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Making land rehabilitation projects work in small-scale mining areas: Insights from a case study in Ghana

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Title Picture Credit: Ferdinand Adu-Baffour

Abstract

Illegal small-scale mining and processing activities (ASM) have led to a vast area of degraded, contaminated, and abandoned local-community lands, posing a major environmental concern in many developing countries. In the absence of effective state mechanisms to enforce more sustainable mining and post-mining practices, there are increasing discussion on whether community-based solutions could be a second-best solution to restore such lands. This paper analyzes a unique case of an NGO-initiated, community-based ASM land restoration project in Ghana, examining the conditions under which communities could ensure sustainable land rehabilitation outcomes. Qualitative methods are used to map out key actors and relationships to make community-based rehabilitation projects work, followed by the stated preferences method to estimate factors influencing the local communities' decision to contribute to mined land restoration, including phytoremediation, a technique to reduce contamination. Our findings reveal that there is community support for reclaiming and remediating former ASM lands using communal labor, however, support depends on land tenure arrangements, among other factors. Chiefs, as community overlords, were perceived among the most influential actors as they have the power to enact and enforce local laws and sanction noncompliance with regards to customary land management. Local community members and landowners, however, were seen to be largely not organized, with different land use priorities and unregulated and insecure land tenure structures. Overall, this study shows that community-based solutions could be a second-best option for mined-land rehabilitation, however, such efforts need to pay close attention to social networks, norms, rules, and practices, to be successful and ensure that community members really benefit.

Key Words

Artisanal and small-scale mining, Land degradation and contamination, Community-based land restoration, Discrete choice experiment, Social network analysis, Local community governance

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1. Introduction

Artisanal small-scale mining (ASM), both licensed and informal, remains an important economic activity sustaining rural livelihoods in many mineral-rich developing countries, particularly within remote and poor areas (IGF, 2018). However, mining also drastically affects ecosystems, impacting livelihoods, health, and safety in host communities and beyond (Akpalu and Normanyo 2017; Bansah et al. 2018; World Bank 2019). Mining on agricultural and forest lands can lead to extreme disturbance of physical soil conditions, gross lack of essential nutrients, and toxicity which prevent vegetation growth (Bradshaw, 1997). This has implications for the future use of such lands, especially for farming, which is important to fight hunger. In many active small-scale mining communities, excavated pits filled with water and diverted watercourses have been created and later abandoned, impacting the landscape and serving as deadly traps for humans and livestock (Bansah et al., 2018; Hilson, 2002; World Bank, 2020). Such environmental damage has increased with the growing use of heavy equipment for earthmoving and of chemicals, like mercury and cyanide, for ore extraction by small-scale miners (Adu-Baffour, Daum, & Birner, 2021; Ferring, Hausermann, & Effah, 2016; Velásquez Ramírez et al., 2021).

Post-mining land restoration can in principle be used to transform such lands to allow for safe productive reuse. The process of restoring degraded and contaminated land includes reclamation, that is, repairing the physical state after soil excavation, revegetation, and remediation or phytoremediation. Remediation can be achieved biologically using specialized green plants and associated microorganisms (Ent & Baker, 2013; Festin, Tigabu, Chileshe, Syampungani, & Odén, 2019; McIntyre, 2003) to remove soil contaminants and minimize their noxious effect on the environment, thereby reducing their risk of entering the food chain and affecting humans, livestock, and wildlife. Phytoremediation goes together with biological restoration, which, according to Ahirwal, Maiti, and Singh (2016) and Festin et al. (2019) enhances soil micro-activity, nutrient accumulation and fertility through revegetation. Such restoration methods have been used and documented for large-scale mines in the Global North (see Tibbett 2010; Tischew and Kirmer 2007), but remains uncommon in Ghana, our case study focus, and much of sub-Sahara Africa, except a few large scale mines (see Sharma and Pandey 2014). As far as the authors are aware, there are no known field applications of the use of this technology in the context of ASM.

There is a lack of effective mechanisms to enforce the restoration of degraded mined lands, most of which are remotely and sparsely distributed, by miners and landowners (Adu-Baffour et al., 2021; Jones Mantey, Nyarko, & Owusu-Nimo, 2016; Mcquilken & Hilson, 2016). Successful land restoration efforts take several years and depend on significant technical knowledge, costly machinery, materials and labor, reducing the incentives of miners and landowners to restore land, especially when mining projects did not turn out to be productive. It could be argued that the responsibility to restore these lands is with those who did the mining. However, this is typically not enforced as state authorities often do not receive sufficient personnel, logistical, and technological resources and are burdened with many diverse governance challenges (Adu-Baffour et al., 2021). In the absence of strong institutions, therefore, the involvement of affected local communities could be the second-best solution (Datta, Chattopadhyay, & Guha, 2012). Mansuri and Rao (2004) argue that this strategy, which considers active involvement of potential beneficiaries from within a defined community in restoration design and implementation, could lead to better designed projects, better targeted and more equitably distributed benefits, and more cost-effective and timely delivery of scarce project inputs.

Ghana is home to a unique project where two environmental NGOs (Tropenbos Ghana and A Rocha Ghana) have initiated a project to restore degraded, heavy-metal-polluted, and abandoned lands by developing demonstration restoration sites together with affected local communities. The project works by providing incentives to community members to contribute labor to this course, as most of them feel neither directly responsible for destroying the environment nor directly entitled to resulting post-restoration benefits to provide voluntary services. While such a strategy for environmental management can work, it is costly and not sustainable for significant upscaling. Increasing numbers of degraded and heavy-metal-polluted productive community areas, created as a result of illegal mining operations, mostly backed by “social licenses to operate” (see Mcquilken and Hilson 2016), impact directly on the general livelihoods, wellbeing, and safety of affected-community inhabitants. This calls for the active involvement of local community actors in land restoration efforts. Against this background, this article analyzes the unique case of an NGO-initiated, community-based ASM land restoration project in Ghana to understand under what conditions and to what extent local communities could accept and engage in mine site restoration without being paid, which is key to ensuring the projects’ sustained success. In meeting this objective, the paper directly addresses two main analytical questions:

i. Which community stakeholders are key for the success of innovative institutional solutions involving local communities in land restoration?

ii. Without paying people, what factors could compel or dissuade voluntary land rehabilitation efforts?

