of an unsuitable species can result in much wasted effort, money and years of time if failures are slow to appear hence large scale planting should be based on proven experience or reliable research (Burley and Wood, 1976).

If the land is to reach its full productive potential, the species to be established must be such as to accomplish a wide range of purposes since it is difficult to justify planting degraded lands for soil conservation purposes alone (Bostanoglu, 1976). On the other hand managing solely for diversity may not be an appropriate strategy since some management practices may exclude valuable but uncommon species from a given habitat (Balda, 1975; Schemnitz, 1980).

Therefore, according to Sengupta (1993), the species selection for establishment will depend on the future landuse of the area, soil conditions and climate. Hossner (1988) noted that species of trees or shrubs that may be used for reclamation have specific characteristics and are adapted to a range of site conditions and land management objectives. Further, climate is a major consideration when selecting plants for erosion control and other targeted landuses. If plants are not adapted to a particular region or area, they on their own cannot successfully fulfill land reclamation objectives.

Law (1984) stated that plants native to the rehabilitated area have been widely recommended as desired species for revegetation. The concept of utilizing native species, according to him, would seem appropriate because native vegetation is an expression of both local soil and climate. Although introduced species have shown desirable short term characteristics, questions arise concerning the ecological impacts on plant communities dominated by aggressive introduced species.

However, Hossner (1988), states that most successful land restoration programmes have used a combination of both native and introduce species at some stage of the reclamation process.

Young (1997) therefore enumerates the characteristics of trees for soil improvements and reclamation as follows;

- Dense network of fine soil roots with capacity for abundant mycorrhizal association.
- High rate of nitrogen fixation,
- High rate of production of leafy biomass,
- Existence of deep roots,
- High and balanced nutrient content in the foliage litter or high quality nitrogen low in lignin and polyphenols,
- Appreciable nutrient content in the root system,
- Either rapid litter decay where nutrient release is desired or moderate rate of litter decay where maintenance of a soil cover is required,
- Absence of toxic substances in the litter or root residues,
- The capacity to grow on poor soils,
- Absence of severe competitive effects with crops particularly for water and
- Low invasiveness.

2.3.3.2.2 Factors affecting revegetation

High surface temperatures can cause high evaporation rates of soil water, reducing water availability and limiting plant establishment. Factors that affect moisture in the environment, such as evaporation due to wind exposure and high surface temperatures are important in extremely acidic areas with pH of 3.5 or less since very few plants can be established in such areas (Sengupta, 1993).

2.3.3.3 Care and maintenance of reclaimed sites

Maintenance that may be required in addition to rehabilitating any failed areas includes watering planted seedlings, fencing to stop excessive grazing of rehabilitated areas, fertilization, pest and weed control and liming to control pH or heavy metals (Minerals Council, 1998).

2.4 Soil fertility

Soil fertility is the capacity of the soil to support plant growth under the given climate and other environmental conditions (Young, 1982). A wider concept of soil fertility is that of land productivity, the capacity of land resources to as a whole (climate, water, soil etc) support the growth of required plants including crops, trees, and pasture on a sustainable basis.

Plant growth may be retarded because the essential elements may be lacking in the soil, they become available too slowly or because they are not adequately balanced by other nutrients. For normal growth in plants, certain nutrients must be present and available for use and their concentration must be adjusted properly (Olaiton and Lombin, 1984).

Mine soils inherit their properties from the materials used to create them. They have a different distribution of N, C, pH, Clay and Micro organisms than do natural soil. Most mine soils have two common properties. They have many more rock fragments than natural soils do and they lack the structure of natural soils. This lack of structure may decrease infiltration and increase runoff as well as erosion (Singer and Munn, 1999).

Many spoils derived from mining and quarrying have poor physical and chemical characteristics which prevent rapid colonization of plants. This can be overcome by applying topsoil that can immediately support plant community although this is usually an expensive tool (Singer and Munn, 1999).

The forest floor on the other hand, exhibits peculiar characteristics acquired under the influence of three factors uncommon to other soils i.e. forest litter, tree roots and specific organisms whose existence depends on the presence of forest vegetation. The forest floor is therefore important as a slow energy release source of nutrients, as an energy source for organisms and as a covering for protecting the soil against runoff, erosion and temperature extremes (Young, 1982).

2.4.1 Soil organic matter and fertility

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residue and other organic compounds synthesised by the soil microbes as the decay occurs. Such material is continually being broken down and resynthesised by soil microorganisms (Brady, 1990).

According to Bonh *et al.* (1985), organic matter contributes to plant growth through its effects on chemical, biological and physical properties of the soil. It has great influence on the water holding capacity and nutrient availability in the soil. Organic matter acts as a slow release form of fertilizer for nitrogen and to a lesser extent for calcium, potassium and phosphorus as well as for some trace elements (Shepherd, 1986). It serves as an energy source for soil microfloral and microfaunal organisms and promotes good soil structure (Bonh *et al.,* 1985). Organic matter binds mineral particles into granules that are largely responsible for looser, easily managed condition of productive soils and increase the amount of water a soil can hold (Brady, 1990).

Moreover, soil organic matter according to (Bonh et al., 1985) supplies nearly all the Nitrogen, about 50 to 60% of the Phosphate, perhaps as much as 80% of the Sulfur and a large part of Boron. The amount of Nitrogen (N_2) fixation by free living bacterium Azotobacter, for example, is related to the amount of readily available energy source in the soil such as carbohydrates in soil organic matter.

On the basis of organic matter content, soils are characterized as Mineral or Organic. Mineral soils form most of our cultivated land and may contain from a mere trace to 20 or 30% of organic matter (Prasad and Power, 1997). Soil is divided into four main classes based on the percentage of organic matter content; zero to one percent is low, 1.1 to 3.0 % is medium, 3.1 to 10 % is high and greater than 10 % very high (Law, 1984).

2.4.2 Soil pH and fertility

Soil reaction or pH is a basic property of a soil which influences many aspects of plant growth and which is relatively difficult to manipulate (Shepherd, 1986). Soil pH controls the solubility and precipitation of chemical compounds of all essential plant nutrients and is therefore a deciding factor on their availability. It has a far reaching influence on soil fertility and plant growth. For example, in strongly acidic soils, Ca, Mg, P, Bo and Mo become deficient while Mn and Fe may reach toxic limits (Prasad and Power, 1997). The root system of plants may also be adversely affected by Al toxicity which is probably the major limiting factor to plant growth and crop production in strongly acidic soils (Bonh *et* *al.*, 1985). The availability of nitrogen is somewhat restricted at low pH values whereas that of phosphorus is best at intermediate and high pH values (Barber, 1995).

Bonh *et al.* (1985) summarises the effects of low pH on plant growth which are generally caused by toxic levels of soluble ions in the soil solution. Such effects can also arise from nutrient imbalances. However, the concentration of nutrient ions may either increase or decrease under acid conditions.

Several soil reaction ranges have been suggested as the optimum for proper plant growth and performance. pH values greater than 8.5 are considered to be very high, 7.0 – 8.6 (high), 5.5-7.0 (medium) and values less than 5.5 (low) (Landon, 1996). Bonh *et al.* (1985) also states, that plants do differ in their pH requirements, however, the soil pH for crop production is generally considered to be between 6.5 and 7.0.

Law (1984) however does not give a quantitative pH range but a qualitative description by stating that the availability of some plant nutrients is limited in both extremely acid and strongly alkaline soils but not in soils that are moderately acid to slightly alkaline.

2.4.3 Effects of some soil nutrients on plant growth

2.4.3.1 Soil Nitrogen (N)

Soil nitrogen (N) is primarily in the organic fraction of the soil. The atmosphere above the soil contains 79% N but this N can only be used by leguminous plants with rhizobium in nodules on their roots. The N in the mineral fraction includes ammonium fixed in the clay minerals, exchangeable ammonium on cation exchange sites and in solution and with that in the organic fraction. Nitrogen in the organic matter come initially from the atmosphere via plants and microorganisms that have since decomposed and left resistant and semi resistant organic compounds during the development. The bulk of soil N is present in the upper soil horizon where the bulk of soil organic matter is located (Barber, 1995).

The nitrogen content of soil decreases when brought under cultivation as a result of increased rate of oxidation of the soil organic matter (Wild, 1988; Mantey, 2004) and because Nitrogen is taken up in greater amounts by agricultural crops than by trees (Young, 1982). For example in Saskatchewan, where rainfall is significantly low, the N content of the top 22.5cm of the soil fell from 0.35% to 0.25% in the first 22 years of cropping (Wild, 1988; Mantey, 2004). N losses from the soil may also be due to leaching, cultivation, burning, denitrification and immobilisation. (Olaitan and Lombin, 1984).

2.4.3.2 Soil Phosphorus (P)

Phosphorous is an important nutrient in crop production since many soils in their native state do not contain sufficient available phosphorus to maximize crop yield. Phosphorus content of soils may vary from 0.02 % to 0.05% with an average of approximately 0.05% (Barber, 1995). Irrespective of the pH of soil, phosphorus concentrations are usually low. Therefore if soil pH is suitably adjusted for phosphorus, the other plant nutrients if present in adequate amounts will be satisfactorily available in most cases (Barber, 1995).
A large fraction of the P present in soil is in mineral form and is not readily available for plant absorption

2.4.3.3 Soil Potassium (K)

The potassium content in soils varies widely and is dependent on the parent material. Compared with other nutrients, the amount of K in the soil is usually high especially in newly opened fallows or in soils derived from basement complexes (metamorphosised rocks) or volcanic ash (Olaiton and Lombin, 1984). According to Barber (1995), soils having little weathering have higher than average potassium content.

Soils derived from sandy parent materials e.g., sedimentary sand stones are characteristically low in K. Over 95% of the K in soil is contained in primary and secondary clay minerals like feldspar and micas. In spite of the relatively high K content of soils, the quantity held in exchangeable form at any one time is often low or very low with an average of about 0.1 to 0.25 me/100g for most tropical soils (Olaiton and Lombin, 1984). The average potassium concentration in the soil is 1.2 me/100g. In general however, agricultural crops have a greater nutrient uptake rates and requirements than forest crops. This is particularly true in the case of potassium which is taken up in 'luxury' amounts (Young, 1982).

2.4.3.4 Soil Calcium (Ca)

Calcium is usually one of the dominant exchangeable cations in most soils. Calcium occurs in soils and plants as the divalent cation ca^{2+}. Ca minerals weather slightly faster than the average soil minerals. There is therefore a tendency for the present Ca in a soil, to gradually decline as weathering and leaching progress. Very low Ca contents occur in highly leached soils with low cation exchange capacities (Olainton and Lombin, 1984).

There is usually a preferential adsorption of Ca ions over other ions. Ca adsorption is highest in humus because humus has a high CEC. Ca supplies are smaller in acid soils than in alkaline soils. The amount of calcium and other basic cations (Mg^{2+}, K^+, Na^+) present in a soil decline as the soil becomes more acidic and vice versa (Olainton and Lombin, 1984).

Ca concentration values are commonly between 20 mg/L and 40 mg/L, 0.5 to 1.0 mg/I on leached soils corresponding values for arid sands are 50 to 100 mg/L (Barber, 1995).

2.4.3.5 Soil Magnesium (Mg)

Magnesium is also one of the dominant exchangeable cations in most soils particularly those of the tropics. Mg is released from primary minerals by weathering. Mg is absorbed as Mg^{2+} (Olainton and Lombin, 1984). Mg content in soils varies widely and range from about 250 ppm in soils derived from sandstones to nearly 400 ppm in soils derived from volcanic ash. Twenty to 50% of the total Mg in soil usually occurs in exchangeable form.

Mg is essential for the formation of chlorophyll and it is also found in plant seeds. Deficiency of Mg results in chlorosis and whitening of the tissues between the veins (Olainton and Lombin, 1984). Fitzpatrick (1986), reported that severe weathering, soil erosion and clay eluviation tends to reduce the Mg content of surface soil horizon and that Mg excess is indicated when exchangeable Mg^{2+} represents more than 40-60% of the CEC. Mg deficiency is indicated by less than three to eight percent exchangeable Mg^{2+}.

2.5 Ability of trees to improve soil fertility

Many leguminous trees fix nitrogen. These species have small lumps and knots on their roots where the nitrogen fixation takes place. They raise the nitrogen level in the soil and their foliage is rich in nitrogen. *Leucaena leucocephalla* is a common example of such species.

According to Caudle *et al.* (1987), some tree species tend to increase topsoil Ca and Mg by mechanisms which are not clearly understood. This effect is marked with *Gmelina arborea* which appears to be a Ca accumulator in Nigeria and Brazil.

Trees with deep penetrating roots according to Ghana Rural Reconstruction Movement (1994), act as nutrient pumps absorbing nutrients from deeper soil layers, concentrating the nutrients in their leaves and returning them to the soil as green manure or litter. Example of these is *Gliricidia sepium*. Shallow rooted species on the other hand, help to control erosion because their roots bind soil together. These species can be used for soil conservation.

When trees close their canopy, according to Caudle *et al.* (1987), they begin to exert four major positive effects on soil properties.

- Soil surface protection with a double layer of canopy and litter.
- Opening soil pores via root expansion and decomposition.
- Capture of nutrients and storage in biomass.
- Recycling nutrients back to the soil.

2.5.1 Some exotic species with soil improving properties

2.5.1.1 *Gmelina arborea* (Roxb.)

Gmelina arborea belongs to the family Verbanaceae and originates from Central America, the Caribbean, East Asia and tropical West Africa. It has a mean annual rainfall and temperature requirements of 1903.5 mm (minimum = 690 m, maximum = 3029 m) and 20.4 °C respectively and may achieve an average height of 22.2 m. It thrives in clayey, sandy and loamy soils which may be acidic, neutral or alkaline. It does best in well drained soils. It is a multi stemmed tree, deep rooting and has spreading crowns. Propagation is by natural regeneration, seedlings, cuttings, grafting and direct sowing. It is tolerant to shade and constant wind. Its uses range from use as food, fodder, fuelwood, timber, erosion control, soil conservation, shade, shelter, land reclamation and other ornamental uses (Carlowitz, 1991).

2.5.1.2 *Senna siamea*

Senna siamea belongs to the family Ceasalpiniaceae. It is an evergreen and strong light demanding tree that occurs naturally in South East Asia. The species was planted in Ghana, Western Nigeria, Tanzania and Uganda and is now naturalized (Carlowitz, 1991).

It thrives well in light to medium textured soils and adapted to well drained soils. It requires soils with pH ranging from neutral to acidic. Its mean annual rainfall and mean annual temperature requirements range from 650 mm –1500 mm. and 21 °C – 28 °C respectively. *Senna siamea* attains a height of 5 m in 3 years and 15 cm at breast height. Total yield of wood for timber, poles and fuelwood may reach 10-15 m^3/ha/yr (Gutteridge, 1997).

The wood of *Senna siamea* has a gross calorific value dry weight basis of 19,380 Kj/Kg and a specific gravity of 12% with moisture content ranging from 0.60 g/m^3 – 0.80 g/m^3. It coppices well and may be used as food, fodder, fuelwood, timber, erosion control, soil conservation, shade, shelter, land reclamation and other ornamental uses (Carlowitz, 1986).

2.5.1.3 *Leucaena leucocephala*

Leucaena leucocephala belongs to the family Leguminoceae which is found in Australia, Oceania, Central America and the Caribbean. It has a mean annual rainfall and temperature requirements of 1940.8 mm and 16.5 °C respectively (Carlowitz, 1991).

It thrives well in well drained soils which are either shallow or deep. It may attain a maximum and a minimum height of 3.5 m and 20.0 m with an average of 8.8 m. Height growth and mean annual volume increment falls in the range of 3-4 m/yr and 20 to 60 cm^3 for many trials (Dommergues, 1987).

The plant has an open canopy which under normal conditions is evergreen and deciduous in dry conditions. It is tolerant to shade, strongly alkaline soils, seasonal water logging, soil compaction etc (Carlowitz, 1991). It performs poorly in acid soils (Dommergues, 1987). Propagation is by natural regeneration, seeds, cuttings and tissue culture. Its uses include food, fodder, erosion control, mulching and for fuelwood (Carlowitz, 1991).

