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Research Paper

I. Mined Lands Reclamation Using Legume-Based Cropping Systems In The Talensi And Nabdam Districts Of The Upper East Region in Ghana.

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ABSTRACT : *This study investigated the use of leguminous plants in the reclamation of mined and degraded lands in some small scale mining areas in the Talensi and Nabdam Districts in the Upper East Region of Ghana. The treatments tested in the field experiments were: sole cropped groundnut (A), sole cropped soybean (B), sole cropped Bambara groundnut (C), groundnut intercropped with soybean (D) and groundnut intercropped with Bambara groundnut (E). Generally the experimental treatments performed poorly on the degraded lands when compared with control plots (undisturbed fields) in two seasons. However, during the second year the performance of the various treatments on the degraded land was better than that in the first year. Groundnut plus soybean was considered the best treatment because it resulted in the best improvement in soil organic carbon and total soil nitrogen. It also gave the best land equivalent ratio (LER).*
Keywords: *Cropping systems, Degraded, Leguminous, Intercropped, Reclamation, Vegetation*

I. INTRODUCTION

The historical development of mining in Ghana can be traced to the pre-colonial era. According to [1] the mining sector in Ghana has experienced significant policy attention since the early 1980s. Since then the mining industry has contributed significantly to Ghana's socio-economic development. Even though the benefits of mining on development have been acknowledged in literature, its activities have also led to the destruction of vegetation, microbial communities and vast areas of lands [2][3] further reiterated the negative impact of mining on the aesthetics of the landscape resulting in the alteration of soil components such as soil horizons, structure and nutrient cycles. Reclaiming the mined lands is critical to the continued use and productivity of the land. The reclamation process usually involves the restoration of the ecological integrity of the mined lands. Traditionally, mined or damaged lands have been restored through long rotation forest fallowing [4]. However, the main challenges faced in the recovery and restoration of severely mined lands are in the management of the systems and the presence of plant species that will grow under the harsh conditions common in degraded soils [5]. Leguminous plants play important role in the restoration and the improvement of soil fertility through the stimulation of different soil organisms leading to modification of the soil structure [6][7]. Application of leguminous crops also helps to prevent erosion (Giller and Wilson 1991). Research conducted in many parts of Sub-Saharan Africa including Ghana has shown that legumes have the potential to sustain soil fertility in smallholder farming systems [8][9]

This study therefore aimed to investigate the growth characteristics of some selected legume crops cultivated on mined lands and the associated soil properties of the degraded lands with the view to assessing the use and level of effectiveness of different legume crops in the reclamation process of some degraded lands in small scale mining areas in the Talensi and Nabdam districts.

II. MATERIALS AND METHODS

2.0Study Area

The study was carried out in two selected mining communities namely Yale and Obuasi in the Talensi and Nabdam Districts of the Upper East Region. The districts are located in the Guinea Savanna Zone and they experience unimodal rainfall pattern which occurs between May and October. These districts fall between latitude 10^{o} 15' and 10:60' North of the equator and longitude 0^{o} 31' and 1^{o} 05' west of Greenwich Meridian occupying a total land area of 912 km2. The annual average rainfall is 1100 mm, the topography is relatively undulating lowland gentle slope from one to five percent. The main occupation of the people is mixed farming on subsistence basis. The soils of the study area are Tongo series (local name) and are classified as Lithic Ustorthents [10]. They were developed from Granitic and Birrimian rocks and are usually coarse sandy loam to gravelly loamy sand with ironstone concretion. The soils usually have less accumulation of organic matter like most soils of the Northern Regions.

2.1 Examination of Changes in Soil Properties in the Legume based Cropping Systems

Field experiments were conducted at Yale and Obuasi to examine soil properties under various legume based cropping systems. Three sole legume cropping systems (viz groundnut, Bambara groundnut and soyabean) and two intercropping systems (viz groundnut with Bambara groundnut with soybean) were grown in the two communities.

2.2Sites for Field Experiment

Two communities that were about 8 km apart were identified as suitable for the experiment. These were Yale (10^{o} 41.443' N and 000^{o} 0 40.201' W) and "Obuasi" (10^{o} 43.629' N and 000^{o} 040.455' W). These sites were selected based on the following criteria: areas where surface mining has taken place; accessibility to the community throughout the study period; readiness of members of the community to release land for the experiment and safety of the experiment from destruction by domestic and wild animals.

2.3Land Preparation

Selected lands were prepared using manual labour. The pits were back-filled with the excavated soil on the soil surface. The land was then hoed and leveled with rakes. An area of 7 m x 12 m at each location was pegged and subdivided into three blocks measuring 12 m x 2 m. Each block was divided into five sub-plots of 2 m x 2 m having 0.5 m wide boundary around it. Additional two blocks each measuring 12 m x 2 m were prepared in an undisturbed area near the experimental plots to serve as comparison yardsticks.

2.4Crops for the Experiment

The following treatments were examined on the plots in the two communities:

a) Sole groundnut crop b) Sole Bambara groundnut crop c) Sole soybean crop d) Soybean intercropped with groundnut e) Groundnut intercropped with Bambara groundnut.

2.5Layout of Experiment

The experimental layout was Randomized Complete Block Design [11]. This was accomplished by using the Random Numbers Method. There were three replications of the treatments on the degraded land while on the control the experiments were replicated twice because of unavailability of lands. The letters A, B, C, D and E were used to represent sole groundnut, sole bambara groundnut, sole soybean, soybean + groundnut intercropped and groundnut + bambara groundnut intercrop respectively.