We achieve this by using a combination of focus group discussions and semi-structured interviews with 47 participants to map out relevant local community-level stakeholders who are key to the success of the rehabilitation process, based on the study case. Based on a survey of 320 randomly sampled community members, we then estimate the relative weights of factors that influence the local communities' decision to – or not to – contribute to rehabilitating degraded and contaminated local lands by eliciting respondents' stated choice options for mined land restoration using phytoremediation. By providing insights into these two questions, our paper contributes to a better understanding of the potential and challenges of community-led restoration projects.

2. The case study project and area

This research was developed around a unique case of an NGO-led community-based mined land restoration pilot project in Ghana. Two environmental NGOs, Tropenbos Ghana and A Rocha Ghana, work in collaboration with strategic stakeholders at the local level to rehabilitate degraded, contaminated and abandoned mined sites in three active mining districts within two regions of the country – the Amansie West and Asante Akim Central Districts of the Ashanti Region and the Abuakwa South District of the Eastern Region. The proliferation of illegal activities by both locals and foreigners and the increasing use of heavy earth-moving machines and chemicals over the last two decades have plagued these districts, which also serve as food and ecosystem service provision hubs, depriving local communities of livelihood assets (J Mantey et al., 2020; Jones Mantey et al., 2016).

Overall, the project seeks to ensure diversified and harmonized land use in mining communities in Ghana by: a) implementing improved national policy for integrated land use in mining areas

b) rehabilitating and reforesting mined lands with local communities

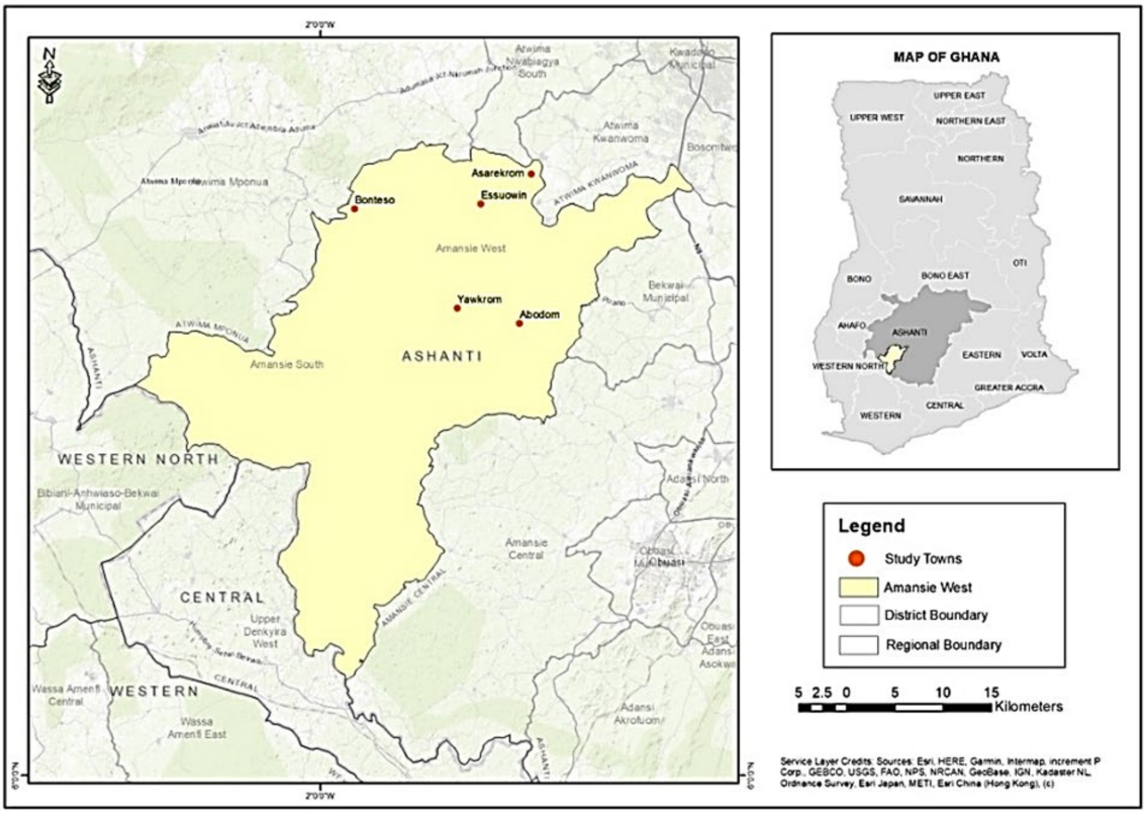
c) integrating agriculture and other land uses in mining areas with local communities.

This research focused on the component of the project that employed a community-based approach to restoring mined and abandoned sites on a pilot scale in important food-producing and forest areas, using tree crop species mainly for soil enrichment, timber, and fuelwood. In contributing to this outcome, the project provides land reclamation services on selected abandoned community-mined-lands, establishes selected-tree nurseries used for revegetating these lands, engages community members to transplant seedlings, and provides technical capacity training to locals.

Project-related empirical findings from FORM International and Awuah (2021) confirmed the presence of high levels of mercury and other heavy metals exceeding WHO/FAO permissible limits in sampled soils and food crops from different areas close to abandoned, as well as active, mining sites in these regions. This justifies the promotion of phytoremediation technology and the use of non-food plant species to remediate productive lands in these areas.

Five active rural mining communities in the Amansie West district, faced with visible environmental impacts of illegal ASM activities, namely, Asarekrom, Abodom, Yawkrom, Essuowin and Boteiso were the focus of this research. These communities also work together actively with Tropenbos Ghana to establish demonstration mined land restoration project sites within them.

Figure 1: Map of Ghana with research study areas



3. Data collection

3.2. Qualitative data collection

The first phase of the study adopted the use of semi-formal interviews and FGDs with stakeholders at the state, private and NGO institutional levels (Table 1) and among inhabitants in the selected communities (Table 2). This helped to better understand existing social dynamics of ASM and potential land rehabilitation outcomes at the community level. Some of the elicited information included the communities' extent and level of involvement in ASM, land tenure arrangements, and options of households' willingness to contribute to degraded mined sites rehabilitation initiatives at the rural community level – which also served as inputs for the DCE design. During the FGDs, net-maps (Schiffer 2007) of key local community actors who influence community-based mined land restoration programs were constructed. A Net-Map is an interview-based mapping tool that helps to better understand multi-stakeholder processes. The tool enables individuals and groups to clarify their view of situations, foster discussions, and develop a strategic approach to their networking activities (Schiffer, 2007). In the net-map session, a large sheet of paper was used to map the answers to the following questions: 1. Which actors are/were involved in degraded and abandoned mined land restoration projects within the community? 2. What roles do/did they play? 3. How are/were they connected or interlinked? 4. How influential are/were they in ensuring a successful implementation? The influence scale used ranged from 0-5 (0 indicating no influence, 5 indicating maximum influence). 5. What are/were the common challenges they face(d)? The visual outcome of the mapping exercise then served as a basis for further discussions and explanations of issues, like land tenure arrangements, which emerged. The sessions were audio recorded, with expressed permission given.

