Assessment of Cost and Benefit Associated with Ecological Restoration in Ghana.

(A case study in Bekwai Municipal Area)

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ABSTRACT

Ghana has had a long-standing problem of illegal gold mining that has led to the destruction of the environment. The government of Ghana is taking steps to not only curb illegal mining but also to restore destroyed lands that resulted from illegal mining. The government intends to spend financially in the area of ecological restoration to returned disturbed lands to their natural states possible, but the question remains whether restoring those disturbed lands will be beneficial to the country.

The study was undertaken in Bekwai Municipal Area in the Ashanti region of Ghana where most locals are farmers. The research studies whether the benefits of ecological restoration outweigh the cost of ecological restoration? The research deployed a quantitative data collection. The data collected was analyzed using benefit-Cost ratio.

The result shows that the benefit of ecological restoration outweighs the cost incurred as dependent on the land use as a carbon sequestration project. In conclusion, investment in ecological restoration is a step in the right direction for a country endowed with gold resources. This will spur growth and at the same time improve and protect the country’s natural resources and environment.

Keywords: Ecological restoration, illegal mining, Clean Development Mechanism, Carbon sequestration,
INTRODUCTION

Management of natural resources in an environment is a major question researcher have delved into, owing to the connected relationship of components in the environment system. Indeed, diverse methods have been designed and applied to provide sound and sustainable environmental management options.

Mining entities both legal and illegal should be responsible for restoring disturbed lands during their operations. As part of being a responsible mining entity, restoration plans are to be designed to bring disturbed lands back to their previous state or even a better land use type.

Mining entities need to be responsible in their operations and restoring lands involve steps that continue to the point of decommissioning where there is not any likelihood of a reclaimed or restored land later having some negative impacts on communities surrounding them. The safety, environmental and social risks arising from badly conducted mine closure can result in significant liabilities for mining companies. For communities, closure can cause severe distress because of the threat of economic and social collapse. In the case of illegal mining entities who are not accountable for their operations, the disturbed lands from their operation could led to enormous negative impact on the economy, environment and social integrity of the community and country in general. Abandoned mines may result in large clean-up costs and closure liabilities for governments (World Bank, 2002).

Illegal mining popularly referred to as “Galamsey” which was derived from the phrase “Gather them and sell” is a social menace causing havoc to many natural ecosystems in Ghana. According to Ghana Minerals Commission, there are about 20,000 to 50,000 illegal miners as of 2013 and their operations are increasing at an exponential rate. These operations have lasted over decades until it was recently banned by the country in 2017. There are no doubts these operations provide some sources of employment in Ghana but needs to be regulated by government in order to prevent it from destroying the society and environment. According (UNDP, 2013) to, management of extractive industries is one of the most critical challenges facing many resource dependent developing countries today. Ghana being one of such countries needs to adopt management systems like the ones used by large scale mining companies to mine responsibly for the less regulated, illegal and small-scale mining industry in Ghana. Restoration economy has proven to be a successful economic model in countries like the
USA where a growing body of evidence suggests the presence of a restoration industry does not only protect public environmental goods, but also contributes to national economic growth and employment. Federal and state agencies have begun to evaluate the impact of their restoration investments on local and state economies, finding that restoration projects support as many as 33 jobs per $1 million invested (Edwards, 2013). This research will provide evidence of the importance of ecological restoration on the economy. (BenDor, 2015) published a study called Estimating the Size and Impact of the Ecological Restoration Economy, which found restoration businesses in all 50 states. California had the most, but four "red" states filled out the top five: Virginia; Florida; Texas; and North Carolina. Fifth place went to North Dakota. By their very nature, restoration projects are in rural areas, and a study by Cathy Kellon and Taylor Hesselgrave of Eco Trust found that Oregon alone had more than 7,000 watershed restoration projects, which generated nearly 6,500 jobs from 2001 through 2010. Many of those jobs went to unemployed loggers. "The jobs created by restoration activities are located mostly in rural areas, in communities hard hit by the economic downturn," report authors wrote. "Restoration also stimulates demand for the products and services of local businesses such as plant nurseries, heavy equipment companies and rock and gravel companies.” The study analyses the benefit and cost involved with the project (Cathy Kellon, 2012). This analysis will assist government in making effective decision concerning the project. To provide a quantitative analysis of the insight ecological restoration can have on Ghana’s economy.