2.5.1Crops Varieties and their various Spacing

A. Groundnut

The groundnut bunch type (variety: JL 24) was grown at the two sites in both years. The crop was sown at one plant per stand. The spacing was 15 cm within rows and 40 cm between rows.

B. Bambara Groundnut

The 'Black Eye' type was grown at the two sites in both years. The crop was sown at one plant per stand. The spacing was 15 cm within rows and 40 cm between rows.

C. Soybean

The Anidaso variety was sown at the two sites in both years. The crop was sown at a spacing of 5 cm within rows and 75 cm between the rows and one plant per hill.

D. Groundnut + soybean intercrop

The same varieties and spacing within rows for their mono-cropping was used with a spacing of 50 cm between rows at the two sites in both years. The ratio of groundnut to soybean rows was 1.1.

E. Groundnut + Bambara Groundnut intercrop

The same varieties and spacing for their monocropping was used at the two sites in both years. The ratio of groundnut to Bambara groundnut rows was 1:1.

2.6 Soil Characterization

The following soil properties were determined for two depths (viz. 0-15 cm and 15-30 cm) to characterize the soil before the plots were cultivated: (1) Organic carbon content (2) Cation exchange capacity (3) pH (4) Total nitrogen content (5) Available phosphorus (6) Exchangeable potassium (7) Dry bulk density and (8) particle density.

2.6.1Bulk Density (g/ cm)

Bulk density was determined by the Core Method. Soil samples from each of the plots were taken before planting. This was done by driving an aluminium cylinder of known volume into the soil to a depth of 15 cm by means of a hammer and content of the cylinder collected. The soil samples from the cylinders were oven dried at 105 ^{o}C for about 24 hours.

Bulk Density (B.D) for each replicate was calculated with the following relationship:

$$\text{B.D. } (g/cm^{3)}) = \frac{\text{Oven Dry Weight (g)}}{\text{Total Volume of Soil } (cm^{3)})}$$

2.6.2Particle Density (g/ cm^3)

The water content of the soil samples were first determined by weighing before and after drying in an oven. Particle density was then determined by the use of the density bottle. Ten grams of the soil samples were weighed into density bottles. Deaerated distilled water was added to fill the bottles. The bottles with the soil were weighed. Other parameters measured for the calculation were weight of empty density bottle and weight of density bottle filled with water.

2.6.3Total Pore Space

Total pore space was calculated by the method described by [12]. Total pore space (%) is calculated by the following formula:

Total Pore Space (%) = $[1-(D_b/D_p]x\ 100$

Where:

D_b is bulk density (g/cm^3)

$D_{p\ is}$ particle density (g/cm^3)

2.7Soil Sampling and Preparation for Chemical Analysis

Soil samples from each of the plots were taken at 0-15 cm and 15-30 cm depths for the chemical analysis. The soil samples were air-dried and sieved through 2 mm sieve. They were then used for the following analyses.

2.7.1Organic Carbon Content (%)

Soil organic carbon content was determined by wet combustion method of [13]. A half gram of each soil sample was weighed. Ten milliliters of potassium bicarbonate solution and 20 ml of concentrated sulfuric acid were added in succession to the soil in a 250 ml conical flask. The flask was gently swirled and allowed to stand for thirty minutes for oxidation to take place. The unreduced $K_2Cr_2O_7$ remaining in the solution after the oxidation of the oxidizable organic material in the soil was titrated with 0.2 N ammonium ferrous sulfate solution after adding 10 ml of barium diphenylamine sulfate indicator.

2.7.2Cation Exchange Capacity (CEC, mol/kg)

Ten grams of each soil sample was weighed into an extraction bottle. Soil samples were washed with 150 ml methyl alcohol (95%) in fractions of 50 ml. The soil samples were extracted with 100 ml 1N KCl and then placed on a mechanical shaker for 30 minutes. The suspensions were then filtered through a number of 42-Whatman filter paper. One hundred milliliters of alcohol were poured onto the residue. The ammonia in the filtrate was determined by distillation into 2% Boric acid and methylene blue indicator [14].

2.7.3Exchangeable Potassium (mg/kg)

Five grams each of the soil samples were weighed into shaking bottles and 50 ml of an extraction solution of 1N ammonia acetate were added and shaken for two hours. The extract was filtered through a 42-Whatman filter paper. The exchangeable K was then measured by using a photometer and the results converted into mg/kg.

2.7.4Total Nitrogen (%)

Bremner's (1960) modification of the Kjeldahls method was used for the total nitrogen determination. Ten grams of fine air-dried soil fractions were put into 300 ml Kjeldahl flask and the following were added: a few milliliters of water to moisten the soils, 20 ml of concentrated sulphuric acid and a scoop of digestion accelerated mixture. The mixture was digested for at least 2 hours for the digest to be clear. The digest was cooled and transferred with distilled water into a 250 ml volumetric flask and the liquid made up to volume. A 5 ml aliquot was distilled in a Markham apparatus with 20 ml of 40% NaOH and the distillate collected in 5 ml of 2% Boric acid. The distillate was titrated with 0.001N Hydrochloric acid. From the result the %N per gram of soil was calculated.

2.7.**5Available** Phosphorus (ppm)

Available Phosphorus was determined by using Bray I Method. Five grams of the prepared soil samples were weighed into bottles. Thirty five milliliters of the phosphorus extraction solution were added and the bottle placed on a mechanical shaker for 5 minutes. The solution was then filtered through a 42-Whatman filter paper to attain a clear solution for the analysis. An aliquot was taken into a beaker and the yellow colour developed and measured on a U.V spectrophotometer at a wavelength of 420µ. The value was converted into parts per million (ppm).