Table 1. Summary of expert interviews

Institutions	***Semi-formal interview sessions***	***Participants***
Tropenbos Ghana	2	4
A Rocha Ghana	1	2
Forestry Research institute of Ghana (CSIR-FoRIG)	4	6
Crop Research Institute (CSIR-CRI)	2	2
Environmental Protection Agency (EPA)	2	2
Minerals Commission (MC)	1	1
Ministry of Lands and Natural Resources	1	1
Amansie West District Assembly	1	1
Total	**14**	**19**

3.3. Quantitative data collection

Guided by the qualitative insights, a quantitative survey was developed, including a discrete choice experiment (DCE) to enable the evaluation of preference and marginal utility values for various mined land restoration attributes by community members. The questionnaire was grouped into three sections: socio-demographics, respondents' perceptions, and attitudes towards illegal ASM activities (henceforth galamsey[1]) and the choice experiment. A total of 320 respondents were randomly sampled (see Table 2). The DCE was designed to evaluate preferences pertaining to a hypothetical rehabilitation case of an abandoned, degraded, and contaminated mined local community land, considering relevant attributes which included land reclamation, phytoremediation for contaminant extraction, restoration project implementation period, resulting vegetative structure, and willing labor contribution (see section 4 for more details). A Likert-type scale was used to rate each respondent's perceptions and attitudes on the different ways galamsey affects local communities using a 5-point ordinance scale (1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree). The survey was conducted by the research team in face-to-face interviews, using paper based illustrative questionnaires to aid respondents' understanding and limit cognitive burden in the case of the DCE.

Table 2. Summary of community-level sampling and data collection

	Qualitative data collection						**Quantitative data collection**
Selected communities	***Semi-formal discussion sessions***	***Participants***	***Focus Group Discussions***	***Participants***		***Net mapping sessions***	***DCE Survey***
				Male	***Female***		
Asarekrom	1	1	1	11	3	1	80
Abodom	1	2	1	9	2	1	60
Yawkrom	2	4	1	6	5	1	60
Essuowin	1	2	1	6	3	1	60
Bonteiso	2	2				1	60
Total	**7**	**11**	**4**	**32**	**13**	**5**	**320**

3.4. Discrete choice experimental design

DCE helps with understanding people's stated choice of alternative goods and services (Kuhfeld, 2005). DCE assumes that utility is derived from the characteristics (i.e. attributes and levels) of goods and services (Louviere, Hensher, & Swait, 2000). The service evaluated in this study was an abandoned mined land rehabilitation and restoration

[1] Within the Ghanaian context, galamsey is a common jargon meant for unlicensed artisanal small scale gold mining and processing. On the ground, however, there are a lot of physical and textural similarities between a galamsey site and one that is licensed, and therefore difficult to differentiate (Jones Mantey et al., 2016)

(hereafter rehabilitation) scenario. The DCE was based on participants' selection of desired degraded land restoration options: profiling systematic variations in these selected rehabilitation input and outcome attributes or no change in current conditions (Carson & Louviere, 2011). In line with Aguilar, Obeng, and Cai (2018), the probability of an individual's willingness to pay/contribute (WTP) to restoring such degraded and contaminated lands can be expressed as:

$$\text{Prob}(\text{WTP} = \text{Yes}, \text{No} | \text{Z}_{\text{restoration}}, \text{Z}_{\text{statusquo}}, \text{w}) = \text{Prob}(\text{U}_{\text{restoration}} > \text{U}_{\text{statusquo}}) \quad (1)$$

where the probability of choosing to contribute to restoration efforts, i.e., restoration (Yes, No), is conditional on rehabilitation inputs and outcomes captured through a set of attributes ($\text{Z}_{\text{restoration}}$), current land conditions profiled in a status quo scenario ($\text{Z}_{\text{statusquo}}$), and individuals' characteristics (w). An individual is willing to contribute to rehabilitation if the utility derived from that choice ($\text{U}_{\text{restoration}}$) is greater than the utility from no changes at no additional cost ($\text{U}_{\text{statusquo}}$). Choices reflect the implicit trade-offs among the different attributes of alternative options and the WTP estimates are interpreted as indicators of the change in utility that respondents expect from specified outcomes (Börger, Hattam, Burdon, Atkins, & Austen, 2014; Chaikaew, Hodges, & Grunwald, 2017).

Table 3 shows the selected attributes and their levels used for the DCE. The selection was guided by information gathered by reviewing the literature and, interacting with experts and implementers of the pilot restoration projects, as well as during the FGDs (see section 3.2). The attributes include relevant factors commonly considered throughout an entire process of mined land restoration as presented below:

2. **Land reclamation:** Laying the foundation for successful land restoration programs begins with repairing the physical state of the degraded area. Proper physical reclamation, according to Ahirwal and Pandey (2020), is done by backfilling the mine voids, leveling the surface topography and regrading of coarse rock, provisioning drainage and dump slop, stabilizing the waste dump, and trans-locating fertile topsoil.

3. **Phytoremediation for contaminant extraction:** The above-mentioned processes of land reclamation, do not remove toxic contaminants like mercury, used during ore extraction, from polluted soils. This can be done using specialized remediating-plant species (see section 1). Tradeoffs regarding which revegetation options to use, for example between economic or food plant species and phytoremediation plant species, could influence decision-making.

4. **Rehabilitation period:** Combined physical and biological restoration processes take time. Empirical findings from Tetteh et al. (2015) for example, indicate only marginal

soil quality restoration of degraded mined lands within a decade of rehabilitation. Indeed, effective restoration of degraded mining lands, particularly those with anthropogenic contamination with heavy metals, for safe and productive reuse, could take decades to complete (Saier and Trevors 2010; Singh and Tripathi 2007), which could also influence the decision to carry out rehabilitation.