MATERIALS AND METHODS

Bekwai Municipal Assembly (BMA) is one of the 27 districts in the Ashanti Region established under Legislative Instrument (L.I. 1906, 2007) as shown in Figure 1. Until recently the Bekwai Municipality was part of the Amansie East District made up of the Bekwai and Bosome-Freho Constituencies. It is in the southern part of Ashanti Region. It shares boundaries with Bosomtwe District in the north, Adansi –North in the south, Bosome-Freho District to the East and Amansie-Central and Amansie –west to the west. The Municipal Assembly lies within latitude 6° 00’N 6° 30’N and Longitudes 1°00’W and 1° 35W. It covers a total land area of about 633sqkm.
Amansie East (Bekwai) is an area endowed with gold deposits in most areas. The area has many galamsey activities going on. The entire District is rich in gold deposits and mining has emerged as the most important economic activity in the communities. Mining companies have acquired almost all the remaining land area in the District for either prospecting or actual mining (Ministry of Food and Agriculture 2010). Apart from the companies with large concessions in the district, there are other interested parties in the mining industry. The activities of small-scale miners, mostly galamsey operators who employ very crude methods to mine for gold are continually increasing in the district. The activities of these various groups are not properly regulated and not well organized as part of a total package development effort even though it goes a long way to alleviate the poverty situation in the district.

AngloGold Ashanti mining company mines on lands owned by the municipality. The rate of deforestation and land degradation is high and collectively has led to government’s bold step to ban this illegal activity.

Figure 1 Map of Ghana showing the location of Bekwai
To perform the cost benefit analysis, the direct cost related to the project was identified. This data was collected from ecological restoration project done at AngloGold Ashanti Obuasi mines in Ghana. In the study, we used methods from the Toolkit for Ecosystem Services Site-based Assessment to calculate the ecosystem service values of a restored land. We chose this toolkit because it enables the collection of site-scale data relevant to decision without the need for specialist technical knowledge of the modeling approaches or GIS software typical of most currently available tools such as Infrastructure Voluntary Evaluation Sustainability Tool (Tallis, 2013). Using the cost benefit scale, the cost associated with ecological restoration was calculated in terms of cost in dollars/hectare of land restored. According to methods derived by Toolkit for Ecosystem Services Site-based Assessment, benefits of ecological services can be calculated in terms of climate change mitigation (Carbon sequestration in tonnes of CO$_2$ in dollars), nature services like tourism, air purification, non-forest products like mushrooms, peat and others services. The benefits associated from this project was based on climate change mitigation where the amount of carbon sequestered by trees on the disturbed land were calculated using the price of Carbon based on US Government CO$_2$ value of $22.78 per tonnes of CO$_2$, adjusted to 2011.

This procedure as shown in Figure 2 for calculating the price of CO$_2$ was based on an extension publication from the University of Nebraska. (Toochi, 2018)

![Figure 2 Procedure for calculating Carbon dioxide sequestered by a tree](Toochi, 2018)

To measure the weight of carbon stored, the following steps where followed:

- I determined the total green weight of the tree, W and multiply by 120%. (Dewald, 2005)
For diameters >11 inches the \( w=0.25(D)^2*2H \); For diameters <11 inches the \( w=0.15(D)^2*2H \)

Where \( H \) is height (feet), \( W \) is weight (pounds), \( D \) is diameter.

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• Secondly determined the dry weight of the tree by multiplying the green weight by 72.5% since the dry weight of a tree is averagely 72.5% of the whole weight. \((\text{Birdsey, 1992})\)

• I determined the weight of carbon in the tree by multiplying the dry weight by 50% because averagely the dry weight of a tree is 50% carbon.