2.7.6PH Determination

The pH was determined on 1:1 soil to water ratio. Twenty grams of the sieved soil sample was weighed into beakers and 20 ml of water added to the soil in each beaker and stirred intermittently for 30 minutes. The suspension was allowed to settle. Standardized pH electrodes were inserted and the readings recorded.

2.8Determination of Selected Soil Properties to Assess Changes

A second chemical analysis of soil was done to assess the state of total nitrogen and organic carbon in the soil after the first experiment. A third determination was also done to assess any changes that have occurred in those properties. The results were statistically analyzed using [15] software.

2.9Measurement of Crop Characteristics

The following characteristics were measured:

2.9.1Plant Height

Five plants from each plot were targeted using the triangulation procedure and eliminating border plants. These plants were labeled and height measurements were taken from the ground to the vertical tip of each plant by using a tape measure. Measurements were made weekly from twelve days after sowing (12 DAS) until senescence of each treatment. The arithmetic means were calculated for the plant heights at the various growth stages. The mean plant height was plotted as a function of time. Those for the control plots were included for comparison.

2.9.2Canopy Cover

Measurements of the canopy cover were made weekly from twelve days after sowing (12 DAS) until senescence of each treatment. The arithmetic means were calculated for the plant growth at the various growth stages. The mean plant height was plotted as a function of time. Those for the control plots were included for comparison.

2.9.3Plant Dry Matter

Five plants from each of the mono-cropped plots and five plants from each of the intercropped plots were uprooted, cut carefully into roots and shoots and dried in an oven at 60 ^{o}C to a constant weight. Soybean weight was determined at 53 days after sowing (DAS), groundnut at 50 DAS and Bambara groundnut at 76 DAS. Analyses of variance (ANOVA Test) were done on the resulting plant dry weight by using [15] statistical software. The mean dry weight for each plot was used as the amount of organic matter that crops are capable of leaving behind for the improvement of the soil. The dry matter was extrapolated to kilogram per hectare for each treatment with their control for comparison.

2.9.4Grain Yield

Ten plants from each of the mono-cropped and five from each crop of the intercropped plots were sampled from the inner rows after other plants have been sampled for other measurements, harvested, threshed, dried to about 12% moisture content. The means and standard error of their means were calculated and the means were extrapolated to kilogram per hectare for each treatment and the results compared with the control plots.

III. RESULTS AND DISCUSSION

3.1Assessment Of Soil Properties In The Legume Based Cropping Systems

3.1.1 Yale soil chemical and physical properties

Some physical and chemical properties of the soils at 0-15 cm and 15-30 cm depths in the various plots on which each treatment was located are shown in Tables 1 and 2. These physical and chemical properties reflect the initial conditions before planting was done.

Table 1: Some Physical and chemical properties at the beginning of the experiment for Yale surface soil (0-15cm)*

Treatments	Total Nitrogen (%)	Organic Carbon (%)	Carbon-Nitrogen Ratio (C:N)	Available P (ppm)	Exchange-able Potassium (ppm)	CEC (mol/g)	pH (1:1 soil to water)	Particle Density (g/cm^3)	Bulk Density (g/cm^3)	Total Porosity %
Groundnut	0.087	0.850	10:1	1.590	0.213	24.28	8.10	2.45	1.49	39
Soyabean	0.073	0.900	8:1	1.603	0.187	27.25	8.03	2.43	1.46	40
Bambara groundnut	0.090	0.903	10:1	2.143	0.170	27.79	8.00	2.55	1.56	39
Groundnut +Soybean	0.070	0.780	9:1	1.557	0.263	26.73	7.93	2.47	1.42	43
Groundnut+Bambara	0.083	0.807	10:1	1.867	0.263	29.59	7.97	2.60	1.45	44
Control	0.150	1.297	12:1	2.900	0.780	29.20	7.47	2.50	1.53	39
LSD (P<0.05)	0.0252	0.1725		0.7717	0.1026	7.293	0.3169	0.172	0.154	

LSD – Least Significant difference

- Data are mean of three replicates

Table 2: Some Physical and chemical properties at the beginning of the experiment for Yale subsoil (15-30cm)*

Treatments	Total Nitrogen (%)	Organic Carbon (%)	Carbon-Nitrogen Ratio (C:N)	Availa-ble P (ppm)	Exchange-able Potassium (ppm)	CEC (mol/g)	pH (1:1 soil to water)	Particle Density (g/cm^3)	Bulk Density (g/cm^3)	Total Poro-sity (%)
Groundnut	0.073	0.700	10:1	2.48	0.187	21.81	7.50	2.64	1.59	40
Soyabean	0.073	0.803	9:1	2.49	0.170	22.74	7.43	2.59	1.65	36
Bambara groundnut	0.093	0.740	12:1	2.79	0.200	21.42	7.30	2.45	1.53	38
Groundnut +Soybean	0.080	0.706	10:1	3.39	0.217	22.04	7.30	2.44	1.59	35
Groundnut+Bambara	0.077	0.703	11:1	2.72	0.230	20.57	7.50	2.49	1.54	38
Control	0.14	1.273	11:1	3.09	0.260	26.52	7.37	2.55	1.56	39
LSD (P<0.05)	0.0154	0.1722		1.053	0.0887	3.910	0.427	0.0997	0.110	