5. **Vegetation structure:** This, as an outcome attribute, is an indication of the level of vegetation spread, biodiversity, wildlife restoration, and other beneficial ecosystem services provision-source. These were desirable features highlighted by participants during the FGDs.

6. **Willingness to pay:** The fifth attribute described is the cost of the different degraded mined land restoration scenarios to the community and the payment vehicle proposed. FGDs revealed that community members, many of whom are smallholders, could not afford the cost of machines and materials required for land reclamation. They were however willing to provide labor services to help restore their degraded community lands. Customary laws in each of the selected rural communities set one day aside each week, known as the "taboo day" or "breaking day", which forbids inhabitants from working on their farms or mining sites. These days are used for communal labor activities when needed. On such days, residents are mandated to contribute around 4 working hours towards communal responsibilities, which is equivalent to "one-man-day". The average daily (usually 4 hours, which is equivalent to "one-man-day") wage for casual labor in these communities is GH₵40[2].

[2] GH₵ 1 is equivalent to US$ 0.129

Table 3. Mined land rehabilitation attributes and levels used in the Choice Experiment design

Attributes	Description	Levels of change in attributes
Land reclamation	Extent of repairing soil physical (technical or engineering restoration) conditions after excavation, to lay the foundation for the restoration program (Ahirwal and Pandey 2020).	High level: effective physical reclamation of degraded land close to or better than its state before it was disturbed due to mineral extraction. Soils of reclaimed land suitable for high-functioning vegetation growth and agricultural activities
		Moderate level: appreciable physical reclamation of mine-degraded land to a level that supports moderate agricultural activity and vegetation growth
		Low level: physical reclamation of degraded land with pits filled, but fertile topsoil placement cover either not done properly or at all and therefore not able to support agriculture or vegetative functioning
		No change: no change in the degraded and contaminated state of mined land
Phytoremediation for contaminant extraction	Considers the level (as a proportion of planted area) of integration of known fast-growing phytoremediation species which remove heavy metal contaminants, with popular economic plant species, including timber wood, fuel wood, and cash crop species, that could provide direct economic benefit in the short and medium term to the landowner. With empirical results confirming high heavy metal contamination of soils in the research focus areas (see Awuah 2021), food crop species are omitted for health and safety reasons.	75% area covered with phytoremediation plant species (high level of heavy metal extraction expected)
		50% area integrated with phytoremediation plant species (moderate level of heavy metal extraction expected)
		25% area integrated with phytoremediation plant species (relatively low level of heavy metal extraction expected)
		No area covered with phytoremediation plant species (no heavy metal extraction expected)
Implementation period (years)	Period it takes to complete the integrated crop land-restoration-project using phytoremediation species which helps to absorb	Greater than 20: period allows for high contaminant absorption and allows for best land restoration outcomes

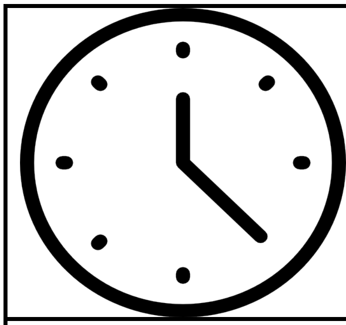
	excess heavy metals and revert contaminated mined lands to safer and more productive uses.	10-20: period allows for moderate contaminant absorption and allows for good land restoration outcomes
		Up to 10: period allows for relatively low absorption, and provides for only marginal land restoration outcomes
		0: no assisted mined site restoration outcomes expected
Vegetative structure	Extent of vegetative cover, biodiversity, and wildlife habitat restoration	High: dense vegetative cover which provides habitat for increased biodiversity, wildlife activity and ecosystem service benefits
		Medium: moderate vegetative cover which provides habitat for some medium biodiversity, wildlife activity and ecosystem service benefits
		Low: low vegetative cover which provides habitats for reduced biodiversity, wildlife activity and ecosystem service benefits
		No vegetation cover: no cover for biodiversity, wildlife activity and ecosystem service benefits
Willingness to pay/contribute to community-land rehabilitation initiative	Amount of labor man-days (4 hours) one will be willing to contribute monthly for the successful implementation of a land rehabilitation project for at least 10 years of the project life.	4 man-days/month
		3 man-days/month
		2 man-days/month
		1 man-day/month
		0 man-days/month

From these 5 attributes, 4 with 3 levels and 1 with 4 levels (see Table 3 for details), a large number[3] of unique land restoration scenarios could be constructed. An orthogonal main effects design (see Louviere et al. 2000) was employed to reduce the total number of attributes and levels to 12 pair-wise comparisons of alternative land restoration scenarios. These were randomly blocked into 4 different versions, each with 3 choice sets. Each set contained 2 unique mined land restoration scenarios and an option to select the 'current situation' or status quo scenario. The inclusion of this status quo scenario in the choice set served as a baseline alternative to help reduce bias and achieve welfare measures that are consistent with demand theory in estimating tradeoffs (Louviere et al., 2000). For this status quo scenario, the community contributes or pays nothing, however, there would be no assisted land restoration outcomes. The profiled DCE scenarios generated were with efficiency parameters of D-efficiency (98.5%), A-efficiency (97.1%) and G-efficiency (92.6%). Figure 2 shows an example of the choice scenarios used in the survey.

Figure 2: Example choice set comprising two profiles and the status quo option

<table>
<tr><td colspan="4">Which of the following mined communal-land restoration scenarios do you favor? Option A and option B would entail labor cost to your household. The 'current situation' option requires no labor contribution but will not improve the physical landscape, remove contaminants, and enhance the vegetation structure of the degraded area over time.</td></tr>
<tr><td>ATTRIBUTES</td><td>OPTION A</td><td>OPTION B</td><td>CURRENT SITUATION</td></tr>
<tr><td>Land reclamation
</td><td>High level</td><td>Low level</td><td>No change</td></tr>
<tr><td>Phytoremediation for contaminant extraction
</td><td>Integrate 50% phytoremediation tree species</td><td>Integrate 75% phytoremediation tree species</td><td>No phytoremediation tree integrated</td></tr>
<tr><td>Implementation period (years)</td><td>10 to 20</td><td>10 to 20</td><td>0</td></tr>
</table>

[3] The number of attributes and levels combined to generate 3^4*4^1=324 mined land restoration scenarios