2.5.1.4 *Acacia mangium*

Acacia mangium belongs to the family Leguminoceae. It originates from Australia and Oceania. It grows well with a mean rainfall of 1381.2 mm and a mean annual temperature of 20.8 °C. It also does well in light and medium or loamy soils. It performs better in well drained soils but can endure seasonal water logging. It can thrive in strongly saline soils and has an average height of 25.6 m. *Acacia mangium* may be used for food, fodder erosion control, shade, ornamental purposes, live fencing and mulching (Carlowitz, 1991).

2.5.1.5 *Cedrella odorata*

Cedrella odorata belongs to the family Meliaceae. It is native to Central America, the Caribbean, West Africa, South Africa, and South East Latin America. It thrives well in deep clayey, sandy and neutral soils which may be acidic, alkaline or neutral. Its annual rainfall requirements ranges from a minimum of 1000 mm to a maximum of 3738 mm with an average of 2352 mm, while its temperature requirements per annum range from 20.4 °C to 29.8 °C. It may reach a mean height of 25.4 m with a minimum and maximum range of 12.5 m and 40.0 m. Propagation is by natural regeneration, seedlings, cuttings, budding and direct sowing. It is self pruning, tolerant to soil compaction, fire resistant and tolerant to strongly acidic soils. Its uses include fuelwood, erosion control, soil conservation, land reclamation, shade, river bank stabilization, medicine, furniture and for boat building (Carlowitz, 1991).

2.5.2 Some Indigenous Species with Soil Improving Properties

2.5.2.1 *Albizia adianthifolia* (Schumach.) Wight, (Pampena)

Albizia adianthifolia belongs to the family Leguminoceae. It is a deep rooted upright tree with medium canopy, spreading crown and is deciduous. It has annual rainfall and temperature requirements of 800 mm–2000 mm and 14.5°C and 28.0°C respectively. It can thrive in clayey or loamy soils which may be acidic or neutral. *Albizia adianthifolia* may reach a minimum height of 10.0 m and a maximum height of 22.5 m with an average of 13.6 m. Propagation is by natural regeneration, seedlings and direct sowing. *Albizia adianthifolia* may be uses for erosion control, soil conservation, nitrogen fixing, soil fertility improvement, as timber, fuelwood, for fencing and as medicine (Carlowitz, 1991).

2.5.2.2 *Albizia zygia* (D.C) J.F. Macbride, (Okoro)

It is usually a small tree, not much bigger than 30 m and 2.4 m girth at breast height. Bole is short, not very straight nor cylindrical. The canopy forms low down and is spreading. It is propagated by seeds and grows rapidly. It may reach a height of up to three meters in two-year old plants. *Albizia zygia* may be used as fodder, fuelwood, for soil conservation, as windbreaks, nitrogen fixing, mulching, shade, medicine, and for food (Ghana Rural Reconstruction Movement, 1994).

2.5.2.3 *Alstonia boonei* (De Wild.), (Onyame dua)

Alstonia boonei is a straight tree of the upper canopy in high forests. Bole appears buttressed. Its crown is small, with horizontal, whorled branches. The tree is commonly found "weeping" in March, through exudation of water from leaves. Propagation is by seed and stumps and has a rapid growth with height increases of two meters per year in the sapling stage. It coppices readily and may be used in carving dolls, fetish emblems, dishes, timber, bee-forage, shade and soil improvement (Ghana Rural Reconstruction Movement, 1994).

2.5.2.4 *Ceiba pentandra* (Linn.) Gaertn., (Onyina, Kapok, Silk-cotton)

Ceiba pentandra is a big tree, which can grow up to a height of 60 m and a girth of nine meters or more. It has huge buttresses, which may extend 7.5 m up the bole and cover a large area on the ground (Ghana Rural Reconstruction Movement, 1994).

It has large, rounded crown made up of huge branches. Cylindrical bole, bearing prickles in the younger stages. Propagation is by seeds and cutting and through natural regeneration. It grows rapidly by 1.8 m or more per year. Often a tree (an old tree that reminds us of the past) its uses range from soil conservation through fodder (seeds, pods, leaves, shoots), fuelwood, shade, live fencing, food (fruit vegetable), medicine to soil improvement. Its wood is used to make canoes and doors. Kapok is used for pillows, mattresses and cushions (Ghana Rural Reconstruction Movement, 1994).

2.5.2.5 *Miliacea excelsa* (Welw.) C.C.Berg. (Odum)

A big emergent tree which can grow up to 49m high and 9m in girth. The stem is tall and cylindrical and has no true buttresses, but root spurs may show considerable development in old trees. Its bole is thick and unbranched up to 24 m or more. It has a dense and dark crown. The wood is durable, almost termite-proof and fire-resistant (Ghana Rural Reconstruction Movement, 1994).

Propagation is by seeds and stumps. Its growth is initially fast, up to one meter in height in the first year for natural planting and up to two meters for artificial planting. These rates however, cannot be maintained. Odum may be used for mulching, nitrogen fixing, fuelwood, fodder (pods, seeds, leaves, and shoots), charcoal, timber, carvings, medicine and shade (Ghana Rural Reconstruction Movement, 1994).

2.6 Anglo gold Ashanti's corporate arrangement for reclamation of the Kubi Site.

Anglo gold Ashanti is fully committed to the eventual reclamation of all areas affected by both historic and on-going mining operations. The main areas earmarked for rehabilitation are open pit mining sites that are under the influence of the Ashanti Mine Expansion Project (AMEP) of which the Kubi site is a part.

2.6.1 Reclamation objective

Within the context of available technology and economic achievability, the overall objective of Anglogold Ashanti's, reclamation plan is to return the Kubi affected areas, as nearly as possible to its optimum economic and ecological values as forestry plantations.

2.6.2 Co-operation policy on the environment.

It is the policy of the company to manage the impact of its activities on the environment. The policy statement on the environment by the company reads as follows;

- To ensure that within economic limits and the need to be internationally competitive, the company's activities are carried out with due regard to ecological and environmental factors through the implementation of international practice.
- To operate in compliance with the spirit and letter of the Government of Ghana Environment Legislation.
- Employ the highest occupational health and safety standards.
- To maintain good communication with persons and communities affected by company operations.
- To make our employees aware of the need to protect the environment and motivate them in taking proper care of it.

The company sees the design, management and implementation of a detailed reclamation plan as essential to cost effective rehabilitation.

2.6.3 Nursery production of plant materials

Two nurseries to raise plant materials have been established to constantly supply seedlings for the large-scale reclamation programme.

The first nursery, located behind Sansu mine offices has been expanded and upgraded. It now has a capacity to produce 500,000 plastic container-grown plants per annum. The planting medium is a mixture of sieved refuse dump soil and poultry droppings.

The second nursery located along the approved road to the south mine offices has a production capacity of 300,000 container plants per annum. Beds of *Vetiveria zizanoides* and *Citronella spp* have been established on a large scale in an open field.

2.6.4 Monitoring of reclamation plan

Monitoring and auditing of the land reclamation programme and other environmental control procedures forms an essential part of mine development, operations and abandonment.

The plan will be reviewed every quarter. Future reclamation activities will be based on this review and where appropriate it will be modified.

A quarterly progress report prepared by the environmental head which will provide details of qualitative, quantitative and financial aspects of the various activities will be provided. As per current practice, the environmental department will submit monthly monitoring reports on reclamation activities to the EPA in accordance with the EPA Act 490. This report will be seen as a major mechanism for monitoring the progress of the reclamation plan.

Post reclamation monitoring for a wide range of parameters will be carried out over a three year period after completion of the reclamation works. The following parameters will be looked at;

- Rate and quality of growth.
- Stability of revegetated embankment especially of waste dumps.
- Water quality of discharges or releases from reclaimed areas.

2.7 Some institutions governing reclamation in Ghana

2.7.1 The Minerals Commission

The environmental assessment regulation does not give the Minerals Commission of Ghana any specific duties but it has involved itself to ensure that sanity prevails in the mining sector. The Minerals Commission is the licensing authority in charge of giving authority for exploration and other minerals operations in the country. They therefore deal with all forms of mining including salt mining. The Commission, whose responsibility is primarily to promote the mining industry, occasionally goes on inspection tours to familiarize themselves with operations of mining companies.

The commission is the institution responsible for recommending mineral policies in Ghana. It is also the link between the industry and government.

2.7.2 The Environmental Protection Agency

The Parliamentary Act 490 of 1994 established the Environmental Protection Agency (EPA). The mission of the Agency among other is generally to be achieved through an integrated environmental planning and management system established on a broad base of public participation, efficient implementation of appropriate programmes and technical services, giving good counsel on environmental management as well as effective and consistent enforcement of environmental laws and regulations.

The EPA is an implementing agency, a regulatory body and catalyst for change towards sound environmental stewardship. As part of its responsibilities, the Environmental Assessment Regulation, 1999 (LI 1652) requires it to ensure that companies undertake Environmental Impact Assessment (EIA) and submit their reclamation plans based on the provisions made by the reclamation guidelines (which indicates the security and technical criteria) for any particular land use after the surrounding communities' opinion or interest and the previous land use have been considered, unless the nature and extent of transformation is so severe that it cannot be returned to the previous land use.

The idea behind land reclamation, according to the EPA, is to ensure that the land has some economic use after mining. Three years or three seasonal cycles is allowed for monitoring by the mining company when they complete reclamation. The EPA is the main regulatory body concerned with reclamation of mined areas.

The criteria used for assessing land use completion are as follows.

1. **Reforested area**

- Tree density equivalent to adjoining secondary forest.

- Understorey providing leaf area index of 1.
- Use of indigenous species not less than 40%.
- Creation of conditions favourable for the return of fauna.

2. Plantation timber or forest resource.

- Planted species stocking rate of 1000 trees /ha.

3. Recreation

- Soils stable and free from erosion through provision of vegetative cover or grass.
- Area functioning for its designed purpose.

4. Water resource or aquaculture

- Dead, inundated and fringing vegetation removed.
- Fresh water inflow assured.
- Littoral zone of 10% of the lake area (pit) must be ensured to sustain biological productivity.

5. Agriculture

- Appropriate topsoil cover.
- On waste dump topsoil cover of 0.5 m thickness is recommended.
- Soils stable and free from erosion.
- Completion of three food crop cycles.
- Qualitative and quantitative analysis of vegetative cover.
- Creation of conditions favourable for the return of fauna.
- Planted cash crops sustainable.

6. Town site

- Soils stable and free from erosion.
- Area functioning for its designed purpose.

According to the EPA an area will be deemed to have a final completion if it continues to retain the criteria for land use as indicated in schedule 2, part 2, when no additional monitoring and maintenance are required after reclamation works have been achieved after 3 seasonal cycles, excluding sites experiencing Acid Rock Drainage (ARD) phenomenon.

Where (ARD) phenomenon occurs, an area will be deemed to have a final completion if it continues to retain the criteria for land use as indicated in schedule 2, part 2, when no additional monitoring and maintenance are required after reclamation works have been achieved after a period of not less than 7 years.

2.8 Some policies and regulations governing reclamation in Ghana

2.8.1 Mineral and mining law 1986 (PNDCL 153)

The Mineral and Mining Law concerns itself mainly with improving the mining sector and making it more attractive to investment and came as part of the transformations under the Economic Reforms Programme. It however gives little attention to specific environmental issues related to the mining industry.

For example, regulation 45 section four sub-section b states that "mining lease shall not be granted to any applicant unless the proposed programme of mining operation submitted by him takes proper account of environmental safety factors" it does not specify which or what environmental safety factors.

Section 72 further states that "the holder of minerals 'rights' shall, in the exercise of his right under the license or lease, have regard to the effect of the mineral operations on the environment and shall take such steps as may be necessary to prevent pollution of the environment as a result of the mineral operations". This regulation does not specify which steps and therefore leaves mining companies the prerogative to decide what they deem 'proper' to be done.

It finally, among the punitive measures in section 80 (f), states that "any person who pollutes the environment contrary to section 72 shall be guilty of an offence" it does not state here again what offence and punitive measures to be applied for such contradictions. It is however only in these sections that environmental concerns are raised. The rest of the law deals with mining leases, surface rights etc

The mineral and mining law on coming into force repealed a number of mining laws most of which were made under colonial rule, including the Minerals Ordinance, 1938 (Cap 155), the Radioactive Minerals Ordinance, 1946 (Cap 151), the Minerals Act, 1962 (Cap 126) and the Mining Rights Regulations, 1905 (Cap 153).

2.8.2 Environmental Protection Agency Act, 1994 (Act 490)

The Parliamentary Act 490 of 1994, which established the Environmental Protection Agency (EPA) repealed the Environmental Protection Council Decree 1974 (N.R.C.D.

239) and the Environmental Protection Council (Amendment) Decree, 1976 (S.M.C.D. 58) and in effect dissolved the Council established under that Decree.

The Act gives the agency the power to manage Ghana's environment in ways it deems fit. For example it has the power to request any person responsible for any undertaking which in the opinion of the Agency has or is likely to have adverse effect on the environment to submit to the Agency in respect of the undertaking an environmental impact assessment. To further strengthen their power section 12 subsection 2 empowers it to restrain any organ or government department with the responsibility for issuing any license, permit, approval or consent from doing so until their directive has been complied with.

Moreover, Section 13 (1) gives the agency the power to enforce recommendations for environmental correction where the agency feels that activities of any undertaking pose a serious threat to the environment or to public health.

The agency also has the mandate to apply punitive measures where a person fails to comply with its directives. Section 13 subsection 4 states that "any person who acts contrary to an enforcement notice under the section commits an offence and shall be liable to summary conviction to a fine not exceeding two million cedis and in default to imprisonment for a term not exceeding one year"

Finally, "where a person to whom a notice has been served under subsection (1) of section 13 fails to comply with the directives contained in the notice within the stipulated time or such further period as the Agency may grant, the Minister, may without prejudice to a prosecution under subsection (4) of section 13, take such steps as he considers appropriate to ensure compliance with the notice".

2.8.3 Environmental Assessment Regulations, 1999 (LI 1652)

In exercise of the powers conferred on the Minister responsible for the Environment under section 28 of the Environmental Protection Agency Act, 1994 (Act 490) and on the advice of the Environmental Protection Agency Board the Environmental Assessment Regulation (1999) was made. This regulation mainly concerns itself with outlining the steps for proper environmental management and punitive measures for non compliance.

On coming into force the regulations empowered the EPA to issue a written notice to persons responsible for any environmental undertaking whether existing or new which has or is likely to have adverse effect on the environment or public health, to seek registration and obtain an environmental permit in respect of the undertaking.

It demands among other things that no environmental permit shall be issued by the Agency for any of the undertakings including conversion of wetlands for industrial, housing or agricultural use, human settlement development undertaking, construction of ports and mining mentioned in Schedule two of the Regulations unless there is, submitted by the responsible person or the company to the EPA, an Environmental Impact Assessment in accordance with these Regulations in respect of the undertaking.

Moreover section five demands for the initial screening of applications and other relevant information for any environmental undertaking to be screened taking into consideration;

a. the location, size and likely output of the undertaking,

b. the technology intended to be used,

c. the concerns of the general public, if any, and in particular concerns of immediate residents if any

d. land use; and

e. any other factors of relevance to the particular undertaking to which the application relates;

An applicant is required under regulation 10 subsection one to submit an environmental impact statement in respect of the proposed undertaking which shall be outlined in a scoping report to the Agency. While regulation 23 requires that for activities which require a reclamation plan the applicant or proponent shall be required to post reclamation bond based on approved work plan for reclamation.

This regulation further requires a company to submit an environmental impact statement after their scoping report has been approved by the agency. The environmental impact statement will then be given public hearing for interest groups to make inputs for improvement after which it will be finally reviewed.