LSD – Least Significant difference

- Data are mean of three replicates

The most critical yet limiting soil nutrients are nitrogen (N), phosphorus (P) and potassium (K). Before cultivation, the total nitrogen (%) of Yale surface soil ranged from 0.07% in groundnut + soybean plot to 0.15%

in the control plot. The total nitrogen in the subsoil (i.e. 15-30 cm) was less than that in the surface soil and this was due to the accumulation of organic matter on the surface of the soils. The mean total nitrogen for the subsoil was 0.08% for the degraded land and that for the control plot was 0.14%. The total nitrogen in both the surface and the subsoil of the control were significantly greater ($P<0.05\%$) than that in either the topsoil or the subsoil of the degraded land. The total nitrogen of Yale soils including the control is very low and may be attributed to the sparse native vegetation and also degradation due to mining activities. This low nitrogen content affects the development of the plants. This implies that for the soil to support good crop growth, nitrogen content has to be enhanced by the application of organic and/or inorganic fertilizers.

Organic carbon content of the Yale soil is very low [16] It ranged from 0.8-0.9% on the degraded land and to 1.297% on the topsoil of the control plot in Yale community. The organic carbon content of the topsoil of the degraded land was 66% of the control land. The organic carbon content of the subsoil was slightly less than that of the topsoil (90% of the topsoil). The organic carbon content of the control plot was significantly ($P<0.05$) more than that of the degraded land. The low organic carbon content of the land can be attributed to the sparse vegetative cover and frequent burning that characterized the Guinea savanna zone. The sparse vegetation cover may be attributed to long dry seasons (about 6-7 months) that the region experiences every year. Furthermore, during the dry season animals feed on the little dry vegetation in the field leading to little return of organic matter onto the soils. The situations on the degraded lands are made worse by the mining activities.

The carbon/nitrogen ratio (C/N ratio) of Yale soils ranged from 8:1 to 10:1 on the topsoil of the degraded land and a mean of 12:1 on the topsoil of the control. The subsoils of the degraded lands had a wider range of C/N ratio was lesser on the degraded land than the control due to the differences in the maturity of the plant material that made up the organic matter of the soil. The plant materials on the degraded land are tender because the plants emerge after the mining, while on the control land the plant material are from old mature plants. The degraded land had better C/N ratio than the control because higher C/N ratio is not favorable to microorganisms in the soil. Higher C/N ratio leads to keen competition for nitrogen by soil organisms [12].

The available P ranged from 1.57-1.87 ppm in the topsoil of the degraded land compared to 2.9 ppm for the control. Available P in the subsoil also ranged from 2.48-3.39 ppm compared to the control plot which had a mean of 3.09 ppm. Generally the available P in both horizons is small and may be attributed to the low return of P into the soil from scarce vegetation and the parent material on which the soils are developed. The soils in the area experience extreme moisture conditions with high moisture conditions concentrated between five months of rainy season. This is followed by extremely low soil moisture contents for seven months in a year. During the rainy seasons the nutrients are leached from the topsoil to greater depths. Their replacement in the dry season is low. The subsoil of Yale had higher available P than that of the topsoil probably because of accumulation of P in that zone. Soil pH is another factor that affects the availability of phosphorus. Unfortunately, the pH range of the soil of the area (7.3 to 8.0) is not within the range

In which phosphorus is most available.

Even though potassium is abundant in most soils, it is mostly in a form that cannot be utilized by plants. It is exchangeable K that plants can use. Even though exchangeable K for the degraded subsoil was less than that for the control, the difference was not significant at $P<0.05$. The surface soil in the degraded land had a mean of 0.22 ppm compared with an exchangeable K of 0.78 ppm. There was no significant difference between the control plot and the degraded land at $P<0.05$. The little difference in exchangeable K between the degraded and the control lands is due to the mobility of the nutrient. Furthermore, the nutrient is taken in large quantities by plants, so on the control plots which were continuously cultivated large amounts were likely to be lost without replacement.

The cation exchange capacity (CEC) was almost the same on both the degraded and the control plots in the two depths (0-15 cm and 15-30 cm). The CEC for the degraded topsoil pooled together was 27.13 mol/kg. The results for subsoils pulled together also gave a mean of 21.72 mol/kg on the degraded land and 26.52 mol/kg on the control plot. Cation Exchange Capacity is not a major problem of the area as the range is within the range in which nutrients are most available. Another factor that makes the CEC suitable is the pH of the soils. Cation Exchange Capacity is most favorable to plants in neutral to the alkaline soils [17].

The soil pH did not differ significantly. Generally, it was slightly alkaline and ranged from 7.4-8.1 and a mean of 7.5 on the control plot. The subsoils had less pH values than the topsoil but they were still near neutral pH. The pH range was good on both the control and the degraded lands as it was known that low pH values (pH less than 5) lead to micro nutrient toxicity of plants because of high availability, while high pH (i.e. pH above 8.5) also lead to decrease in availability of some nutrients. There was not much pH variation between the degraded and the pristine lands because the activities of the miners did not affect the pH of the soils. pH is most affected by rainfall regime or irrigation and the application of chemical fertilizers [12]

The physical properties of soil in the experimental field generally showed typical characteristics of soils that other researchers have worked within the area [16]. The topsoil of both the degraded and the control plots had mean particle density of 2.51 g/cm^3. The particle density did not differ significantly with other measurements taken in experiments near and far from the experimental sites. The mean bulk density of the degraded land was 1.5 g/cm^3 for the top soil and 1.6 g/cm^3 for the sub soil respectively. The control plot had a mean bulk density of 1.5 g/cm^3 for both the top and the sub soils. The control plot had less bulk density on the subsoil because of higher organic matter than the degraded as the amount of organic matter in a soil affects the bulk and particle densities. Organic matter has less density than the mineral particles of the soil. Secondly, organic matter promotes soil granulation which in turn enhances pore formation.