			
Vegetative structure 	High canopy cover	Low canopy cover	No vegetation cover
Willingness to pay/contribute towards the land restoration initiative 	2-man-days-monthly	4-man-days-monthly	No labor contribution
I prefer			

4. Data analysis

4.1. Qualitative data analysis

Data from semi-formal discussions and FGDs was transcribed, and the content was analyzed. The five individual net-maps developed in each community were aggregated and cross-checked with project implementers from Tropenbos Ghana and at the community level. This was done as part of data triangulation efforts, a method to ensure scientific rigor in qualitative data analysis (Bitsch, 2005). The roles of actors and their interlinkages, including command and control, information sharing, fund flows, and service provision linkages, were identified and analyzed. Influence levels were analyzed considering the number of ingoing and outgoing ties that each identified actor has within the social network (degree centrality) as well as participants' perceived influence levels, which were provided during the FGDs. Degree centrality is a simple measure of the total connections an actor has to other actors within a network which constitutes a partial indication of their centrality within a social network structure (Jennifer, 2013). Perceived influence scores for each of the actors were averaged across the interviews to derive an overall influence score for actors in the aggregated social network.

4.2. Quantitative data analysis

The quantitative survey responses were descriptively analyzed (see Table 7) for selected socio-demographic attributes. The DCE was analyzed following the random utility model (McFadden, 1974). As expressed in equation 2 below, according to this model, the utility, U_{nj}, a decision maker 'n' obtains from choosing a land rehabilitation option 'j' from a set of alternative rehabilitation options (in this case [choice A, choice B] = 1, or a [current situation] = 0), is latent, though their choices, reflecting WTP, are observable.

$$U_{nj} = \text{prob WTP}(0{,}1) = V_{nj} + \varepsilon_{nj} \quad (2)$$

The deterministic component, V_{nj}, in equation 2, is a function of explanatory variables, X_{nj}, which include both observable attributes of alternative rehabilitation options, x_{nj}, and of the decision maker, z_n. The error term, ε_{nj} , is unknown and treated as random (Hole, 2013). V_{nj} is an indirect utility obtained by the nth individual choosing the jth mined land rehabilitation option from choice j. V_{nj} can be expressed as a linear function of explanatory variables in equation 3 as follows:

$$V_{nj} = x_{nj}\beta + z_n\gamma_j + \varepsilon_{nj} \quad (3)$$

where β and γ_j are the vector coefficients associated with the information matrices x_{nj}, describing observable attributes of alternative rehabilitation option relating to the jth choice (i.e., rehabilitation attribute levels), and z_n, attributes of the individual decision maker (i.e., vectors of socio-demographic and perception characteristics of the nth individual) respectively. A mixed logit (MXL) model was used to account for response heterogeneity and specific effects captured in repeated scenarios (Aguilar et al., 2018; Obeng, Dakurah, Oduro, & Obiri, 2021). Equation 2 can hence be expanded to:

$$U_{nj} = \text{prob WTP}(0,1) = \beta x_{nj} + \gamma_j z_n + \varepsilon_{nj} \quad (4)$$

where the derived utility has three components: β is the vector of coefficients associated with selected land rehabilitation service attributes; γ_j is a vector of coefficients which represent peculiar individual characteristics; and ε_{nj} is an independently and identically distributed random error term. MXL coefficients were estimated using 50, 100 and 500 Halton draws (Hole, 2007).

Three different econometric models were estimated. The first included selected land rehabilitation attributes only, the second controlled for socio-demographic characteristics and the third was expanded to include perception drivers. Table 4 presents the description of variables used in the regression. The current situation (status quo) was assigned as the alternate specific constant (ASC). Aguilar et al. (2018) and Obeng et al. (2021) define the ASC coefficient as the mean difference in utility from the alternative different land management options and the status quo. To identify sources of heterogeneity in preferences (Veisten, 2007) and to promote model accuracy (Aguilar et al., 2018; Hu, Woods, & Bastin, 2009), socio-demographic as well as perception variables were interacted with the ASC.

Labor cost for each household is the product of the average daily wage for casual labor and the number of communal labor-man-days dedicated to rehabilitation in a month (see Table 4). Following Hensher A., Rose M., and Greene H. (2005), the marginal WTP for all attributes were calculated as:

$$\text{WTP}_{res} = -(\beta_{res\ attribute} / \beta_{labor\ cost\ to\ household}) \quad (5)$$

Using estimated coefficients from the first model, the relative importance (RI) that each attribute had on average choices were calculated as shown in equation 6 below:

$$\text{RI}_i = (\text{Range}_{res\ attributei} / \sum \text{Ranges}_{res\ attributes}) \times 100 \quad (5)$$

Analyses were done with Stata version 17.

Table 4. Description of variables used in the MXL regression model

Variable	Description
Dependent variable	Discrete choice between land rehabilitation alternative A, B, and Status Quo
Variables specific to the choice alternatives	
ASC	Alternative specific constant (status quo option) = 1; proposed land rehabilitation option = 0
High level land reclamation	Effective physical reclamation of degraded land*
Moderate level land reclamation	Appreciable physical reclamation of degraded land*
75% area phytoremediation	75% of rehabilitation area cultivated with phytoremediation species*
50% area phytoremediation	50% of rehabilitation area cultivated with phytoremediation species*
>20 years implementation period	More than 20-year land remediation and rehabilitation period*
10 to 20 years implementation period	Between 10-to-20-year land remediation and rehabilitation period*
Dense vegetation cover	High increase in vegetation cover *
Medium vegetation cover	Moderate increase in vegetation cover *
Cost	Cost to household (monthly labor contribution to proposed land rehabilitation initiative for at least 10 years) GH₵ 40, GH₵ 80, GH₵ 120, GH₵ 160
Variables specific to the respondents interacted with the ASC	
Socio-demograhic factors	
Gender x ASC	Gender of respondents: female = 1, male = 0
Age x ASC	Age of respondents
Education x ASC	Education level of respondents: received formal education = 1, no formal education = 0
Residence status x ASC	Residence status of respondent: native = 1, settler = 0
Land access x ASC	Respondents' access to land*
Income x ASC	Yearly household income in GH₵
Mining engagement x ASC	Respondent engages in ASM activities*
Farming x ASC	Respondent engages in farming activities*
Perception factors	
Perceived impacts of galamsey on the environment x ASC	The mean response scores for impact of illegal ASM on the environment and welfare**

1 USD equals 7,75 GH₵, * Binary variable (1 = yes, 0 = no), ** Binary variable (1 = strongly agree or agree, 0 = strongly disagree, disagree, neither agree nor disagree)

5. Results

5.1. Which stakeholders are key for the success of community-based post-mined land restoration?

Quantitative findings, including net-mapping was used to analyze how networking influences or could influence land restoration outcomes. The subsections that follow present the key actors involved in community-based land rehabilitation works, their roles and interrelationship types as well as common challenges that hinder their efforts.