The regulation grants the EPA the authority to Suspend, cancel or revoke permits and certificates of persons who breach any of the sub sections of regulation 26. It also provides punitive measures under regulation 29 which may result in a fine or imprisonment for a term or to both.

3.0 MATERIALS AND METHODS

3.1 Study Area

The Anglogold Ashanti's Kubi concession lies between longitudes 1°40'13" and 1°45'59" west and latitudes 5°57'4" and 6°3'58" north with a total area of 44km^2. It is located immediately north east of Dunkwa-on-Offin in the Adansi West district of the Ashanti region (AGC, 2003). It is within this concession that the project site is located with an approximate area of 19,456 m^2 and was reclaimed in 1998. More than 70 percent of the Supuma Forest Reserve lies within this concession (Appendix 'L').

3.1.1 Soil

The soils are predominantly forest Ochrosols that have developed over Tarkwaian and Birimian rock systems with their colors being red, brown or yellow. They are porous, thoroughly weathered and well drained soils. However, they are less highly leached and are more productive than Oxysols, supporting a wide range of crops and tree species. The surface soil reaction is between 5.5 and 7.0. The reaction tends to become more acidic with depth (Danso, 1975). They are rich in humus and suitable for agricultural practices (Adansi West Dist, 2000)

3.1.2 Vegetation

The original vegetation of the site as classified by Hall and Swaine (1981) is moist evergreen forest. However, the present vegetation is a degradation of the original one characterized by a myriad of vegetation types representing different ages of regrowth. It is a combination of logging and farming activities over the years that has altered the original vegetation. There are notably secondary forests or broken forests upland regrowths and some swamps. Some of the common trees found there are *Ceiba pentandra,* (Onyina) *Triplochiton scleroxylon* (Wawa), *Terminalia superba* (Ofram) and *Pycnanthus angolensis* (Otie). There are also farmlands producing cocoa and food crops. The shrubs that are found include *Rinonea ablongifolia, Baphia nitida* and *Acacia pennata* while the herbs and grasses include *Geophilla spp* and *leptaspis cochleata,* (AGC, 2003).

3.1.3 Climate

The average annual rainfall of the area ranges from 1000 mm to 1800 mm. There are two well defined rainfall seasons. The major season occurs from mid March to the end of July with a peak fall in June. The minor rains commence in September and end in mid November. From mid November to March dry desiccating harmattan winds blow across the area from the north (Adu, 1992).

The average daily temperature of the area is between 26 °C and 29 °C with an annual mean temperature of about 27.1 °C. Humidity ranges between 65 % and 81 % (AGC, 2003).

3.1.4 Kubi Communities

The main settlements around the Kubi reclaimed site were Kubi Kwanto, Old Kubi and Ohia Mpe Anika. These communities are within 1000m of the reclaimed site and their livelihoods were affected in several ways by the mining activity.

3.1.4.1 Ohia Mpe Anika

Ohia Mpe Anika has a population of about 100 people and is about 600m from the reclaimed site. The standard of living is low. There is no connected electricity supply and many buildings are in a state of disrepair. Few of the buildings have roofs with corrugated iron sheets while a majority are roofed with thatch.

Ohia Mpe Anika village has a hand-dug well fitted with a hand pump. This not withstanding, reliance is placed on surface water supplies (Supuma Stream) with some potential for pollution and vector transmitted disease.

The principal occupation of the people of Ohia Mpe Anika is farming for tree crops such as cocoa, Cola and oil palm and food crops like cassava, maize, potato, cocoyam, water yam and plantain. Farming is normally on a small scale, meeting the local food needs of the community.

3.1.4.2 Old Kubi

Old Kubi has a population of about 30 people and is about 650m from the reclaimed site. The settlement has about 10 houses most of which are structurally defective, made of mud and wattle and roofed with thatch.

The mainstay of the villagers is farming. The main crop cultivated is cocoa. The people practice mixed cropping. Sales outlet of food crops are middlemen from Obuasi and Bekwai.

There are no medical facilities so inhabitants travel to Obuasi and Dunkwa for medical attention. The community has one borehole facility provided by Anglogold Ashanti. Old Kubi has no pit latrine so the people defecate in bushes.

3.1.4.3 Kubi Kwanto

Kubi Kwanto is perhaps the largest settlement in the area. It has a population of about 800 people and approximately one kilometer to the reclaimed site. The standard of living of the people is low. There is no electricity supply to the community but many buildings including the primary school and J.S.S. are in good state. A majority of these buildings are roofed with corrugated iron sheets while a few are roofed with thatch.

Places of convenience are not adequate and inhabitants depend upon a pit latrine. Inhabitants travel to Dunkwa or Obuasi for medical treatment. Traditional medicine still plays an important role especially in midwifery and the treatment of routine complaints.

Kubi Kwanto has three hand dug wells fitted with hand pump. Less reliance is therefore placed on surface water supplies.

The principal occupation of the people of Kubi Kwanto is farming for cash crops such as cocoa and oil palm and food crops like cassava, maize, potato, cocoyam, and plantain. The growing of food crops is normally for subsistence. Galamsey' activities involving a few people were present before Anglogold Ashanti began their operations.

3.1.5 Reclamation of the Kubi Site

The Kubi site was reclaimed in 1998. At least two meetings were held with the District Assembly, Traditional Authorities and opinion leaders before the reclamation exercise began. During these meetings representatives of the EPA and mines department were present. At the community meetings, the reclamation proposal was discussed and the landuse agreed (Personal Communication, 2005).

The affected mined site was reclaimed by planting 7000 seedlings per ha at an interval of 1.5 meters. The planting stock comprised 40% indigenous species and 60% exotic species. Some community members were taken as casual workers from the communities for jobs such as tree planting and watering, which did not need any special skills. In view of this no formal training was given to the workers. During the mining stage the communities occasionally complained of dust. The main problem Anglogold Ashanti faced was 'galamsey' activities around the site (Personal Communication, 2005).

Plate 1.0; Trees on the reclaimed site along the main Ohia Mpe Anika road

Plate 2.0; A view of the reclaimed site from within

3.2 Materials

The materials that were used to facilitate this study included both open ended and structured questionnaires to assess stakeholder commitment and collaboration in reclamation, a cutlass for cleaning (where necessary), poles for marking plot boundaries, paint for marking tree backs, metre tape for field measurement, diameter tape for direct diameter at breast height measurements, Haga altimeter for total tree height measurements, Sunto compass for taking bearings, clean rust-free hand trowel for taking soil samples, clean polythene bags for storing samples, Paper carton for handling and transporting samples, Marker for labeling samples, a one meter by one meter quadrat for undergrowth sampling and field data sheets for recording field proceedings and other indicators.

3.3 Methodology

3.3.1 Reclaimed site sampling design

A baseline was laid on the side of the reclaimed site which runs along the main Ohia Mpe Anika road with the use of ranging poles secured at both ends of the length and a Sunto compass. A perpendicular line was erected by taking a 90° bearing to the baseline at the mid point (Plate 3.0), which was approximately 81m to both sides, using ranging poles, a meter tape, cutlasses and the Sunto compass. This resulted in dividing the two hectare reclaimed site into two blocks.

Using the same method and tools the midline was used as a baseline, forward and reverse bearings were taken at its mid point to further demarcate the entire reclaimed site into four main blocks with each block having a size of approximately 78.5m x 62m (4867 m^2), each of the four main blocks were further demarcated into sub plots of area 12m x 15m (180 m^2) (Anglaare et. al., 1997).

The data was collected from five subplots selected at random (by picking plot numbers randomly mixed on a sheet of paper), within each of the four main blocks. In all twenty subplots were assessed. This resulted in a sampling intensity of 18.5 percent, which gives a fair representation of the area.

Data collected on the sampled plots were; tree heights and diameters of the reclamation species, reclamation species and undergrowth diversity and soil chemical properties. Tree diameter measurement was restricted to trees with a minimum height of 1.5m ($h \geq 1.5m$) (NB; the blocks were used to ease data collection hence do not represent different treatments).

3.3.2 Trees diameter and height measurement

On every sampling plot, the diameter at breast height (i.e. 1.3 m from the base) of reclamation species was directly measured with a diameter tape and recorded unto field data sheets (Plate 4.0). The total heights of the trees were also measured with the use of a Haga altimeter and recorded.

The target of measuring five trees of each of the reclamation species per plot was not achieved because in some of the sampling plots some trees had either not reached the minimum height of 1.5 meters to be measured, had died or could not simply be found on the subplot. This was especially so for the indigenous species. Hence in all a total of 333 trees were measured and marked with paint on the twenty subplots.

3.3.3 Species diversity assessment

The total number of reclamation species within each plot was counted and tallied according to the different species while all the undergrowth in four randomly thrown 1m x 1m quadrat within each plot were counted and tallied according to the different species (Adu-Anning and Blay, 2001).

Plate 3.0; Taking a bearing with a Sunto compass

Plate 4.0; Measuring tree diameter at breast height with a diameter tape

3.3.4 Soil sampling

Composite soil samples each bulked for a total of 15 hand trowel points were taken at a rate of three from each plot in a main block, at random to a depth of 30cm of the soil (the soil zone which contains the bulk of the feeding roots) to estimate the soil chemical parameters (Adu-Anning and Blay, 2001).

Composite samples were obtained by mixing randomly collected samples in each plot of the different blocks together in a plastic bowl. The mixture was then poured into transparent polythene bags, labeled and stored in a paper carton for transportation. The bowl was wiped with a clean rag after each round of mixing to prevent cross contamination of different samples from the different blocks. One composite sample was collected for each of the four main blocks on the reclaimed site.

Two composite topsoil samples taken at random locations in the adjacent farms and parts of the Supuma Forest Reserve respectively were treated in the same way as that of the reclaimed site for comparison.

The samples were air-dried, sieved with 2mm sieving material and subsequently analyzed for their N, P, K, Ca, Mg, pH, and Organic matter content (Adu-Anning and Blay, 2001). In all eight soil samples were analyzed.

3.3.4.1 Soil Chemical Analysis

Soil pH was determined by adding 25ml of distilled water to 10g of air dried soil and taking the pH reading with a pH meter.

Total nitrogen concentration was determined by weighing 10 g soil into a 500 ml Kjedahl flask, moistening with 10ml of distilled water and adding Selenium powder and Sodium Sulphate as catalyst. Using Bunsen burner flame, 30ml of concentrated sulphuric acid was added to digest for 2 hours. It was then cooled and decanted into a 100ml volumetric flask and made up to the mark with distilled water.

An aliquot of 10ml was taken into the distillation unit. 20ml 40% NaOH was added and the distillate was collected over 10ml of 4% Boric Acid for about 5 minutes. The presence of nitrogen gave a blue colour. It was then titrated with 0.1 M HCL until the blue colour changed to pink.

To determine available Phosphorus concentration, 2g of soil was weighed into a shaking bottle. Twenty milliliters (20ml) of P1 extractant was added and the mixture was shaken for one minute. It was then filtered and 10 ml aliquot taken into a 25 ml volumetric flask. The colour developed to blue. Distilled water was added to make up to the 25 ml mark. P was determined on a spectrophotometer at a wavelength of 520 nm. The readings gave percentage transmittance. The percentage T values were converted to 2 Log T. A graph was plotted using P standard solutions to obtain actual concentration of P.

Organic Carbon however was determined by weighing 2 g air dried soil and adding 20ml of concentrated Sulphuric Acid and 10ml 1 normal Potassium Dichromate solution. It was left to cool for about 30 minutes then 200ml distilled water and 10ml Orthophosphoric acid added. One milliliter of Diphenylamine indicator was added and titrated with 1 normal Ferrous

Sulphate. This method is termed the Walkley and Black oxidation method. The Organic Matter content was determined by multiplying the Organic Carbon concentration by the Van Bemelen factor (i.e. 1.724) to obtain the Organic Matter concentration.

In determining exchangeable K, 10 g of air dried soil was weighed into a 250 ml shaking bottle. A 100 ml of 1 M Ammonium Acetate Solution was added and the mixture shaken on a mechanical shaker for 2 hours. It was removed and filtered. An aliquot of 10 ml was taken and read for Potassium on a flame photometer. A graph was plotted for K to obtain actual concentration of K in the soil solution.

Calcium on the other hand was determined by taking an aliquot of 10 ml of the extracting solution used for the K into a 100 ml conical flask. Ten milliliters (10m) of 10 M KOH, 1 ml Triethanolamine and a few grams of calcion red indicator were added. The solution was then titrated with 0.02 M EDTA to obtain a blue colour from the original pink colour.

Finally, Magnesium concentration was determined by measuring 10 ml of the extracting solution into a 100 ml conical flask then adding 5 ml of Ammonium Chloride buffer solution and a few drops of Erichrome Black T indicator. It was titrated with 0.02 M of EDTA from the original pink colour to blue colour as end point.

3.3.5 Personal interviews and questionnaires administration

Personal interview method using designed guiding questions was used since it is considered an efficient and most effective method for obtaining information from a population (Ary et. al., 1990; Koudou and Vlosky, 1995). The interviews were held with the Environmental manager of Anglogold Ashanti (Appendix 'I'), to assess the level of technical commitment to the reclamation process, end use of the reclaimed area and the levels of collaboration with the community members, The Regional forestry manager, EPA official in charge of mining operations, Department of mining and Minerals Commission officials (Appendix 'H') were also interviewed to assess the level of monitoring and evaluation and the parameters used in the assessment of success of the reclamation process.

Finally, a Semi-structured questionnaire was used in the three main communities namely Kubi Kwanto, Old Kubi and Ohia Mpe Anika to assess information on collaboration and the involvement of the community in the reclamation and their overall understanding and impressions of the reclamation process (Appendix 'J').

A total of 134 respondents of age 18 and above were administered with questionnaires in the three communities in the Kubi area. Twenty two, 69, and 43 questionnaires were administered in Old Kubi, Kubi Kwanto and Ohia Mpe Anika respectively.

3.3.6 Data Recording and Analysis

The reclamation trees and undergrowth tallies per sample plot, tree diameters and height measurements were recorded on field assessment forms (Appendix 'K') and the data processed by computing Mean annual height increment (m/yr), Mean annual diameter increment (cm/yr), Dominant height (m), Mean height (m), Mean diameter (cm), Mean basal area (m^2/ha) and species diversity. Soil samples were tagged with sample labels (Appendix 'G') to ensure easy identification of samples.

The Shannon Weiner diversity index was used to assess the tree and understorey species on the reclaimed site for their species richness and evenness (which are indicators of the site's potential to establish a diverse self sustaining ecosystem). Shannon Wiener diversity index is given by the formula:

$$\textbf{Shannon Wiener Index} = \mathbf{H'} = -\sum_{i=1}^{S} Pi \log e\, Pi$$

Where Pi is the proportional abundance and S is the number of species.

GENSTAT software was used to conduct a one way analysis of variance (ANOVA) to test the significance of the difference among the soil chemical parameters observed for the reclaimed site, the adjacent farms and the forest reserve (control site). Bar charts were used to pictorially depict the difference between the values observed for the sites.

The significance of the differences among the tree diameter and height values of the different reclamation species were also tested by conducting a one way ANOVA while Fischer's LSD test for means separation was done using GENSTATS software (Nichols et. al., 1998). Community responses were also analyzed using SPSS software and presented in graphs and tables.

4.0 RESULTS

4.1Communities' involvement, knowledge and perceptions of the reclaimed site

Presented below are responses given by community members during the interview.

4.1.1 Previous landuse of the mined area

Prior to mining, the whole area including the uncovered pits was used as farmlands, settlements, source of their drinking water and also for small scale mining. The communities derived a number of benefits such as food, medicinal plants, fuelwood and income from the areas. About 15 of the community members were only involved directly in the reclamation activities as casual workers.

4.1.2 Common problems of communities

Members of the communities experienced at least one problem or the other as a result of the mining activity in the area. These issues ranged from cracks in their buildings resulting from blasting, water pollution, dusty roads destruction of farms and houses, increasing incidence of malaria as a result of stagnant water.