• I determined the weight of carbon dioxide sequestered in the tree by calculating the atomic weight of carbon in one molecule of carbon which is 3.6663 and multiplying it by the weight of carbon which is 50% of the dry weight.

• Finally, I determined the weight of carbon dioxide sequestered by the tree in a year by dividing the weight of carbon dioxide sequestered in the tree by the age of the tree.

Data collected from AngloGold Ashanti Obuasi mines showed that the cost of ecological restoration of mine land for forest cover was $2000/hectare as shown on Table 1 and the benefits derived from Ecological restoration within a period was used to analyze if financing ecological restoration was beneficial.

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\[ Table 1 Cost of Adubriem Ecological restoration Project \]

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\[ \begin{array}{|c|c|c|} 
\hline
\text{ACTIVITIES} & \text{No. of People} & \text{cost ($)/time} \\
\hline
\text{ENGINEERING WORKS} & 5 & 500 \\
\hline
\text{CLEAN UP AND CONTAMINATION} & 5 & 500 \\
\hline
\text{TOPSOIL SPREADING} & 1 & 200 \\
\hline
\text{SEED COLLECTION AND TREE NURSERY MANAGEMENT} & 5 & 200 \\
\hline
\text{GRASSING AND PLANTING} & 7 & 200 \\
\hline
\text{MAINTENANCE EG THINNING} & 2 & 200 \\
\hline
\text{MONITORING} & 2 & 200 \\
\hline
\text{TOTAL} & 27 & 2000 \\
\hline
\end{array} \]

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A simple random sampling based on the principle of the first law of geography which according to (Tobler, 1970) states that" everything is related to everything else but near things are more related than distant things and a sample number of 30 trees were monitored to determine the amount of carbon sequestered.

Every restoration project has an objective and the government of Ghana has made it clear that restoring and protecting Ghana’s forest cover will be the objective of the ecological restoration projects. To make sure that objective works out there was the need for participatory land use plan which included all stakeholders. This research quantified the amount of carbon to be sequestered by trees for carbon credits which could serve as a source of income for the community while preserving the forest cover for other ecological services in the future. The forest could also provide community members with benefits like recreation, Non-Forest Products and other agroforestry benefits like intercropping trees with suitable crops.