Total porosity is the portion of the soil volume that air and water occupy. It depends on the arrangement of the soil particles and the amount of organic matter in the soil. The topsoil of the degraded Yale land had total porosity in the range of 39% to 44%, while the control had 39%. The high total porosity on the degraded land can be attributed to the disturbance of the soil through the mining activities. The lower total porosity of the subsoil of the degraded land was due to compaction and low amount of organic matter present.

3.1.2 Obuasi soil chemical and physical properties

Some physical and chemical properties of the samples of Obuasi soil, the second experimental site, are shown in Tables 3 and 4. The total N in the topsoil of the Obuasi experimental field showed no significant differences between the degraded and the control plots at P<0.05 with the exception of the groundnut + bambara groundnut plot which had a low mean value of 0.117%. The top soils pulled together had mean total nitrogen of 0.13% on the degraded land and 0.15% on the control plot. These values are low even though better than the Yale soil because Amoako (2003) working on Bekwai series had larger mean values of 0.224%.

Table 3: Some Physical and chemical properties at the beginning of the experiment for Obuasi Topsoil (0-15cm)*

Treatments	Total Nitrogen (%)	Organic Carbon (%)	Carbon-Nitrogen Ratio (C:N)	Available P (ppm)	Exchangeable Potassium (ppm)	CEC (mol/g)	pH (1:1 soil to water)	Particle Density (g/cm^3)	Bulk Density (g/cm^3)	Total Poro-Sity (%)
Groundnut	0.137	1.083	12:1	2.327	0.703	28.16	6.93	2.29	1.34	41
Soybean	0.120	1.127	11:1	2.447	0.760	24.28	6.93	2.37	1.44	39
Bambara groundnut	0.130	1.153	11:1	2.773	0.657	25.26	7.03	2.42	1.41	42
Groundnut +Soybean	0.130	0.980	13:1	2.070	0.677	26.21	7.07	2.32	1.43	38
Groundnut +Bambara	0.117	0.867	13:1	2.617	0.770	24.39	7.03	2.44	1.39	43
Control	0.150	1.150	8:1	3.060	0.810	27.41	7.2	2.40	1.36	43
LSD (P<0.05)	0.0263	0.1425		0.6626	0.2124	6.127	0.3404	0.191	0.126	

LSD – Least Significant difference

- Data are mean of three replicates

Table 4: Some Physical and chemical properties at the beginning of the experiment for Obuasi subsoil soil (15-30cm)*

Treatments	Total Nitrogen (%)	Organic Carbon (%)	Carbon-Nitrogen Ratio (C:N)	Available P (ppm)	Exchangeable Potassium (ppm)	CEC (mol/g)	pH (1:1 soil to water)	Particle Density (g/cm^3)	Bulk Density (g/cm^3)	Total Poro-Sity (%)
Groundnut	0.123	1.003	12:1	2.01	0.233	32.44	7.07	2.55	1.52	40
Soyabean	0.150	1.117	13:1	2.24	0.213	33.26	7.13	2.59	1.45	44
Bambara groundnut	0.153	1.117	14:1	2.05	0.263	34.32	6.93	2.56	1.44	44
Groundnut +Soybean	0.133	0.923	14:1	2.80	0.283	35.10	6.93	2.46	1.51	39
Groundnut+ Bambara	0.123	0.923	13:1	2.90	0.226	33.70	6.97	2.67	1.55	42
Control	0.160	1.060	10:1	3.38	0.270	33.98	7.4	2.60	1.42	45
LSD (P<0.05)	0.0307	0.1561		0.623	0.0394	4.758	0.4574	0.126	0.097	

LSD – Least Significant difference

- Data are mean of three replicates

Organic carbon content pulled together was 1.04% on the degraded plots and 1.15% on the control plots. The control plots had higher organic carbon content because previous cultivation on those lands led to the incorporation of plant matter into the soil during land preparation and weeding during crop production.

The C/N ratio of Obuasi topsoil ranged from 11:1 to 13:1 on the degraded land and a mean of 8:1 for the control. The subsoil also had a range of 12:1 to 14:1 for the degraded land and 10:1 for the control. The higher C/N ratio on the degraded land was due to the presence of manure plant matter making up the organic matter of the soil. Manure plant matter has high C/N ratio [12].

The degraded plot had available P ranging from 2.33 ppm to 2.77 ppm, while the control plots had a mean of 3.06 ppm on the topsoil. The subsoil also had a range of 2.01 ppm to 2.90 ppm on the degraded land and a mean of 3.38 ppm on the control plot because of less organic matter content on the degraded land. The available P of the soil can be improved by addition of fertilizers. Secondly, the soil can be treated to bring the pH range to between 6 and 7 and thus make P more available to plants [12]

The CEC was larger in the Obuasi soils than in the Yale soils. The CEC data of the topsoil pulled together averaged 25.66 ± mol/kg on the degraded land and a mean of 27.41 ± mol/kg on the control plots. The subsoil of the degraded land pooled together was 33.77 ± mol/kg and the control subsoil had a mean of 33.98 ± mol/kg. The large CEC of the Obuasi soil is because of its large clay and organic matter contents.