4.1.3 Current Events

Currently mining is on going on a 0.89 ha area of the Supuma Shelterbelt Forest Reserve very close to the reclaimed site. There have been occasional confrontations between the communities and the mine workers following the prevailing environmental problems in the area. This has led to the formation of a committee made up of community representatives and the Community Development Department of Anglogold to mediate between the communities and the company.

4.1.4 Community consultation on final landuse

Out of the 134 respondents 52.24 % representing 70 respondents indicated that no prior discussions were held with them on the final landuse the reclaimed site was going to be put while 47.76% representing 64 respondents indicated that prior discussions were held.

4.1.5 Communities' Knowledge of the reclaimed sites' end use

Over fifty eight percent (58.21%) of all the respondents had no idea of the final landuse of the reclaimed site while 41.79 percent of all the respondents were aware that the site was going to be maintained as a tree plantation. The 'No Idea' to 'Tree Planting' responses were respectively distributed among the communities as follows; Kubi Kwanto 41 respondents as against 28, Kubi Lagos 13 against 9 and Ohia Mpe Anika, 16 against 27 respondents. Below is a graphical distribution of responses from the three communities

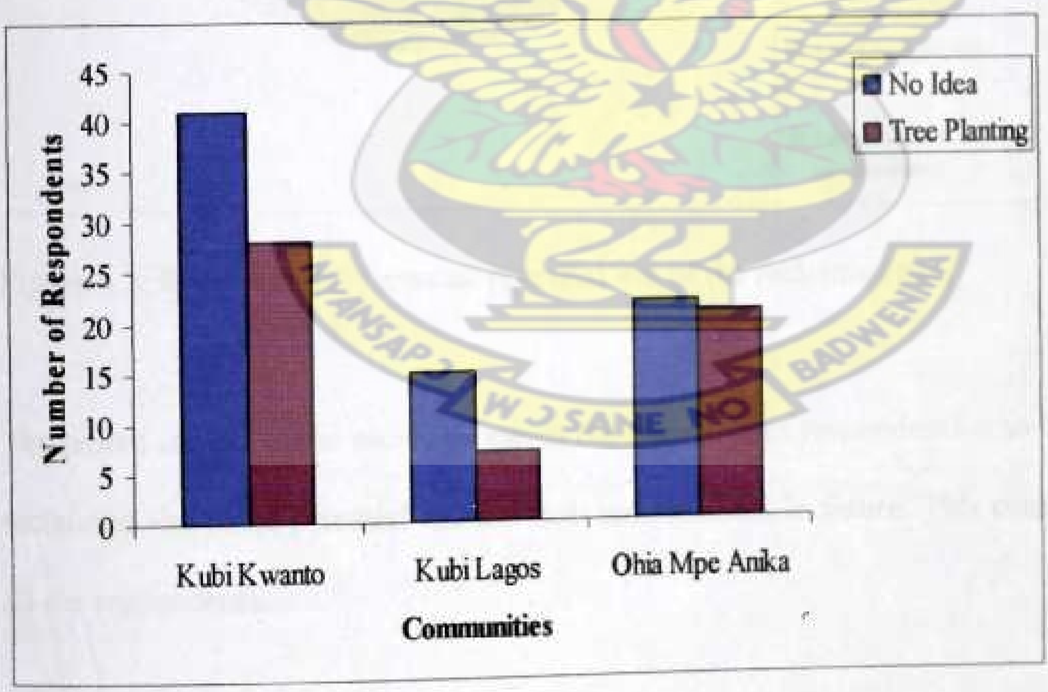


Figure 4.1; Communities' knowledge of reclaimed site's end use.

4.1.6 Views of respondents regarding the potential use of the reclaimed site

About eighty five percent (85.1%) of all the respondents indicated that the reclaimed site had no potential use for the benefit of their communities while 14.9% claimed that the site had potential use to their communities. Below are the reasons for the responses given by these two groups with regards to the potential or otherwise of the reclaimed site.

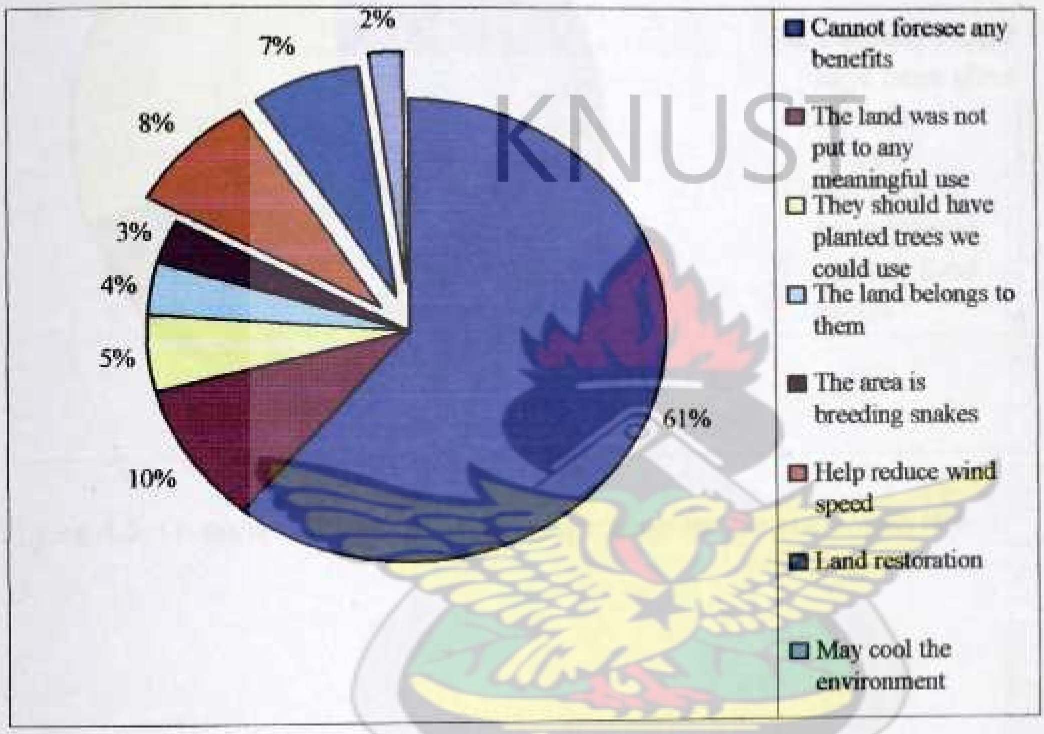


Figure 4.2; Respondents' views on potential use of the reclaimed site;

The pulled sectors of the chart represents the responses of respondents who believe that the reclaimed site has a potential use for their communities in future. This constitutes 17% of all the respondents.

4.1.7 Communities' aspiration for the reclaimed site

Over twenty four percent (24.6%) of all the respondents had no idea about what had gone wrong with the reclamation activities and what should have been done with the site. About

44.8% were of the view that the land should have been given back to the communities for farming and 30.6% said the company should have planted cash or food crops. Below is a pictorial representation of the communities' aspiration with respect to the reclaimed site

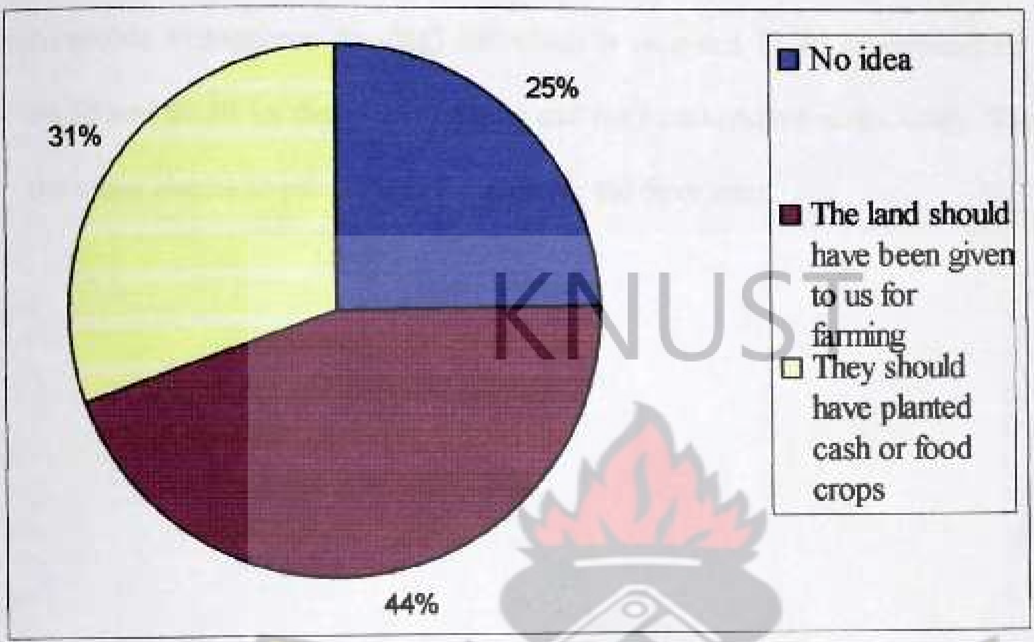


Figure 4.3; Overview of communities' aspiration for the reclaimed site.

4.2 Mean soil chemical properties

The mean chemical properties for the reclaimed site were generally lower than that of the adjacent farms and the forest reserve with the exception of C/N Ratio for which it recorded 11.22 as against 10.28 for the adjacent farms and 8.34 for the forest reserve and the Available Phosphorus (mg/Kg) for which it recorded 71.40 corresponding to values of 69.50 and 60.50 for the adjacent farms and the forest reserve respectively. Table 4.1 shows the mean chemical parameters recorded for the three sites.

Table 4.1; Mean soil chemical properties for the different sites

Study Sites	Soil chemical properties								
	pH 1:25 (H_2O)	Organic Carbon (%)	Total Nitrogen (%)	Available phosphorus (mg/Kg)	Organic Matter (%)	Exchangeable Cations (Cmol/Kg)			C/N Ratio
						Calcium (Ca)	Magnesium (Mg)	Potassium (K)	
Reclaimed site	5.79 ± 0.13^{a}	1.12 ± 0.34^{a}	0.10 ± 0.03^{a}	71.40 ± 8.88^{a}	1.94 ± 0.34^{a}	4.6 ± 0.95^{a}	1.10 ± 0.35^{a}	$0.20 + 0.04^{a}$	11.22 ± 1.10^{a}
Adjacent farms	5.84 ± 0.69^{a}	1.77 ± 0.46^{c}	0.18 ± 0.05^{b}	69.50 ± 3.54^{b}	3.05 ± 0.46^{c}	6.70 ± 3.82^{a}	3.50 ± 1.56^{ab}	$0.14 + 0.10^{a}$	$10.28 + 1.41^{ab}$
Forest reserve	4.96 ± 0.21^{b}	1.98 ± 0.07^{b}	0.24 ± 0.02^{b}	60.50 ± 7.78^{b}	3.42 ± 0.07^{b}	3.80 ± 0.28^{a}	2.60 ± 0.28^{b}	0.22 ± 0.01^{a}	$8.34 + 0.51^{b}$

NB; In table 4.1 above, means in the same column with the same letter as superscript are not significantly different ($P \leq 0.05$).

4.2.1 Mean Exchangeable Cations concentrations

The adjacent farms recorded higher mean concentrations of the exchangeable cations (i.e. 6.7, 3.5 and 0.14 Cmol/Kg for Ca, Mg and K respectively) than the reserve and the reclaimed site with the exception of potassium for which the reserve had the overall highest concentration i.e. 0.22 Cmol/Kg. The reclaimed site on the other hand had a higher mean calcium concentration (4.60 Cmol/Kg) than the forest reserve (3.80 Cmol/Kg) while the reserve also had a higher mean magnesium concentration (2.60 Cmol/Kg) over the reclaimed site's concentration of 1.10 Cmol/Kg (Figure 4.4).

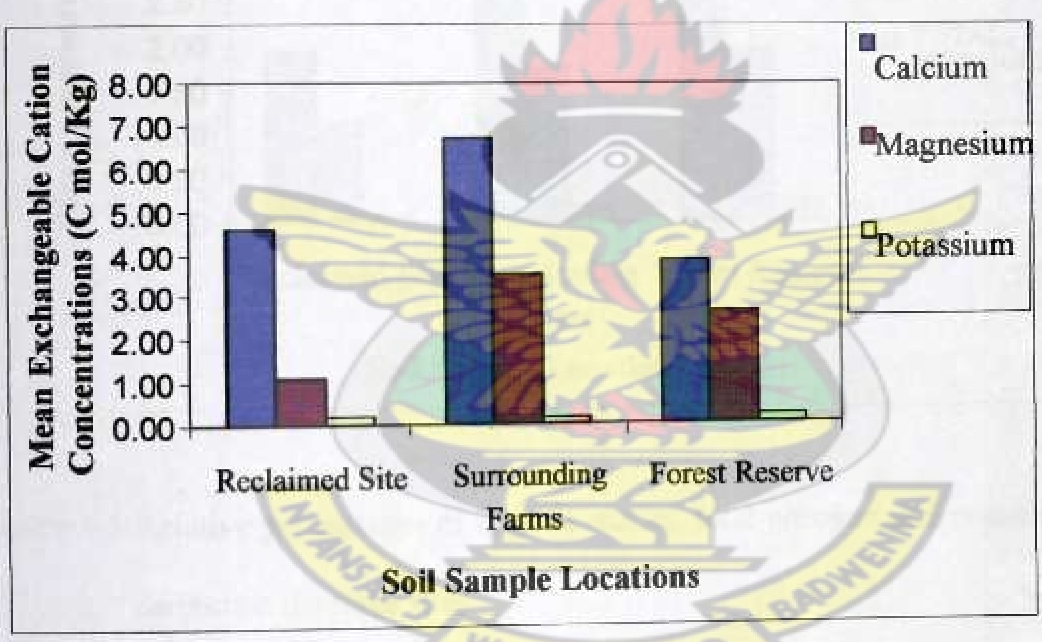


Figure 4.4 Exchangeable cations concentration in soils of the different land use types on the Kubi site.

4.2.2 Mean percentage of Organic Matter, Total Nitrogen and Organic Carbon

With a pH lower than all the three sites (i.e. 4.96), the forest reserve had the highest percentage of organic matter (3.42%), total nitrogen (0.24%) and organic carbon (1.98%) per given mass followed by the adjacent farms and then the reclaimed site in the order given. The reclaimed site also had the highest carbon nitrogen ratio (11.2) followed by the farms (10.28) with the forest reserve recording the lowest (8.34) (Figure 4.5).

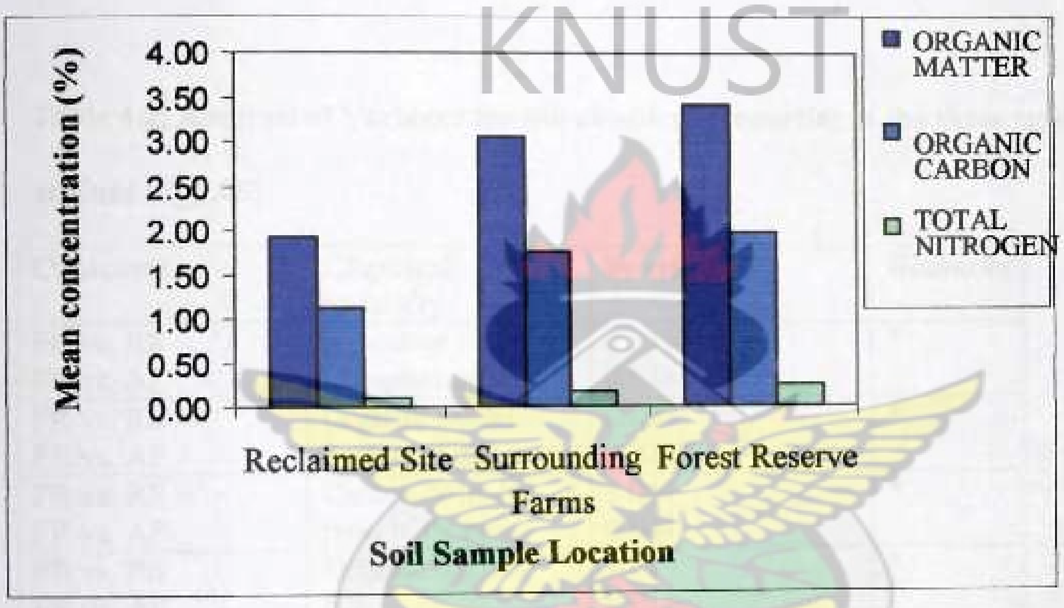


Figure 4.5 Relative percentages of organic matter, total nitrogen and organic carbon on the three sites.