RESULTS AND DISCUSSIONS

We identified and measured the weight of carbon dioxide found in the tree species on the project site as shown in Table 2. From the data collected the amount of carbon dioxide sequestered by trees involved in the study was calculated as seen in Table 3 and Figure 3. The cost of Adubriem ecological restoration project was $2000/ha as shown in Table 1 and this was used to equate the benefits derived from ecological restoration in terms of Carbon sequestration. The cost of Carbon sequestered by 1500 trees was $2,111 in 2017, $2.815.37 in 2018 and $7,352.66 in 2019 as shown in Figure 4
| TREE CODE | GPS COORDINATES | (WCO)IBS | (WCO)IBS | (WCO)IBS |
|-----------|----------------|---------|---------|---------|
| A1        | Asanfna-1      | 607540  | 583495  | 109.0606031 | 333.142142 | 1009.556 |
| A2        | Asanfna-2      | 607524  | 583475  | 144.678361 | 369.363008 | 1332.672 |
| C1        | Cedrela-1      | 607455  | 583497  | 200.7408146 | 487.225893 | 1433.415 |
| C2        | Cedrela-2      | 607541  | 583409  | 64.07643626 | 197.038557 | 1026.329 |
| C3        | Cedrela-3      | 607532  | 583470  | 113.5935736 | 293.212223 | 1007.878 |
| C4        | Cedrela-4      | 607529  | 583471  | 137.9338507 | 397.153886 | 1467.948 |
| E1        | Emire-1        | 607480  | 583474  | 76.70399898 | 222.9626   | 831.3268 |
| E2        | Emire-2        | 607503  | 583452  | 51.34832681 | 147.34714  | 787.172  |
| E3        | Emire-3        | 607443  | 583565  | 44.78949901 | 244.159539 | 1088.452 |
| ED1       | Edinam-1       | 607506  | 583468  | 53.74566394 | dead       | dead     |
| ED2       | Edinam-2       | 607522  | 583533  | 50.06710372 | 213.946179 | 1166.126 |
| ED3       | Edinam-3       | 607495  | 583574  | 61.87299186 | 199.175756 | 1088.452 |
| G1        | Glicidea-1     | 607456  | 583568  | 134.5108413 | dead       | dead     |
| G2        | Glicidea-2     | 607504  | 583572  | 185.6189756 | 664.459227 | 1885.567 |
| G3        | Glicidea-3     | 607543  | 583510  | 143.049906  | 326.856684 | 1592.641 |
| G4        | Glicidea-4     | 607539  | 583436  | 232.4458052 | dead       | dead     |
| K1        | Kyenken-1      | 607480  | 583515  | 144.3946915 | 415.462317 | 1303.274 |
| K2        | Kyenken-2      | 607498  | 583490  | 98.77846065 | 306.186334 | 1247.612 |
| L1        | Lucinea-1      | 607472  | 583584  | 127.0963927 | 493.360976 | 1843.196 |
| L2        | Lucinea-2      | 607445  | 583584  | 201.9310457 | 519.272731 | 1914.132 |
| CG1       | Cola gigantea-1| 607495  | 583574  | 133.6378671 | 334.812049 | 1677.661 |
| CG2       | Cola gigantea-2| 607497  | 583580  | 186.8808644 | 425.188464 | 1578.194 |
| TS1       | Triplochiton sclerocylon-1 | 607532 | 583472 | 80.25632916 | 408.711051 | 1762.855 |
| TS2       | Triplochiton sclerocylon-2 | 607529 | 583470 | 178.3363406 | 471.336131 | 2002.055 |
| T1        | Terminalia ivorensis-1 | 607540 | 583496 | 148.7592707 | 422.554241 | 1873.035 |
| T2        | Terminalia ivorensis-2 | 607524 | 583475 | 54.20101164 | 158.074466 | 1020.004 |
| T3        | Terminalia ivorensis-3 | 607455 | 583498 | 108.94743 | 354.397086 | 1455.201 |
| AF1       | Albizia ferruginea-1 | 607539 | 583472 | 105.4396198 | 488.372721 | 1876.694 |
| AF2       | Albizia ferruginea-2 | 607480 | 583474 | 153.414469 | 416.44751 | 1433.601 |
| AF3       | Albizia ferruginea-3 | 607513 | 583452 | 179.9941581 | 442.250547 | 1429.259 |

Table 2 Weight of Carbon dioxide (Ibs) sequestered by Trees in Adubriem Ecological restoration Project.
Table 3 Amount of carbon dioxide sequestered by Trees of study site.