The exchangeable K of the degraded Obuasi topsoil ranged from 0.226 ppm to 0.283 ppm. The topsoil of the control plot had a mean exchangeable K of 0.810 ± ppm. The subsoil of the degraded land had exchangeable K ranged from 0.657 ppm to 0.770 ppm, while a mean of 0.270 ± ppm on the control subsoil. The control plot had slightly higher exchangeable K than the degraded land on both the topsoil and the subsoil. The problem with potassium is not its availability in the soil because it is found in large quantities. However, most K in the soil is not in the exchangeable form from which plants can utilize.

The pH Obuasi soil was slightly less than that of Yale soils. The pH ranged from 6.93 to 7.07 for topsoil of the degraded land and a mean of 7.4 ± on the topsoil of the control plots. The subsoil had a pH ranging from 6.93 to 7.13. The pH of Obuasi soils did not have any negative effects on the soil nutrients status as it was within the optimum range for all the crops. The pH range was also favourable for the conversion of most soil nutrients to available forms suitable for sustained plant uptake.

The particle density and bulk density of Obuasi soils were less than those of Yale soils on both the degraded and the control lands at the two depths. This was because of the higher organic matter content of Obuasi soils had particle density range of 2.29 (g/cm^3) to 2.44 (g/cm^3) on the topsoil and a mean of 2.40 (g/cm^3). The subsoils also had particle density ranging from 2.46 (g/cm^3) to 2. 67 (g/cm^3) while the control had a mean of 2.60 (g/cm^3). The bulk density also ranged from 1.44 (g/cm^3) to 1.55 (g/cm^3) on the degraded topsoil and 1.42 (g/cm^3) on the control plot. The less bulk density on the control as compared to the degraded land is due to the higher organic matter content on the control plot.

The soils of Obuasi had better soil properties than Yale. The total nitrogen, organic carbon, available phosphorus and exchangeable potassium were all higher than those of Yale but slightly lower than the control plot of Obuasi. This higher nutrient status of Obuasi is due to several factors. The first is the difference between the parent materials of the two soils. The Yale soils were formed from sandstone while the Obuasi soils were developed from greenstone. Another factor leading to the difference in the nutrient status is the kind of mining that is done in the two areas. In Obuasi, surface mining is done by creating small pits on the land while in Yale the surface soil may be completely scraped. The fallow period also affects the nutrient status of the soil. While most places in Obuasi were abandoned for a long time, Yale soils have been mined recently.

3.2 Crop Characteristics Measurement

3.2.1Plant Height

Height differences between the degraded and the control lands were observed in Yale for the various crops. This was due to the initial differences in nutrient status of the two areas. The measurements of the initial soil properties indicate very large differences between the degraded and the control plots in Yale than Obuasi lands. The plants heights in the second experiment were more uniform than those in the first experiment. Also the difference in plant height between the control plots and the degraded land during the second experiment was very small. This uniformity occurred because cultivation of the soil in the first experiment redistributed the soil nutrient evenly. Secondly, the incorporation of plant matter into the soil during land preparation and weeding led to some improvement in the nutrient status of the soils on the degraded land. Generally, there was more improvement in Yale crops during the second experiment than crops at the Obuasi site, even though plant height at Yale site was shorter than that at Obuasi. This difference may be due to the existing high nutrient status of Obuasi soils during the first experience (as a result of less disturbance of the Obuasi site during the mining activities than Yale site). The plant heights showed that the farmers will need to replenish soils on Yale site with fertilizers (both organic and inorganic) before they can be brought to or beyond the nutrient status of the nutrient lands of the area

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3.2.2 Canopy Cover

Generally, sole soybean crop produced the largest canopy cover at both Yale and Obuasi sites during the two seasons. There were no significant differences (P<0.05) between the degraded land and the control plots in the first season at both locations for all the treatments. Even though the degraded lands had less canopy cover than the control treatments, it was not statistically different from the control as the standard error bars overlapped indicating no significant differences. In the second experiment the crop canopy cover differences were also not significant at both Obuasi and Yale sites. The canopy cover of the degraded lands was almost similar to those of the control. The canopy cover in both locations at the peak growth in both years was in the order: Sole > Groundnut + soybean > Sole Groundnut > Groundnut + Bambara Groundnut > Sole Bambara Groundnut.

This shows that soybean is the best treatment in terms of canopy cover at the spacing of the various crops and crop combination. This will reflect on their protection of the soil surface against rainfall impact. Therefore, sole soybean and its combination with groundnut have proved to be useful as the agronomic method for soil conservation as described by [18]. The greater canopy cover would ensure that the impact of raindrop and wind on the soil would be minimized. Even though sole groundnut produced a higher canopy cover than Bambara groundnut at 47-54 days after sowing (DAS) (maximum growth period) it cannot be concluded that groundnut has a better canopy cover than Bambara groundnut because the groundnut variety (JL 24) takes a shorter time to mature thereby leaving the soil bare after harvest while Bambara groundnut takes a longer time to mature thereby protecting the soil for a longer period.