5.1.1. Types of stakeholders identified

Figure 3 shows an aggregated net map of the key stakeholders who actively contribute to community mined land rehabilitation outcomes. Nine stakeholder types: traditional authorities/chiefs, unit committees, assembly men – together with the district assembly, minerals commission (MC) and the environmental protection agency (EPA) as central government representatives, NGOs (e.g., Tropenbos Ghana, A Rocha Ghana) and local businesses (e.g., Armajaro Ghana), machinery service providers, miners, landowners, and community members, were perceived as important actors who influence ASM mine land rehabilitation outcomes at the local level. Their specific roles within the ASM land management social network are presented in Table 5.

Figure 3: Net mapping active stakeholders involved in restoring degraded and contaminated mined lands for future use

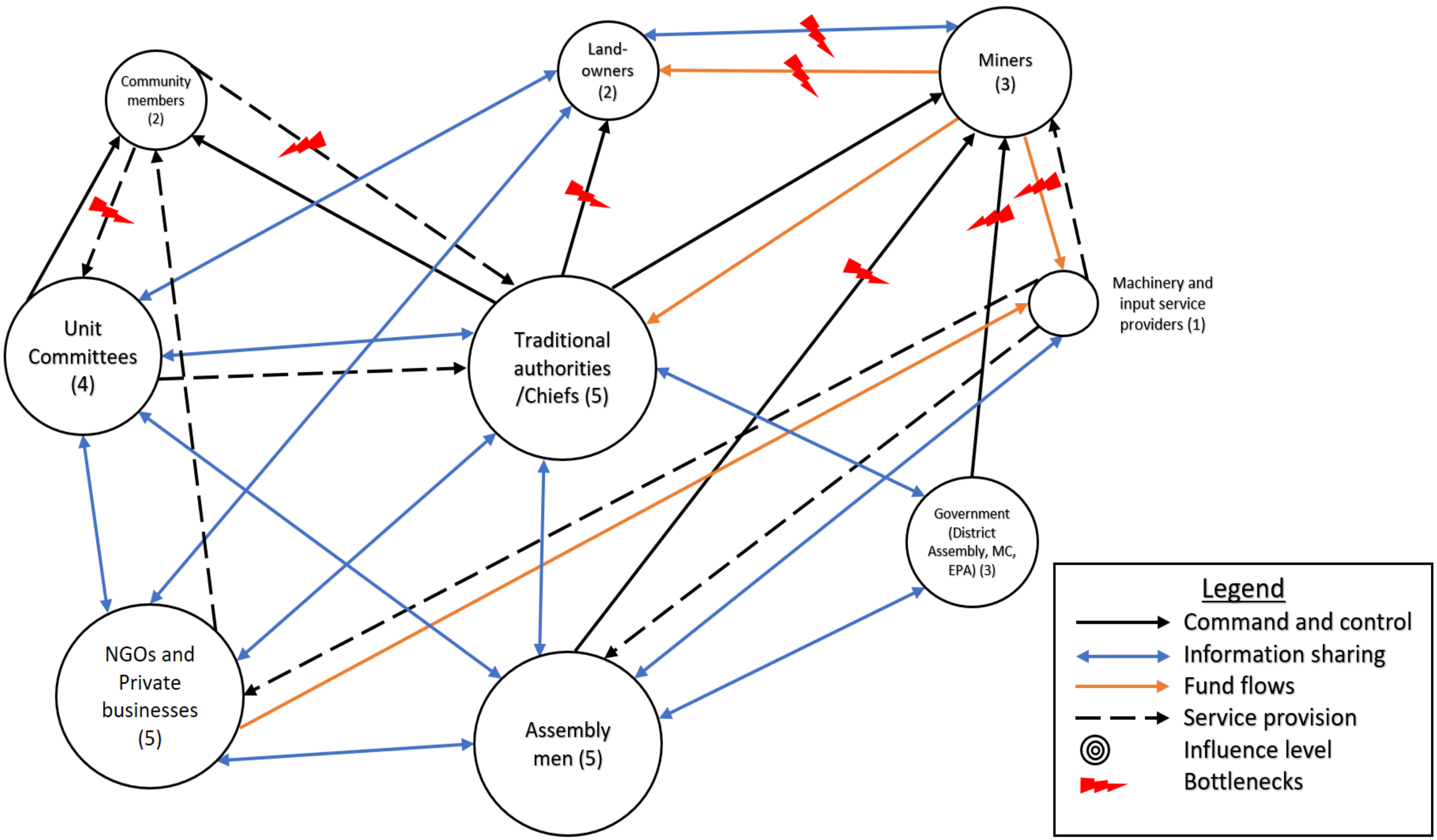


Table 5. Roles of identified actors

Actor	Role
Traditional authority/ chiefs	These are the overlords of rural communities. They must give their consent on all matters impacting the welfare and development of community inhabitants, like the introduction of mining and land restoration projects. They significantly influence land tenure arrangements, especially those on lands that have been degraded and abandoned through mining operations, as well as mobilizing communal labor for rehabilitation works on such lands.
Unit committees	They are made up of experienced and respected community elders, and function as the administrative arm of the chiefs which directs in-community activities. They are responsible for developing and implementing land restoration project plans at the community level, as well as organizing and supervising the community labor force (communal or hired) to work on restoration sites.
Assembly men	They discuss issues relating to community level-land restoration both at the local traditional authority and district assembly -levels. They broker with institutions of the state, the private sector, and NGOs for restoration projects to be brought to the community. They also arrange for machinery services like bulldozers and excavators needed for land reclamation, particularly, filling pits and leveling mine-lands.
District assembly, Minerals commission, EPA	District assemblies are responsible for identifying and rolling out central government projects initiatives, such as those related to mining and mined land restoration at the local community level. They also monitor active mining operations within communities, sometimes, together with a mix of the police and the military personnel (Operation Vanguard) in areas of illegal operations. The EPA and Minerals commission are state regulators responsible for ensuring compliance to mining regulations, especially with regards to land rehabilitation, by licensed miners at the community level.
NGOs and private businesses	NGOs provide technical trainings (e.g., on nursery development and management, transplanting etc.) and financial support for restoration projects. Specific to this study case, they develop model mined land restoration fields which serve as demonstration sites for learning especially by miners and landowners within the community. Just as with some identified actors within the private sector, they also provide local communities with planting materials used to revegetate reclaimed lands.
Miners	They are responsible for carrying out concurrent land reclamation while mining as well as post-mining revegetation. These practices are usually enforced by authorities (for licensed miners) and landowners (in ideal cases) to ensure that mined community lands are returned to their owners in their functional states.
Landowners	These are local community members who rent out customary lands they own to miners for their operations. They agree terms with miners (and enforce them in ideal cases) to rehabilitate lands after ore extraction. In the case where this is not done, they can work together with the Unit Committee and assembly man to access machinery and community members to contribute labor towards rehabilitating degraded lands if they have the means to afford the cost.
Community members	They provide the communal or hired labor required for restoring degraded and contaminated mined lands within the community
Machinery service providers	They lease out bulldozers and excavators used for mining and land rehabilitation works.