| TREE CODE | TREE | GPS COORDINATES | CO2 SEQ. | CO2 SEQ. | CO2 SEQ. |
|-----------|------|-----------------|----------|----------|----------|
| A1        | Asanfna-1 | 607540 583495  | 109.0606 | 166.5711 | 336.5187 |
| A2        | Asanfna-2 | 607524 583475  | 144.6784 | 184.6815 | 444.2239 |
| C1        | Cedrela-1 | 607455 583497  | 200.7408 | 243.6129 | 477.8049 |
| C2        | Cedrela-2 | 607541 583409  | 64.07644 | 98.51928 | 342.1098 |
| C3        | Cedrela-3 | 607532 583470  | 113.5936 | 146.6061 | 335.9593 |
| C4        | Cedrela-4 | 607529 583471  | 137.9339 | 198.5769 | 489.3161 |
| E1        | Emire-1   | 607480 583474  | 76.704   | 111.4813 | 277.1089 |
| E2        | Emire-2   | 607503 583452  | 51.34833 | 73.67357 | 262.3907 |
| E3        | Emire-3   | 607443 583468  | 44.7895  | 122.0798 | 319.2203 |
| ED1       | Edinam-1  | 607506 583468  | 53.74566 | 67.34247 | 242.885  |
| ED2       | Edinam-2  | 607522 583533  | 50.0671  | 106.9731 | 388.7085 |
| ED3       | Edinam-3  | 607495 583574  | 61.87299 | 99.58788 | 362.8173 |
| G1        | Glicidea-1| 607456 583568  | 134.5108 | dead     | dead     |
| G2        | Glicidea-2| 607504 583572  | 185.619  | 332.2296 | 628.5222 |
| G3        | Glicidea-3| 607543 583510  | 143.0499 | 163.4283 | 530.8802 |
| G4        | Glicidea-4| 607539 583436  | 232.4458 | dead     | dead     |
| K1        | Kyenken-1 | 607480 583515  | 144.3947 | 207.7312 | 434.4247 |
| K2        | Kyenken-2 | 607498 583490  | 98.77846 | 153.0932 | 415.8708 |
| L1        | Lucinea-1 | 607472 583584  | 127.0964 | 246.6805 | 614.3986 |
| L2        | Lucinea-2 | 607445 583584  | 201.931  | 259.6364 | 638.0441 |
| CG1       | Cola gigantea-1 | 607495 583574 | 133.6379 | 167.406  | 559.2204 |
| CG2       | Cola gigantea-2 | 607497 583580 | 186.8809 | 212.5942 | 526.0647 |
| TS1       | Triplochiton sclerocylon-1 | 607532 583472 | 80.25633 | 240.3555 | 587.6184 |
| TS2       | Triplochiton sclerocylon-2 | 607529 583470 | 178.3363 | 235.6681 | 667.3517 |
| T1        | Terminalia ivorensis-1 | 607540 583496 | 148.7593 | 211.2771 | 624.3446 |
| T2        | Terminalia ivorensis-2 | 607524 583475 | 54.20101 | 79.03723 | 340.0013 |
| T3        | Terminalia ivorensis-3 | 607455 583498 | 108.9474 | 177.1985 | 485.0668 |
| AF1       | Albizia ferruginea-1 | 607539 583472 | 105.4396 | 244.1864 | 625.5646 |
| AF2       | Albizia ferruginea-2 | 607480 583474 | 153.4431 | 208.2224 | 477.8671 |
| AF3       | Albizia ferruginea-3 | 607513 583452 | 179.9942 | 221.1253 | 476.4196 |
Figure 3 Amount of Carbon dioxide sequestered by trees (lbs/hectare of 1500 trees)

Figure 4 Cost of Carbon dioxide sequestered by 1500 trees.
Article 3.3 of the Kyoto Protocol stated that net changes in Greenhouse Gases emissions by sources and removals by sinks through direct human-induced activities, limited to afforestation, reforestation and deforestation that occurred since 1990, can be used to meet Parties’ emission reduction commitments (United Nations, 1998). At the inception of the Kyoto Protocol, only afforestation and reforestation activities were identified as qualifying for the carbon development mechanism due to environmental and market concerns with other activities within the full scope of Reducing Emissions from Deforestation and Forest Degradation. The negotiation of modalities and procedures for forestry carbon development mechanism took two years longer than for other carbon development mechanism sectors, which also caused some delay in investment in the sector. Under carbon development mechanism Afforestation/Reforestation, the approved methodologies give project developers options to manage and harvest forests for agroforestry, bioenergy, timber production or urban forestry (Neeff, 2006). (Biocarbon fund, 2011), scaling up Afforestation/Reforestation activities is critical to mitigating climate change, improving rural livelihoods, improving resilience to climate change, conserving biodiversity, restoring degraded lands, and strengthening the human, social, and financial capital of local communities. Ecological restoration projects could also provide additional environmental and social benefits which include reductions in air pollution, water pollution which extends to improve water availability, reduced soil erosion and protected biodiversity. (F.A.O, 2001), a healthy forest sector can contribute positively to the economic development of Uganda, by providing environmental services in terms of climate regulation, soil conservation, and carbon sequestration. Furthermore, the forestry sector has multiple socio-economic benefits by offering significant employment, providing raw materials for the construction industry and the national energy demand, as well as contributing medicinal, cultural, and spiritual values held by rural communities. These carbon development mechanism projects could inculcate other management practices to maximize profits and benefits for people in the area. Bekwai municipality has many destroyed lands which could be used for carbon development mechanism forestry projects which can achieve government’s object of creating forest cover through ecological restoration, provide local people with incentives from carbon sequestration projects whiles managing their farmlands to maximize crop yields and finally non-market values such as preventing soil erosion, water pollution, air pollution and mitigating of climate change just to mention a few.
CONCLUSION