4.2.3 Analysis of Variance (ANOVA); Contrasts

The analysis of variance conducted to contrast the mean soil chemical properties of the three sites showed that for available Phosphorus (P), Organic matter content (OM), Carbon Nitrogen ratio (C/N ratio), Organic carbon (C), Total Nitrogen (N), and the Hydrogen ion concentration (pH), there were significant differences between the means. While there were no significant differences between the mean Exchangeable Calcium (Ca), Potassium (K), and Magnesium (Mg). Details of ANOVA for the various soil nutrients among the different landuse types are shown in table 4.2.

Table 4.2; Analysis of Variance for soil chemical properties of the three landuse types at Kubi ($P \leq 0.05$)

Contrasts	Chemical property	P- value	Remarks
FR vs. RS FR vs. AF	Available Phosphorus (P)	0.036 0.036	*
FR vs. RS FR vs. AF	Organic Matter content (OM)	0.020 0.020	*
FR vs. RS FR vs. AF	Carbon Nitrogen ratio (C/N ratio)	0.044 0.044	*
FR vs. RS FR vs. AF	Organic Carbon (C)	0.019 0.019	*
FR vs. RS FR vs. AF	Total Nitrogen (N)	0.012 0.012	*
FR vs. RS FR vs. AF	Hydrogen ion Concentration (pH)	0.028 0.028	*
FR vs. RS FR vs. AF	Exchangeable Calcium (Ca)	0.285 0.285	ns
FR vs. RS FR vs. AF	Exchangeable Potassium (K)	0.347 0.347	ns
FR vs. RS FR vs. AF	Exchangeable Magnesium (Mg)	0.653 0.653	ns

FR=Forest reserve, RS=Reclaimed site, AF=Adjacent farms

* = significant difference. **ns** = no significant difference

4.3 Growth parameters of the reclamation species

The growth parameters depict the growth performance of the species on the Kubi reclaimed site. In all, *Acacia mangium* recorded the highest performance values (i.e. 13.23 m and 8.94cm for mean height and mean diameter respectively) followed by *Senna seamia* with mean height and diameter values of 11.75m and 4.37cm respectively while *Leucaena leucocephala* and *Cedrella odorata* recorded the lowest performance values i.e. 9.16 m and 2.97cm and 8.81m and 3.50cm respectively for mean height and diameter at breast height. *Albizia adianthifolia* was the only indigenous species that performed favorably against the exotic species with height and diameter at breast height (dbh) values of 10.20 m and 3.21cm respectively which were not significantly different from diameter and height values of the other species on the site except that of *Acacia mangium* (Table 4.3).

Table 4.3; Growth performance of tree species on the seven-year-old reclaimed mined site

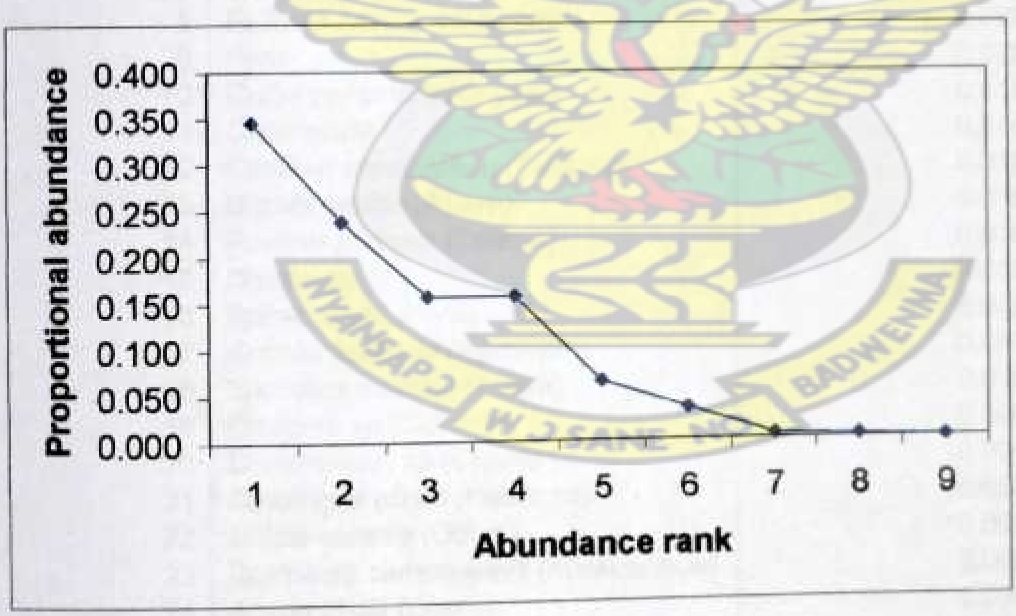
Tree parameters	*Acacia mangium*	*Senna seamia*	*Gmelina aborea*	*Cedrella odorata*	*Leucaena leucocephala*	*Albizia adianthifolia*
Mean tree volume (m^3)	0.083	0.018	0.014	0.009	0.006	0.008
Mean annual height increment (m/yr)	1.89 ± 1.99	1.68 ± 1.27	1.43 ± 1.27	1.26 ± 3.62	1.31 ± 1.89	1.46 ± 2.23
Mean annual diameter increment (cm/yr)	1.28 ± 2.16	0.62 ± 1.07	0.60 ± 1.72	0.50 ± 2.83	0.42 ± 2.13	0.46 ± 0.27
Dominant height (m)	17.30	15.2	12.95	12.58	13.9	11.76
Mean height (m)	13.23 ± 1.99^{a}	11.75 ± 1.27^{ac}	10.03 ± 1.27^{b}	8.81 ± 3.62^{b}	9.16 ± 1.89^{b}	10.20 ± 2.23^{bc}
Mean diameter (cm)	8.94 ± 2.16^{a}	4.37 ± 1.07^{b}	4.21 ± 1.72^{b}	3.50 ± 2.83^{b}	2.97 ± 2.13^{b}	3.21 ± 0.27^{b}
Mean basal area (m^2/ha)	0.0063 ± 2.16	0.0015 ± 1.07	0.0014 ± 1.72	0.0010 ± 2.83	0.0007 ± 2.13	0.0008 ± 0.27

NB; In Table 4.3 above, means in the same row with the same letter superscripts are the same.

4.4 Species diversity

4.4.1 Reclamation species diversity

There was a low Shannon Weiner species diversity index (H^{1}) of 1.617 and a species Evenness or Equitability index of 0.74. With a proportional abundance of 0.347 representing 1947 trees per ha. *Senna seamia* ranked most abundant while *Entandophragma angolense* ranked least with a proportional abundance of 0.001 representing three trees per ha. The combined proportional abundance of the four indigenous species planted i.e. *Albizia adianthifolia, Ceiba pentandra, Terminalia ivorensis, Entandophragma angolense* was 0.036 representing a total of 199 trees per ha as against the exotic species planted which indicated a combined proportional abundance of 0.964 accounting for over 5000 tress per ha (Figure 4.6).



Legend;

Rank	Tree species
1	*Senna seamia*
2	*Acacia mangium*
3	*Leucaena leucocephala*
4	*Gmelina aborea*
5	*Cedrella odorata*
6	*Albizia adianthifolia*
7	*Ceiba pentandra*
8	*Terminalia ivorensis*
9	*Entandophragma angolense*

Figure 4.6 Rank-abundance curve of the tree species used in reclaiming the Kubi site

4.4.2 Undergrowth diversity

There was a high Shannon Weiner diversity index (H^I) of 2.491 and Species Evenness or Equitability index of 0.74. Of the 28 different undergrowths observed, *Leucaena leucocephala* ranked most abundant with a proportional or relative abundance of 0.349 representing 19,000 plants per ha while the combined proportional abundance of undergrowths of the indigenous trees, climbers and shrubs was 0.651 representing over 35,500 plants per ha.

Table 4.4; Kubi reclaimed site's undergrowth species proportional abundance values

Species rank	Species	Proportional abundance (Pi)
1	*Leucaena leucocephala*	0.349
2	*Salacia Africana*	0.128
3	*Chromolaena sp* (Akyeampong*)*	0.083
4	*Funtumia africana* (Funtum*)*	0.055
5	*Nibodia levis* (Sasamansa*)*	0.037
6	*Funtumia elastica*	0.037
7	*Solarium erianthioris* (Pepediawuo)	0.028
8	*Palisota hirsute* (Nsemenini)	0.028
9	*Fern*	0.028
10	*Ceiba pentandra (Onyina)*	0.018
11	*Cider acuta*	0.018
12	*Cantium sopcodatum* (Tatiadupo)	0.018
13	*Bliphia sapida* (Akyee)	0.018
14	*Paulinia pivinata* (Toantin)	0.018
15	*Cissus sp*	0.018
16	*Aphanostylis manii*	0.009
17	*Antiaris toxicaria* (Kyenkyen)	0.009
18	*Spondias mombin* (Atowa)	0.009
19	*Discorea sp* (Climber)	0.009
20	*Combrentum sp* (Climber)	0.009
21	*Sacamone afzelii* (Kwatema)	0.009
22	*Milicia excelsa* (Odum)	0.009
23	*Spathodia campanulata* (Kuokuonisuo)	0.009
24	*Albizia zygia* (Okoro)	0.009
25	*Ficus sur*	0.009
26	*Albizia adianthifolia* (Pempena*)*	0.009
27	*Terminalia ivorensis* (Emire)	0.009
28	*Trichilia tessmanii*	0.009
	grand total	1.000
	Shannon Weiner index $H^I = 2.491$	

5.0 DISCUSSION

5.1 Communities' involvement

Mining activities bring a number of social and environmental problems. These may include increase in endemic diseases among users of water that has been contaminated by the mining operations, increasing sediment load which results in increased turbidity (Law, 1984), displacement of forest dwelling communities, distortion of land economy, chronic pollution, noise from crushing and transport (Duncan and Sayer, 1991) and production loss (Gormey, 1997). Dust may also cause respiratory diseases such as bronchitis and pneumonia (Nemerow, 1978). The problems that the Kubi communities experienced were not different from the fore mentioned since they lost farmlands, settlements and livelihood activities such as hunting. Furthermore, they experienced increased malaria incidents and lost benefits such as herbs and fuelwood they obtained from the site.

According to the Environmental Department of Anglogold, at least two separate discussions were held with the communities to agree on the end-use to which the site was going to be put. Out of the 134 respondents from the three communities, 52% representing 70 respondents indicated that no prior discussions were held with them to discuss the final landuse to which the reclaimed site was going to be put, while 48% indicated that discussions were held with them. The above notwithstanding, a further 58.21% of all the respondents had no idea of the final landuse of the reclaimed site while 41.79% of the respondents were aware that the site was going to be maintained as a tree plantation, indicating that over 12% (i.e.12.94%) of the people who reported that discussions were held with them had no idea of what the site was going to be put to (Figure 4.1).

It was observed during the study that even though meetings were held with the communities, the meetings did not give them the opportunity to make inputs into the reclamation plan and final landuse envisaged by the company. The two meetings only informed the communities of the company's plans and other social responsibilities towards the community. However, according to the EPAs guidelines for reclamation, and the Environmental Assessment Regulation, 1999 (LI 1652), companies are expected to undertake Environmental Impact Assessment and submit their reclamation plans for any particular land use after the surrounding communities' opinion or interest and the previous land use have been considered unless the nature and extent of transformation is so severe that it cannot be returned to the previous land use.

Furthermore, The Ministry of Lands, Forestry and Mines, through the Minerals Commission, after carrying out pilot reclamation schemes to rehabilitate three degraded areas in the Western, Greater Accra and the Eastern regions, identified stakeholder participation as very paramount for the sustainability of the project. Consequently, the participation of communities through the planning, design and implementation stages was ensured (Ghana Minerals Commission, 2005). However, reclamation of the Kubi pit did not give attention to community participation in the planning and decision making process. The communities also did not have any expertise to monitor the reclamation activity or make any inputs.

This study further showed that 82.8% of all the respondents did not believe the reclaimed site could benefit their communities in any way. According to them, their land had not been put to any meaningful use since the company had planted trees they could not use. Also the area was breeding snakes which posed threats to them. Only 17.2% representing 23 out of the 134 respondents believed in the potential of the reclaimed site and stated environmental benefits their communities could get from the trees as follows; cooling the environment, reducing wind speed' and 'land restoration (Figure 4.2).

The above further strengthened the case of non involvement of the Kubi communities and raises another issue of the lack of the sense of ownership of the project by the community members hence the responses such as "The land belongs to them", "They should have planted trees we could use" and "The area is breeding snakes" which account for 11.94% of all the respondents.

According to Law (1984), reclamation primarily depends on the goals set by society which in turn are determined by what society wants and needs from its natural resources by the physical and ecological conditions of the site and the economic and social trade offs. This implies that there is the need to hold discussions with the communities and consider the various options that the community wants before a decision can be made. This, according to Depuit (1988), would ensure that society retains multiple use opportunities of the site.

The above arguments were confirmed by the study as 44.8% of the entire respondents were of the view that the land should have been given back to them for farming while 30.6% said the company should have planted cash or food crops. Figure 4.3 shows that in this study, the communities' aspiration with respect to the reclaimed site were clearly different from that of the mining company. All these not withstanding, Hossner (1988), warns that any intended use must be reasonable and feasible.

5.2 Soil Chemical Properties

5.2.1 Soil reaction (pH)

The pH values obtained for the three sites were within the range 4 to 6 (Table 4.1). According to Landon (1996), pH values greater than 8.5 are considered to be very high, 7.0 – 8.6 is high, 5.5-7.0, medium and values less than 5.5 are low. The values observed for the reclaimed site and the adjacent farms were within the medium range while that of the forest reserve was within the low range.

Furthermore, with the exception of the value obtained for the forest reserve, values observed for the reclaimed site and the adjacent farms fell within the surface soil, (≤30 cm depth) reaction range of between 5.5 and 7.0 observed by Danso (1975) for the soil type in the study area.

The differences between the mean values obtained for the forest reserve and the reclaimed site were significant since the ANOVA showed a probability value of 0.028 which is lower than the degree of freedom at which the means were tested. The same could be said of the contrast between the forest reserve and the adjacent farms ($P \leq 0.05$)

5.2.2 Organic Matter content

According to Law (1984), soil can be divided into four main classes based on the percentage of organic matter content; zero to one percent is low, 1.1 to 3.0 % is medium, 3.1 to 10 % is high and greater than 10 % very high. On the basis of the above classification proposed by Law (1984), the organic matter content of the reclaimed site and the adjacent farms were within the medium concentration while that of the forest reserve was high (Table 4.1).

This, however, is not surprising given the young nature of the reclaimed land, and the fact that the farms have been put under cultivation for a long time. In general agricultural crops have greater nutrient uptake rates and requirements than forest crops (Young, 1982), and this may be accountable for the lower organic matter content on the farm lands compared to that of the forest reserve.

The forest reserve on the other hand has a typical forest floor which exhibits peculiar characteristics acquired under the influence of three factors uncommon to other soils; forest litter, tree roots and specific organisms whose existence depends on the presence of forest vegetation (Young, 1982).

In the light of the fact that forest trees have a low nutrient requirements, the forest litter and the tree roots which decompose gradually makes the forest floor important as a 'slow release' source of nutrients, as an energy source for organisms and as a covering for protecting the soil against runoff, erosion and temperature extremes (Young, 1982) hence the high organic matter content.