5.1.2. Linkages among different actors

The identified actors are connected via various linkages, namely, command and control, service provision, information sharing, and fund flows. Command-and-control linkage describes actors' ability to impose their will on other actors and apply sanctions in the case of noncompliance. An outgoing linkage implies an actor enforces command and control, while an ingoing one shows an actor receiving orders, or sanctions. Traditional authorities, unit committees, assembly men, as well as government representations from the district assembly, MC, and EPA, use their abilities to command and sanction to influence behaviors of miners, landowners and community members (see Figure 3 and Table 6).

Chiefs or traditional authorities, as community overlords, have the power to enact and enforce local laws that seek to protect community lands. They must give consent before mining and/or land use projects can be initiated within communities. Chiefs determine land tenure arrangements, particularly the fate of community lands that have been mined, degraded, and abandoned, and the sharing of benefits from those lands which must be restored using communal efforts. Chiefs have the power to take back individual or family-owned degraded mined lands from their original owners and convert their status to community property. Chiefs also directly and indirectly (through the unit committees) order communal labor efforts on lands earmarked for restoration programs within the community.

Central government representatives at the local level, including the district assembly and assembly men as well as MC and EPA district officers conduct compliance monitoring visits to licensed mines in active mining communities and sanction non-compliance. Practices like concurrent land reclamation (Salati, Mireku-Gyimah, & Eshun, 2016) by operators, during active mining, which is key to managing the overall cost of restoration, is enforced by these regulators. Operation Vanguard[4] for example, works together with the district assembly to patrol and control areas of illegal ASM activities.

Findings from field discussions highlighted that, with regards to land rehabilitation at the local level, common services provided by actors include:

[4] A special security task force consisting of a mix of the police and the military to control illegal mining activities across the country

- training services, such as tree nursery development, management and transplanting, NGOs provide to communities
- paid services, as in the case of mechanization service provision and employed or hired field labor
- administrative, coordinating, and supervisory service, as in the case of unit committee members who function as the administrative arm of chiefs that direct in-community activities
- obligatory service, as with community members who provide communal labor required for rehabilitating degraded and contaminated mined lands within communities.

Communal labor services were mandatory for all inhabitants within the study communities and were customarily defined and enforced by the chiefs. In situations where rehabilitation sites are privately owned, responses from the FGDs highlighted that the landowner hired laborers from within the community.

Another type of link is information sharing, that is, the exchange of information between actors within the social network. Unlike other linkages, information flow usually goes both ways (see Figure 3). The best-connected actors in terms of information flow are the traditional authorities, unit committees, assembly men, NGOs, and landowners (Table 6). Notable among these interactions is the coordination and brokerage roles played by assembly men on issues relating to land restoration at the local level. They broker with institutions from the state (district assembly), private sector (mostly other miners and private businesses), and NGOs for restoration projects and machinery services like bulldozers and excavators needed for land reclamation to be brought to the community.

Fund flows in the context of this study refers to both monetary and material resources needed for degraded mined land rehabilitation. Most critical is funding, needed to access earth-moving mechanization services for land reclamation. Ideally, reclamation would be done concurrently during ore extraction by miners. In many existing cases however, due to illegal activities, concurrent land reclamation is not done, and mined lands are abandoned in their degraded states. After receiving land use compensation payments from miners, landowners do not ensure that these lands are reclaimed by miners – a common challenge faced with illegal ASM, shown as a bottleneck in Figure 3. In such cases, funding support can be provided by environmental NGOs and those within the private sector, like other miners, as part of their voluntary social responsibility. Findings from the mapping exercise highlighted that Tropenbos Ghana, for example, provides both technical trainings and financial and material support services to develop model mined land restoration fields which serves as demonstration sites for learning, especially by miners, landowners, and community members within the community. FGDs in Essuowin revealed that resources for reclaiming their model demonstration restoration site was provided by some resident miners while Armajaro Ghana, a cocoa aggregation business, provided the community with planting materials to revegetate the site.

5.1.3. Actors' networking properties and influence

Table 6 sums the degree centralities of all linkage types for each actor group together with their levels of perceived influences. The results reveal the influence of each actor on mined land rehabilitation outcomes. Chiefs had the highest degree centrality count (14) and perceived influence (5). This was mostly attributed to their position as being able to command and control other actors as well as their connectedness to information flow linkages. This was partly captured during the FGD in Asarekrom as illustrated in the following quote:

"There are a lot of galamsey activities happening in our community because our community leaders allow it. For our close neighboring community however, the chief has warned that he does not want any galamsey in his town and all community members have no choice but obey… Their rivers still look clear, and their farming and forest landscapes are still intact".

Next were assembly men with a degree centrality count of 12 and considered among the most influential actors primarily due to their brokerage and coordinating roles as well as their connection with the state. NGOs with a total degree centrality count of 9 were also classified among the most influential actors (influence score of 5) for their roles as rehabilitation project initiators, as well as technical and resource support service providers within mining communities. Next were unit committees, with an influence score of 4 and a total degree centrality count of 11. State institutions, like the District Assembly as well as MC and EPA field officers, followed, with a total degree centrality of 5, had an influence score of 3 mostly due to their roles as enforcers of sustainable mining practices, including post-mined land restoration at the local level. The District Assembly possesses constitutional and administrative power at the municipal and district level and is an influencing force in mining related matters at the local level. Miners were also perceived to have an equal level of influence (3) as state institutions though with greater (9) total degree centrality. Landowners, though relatively more connected (with degree centrality of 8) were given an influence score of 2 like other community members. Machinery service providers had the least perceived influence score of 1.