Treatment	Yale 2005 Degrade	Yale 2005 control	Yale 2006 degraded	Yale 2006 control	Obuasi 2005 degraded	Obuasi 2005 control	Obuasi 2006 degraded	Obuasi 2006 control
Groundnut	771	813	741	808	755	818	820	840
Soybean	437	489	504	517	535	549	558	575
Bambara groundnut	1603	2167	2234	2365	1987	2296	2352	2342
Groundnut + Bambara Groundnut	1187	1490	1489	1586	1371	1554	1585	1591
Groundnut + Soybean	636	691	675	711	703	736	745	767
Least significant difference	128.3	305.4	131.1	55.7	96.5	75.2	17.7	26.3

Table 5: Plant root dry matter weight (kg/ha)

3.2.3Plant Root Dry Matter Weight

Generally, all the treatments in the degraded area showed less dry matter than their corresponding treatments on the control plots. The results (Table 5) show significant differences (P<0.05) between the treatments on the degraded land and their control plots in the first year than the second year. This was due to the improved fertility status in the second year as indicated by the results of the total N and carbon content measured at the beginning of the second year's experiments.

It may also probably be due to better management and good weather conditions. The order of root weight (kg/ha) was: Sole Bambara Groundnut > Groundnut + Bambara Groundnut > Sole Groundnut > Groundnut + Soybean > sole Soybean.

Table 6: Shoot dry matter weight (kg/ha)

Treatment	Yale 2005 Degraded	Yale 2005 control	Yale 2006 degraded	Yale 2006 control	Obuasi 2005 degraded	Obuasi 2005 control	Obuasi 2006 degraded	Obuasi 2006 control
Groundnut	2018	2263	2317	2399	2347	2335	2442	2460
Soybean	4403	4925	5067	5449	5305	5685	5598	5980
Bambara groundnut	2705	2983	3047	3234	3090	3329	3480	3587
Groundnut + Bambara Groundnut	2362	2623	2682	2816	2719	2832	2961	3024
Groundnut + Soybean	4109	4598	4727	5004	4917	5198	5175	5469
Least significant difference	146.7	94.8	203.3	105.0	80.4	70.1	72.5	57.8

3.2.4Shoot Dry Matter Weight

The order of the shoot dry matter (kg/ha) was: Sole Soybean > Groundnut +Soybean > Sole Bambara Groundnut > Groundnut + Bambara Groundnut > Groundnut (Table 6). Even though sole soybean had the least root dry matter weight (kg/ha), it had the highest shoot dry matter (kg/ha). The treatments showed significant differences ($P>0.05$) in shoot dry matter.

Table 7: Total dry matter weight (Kg/ha)

Treatment	Yale 2005 degraded	Yale 2005 control	Yale 2006 degraded	Yale 2006 control	Obuasi 2005 degraded	Obuasi 2005 control	Obuasi 2006 degraded	Obuasi 2006 control
Groundnut	2789	3075	3063	3207	3114	3143	3260	3300
Soybean	4840	5413	5571	5908	5840	6233	6155	6555
Bambara groundnut	4308	5150	5282	5598	5078	5625	5832	5930
Groundnut + Bambara Groundnut	3549	4112	4170	4403	4090	4387	4546	4615
Groundnut + Soybean	4746	5290	5402	5714	5621	5934	5921	6236
Least significant difference	186.1	396.2	194.8	153.0	54.8	79.4	77.9	35.9

3.2.5Total Dry Matter Weight

The order of total dry matter weight (kg/ha) was: Sole Soybean > Groundnut + Soybean > Sole Bambara Groundnut > Groundnut + Bambara Groundnut > Groundnut (Table 7). In general, sole soybean treatment showed larger dry matter weight (kg/ha). The dry matter measures the amount of organic matter the treatment may yield for the improvement of the soil after each season. The total organic carbon content is affected by the amount and quality of organic matter present in the soil. In terms of quantity, sole soybean can therefore be considered as the best treatment for the improvement of organic matter in the area. The lower dry matter weight on the degraded lands is because of the less nutrient status of the soils. The improvement in the dry matter in the second year indicates an increase in the soil nutrient status, probably better management practices and good weather conditions. It was also noted that the spacing should be considered in trying to reclaim the land. Dry matter measurement is also an indicator of the amount of nitrogen that has been fixed by legumes growing in an area (Danso et al., 1987). The presence of organic matter ensures the presence and availability of most soil nutrients. Organic matter enhances the activities of living organisms which are important for the development of soils and availability of some nutrients.

3.2.6Grain Yield

Generally, the grain yield was higher ($P<0.05$) in the second year than the first year. Crop yield at the "Obuasi" site were higher than those at Yale site. Also, crop yield on the control plots were higher than those on the degraded lands in both seasons at both locations. There were no significant differences between the grain yields on the degraded plots and the control in the second year's experiment at Obuasi site. On Yale experimental site however, grain yields of groundnut, Bambara groundnut and soybean were larger on the control plots than the degraded land in the first year. The increases in crop yield of the undisturbed plots over the degraded land were 25.6%, 17.4% and 26.0% respectively for groundnut, soybean and Bambara groundnut at Yale sites during the first year. In the second year, the yield increases were less than the first year. The increases in the second year were 9.0%, 9.8% and 8.5% for groundnut, soybean and

Table 8. Groundnut grain yield (kg/ha)

Location	Degraded land	Control	Increase in yield (%)#
Yale 1	1.223 ± 49.5*	1.536 ± 35.4	25.6
Yale 2	1.450 ± 43.1	1,580 ± 24.0	9.0
Obuasi 1	1,442 ± 46.8	1,647 ± 30.2	14.2
Obuasi 2	1,666 ± 59.9	1,691 ± 31.6	1.5

*Standard Error of the Mean

#Percentage increase in grain yield on pristine land is over degraded land

Table 9. Soybean grain yield (kg/ha)