5.2.3 Total Nitrogen and Organic Carbon

From Table 4.1 the mean total nitrogen contents observed for the reclaimed site and the adjacent farms were low while those recorded for the forest reserve were medium according to the classification by the Crops and Soil Science Department of the College of Agriculture and Natural Resources (Appendix 'N').

The forest reserve had a higher organic matter content than the reclaimed site and the adjacent farms hence its high nitrogen content, because soil organic matter according to Bonh, et al. (1985), supplies nearly all the Nitrogen in the soil. The total nitrogen content of the forest reserve could have been higher but for its low hydrogen ion concentration since the availability of nitrogen is somewhat restricted at low pH values (Barber, 1995).

The nitrogen content of soil decreases when brought under cultivation as a result of increased rate of oxidation of the soil organic matter ((Wild, 1988; Mantey, 2004)) and because Nitrogen is taken up in greater amounts by agricultural crops than by trees (Young, 1982). N losses from the soil may also be due to leaching (Olaitan and Lombin, 1984). All these could have accounted for the low total nitrogen content of the adjacent farms. For the reclaimed site however, its young nature could have been a reason for the low nitrogen content recorded as in the case of the organic matter content.

Finally, according to Bonh et al. (1985), the amount of Nitrogen (N_2) fixation by free living bacterium Azotobacter, for example, is related to the amount of readily available energy source in the soil such as carbohydrates in soil organic matter. The Organic Carbon contents of the reclaimed site, adjacent farms and forest reserves were 1.12%, 1.77% and 1.98% respectively. These observations gave the forest reserve a better disposition for higher nitrogen fixation over the reclaimed site and the adjacent farms respectively.

The C/N Ratios of the three sites i.e. 11.22 for the reclaimed site, 10.28 for the adjacent farms and 8.34 for the forest reserve were well within the easily decomposable range of 1:20 (Appendix 'N').

5.2.4 Exchangeable Cations

5.2.4.1 Exchangeable Calcium (Ca)

The mean exchangeable Calcium concentration for the three sites were in the order adjacent farm > reclaimed site > forest reserve (table 4.1). Troech, (1993) contended that Ca supplies are smaller in acid soils than in alkaline soils and that the amount of calcium and other basic cations (Mg^{2+}, K^{+}, Na^{+}) present in a soil decline as the soil becomes more acidic and vice versa.

Prasad and Power (1997) further strengthened this case by stating that in strongly acidic soils, Ca, Mg, P, Bo and Mo become deficient while Mn and Fe may reach toxic limits.

This study confirms that contention for the exchangeable Ca concentration as the mean pH values for the adjacent farm > the reclaimed site > the forest reserve respectively showed a similar relationship with the mean exchangeable calcium concentrations.

The higher Ca concentration of the reclaimed site over that of the forest reserve may also be partly associated with the reclamation species used especially *Gmelina arborea* because Caudle *et al.* (1987), observed that some tree species tend to increase topsoil Ca and Mg by mechanisms which are not clearly understood. This effect according to them is marked with *Gmelina arborea* which appears to be a Ca accumulator in Nigeria and Brazil.

The locations of the farms on the other hand may account for the high exchangeable Ca concentration as runoff from the reclaimed site which is slightly hilly is deposited in these areas. Without that the concentration for the adjacent farm might have been lower given the high nutrient uptake by agricultural crops and the fact that there is usually a preferential adsorption of Ca ions over other ions (Troech, 1993).

Besides, the clayey nature of the soil of the adjacent farms and the fact that soils in the area are less highly leached and thus more productive (Danso, 1975) gives it a high CEC and hence the high exchangeable Ca concentration over the forest reserve's samples which have a low pH because very low Ca concentrations occur in highly leached soils with low cation exchange capacities (Troech, 1993).

But for the low pH the forest reserve would have had a high Ca content because soils in the area are rich in humus and suitable for agricultural practices (Adansi West Dist, 2000). Troech, (1993) stated that Ca adsorption is highest in humus because humus has a high CEC. Unfortunately, Ca supplies are lower in acid soils than in alkaline soils (Troech, 1993) hence the low Ca content of the forest reserve.

5.2.4.2 Exchangeable Magnesium (Mg)

Mean Exchangeable Magnesium contents observed were related as reclaimed site < the forest reserve < the adjacent farms (Table 4.1).

Most mine soils have two properties in common. They have many more rock fragments than natural soils and lack the structure of natural soils. This lack of structure may decrease infiltration and increase runoff and erosion (Singer and Munn, 1999). On the other hand, severe weathering, soil erosion and clay eluviation tends to reduce the Mg content of surface soil horizon Fitzpatrick (1986). This may be accountable for the low exchangeable Mg content of the reclaimed site since the reclaimed site exhibits all the traits discussed above.

The forest reserve on the other hand has a low pH and as stated earlier the amount of calcium and other basic cations (Mg^{2+}, K^{+}, Na^{+}) present in soil decline as the soil becomes more acidic and vice versa (Troech, 1993) hence its Mg content being lower than that of the adjacent farms. However, because it has a higher organic matter content it has more cation exchange sites and better surface soil protection as a result of the forest floor than the reclaimed site. This gives it a higher Mg concentration than the reclaimed site.

5.2.4.3 Exchangeable Potassium (K)

The farms recorded the least Mean Exchangeable K values followed by the reclaimed site with the forest reserve recording the highest values. These values are generally low compared to the mean concentrations of the other exchangeable cations (Table 4.1).

This according to Olaiton and Lombin (1984) is because in spite of the relatively high K content of soils, the quantity held in exchangeable form at any one time is often low or very low with an average of about 0.1 to 0.2 me/100g for most tropical soils.

In general however, agricultural crops have a greater nutrient uptake rates and requirements than forest crops. This is particularly true in the case of potassium which is taken up in 'luxury' amounts (Young, 1982). Based on the above, the high organic matter content of the forest reserve may have compensated for its low pH recorded to give it a higher exchangeable potassium concentration over the adjacent farms even though the farms are receiving runoff water from the reclaimed site.

5.2.5 Available Phosphorus (P)

The phosphorus concentration for the study sites related as follows; reclaimed site> the adjacent farms > the forest reserve (Table 4.1). Even though Barber (1995) stated that irrespective of the pH of a soil, phosphorus concentrations are usually low, the observed values were all high according to the classification by the Crops and Soil Science Department of the College of Agric and Natural Resources (Appendix 'N'). This was however not surprising especially for the adjacent farms and the reclaimed site which had medium pH values since the availability of phosphorus is best at intermediate and high pH values (Barber, 1995).

For the forest reserve with high organic matter content, the high phosphorus content may be due to the fact that organic matter acts as a slow release form of fertilizer for nitrogen and to a lesser extent for calcium, potassium and phosphorus as well as for some trace elements (Shepherd, 1986).

5.3 Survival rate and growth performance of trees

According to the Anglogold Ashanti's Environmental Department the site was planted with 7000 seedlings per ha at an interval of 1.5 meters made up of 40% indigenous species and 60% exotic species. This study observed an estimate of 5,611 trees per hectare on the site. This indicates a survival rate of 80% with the indigenous species accounting for only 3.6 percent of the total number of trees observed. Meanwhile the EPAs reclamation criteria recommends planted species stocking rate of 1000 trees /ha and use of indigenous species not less than 40%.

The number of trees planted per hectare by the company to reclaim the mined site may be partly responsible for the poor performance of the few indigenous species that were planted since competition favours the more aggressive species over the less aggressive ones. For this reason, Law (1984) cautions that the primary reasons introduced species have been widely used in seed mixes for revegetation is because of their rapid establishment and aggressive growth characteristics which help to quickly establish vegetation cover over the land while the native species gradually take over.

As observed from Table 4.3, the mean height values for the reclamation species ranged from a maximum of 13.23m to 8.81m. *Acacia mangium* recorded the highest while *Cedrella odorata* recorded the lowest. Hence for the six reclamation species that performed well on the site the mean tree heights observed was in the order *Acacia mangium* > *Senna* seamia > *Albizia adianthifolia* > *Gmelina aborea* > *Leucaena leucocephala* > *Cedrella odorata* respectively.

The diameter values on the other hand ranged from a maximum of 8.94 cm for *Acacia mangium* to a minimum of 2.97 cm for *Leucaena leucocephala* in the order *Acacia mangium* > *Senna seamia* > *Gmelina aborea* > *Cedrella odorata* > *Albizia adianthifolia* > *Leucaena leucocephala* (Table 4.3). *Albizia adianthifolia* was the only local species.

A least significance difference (LSD) test for the mean tree height values of the different species showed that values obtained for *Acacia mangium* and *Senna seamia, Senna seamia* and *Albizia adianthifolia* were the same while values obtained for *Gmelina aborea, Cedrella odorata, Leucaena leucocephala* and *Albizia adianthifolia* were the same. More so, the mean diameters observed for all the reclamation species were the same except for *Acacia mangium* which was different from the rest. This indicated that the differences in the ANOVA were not due to the said means and may be accounted for by some other factors (Appendices 'C' and 'D').

The observed variations in the height and diameter measurements of the different species may therefore be accounted for by the fact that the rate and duration of plant growth is dependent on both genetic or internal factors and environmental factors, which are determined by the conditions of the surroundings under which an organism grows (Avery and Burkhart, 1983).

The observed values for the different species are for that reason likely to even vary from species of its same type that may be growing under different conditions. For example a mean annual height growth range of 3-4 m/yr has been reported for *Leucaena leucocephala* for many trials (Dommergues, 1987). However, this study recorded a mean annual height increment of 1.31 m for *Leucaena leucocephala*. This value recorded was very low compared to the observations from the above quoted study. The mined condition under which the *Leucaena* species is growing may be accountable for this difference.

Nevertheless, the response to different environmental conditions may differ from species to species. While the performance of some species may be badly affected as shown above, others may not be.

Thus, this study recorded a mean annual height increment of 1.67 m for *Senna siamea* which was comparable to observations made by Gutteridge (1997), who stated that *Senna siamea*, attains a height of 5m in 3 years and 15m in 10 years. These represent annual height increments of 1.66 m and 1.5 m respectively.

5.4 Species diversity, richness and evenness on the Kubi Site

The study showed a Shannon Weiner diversity index H^I of 1.617 and a Species Equitability or Evenness Index (J') of 0.74 for the reclamation species while all the species used were multipurpose.

The use of multipurpose trees was good because according to Bostanoglu (1976), if the land is to reach its full productive potential, the species to be established must be such as to accomplish a wide range of purposes since it is difficult to justify planting degraded lands for soil conservation purposes alone.

There was a very low species evenness on the site hence the rank abundance curve (Figure 4.6). With a ranking of one to nine where one indicated the most observed and nine indicated the least observed species, *Senna siamea* ranked first with a proportional abundance of 0.347 indicating approximately 1947 tress per hectare, while *Entandophragma angolense* had the least proportional abundance of 0.001 indicating approximately three trees per hectare. This result showed wide numerical variations between the different reclamation species used on the site. (Appendix 'E').

The combined proportional abundances of the four indigenous species (i.e. *Albizia adianthifolia, .Ceiba pentandra, Terminalia ivorensis* and *Entandophragma angolense*) was 0.036 or 3.6% with the difference of 0.964 or 96.4% accounted for by exotic species. The proportional abundance value for the indigenous species as observed was negligible compared to that of the exotic species. It was also insignificant compared to the EPA's proposed use of indigenous species (not less than 40%) in reclaiming mined lands.

According to Law (1984) the primary reasons introduced species have been widely used in seed mixes for revegetation is because of their rapid establishment and aggressive growth characteristics which help to quickly establish a vegetation cover over the land while the native species gradually take over.

This study showed a skewed interest on the part of the company in the use of exotic species over the indigenous species for the reclamation programme. Contrary to this interest, Law (1984) stated that plants native to the rehabilitated area have been widely recommended as desired species for revegetation. The concept of utilizing native species, according to him would seem appropriate because native vegetation is an expression of both local soil and climate. Furthermore although introduced species have shown desirable short term characteristics, questions arise concerning the ecological impacts on plant communities dominated by aggressive introduced species.

Hossner (1988) supports this by stating that climate is a major consideration when selecting plants for erosion control and other targeted landuses. If plants are not adapted to a particular region or area, they on their own cannot successfully fulfill land reclamation objectives. Hossner (1988) however, states further that most successful land restoration programmes have used a good combination of both native and introduced species at some stage of the reclamation process.

The undergrowth had a high Species richness and a high Shannon Weiner diversity index of 2.491 these were all higher than that of the reclamation species (Table 4.4). However, there was an equally low Species Equitability or Evenness Index (J') of 0.74. (Figure 4.7)

In all, 28 different species were identified in sampling the undergrowth. These were made up of seedlings and saplings of mainly indigenous trees, climbers and shrub species with the exception of seedlings of *Leucaena leucocephala* which featured prominently in almost every sample. *Leucaena leucocephala* was the most abundant while species such as *Albizia adianthifolia* (Pampena) and *Terminalia ivorensis* (Emire) had the least proportional abundance (Figure 4.7). The high diversity indices observed indicate that with good management the site could become ecologically self sustaining.

Arnon and Johnson (1942) stated that initial revegetation effort establishes the building blocks for a sustaining system so that successional processes lead to the desired vegetation complex. However, *Leucaena leucocephala* having a proportional abundance of 0.34 or 34 % is likely to take over the site and suppress the growth of the other species if not controlled.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The local tree species performed poorly as against the exotic species since most of them had not achieved the minimum height of 1.5 meters set by this assessment for measurement. Reclaiming at a rate of 7000 trees per ha., the site was obviously over crowded and accounted for the failure of the indigenous species since competition naturally favours the more aggressive species over less aggressive ones. The tree species diversity status of the reclaimed site was low.

- Management of the reclaimed site was insufficient. There were no sampling plots for monitoring growth or any of the standards set in the reclamation criteria of the EPA for reforested areas or forest resources. This is particularly unacceptable since a portion of the Supuma Shelterbelt Forest Reserve is already being mined.

- Much has been done in terms of institutional arrangements particularly by the governmental institutions for ensuring proper reclamation. However, the communities do not have any systems on their own and have not also been trained to develop any such procedures to check or monitor reclamation activities.

- This study also showed that the members of the Kubi communities were not involved in the reclamation process. This appears to be the case in many mining communities and a potential cause of conflict between mining companies and communities.

6.2 Recommendations

- There need to be clear statistical or scientifically proven methods for monitoring and measuring reclamation success. For example in the case of tree plantations there needs to be a statistical approach to monitoring changes in the established vegetation and the adherence to the standards such as the 40% indigenous species and their growth performance. Walk through assessments, as have always been the case, are not good methods since they are purely based on judgment and cannot be rechecked or properly monitored. In this area the involvement of the FSD will be of great benefit.

- Established stands should be managed in order to ensure greater success of reclamation activities and to also ensure that the targeted use is achieved and utilized. Much attention should be given to the indigenous species to ensure their survival, proper performance and subsequent restoration of the natural ecology of mined sites.

- Efforts must be made to manage the spread of *Leucaena leucocephala* as it currently accounts for over 30% of the undergrowth on the reclaimed site.

- Not withstanding all the arrangements and commitments by the governmental institutions, enough pressure should be put on the companies to ensure their compliance to environmental standards so as to lessen the plight of mining communities and safeguard our environment. Civil society participation in the entire process including monitoring of reclamation and other mining operations is very important. This will bring about greater transparency and sanity in mining operations and will ensure that benefits from mining accrue to mining communities.

- Even though the recent formation of a committee of Anglogold Ashanti representatives and the communities' representatives is a good step towards community involvement and can be replicated in other mining communities, there is the need to build the capacities of community representatives to enable them contribute meaningfully in decision making with regards to reclamation. The selection of community representatives should also be transparent and representative of the different interests in the mining communities. In this respect, civil society needs to be involved in the sensitization and capacity building of mining communities on their rights and responsibilities to ensure constructive dialogue between them and the companies. This Right Based Approach without doubt will help reduce the pressure on the governmental institutions as the sole agencies for ensuring compliance.