From the research, the benefits derived from ecological restoration outweighs that of the cost. The benefits are sustainable, multiple and community wide depending on the end use of the restored land which in this case is for carbon sequestration and farming. Clean Development Mechanism remains uncertain but a promising mechanism that can help developing countries gain financial and improve environmental quality. Restoring ecosystems help reduce deforestation and degradation but also can help affected communities get incentives and sorts of income from carbon sequestration land use plan. According to (Surendran, 2016) 60% of Clean Development Mechanism projects displayed some economic sustainable development.

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## APPENDICES

| TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE CODE | TREE COD...
| TREE CODE | TREE | GPS COORDINATES | 2017 (D) INCHES | 2018 (D) INCHES | 2019(D) INCHES | (H) FEETS | (H) FEETS | (H) FEETS |
|-----------|------|----------------|----------------|----------------|----------------|-----------|-----------|-----------|
| A1        | Asanfna-1 | 607540 | 583495 | 6.38 | 40.7044 | 8.86 | 78.4996 | 9.44 | 89.1136 | 5.6 | 8.87 | 10.3 |
| A2        | Asanfna-2 | 607524 | 583475 | 6.62 | 43.8244 | 8.24 | 67.8976 | 9.36 | 87.6096 | 6.9 | 11.37 | 13.83 |
| C1        | Cedrela-1 | 607455 | 583497 | 6.51 | 42.3801 | 8.78 | 77.0884 | 10.15 | 103.0225 | 9.9 | 13.21 | 12.65 |
| C2        | Cedrela-2 | 607541 | 583409 | 5.86 | 34.3396 | 8.5 | 72.25 | 10.8 | 116.64 | 3.9 | 5.7 | 8 |
| C3        | Cedrela-3 | 607532 | 583470 | 5.08 | 25.8064 | 7.3 | 53.29 | 8.37 | 70.0569 | 9.2 | 11.5 | 13.08 |
| C4        | Cedrela-4 | 607529 | 583471 | 5.48 | 30.0304 | 7.93 | 62.8849 | 9.22 | 85.0084 | 9.6 | 13.2 | 15.7 |
| E1        | Emire-1 | 607480 | 583474 | 6.97 | 48.5809 | 8.91 | 79.3881 | 9.72 | 94.4784 | 3.3 | 5.87 | 8 |
| E2        | Emire-2 | 607503 | 583452 | 5.46 | 29.8116 | 7.58 | 57.4564 | 9.5 | 90.25 | 3.6 | 5.36 | 7.93 |
| E3        | Emire-3 | 607443 | 583565 | 5.03 | 25.3009 | 9.65 | 93.1225 | 10.4 | 108.16 | 3.7 | 5.48 | 8.05 |
| ED1       | Edinam-1 | 607506 | 583468 | 5.51 | 30.3601 | 7.09 | 50.2681 | 9.1 | 82.81 | 3.7 | 5.6 | 8 |
| ED2       | Edinam-2 | 607522 | 583533 | 5.81 | 31.7561 | 8.92 | 79.5664 | 10.66 | 113.6356 | 3.1 | 5.62 | 9.33 |