Location	Degraded land	Control	Increase in yield (%)#
Yale 1	7,498 ± 182.2*	8,800 ± 170.7	17.4
Yale 2	8,242 ± 161.1	9,047 ± 140.6	9.8
Obuasi 1	8,590 ± 320.0	9,981 ± 160.1	16.2
Obuasi 2	9,643 ± 210.6	9,988 ± 221.5	3.6

*Standard Error of the Mean

#Percentage increase in grain yield on pristine land is over degraded land

Table 10. Bambara Grain Yield (kg/ha)

Location	Degraded land	Control	Increase in yield (%)#
Yale 1	1,469 ± 60.3*	1,851 ± 54.3	26.0
Yale 2	1, 856 ± 43.3	2,014 ± 35.7	8.5
Obuasi 1	1,471 ± 60.4	1,854 ± 54.4	26.0
Obuasi 2	1,606 ± 57.8	1,926 ± 35.5	19.9

*Standard Error of the Mean

#Percentage increase in grain yield on pristine land is over degraded land

Table 11. Groundnut + Bambara[P] Intercrop Grain Yield (kg/ha)

Location	Crop	Degraded Land	Control
Yale 1	Groundnut	612 ± 22.3*	768 ± 18.6
	Bambara Groundnut	725 ± 25.1	926 ± 22.6
	Land Equivalent Ratio	0.99	1.00
Yale 2	Groundnut	720 ± 20.7	775 ± 14.2
	Bambara Groundnut	928 ± 23.8	1,007 ± 16.9
	Land Equivalent Ratio	0.99	0.99
Obuasi 1	Groundnut	721 ± 24.7	779 ± 21.5
	Bambara Groundnut	735 ± 25.4	926 ± 26.3
	Land Equivalent Ratio	1.00	1.00
Obuasi 2	Groundnut	823 ± 21.7	846 ± 19.0
	Bambara Groundnut	792 ± 29.8	962 ± 18.6
	Land Equivalent Ratio	0.98	1.00

*Standard Error of the Mean

[P]one row of groundnut to one row of Bambara groundnut

The yield in cropped treatments showed that there was no interaction between the groundnut and the Bambara plants that could have affected them thus dry matter and grain yields were similar to their sole cropped treatments since the spacing was the same. But groundnut + soybean intercrop showed significant interaction between the plants. During physical observation in the field, the soybean plants because of their height (up to 90 cm) shaded the groundnut. The groundnut plants in reaction to this shading also started growing unusually taller than normal height (up to 40 cm). The yield per plant of soybean was not affected but even though the groundnut yielded almost the same number of pods as the sole cropped site, the 100-seed weight was less than that for the sole groundnut and groundnut + Bambara treatments. Another problem encountered was the high incidence of pod borers on the groundnut in the groundnut + soybean mixture. This was due to the high soil moisture accumulated due to the covering created by soybean plants.

The land equivalent ratio (LER) (Tables 12) showed that groundnut + soybean intercrop will benefit the farmer than growing either groundnut or soybean as sole crop on two different pieces of land [19]. Land equivalent ratio (LER) is the comparison of the overall performance of intercropping (the combined yield of all components) with the yield obtained by growing component crops in sole cropping. All the results of the two locations in the two seasons showed land equivalent ratios that were greater than one for the groundnut + soybean intercrop on both the degraded and the control plots. Groundnut + Bambara groundnut had land equivalent ratio of one. This implies that the farmer may consider growing the intercrop or not because he or she neither loses of gains if he or she practices intercropping. But it must be noted that a change in the proportion of the component plants will also lead to a change in the land equivalent ratio [20].

Table 12. Groundnut + Soybean[P] Grain Yield (kg/ha)

Location	Crop	Degraded Land	Control
Yale 1	Groundnut	443 ± 15.2*	506 ± 10.5
	Soybean	5,624 ± 105.3	6,606 ± 16.6
	Land Equivalent Ratio	1.11	1.08
Yale 2	Groundnut	490 ± 21.5	575 ± 18.4
	Soybean	6,181 ± 141.3	6,734 ± 155.1
	Land Equivalent Ratio	1.09	1.10
Obuasi 1	Groundnut	549 ± 20.9	594 ± 18.6
	Soybean	7257 ± 190.7	7366 ± 101.3
	Land Equivalent Ratio	1.23	1.10
Obuasi 2	Groundnut	634 ± 26.8	644 ± 15.4
	Soybean	7120 ± 201.6	7374 ± 106
	Land Equivalent Ratio	1.12	1.12

*Standard Error of the Mean

[P]two row of groundnut to one row of soybean

IV. CONCLUSION

This study revealed that gold mining in the Talensi and Nabdam districts has brought about many challenges to the inhabitants of the district. The most pressing problems encountered by the inhabitants are land degradation, water pollution, spread of diseases, increase in occurrence of social vices and decadence of moral values. The refilling of pits followed by planting leguminous crops showed that the productivity of the degraded lands could be improved. Even though the two year experiment could not distinguish clearly the best treatment for combating the degradation problem, it was realized that groundnut plus soybean intercrop gave the best improvement of the soil total nitrogen and organic carbon content. The study revealed that intercropping as a means of restoring soil fertility is a very complex technology demanding expertise in the selection of the various components, spacing of the crops and the cultural practices to be employed before good results can be achieved. Some suggested recommendations include: education of farmers on the benefits derived from growing leguminous crops on their degraded lands; provision of subsidies by government and/or non-governmental organizations to farmers who are ready to cultivate these degraded lands. Further long-term field studies should be conducted in order to clearly distinguish the residual effects of the various treatments as well as the impact of mercury contamination on water bodies in the communities.

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