- Further studies need to be conducted into the heavy metal levels on the site since they can contaminate ground water.

- Mining cannot be stopped in Ghana now especially when it accounts for almost 25% of the GDP, about 10% of Government revenue and employs over 14,000 workers. For this reason compliance with high social and environmental standards should not be compromised to ensure a good balance between the activity and environmental quality.

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APPENDICES

APPENDIX 'A'

Summaries of Communities' Responses to Questionnaire

Did The Company Hold Discussions With The Community, Land Owners And Users To Agree On The Final Land Use?

Community	No	Yes
Kubi Kwanto	41	28
Old Kubi	13	9
Ohia Mpe Anika	16	27
Total	**70**	**64**
Percentage of Total	52.24%	47.76%

What Final Use Is The Site Going To Be Put To?

Community	No Idea	Tree Planting
Kubi Kwanto	41	28
Old Kubi	15	7
Ohia Mpe Anika	22	21
Total	78	56
Percentage of total	58.21%	**41.79%**

How Is The Land Use Going To Benefit The Community?

Community	No Idea	No Benefit	Trees will serve as wind breaks	May Restore The Land
Kubi Kwanto	39	17	8	5
Old Kubi	18	4	0	0
Ohia Mpe Anika	29	14	0	0
Total	**86**	**35**	**8**	**5**

APPENDIX A (continued)

Is There A Way by Which Your Community Monitors the Reclamation Activities?

Community	No	Yes
Kubi Kwanto	61	8
Old Kubi	22	0
Ohia Mpe Anika	43	0
Total	**126**	**8**
Percentage of Total	**94.0%**	**6.0%**

Do You Think The Reclaimed Site Has Or Can Develop Into Some Form That The Community Will Benefit From?

Community	No	Yes
Kubi Kwanto	61	8
Old Kubi	19	3
Ohia Mpe Anika	34	9
Total	**114**	**20**
Percentage of Total	**85.1%**	**14.9%**

If yes state some possible benefits

Community	Help reduce wind speed	Land restoration	May cool the environment
Kubi Kwanto	8	0	0
Old Kubi	0	0	3
Ohia Mpe Anika	0	9	0
Total	**8**	**9**	**3**

APPENDIX 'A' (continued)

If Yes State Why/ If No Why?

Community	Cannot foresee any benefits	The land was not put to any meaningful use	They should have planted trees we could use	The land belongs to them	The area is breeding snakes	Help reduce wind speed	Land restoration	May cool the environment
Kubi Kwanto	45	13	0	0	0	11	0	0
Old Kubi	15	0	0	0	4	0	0	3
Ohia Mpe Anika	22	0	7	5	0	0	9	0
Total	**82**	**13**	**7**	**5**	**4**	**11**	**9**	**3**
Percentage of total	**61.19%**	**9.70%**	**5.22%**	**3.73%**	**2.99%**	**8.21%**	**6.72%**	**2.24%**

What Do You Think Has Gone Wrong With The Reclamation Activity?

Community	No idea	The land should have been given to us for farming	They should have planted cash or food crops
Kubi Kwanto	19	28	22
Old Kubi	5	10	7
Ohia Mpe Anika	9	22	12
Total	**33**	**60**	**41**
Percentage of total	**25%**	**45%**	**31%**

APPENDIX 'B'

Appendix B i; Table Showing Tree Heights and Diameters for Block A

Plot	*Acacia mangium*		*Senna seamia*		*Gmelina aborea*		*Cedrella odorata*		*Leucaena leucocephala*		*Albizia*	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diame (cm)
1	14.04	10.16	10.38	3.52	9.33	3.07	5.65	0.85		-	-	-
2	10.40	6.60	12.30	4.78	8.68	3.10	-	-	-	-	-	-
3	12.79	8.64	11.67	4.78	8.90	2.87	5.79	1.04	-	-	-	-
4	13.37	8.07	11.01	4.23	9.12	3.40	-	-	8.71	3.35	-	-
5	12.61	8.71	10.30	3.93	9.10	4.01	-	-	7.45	2.53	-	-
Total	63.21	42.18	55.66	21.24	45.13	16.45	11.44	1.89	16.16	5.88	0	
Mean	**12.64**	**8.44**	**11.13**	**4.25**	**9.03**	**3.29**	**5.72**	**0.95**	**8.08**	**2.94**	**0.00**	**0.0**

Appendix B ii; Table Showing Tree Heights and Diameters for Block B

Plot	*Acacia mangium*		*Senna seamia*		*Gmelina aborea*		*Cedrella odorata*		*Leucaena leucocephala*		*Albizia*	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diamete (cm)
1	17.30	12.33	12.44	3.17	10.67	5.00	-	-	8.50	1.50	-	-
2	13.30	11.24	12.54	5.08	10.30	3.45	-	-	8.00	0.80	-	-
3	13.00	6.90	13.15	5.13	10.38	3.06	-	-	7.98	0.64	-	-
4	15.23	11.38	11.78	4.11	10.58	4.33	-	-	9.01	3.77	-	-
5	14.41	10.92	13.76	5.41	9.85	3.97	-	-	8.86	4.40	-	-
Total	73.24	52.77	63.67	22.9	51.78	19.81	0	0	42.35	11.11	0	
Mean	**14.65**	**10.55**	**12.73**	**4.58**	**10.36**	**3.96**	**0.00**	**0.00**	**8.47**	**2.22**	**0.00**	**0.0**

Appendix B iii; Table Showing Tree Heights and Diameters for Block C

Plot	*Acacia mangium*		*Senna seamia*		*Gmelina aborea*		*Cedrella odorata*		*Leucaena leucocephala*		*Albizia*	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
1	7.35	2.70	10.14	3.21	10.68	5.08	-	-	6.25	0.55	7.65	2.90
2	13.34	9.74	15.20	6.70	8.60	3.05	-	-	9.16	1.52	-	-
3	13.90	8.16	11.00	2.87	10.56	4.53	-	-	13.90	8.16	-	-
4	13.39	9.06	12.33	5.56	10.69	5.12	-	-	10.37	4.08	-	-
5	14.02	10.31	10.48	4.73	8.70	3.04	-	-	11.08	4.64	-	-
Total	62	39.97	59.15	23.07	49.23	20.82	0	0	50.76	18.95	7.65	2.90
Mean	**12.40**	**7.99**	**11.83**	**4.61**	**9.85**	4.16	0.00	**0.00**	**10.15**	**3.79**	**7.65**	**2.90**

Appendix B iv; Table Showing Tree Heights and Diameters for Block D

Plot	*Acacia mangium*		*Senna seamia*		*Gmelina aborea*		*Cedrella odorata*		*Leucaena leucocephala*		*Albizia*	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
1	14.64	8.60	11.30	4.64	10.20	3.33	5.15	0.85	-	-	-	-
2	-	-	11.20	1.96	13.03	10.57	12.58	6.12	9.83	2.68	11.20	3.30
3	13.73	10.08	11.34	4.67	12.95	5.75	12.36	5.97	-	-	11.76	3.42
4	11.84	7.70	10.81	3.98	9.52	4.21	11.32	6.14	-	-	-	-
5	12.73	8.56	11.79	4.86	8.78	3.27	-	-	-	-	-	-
Total	52.94	34.94	56.44	20.11	54.48	27.13	41.41	19.08	9.83	2.68	22.96	6.72
Mean	**13.24**	**8.74**	**11.29**	**4.02**	**10.90**	**5.43**	**10.35**	**4.77**	**9.83**	**2.68**	**11.48**	**3.36**

Appendix B v; Table Showing Mean Height and Diameter Values for the Reclamation Species on the Site

BLOCK	*Acacia mangium*		*Senna seamia*		*Gmelina aborea*		*Cedrella odorata*		*Leucaena leucocephala*		*Albizia*	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
Block A	12.64	8.44	11.13	4.25	9.03	3.29	5.72	0.95	8.08	2.94	0	
Block B	14.65	10.55	12.73	4.58	10.36	3.96	0	0	8.47	2.22	0	
Block C	12.4	7.99	11.83	4.61	9.85	4.16	0	0	10.152	3.79	7.65	2.9
Block D	13.24	8.74	11.29	4.02	10.90	5.43	10.35	4.77	9.83	2.68	11.48	3.3
Mean of means	13.23±1.99	8.92±2.16	11.75±1.27	4.37±1.07	10.03±1.27	4.21±1.72	8.04±3.62	2.86±2.83	9.13±1.89	2.91±2.13	9.57±2.23	3.13±0.27

APPENDIX 'C'

Analysis Of Variance and Least Significant Difference Results for the Reclamation Species' Diameter

```
 64 "One-way ANOVA (no Blocking)."
 65 BLOCK "No Blocking"
 66 TREATMENTS Species
 67 COVARIATE "No Covariate"
 68 ANOVA [PRINT=aovtable,information,means,%cv; FPROB=yes; PSE=diff,lsd;
LSDLEVEL=5]\
 69 Diameter
```

69..

***** Analysis of variance *****

Variate: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Species	5	391.836	78.367	22.89	<.001
Residual	75	256.734	3.423		
Total	80	648.570			

* MESSAGE: the following units have large residuals.

units 40	-6.24	s.e. 1.78
units 57	5.19	s.e. 1.78
units 71	6.36	s.e. 1.78

***** Tables of means *****

Variate: Diameter

Grand mean 5.07

Species	Acacia	Albizia	Cedrella	Gmelina	Leucaena	Senna
	8.94	3.21	3.50	4.21	2.97	4.37
rep.	19	3	6	20	13	20

*** Standard errors of differences of means ***

APPENDIX 'C' (Continued)

Table	Species
rep.	unequal
d.f.	75
s.e.d.	1.511X min.rep
	1.146 max-min
	0.585 max.rep

(No comparisons in categories where s.e.d. marked with an X)

*** Least significant differences of means (5% level) ***

Table	Species
rep.	unequal
d.f.	75
l.s.d.	3.009X min.rep
	2.282 max-min
	1.166 max.rep

(No comparisons in categories where s.e.d. marked with an X)

***** Stratum standard errors and coefficients of variation *****
Variate: Diameter

d.f.	s.e.	cv%
75	1.850	36.5

APPENDIX 'D'

Analysis Of Variance and Least Significant Difference Results for the Reclamation Species' Height

```
70 "One-way ANOVA (no Blocking)."
71 BLOCK "No Blocking"
72 TREATMENTS Species
73 COVARIATE "No Covariate"
74 ANOVA [PRINT=aovtable,information,means,%cv; FPROB=yes; PSE=diff,lsd;
LSDLEVEL=5]\
75 Height
75...............................................................................
```


***** Analysis of variance *****

Variate: Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Species	5	199.119	39.824	11.90	<.001
Residual	75	250.938	3.346		
Total	80	450.058			

* MESSAGE: the following units have large residuals.

units 40	-5.88	s.e. 1.76
units 57	4.74	s.e. 1.76

***** Tables of means *****

Variate: Height

Grand mean 10.98

Species	Acacia	Albizia	Cedrella	Gmelina	Leucaena	Senna
	13.23	10.20	8.81	10.03	9.16	11.75
rep.	19	3	6	20	13	20

*** Standard errors of differences of means ***

Table	Species
rep.	unequal

Appendix 'D' (Continued)

d.f. 75
s.e.d. 1.494X min.rep

1.133 max-min
0.578 max.rep

(No comparisons in categories where s.e.d. marked with an X)

*** Least significant differences of means (5% level) ***

Table	Species
rep.	unequal
d.f.	75
l.s.d.	2.975X min.rep
	2.256 max-min
	1.152 max.rep

(No comparisons in categories where s.e.d. marked with an X)

***** Stratum standard errors and coefficients of variation *****

Variate: Height

d.f.	s.e.	cv%
75	1.829	16.7

APPENDIX 'E'

Reclamation Species Distribution over an Area of One Hectare

Rank	Tree species	Number	proportion (Pi)	log e Pi	Pi log e Pi
1	*Senna seamia*	1947	0.347	-1.058	-0.367
2	*Acacia mangium*	1339	0.239	-1.433	-0.342
3	*Leucaena leucocephala*	886	0.158	-1.846	-0.291
4	*Gmelina aborea*	877	0.156	-1.856	-0.290
5	*Cedrella odorata*	363	0.065	-2.738	-0.177
6	*Albizia*	166	0.030	-3.520	-0.104
7	*Ceiba pentandra*	22	0.004	-5.541	-0.022
8	*Terminalia ivorensis*	8	0.001	-6.553	-0.009
9	*Entandophragma angolense*	3	0.001	-7.534	-0.004
	Total	**5,611**	**1.000**		**-1.617**

Shannon Wiener Index = H' = $-\sum_{i=1}^{S} \text{Pi} \log e \text{ Pi} = -(-1.607)$

$= \mathbf{1.617}$

APPENDIX 'F'
Undergrowth Distribution over an Area of One Hectare

Species Number	Undergrowth species	Numbers observed	Pi	log e Pi	Pi log e Pi
1	*Leucaena leucocephala*	19000	0.349	-1.054	-0.367
2	*Salacia africana*	7000	0.128	-2.052	-0.264
3	*Chromolaena sp (Akyampong)*	4500	0.083	-2.494	-0.206
4	*Funtumia africana* (Funtum)	3000	0.055	-2.900	-0.160
5	*Nibodia levis* (Sasamansa)	2000	0.037	-3.305	-0.121
6	*Funtumia elastica*	2000	0.037	-3.305	-0.121
7	*Solarium erianthioris* (Pepediawuo)	1500	0.028	-3.593	-0.099
8	*Palisota hirsuta* (Nsemenini)	1500	0.028	-3.593	-0.099
9	*fern*	1500	0.028	-3.593	-0.099
10	*Ceiba pentandra* (Onyina)	1000	0.018	-3.593	-0.066
11	*Cider acuta*	1000	0.018	-3.593	-0.066
12	*Cantium sopcodatum* (Tatiadupo)	1000	0.018	-3.593	-0.066
13	*Bliphia sapida* (Akyee)	1000	0.018	-3.593	-0.066
14	*Paulinia pivinata* (Toantin)	1000	0.018	-3.593	-0.066
15	*Cissus sp*	1000	0.018	-3.593	-0.066
16	*Aphanostylis manii*	500	0.009	-4.691	-0.043
17	*Antiaris toxicaria* (Kyenkyen)	500	0.009	-4.691	-0.043
18	*Spondias mombin* (Atowa)	500	0.009	-4.691	-0.043
19	*Discorea sp* (Climber)	500	0.009	-4.691	-0.043
20	*Combrentum sp* (Climber)	500	0.009	-4.691	-0.043
21	*Sacamone afzelii* (Kwatema)	500	0.009	-4.691	-0.043
22	*Milicia excelsa* (Odum)	500	0.009	-4.691	-0.043
23	*Spathodia campanulata* (Kuokuonisuo)	500	0.009	-4.691	-0.043
24	*Albizia zygia* (Okoro)	500	0.009	-4.691	-0.043
25	*Ficus sur*	500	0.009	-4.691	-0.043
26	*Albizia adianthifolia* (Pempena)	500	0.009	-4.691	-0.043
27	*Terminalia ivorensis* (Emire)	500	0.009	-4.691	-0.043
28	*Trichilia tessmanii*	500	0.009	-4.691	-0.043
	Total	**54,500**	**1.000**		**-2.491**

Shannon Wiener Index = H' = $-\sum_{i=1}^{S} Pi \log e\ Pi = -(-2.491)$ **=2.491**

APPENDIX 'G'

SOIL SAMPLE LABEL

Name of Sampler_ Joseph Yeboah _____ Date; 14th January, 2005

Sample plot location ____________ Sample Plot / Sample Number __________

Ph ______________________________
Ca Content ______________________________
Mg Content ______________________________
N Content ______________________________
P Content ______________________________
K Content ______________________________
OM Content ______________________________

SOIL SAMPLE LABEL

Name of Sampler_ Joseph Yeboah _____ Date; 14th January, 2005

Sample plot location ____________ Sample Plot / Sample Number __________

Ph ______________________________
Ca Content ______________________________
Mg Content ______________________________
N Content ______________________________
P Content ______________________________
K Content ______________________________
OM Content ______________________________

SOIL SAMPLE LABEL

Name of Sampler_ Joseph Yeboah _____ Date; 14th January, 2005

Sample plot location ____________ Sample Plot / Sample Number __________

Ph ______________________________
Ca Content ______________________________
Mg Content ______________________________
N Content ______________________________
P Content ______________________________
K Content ______________________________
OM Content ______________________________

APPENDIX 'H'

SAMPLE QUESTIONNAIRE FOR EPA, FSD AND MINERALS COMMISSION OFFICIALS

Is there a Policy statement/regulation necessitating reclamation? Yes/No
If yes please state. ____

____

____

____

____

What role does the policy or regulation provide for your outfit? (Please state) __

____

____

____

____

____

Apart from your outfit what other institutions are involved in the monitoring and evaluation of reclamation ____

____

____

____

____

Is there a National Reclamation Guideline? Yes/No

Do companies present a reclamation proposal document for discussions and approval before reclamation proceeds Yes/No

If yes please state the expectations of such a document ____________________________

____

____

____

____

____

____

____

What goes into the identification of end use for an area prior to reclamation (please state) ____

____

____

____

____

____

____

Are companies given any technical support during reclamation? Yes/No

If yes please state____

How often is monitoring and evaluation of reclamation carried out? __________

What indicators are used in monitoring and evaluation during reclamation? (Please state)

Are there any assessments after project completion Yes/No

If yes please state the indicators for the assessment of success________________

Other comments____

Thank you

APPENDIX 'I'
QUESTIONNAIRE FOR ANGLOGOLD ASHANTI.