| ED3       | Edinam-3 | 607495 | 583574 | 6.26 | 39.1876 | 8.04 | 64.6416 | 9.75 | 95.0625 | 3.3 | 6.44 | 10.41 |
| G1        | Glicidea-1 | 607456 | 583568 | 5.25 | 27.5625 | dead | dead | dead | dead | 10.2 | dead | dead |
| G2        | Glicidea-2 | 607504 | 583572 | 6.26 | 39.1876 | 9.7 | 94.09 | 10.62 | 112.7844 | 9.9 | 14.76 | 15.2 |
| G3        | Glicidea-3 | 607543 | 583510 | 5.67 | 32.1489 | 7.48 | 55.9504 | 10 | 100 | 9.3 | 12.21 | 14.48 |
| G4        | Glicidea-4 | 607539 | 583436 | 6.77 | 45.8329 | dead | dead | dead | dead | 10.6 | dead | dead |
| K1        | Kyenken-1 | 607480 | 583515 | 6.03 | 36.3609 | 8.77 | 76.9129 | 9.3 | 86.49 | 8.3 | 11.29 | 13.7 |
| K2        | Kyenken-2 | 607498 | 583490 | 5.47 | 29.9209 | 8.04 | 64.6416 | 9.18 | 84.2724 | 6.9 | 9.9 | 13.46 |
| L1        | Lucine-1 | 607472 | 583584 | 5.18 | 26.8324 | 8.73 | 76.2129 | 10.5 | 110.25 | 9.9 | 13.53 | 15.2 |
| L2        | Lucine-2 | 607445 | 583584 | 6.31 | 39.8161 | 8.45 | 71.4025 | 10.4 | 108.16 | 10.6 | 15.2 | 16.09 |
| CG1       | Cola gigantea-1 | 607495 | 583574 | 5.51 | 30.3601 | 7.02 | 49.2804 | 9.92 | 98.4064 | 9.2 | 14.2 | 15.5 |
| CG2       | Cola gigantea-2 | 607497 | 583580 | 6.86 | 47.0596 | 8.5 | 72.25 | 10.01 | 100.2001 | 8.3 | 12.3 | 14.32 |
| TS1       | Triplochiton sclerocyon-1 | 607532 | 583472 | 5.08 | 25.8064 | 8.3 | 68.89 | 10.55 | 111.3025 | 6.5 | 12.4 | 14.4 |
| TS2       | Triplochiton sclerocyon-2 | 607529 | 583470 | 6.4 | 40.96 | 8.3 | 68.89 | 10.6 | 112.36 | 9.1 | 14.3 | 16.2 |
| T1        | Terminalia ivorensis-1 | 607540 | 583496 | 6.97 | 48.5809 | 8.88 | 78.8544 | 10.55 | 111.3025 | 6.4 | 11.2 | 15.3 |
| T2        | Terminalia ivorensis-2 | 607524 | 583475 | 5.46 | 29.8116 | 7.6 | 57.76 | 10.7 | 114.49 | 3.8 | 5.72 | 8.1 |
| T3        | Terminalia ivorensis-3 | 607455 | 583498 | 5.03 | 25.3009 | 7.38 | 54.4644 | 9.29 | 86.3041 | 9 | 13.6 | 15.33 |
| AF1       | Albizia ferruginea-1 | 607539 | 583472 | 6.51 | 42.3801 | 8.93 | 79.7449 | 10.2 | 104.04 | 5.2 | 12.8 | 16.4 |
| AF2       | Albizia ferruginea-2 | 607480 | 583474 | 5.81 | 33.7561 | 8 | 64 | 9.3 | 86.49 | 9.5 | 13.6 | 15.07 |
| AF3       | Albizia ferruginea-3 | 607513 | 583452 | 6.26 | 39.1876 | 8.4 | 70.56 | 9.6 | 92.16 | 9.6 | 13.1 | 14.1 |

Table 4 Tree data collection

D, Diameter

H, Height