PROJECT DATA (General)

Company ____________________

Total land area of the reclaimed site ____________________

Location of reclaimed area ____________________

Year of reclamation ____________________

Duration of reclamation ____________________

____

Cost of reclamation

Open pit Backfilling.

1. **Running cost of machines** ____________________
2. **Labour (operators/supervisors)** ____________________

Open pit revegetation

1. **Staff** ____________________
2. **Seedlings** ____________________
3. **Fertilizers** ____________________
4. **Fuel** ____________________
5. **Training** ____________________
6. **Others** ____________________

____

Policy statement/regulation necessitating reclamation if any (please state)
....
....
....
....
....

Is there a National Reclamation Guideline? Yes/No

If yes was the project incorporated into it? Yes/No

BEFORE PROJECT

Was there a document for

Identification? i.e. EIA Yes/No

Preparation? i.e. Reclamation plan Yes/No

Were there discussions

With landowners/local people Yes/No

With EPA Yes/No

With FSD Yes/No

With MINERAL COMMISSION Yes/No

Other (please state)

Was there a document for

Approval Yes/No

Agreement Yes/No

Please specify source (EPA, FSD, Min. Commission, other)

How well could the local people cope
In terms of staff, material support (please comment) ....
....
....
....
Any other support /cost (please explain) ....
....
....

Objectives/targets/end use
Was the end use well defined? Yes/No
If yes state ....
....
Was the time span realistic? Yes/No
Please give reasons for choice of end use ....
....
....
....

B DURING PROJECT

Reclamation technique.
Please name technique used ....
Give reasons for choice of technique ....
....
....
....

Reclamation species please name and give reasons for choice.
(a)Grasses..
....

Reasons ....
....
....

(b) Tree species ....
....
....
Reasons ....
....
....
....
....

Monitoring
Were there plans for regular monitoring at company level? Yes/No
Did the monitoring happen as planned? Yes/No
Please give details if yes ……………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
……………………………………………………………………………

Was there monitoring by EPA Yes/No
Please give details if yes ……………………………………………………………………
………………………………………………………………………………………………
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………………………………………………………………………………………………
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Was there monitoring by FSD Yes/No
Please give details if yes ……………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
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Was there monitoring by Minerals Commission Yes/No
Please give details if yes ……………………………………………………………………
………………………………………………………………………………………………
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……………………………………………………………………………

Strength and type of practical/technical support

From EPA (please comment) ……………………………………………………………
………………………………………………………………………………………………
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From FSD (please comment) ……………………………………………………………
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From Minerals Commission (please comment) ……………………………………
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From communities (please comment) ……………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………………………

Constraints
Please list and give details of constraints encountered
(a) ……………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………

(b) ……………………………………………………………………………………
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(c) ……………………………………………………………………………………
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(d) ……………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………

C AFTER PROJECT

Have there been any assessments after project at company level?
Were there specified assessment/evaluation dates?
Did evaluation take place as planned?
What indicators were used? Please give details ……………………………………

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……………………………………………………………………………………………………
………………………………………………………………………………………

Have there been any assessments after project by EPA?
What indicators were used? Please give details ……………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………………………
Was there specified assessment/evaluation dates? Yes/No
Did evaluation take place as planned? Yes/No

Have there been any assessments after project by FSD? Yes/No
What indicators were used? Please give details ……………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………………………
Was there specified assessment/evaluation dates? Yes/No
Did evaluation take place as planned? Yes/No

Have there been any assessments after project by Mineral Commission? Yes/No
What indicators were used? Please give details ……………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………………………
Was there specified assessment/evaluation dates? Yes/No
Did evaluation take place as planned? Yes/No

Any assessment by other agencies (please specify)

What happened at the end of the project.
Please tick as appropriate and give details.

- **Handed over to community**
- **Maintenance of structures**
- **Other**

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………

Have communities profited from it? Yes/No
Please specify ……………………………………………………………………………

D TRAINING

To be completed if training was a significant component

1 Formal programme

In-country

	Short <1week	Medium 1weekto1month	Long >1month
Unskilled			
Technician			
Professional			

Out of country	Number of people sent
Specialist/technical causes	
1st degree	
academic graduate	
Study tours, other experience gaining.	

APPENDIX 'J'
SAMPLE QUESTIONNAIRE FOR COMMUNITIES

Were you in the community before mining begun? Yes/No

What was the previous use of the mined area? ______________________________
____
____
____

What are some of the problems that the community suffered as a result of the mining activity? ______________________________
____
____
____

Did the companies hold discussions with the community / landowners/ users to agree on the final landuse before proceeding to reclaim? Yes/No

What Final Use Is The Site Going To Be Put To? ______________________________
____
____

How is the landuse going to benefit the community? ______________________________
____
____
____
____

What was the level of community involvement?
Direct; ______________________________
____
Indirect; ______________________________
____

Is there a way by which communities monitor whether the site has been reclaimed according to the agreed land use? Yes/No ______________________________
____

Do you believe that the reclaimed site has or can develop into some form that the community will benefit from? Yes/No
Explain ______________________________
____

What do you think should have been done on the reclaimed land?
Explain ______________________________
____

APPENDIX 'K'

FIELD ASSESSMENT FORM

Name of Company______________________________

Location of Reclaimed Area__________________________

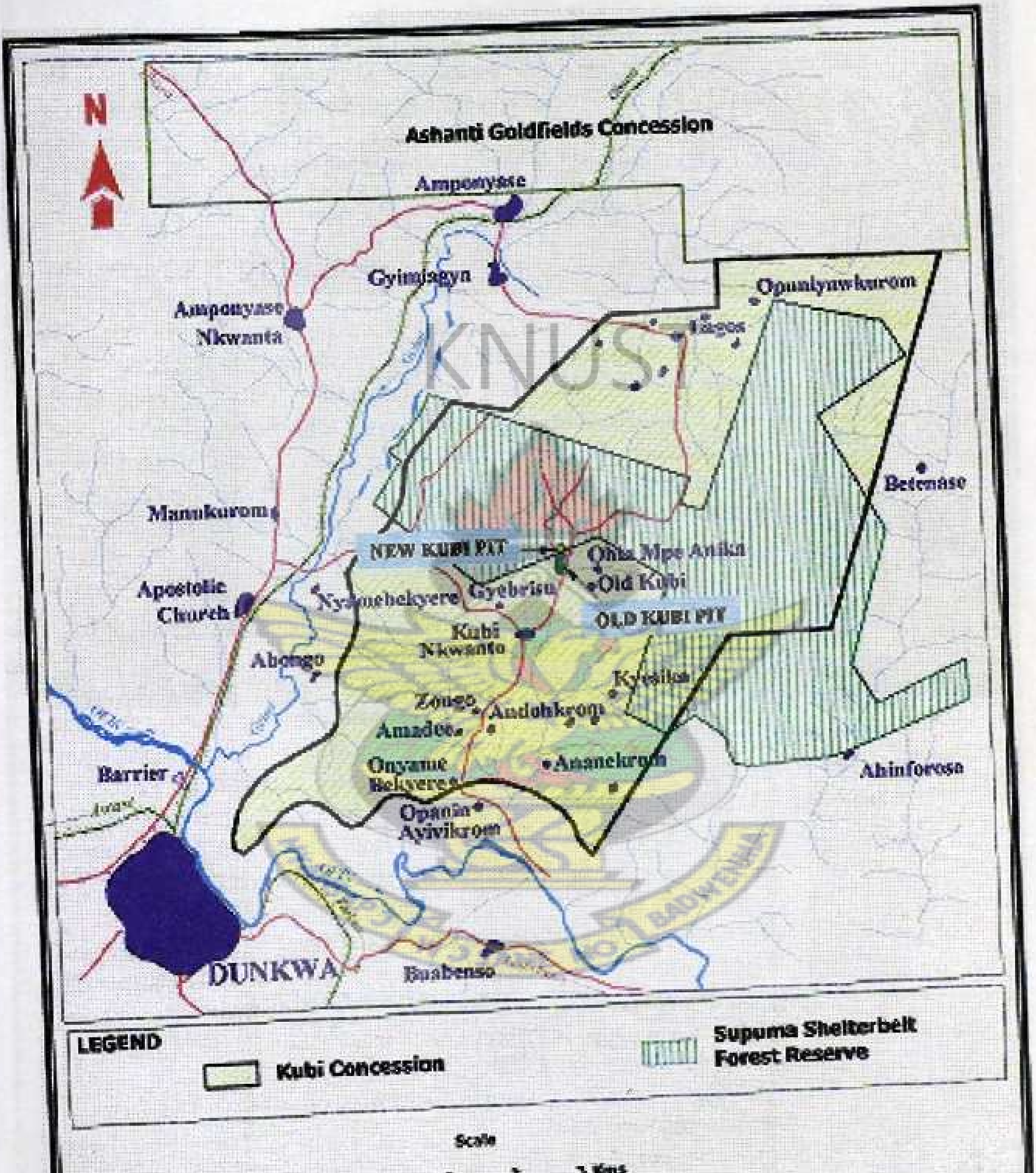
Size of Reclaimed Area___________________________

Assessed By__________________ Date________________

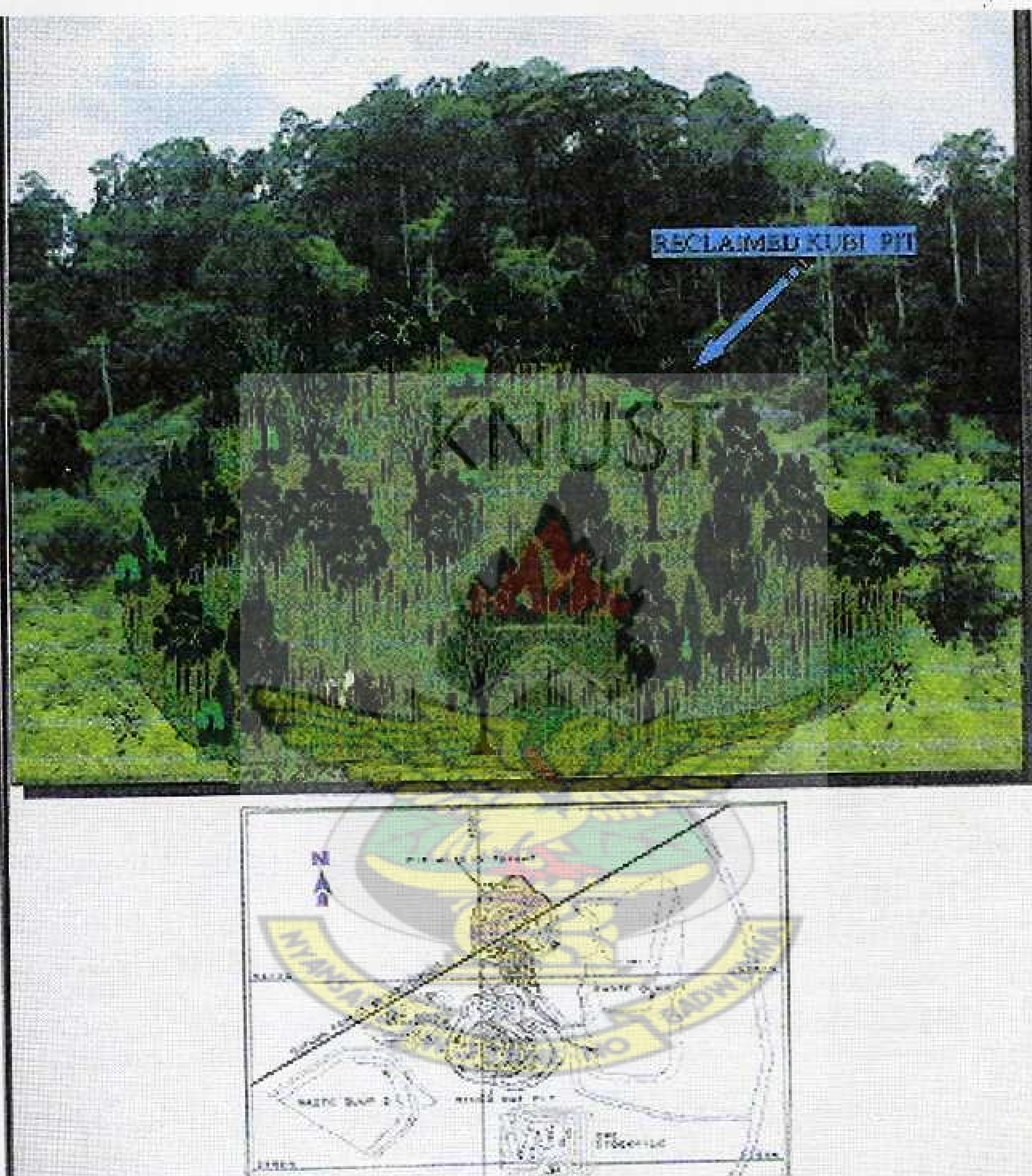
Species		
Tally	height	diameter
Total	Mean	
Species		
Tally	Height	Diameter
Total	Mean	

APPENDIX 'L'

A Map of Anglo Gold Ashanti's Kubi Concession within Which Lies the Supuma Shelterbelt Forest Reserve



APPENDIX 'M'
Conceptual view of the reclaimed Kubi pit



APPENDIX 'N'

GUIDE TO THE RESULTS

Classification by the Soil Science Department of the College of Agric and Natural Resources, KNUST.

Soil Chemical Property	Range	Remarks
Available Phosphorus (PPM or mg/Kg)	Less than 3.0 mg/Kg	very low
	3.0 – 7.0 mg/Kg	Low
	7.0 – 20.0 mg/Kg	Medium
	20.0 mg/Kg and above	Adequate to high
Soil Total Nitrogen (N)	1.0 % and above	Very high
	0.5 % - 1.0 %	High
	0.2 % - 0.5%	Medium
	0.1 % - 0.2 %	Low
	Less than 0.1%	Very low
Exchangeable Potassium (K) Me/100g or Cmol/Kg	0.2 – 0.05	Low
	0.5 – 0.2	Medium
	0. 5 and above	High
pH	4.0	Intensely Acidic
	5.0	Moderately Acidic
	6.0	Slightly Acidic
	7.0	Neutral
	8.0	Slightly Alkaline
	9.0	Moderately Alkaline
C/N Ratio	1 -20	Easily Decomposable
	20 and Above	Scarcely Decomposable