Table 6. Breakdown of actors' degree centrality linkages and perceived influence

	Command and control		Information sharing		Funds flow		Service provision			Perceived Influence levels
Degree centrality	**In-degree**	**Out-degree**	**In-degree**	**Out-degree**	**In-degree**	**Out-degree**	**In-degree**	**Out-degree**	**Total**	
Traditional authorities	0	3	4	4	1	0	0	2	14	5
Assembly men	0	1	5	5	0	0	1	0	12	5
NGOs and private businesses	0	0	4	4	0	1	1	1	11	5
Unit committees	0	1	4	4	0	0	1	1	11	4
Miners	3	0	1	1	0	3	1	0	9	3
Government (DA, MC, and EPA)	0	1	2	2	0	0	0	0	5	3
Landowners	1	0	3	3	1	0	0	0	8	2
Community members	2	0	0	0	0	0	1	2	5	2
Machinery and input service providers	0	0	1	1	2	0	0	3	7	1

5.1.4. Key challenges to community-based mined land restoration initiatives

Two critical factors fuel abandonment of degraded mined lands by miners, consequently increasing remediation costs, and for which reason the proactive involvement of certain grass root local community actors is crucial. These factors include:

1) the proliferation of illegal mining operations with limited outreach by state regulators. Most of these illegal operations, despite not having formal permits, receive "social licenses" from traditional authorities, landowners and communities to operate, and

2) the uncertain returns and pressures on illegal ore extraction operations which then mean increased likelihood of lack of available resources and time to carry out rehabilitation works on affected lands.

Results of the FGDs and mapping exercises however revealed low influence levels of critical actors like landowners, community members and machinery service providers in achieving post-mined land restoration outcomes. Some reasons for the lagged posturing of these actors were captured in these quotes during the FGDs as:

"Most landowners out of ignorance do not agree on land reclamation terms with miners… but these miners are also just too powerful, well-connected, and stubborn! Even if you agree with them to fill the pits after mining, they end up doing their own thing because they think they have given you compensation-money" – FGD in Abodom

"Part of the blame must be shifted to the government task force! Sometimes, these Chinese miners do not complete their operations before they are chased out. Pits are left uncovered this way!" – FGD in Asarekrom

Asked why ordinary community members had such little influence in enforcing responsible land management and post-mine land rehabilitation by miners, a farmer participating in the FGD in Essuowin retorted:

"You see, individual smallholder farmers, like me, do not have the voice or resources to impose our will… My cocoa farm was destroyed because close-neighboring farms were given up for mining by their owners. The miner ended up cutting down some of my cocoa trees too. Nothing was done when I complained to the community elders. Eventually I lost all my trees and had to give up on the farm"

Customary land tenure arrangements, dominated by family and shared land ownerships, mostly intended for farming, mean that community land use decisions are made by these groups of landowners (Adu-Baffour et al., 2021). In mining communities, where lands are usually leased out over relatively short-term periods for ore extraction purposes, it is assumed that the decision to ensure that these lands are returned in the desired functional state by a miner should primarily fall on these landowners. After all, under proper land tenure arrangements, these lands remain their properties. Findings from the FGDs however identified landowners being among the less influential actors when it comes to contributing to community-based mined land rehabilitation outcomes. They generally seemed to lack the incentives to ensure that miners manage their lands responsibly. One reaction was succinctly captured during a FGD sessions as:

"For a piece of land that is probably valued at GH₵ 4000, a landowner sometimes charges as high as GH₵ 6000. But after taking such an amount, he loses interest to monitor or ensure that his land is managed properly by the miners who disappear after their operations… Part of this money could be left with the miner to purchase fuel for the excavator he is working with to reclaim the land at least!".

The FGDs also confirmed the significant power of chiefs, who can transfer ownership of lands, especially those that have been poorly managed due to illegal mining operations and have been abandoned in their degraded and contaminated states. By re-converting such lands into community-owned property, communal labor contributions could be used to rehabilitate these lands. The relevance of transferring ownership of ASM-degraded lands was captured in a FGD session in Abodom as:

“Communal labor is not used on individual property. It can only be used on community property where benefits are equally enjoyed by the community and not by only just a few. If Nananom (chiefs) convert lands which need to be worked on to communal property status, then the community will take part in its rehabilitation as expected”.

Rehabilitation programs begin with land reclamation requiring the use of earth moving equipment, mostly excavators and bulldozers, which are rented out together with operators by heavy machinery service providers mostly located in bigger cities at a daily charge. The high cost of renting, transporting, and operating these machines mean that only well-resourced miners have the means to access them. To help manage their operational costs while ensuring environmental stewardship, regulators train and enforce miners (licensed ones) to practice concurrent reclamation during mining – a practice not popular with illegal mine operators. The burden of rehabilitating degraded lands which have been abandoned by miners fall back on landowners, just as ramifications of exposed pits are suffered by community members. Both actor groups neither have direct linkages to machinery service providers, as shown in Figure 3, nor the means to outsource them. One response from a miner in the FGD in Abodom expressed the situation in this quote:

“Just to backfill one hectare of an affected land alone, you need to rent an excavator with an operator which costs GH₵4000 for 8 hours and buy around 20 gallons of fuel which costs an extra GH₵4000. Most smallholder farmers and landowners do not have that kind of money”.

In Asarekrom, participants of the FGD acknowledged the rare support acquired from Tropenbos Ghana to reclaim and revegetate its 2.3 ha abandoned community land with this comment:

“*As for Tropenbos, they have been very supportive! They brought machines to fill up pits and helped organize the community to transform these degraded mined lands. We do not know how else we could have done all this without them. They have shown us that we can transform these degraded lands!”*

5.2. What factors could compel or dissuade voluntary land rehabilitation efforts?

This section reveals estimated relative weights of land rehabilitation factors that influences an individual's decision to contribute to community-based rehabilitation efforts. As explained in section 5.3, estimated values consider each respondent's socio-demographic characteristics, perceptions and attitudes towards galamsey and their environments.

5.2.1. Respondents' socio-demographic characteristics

Descriptive information of relevant demographic variables at the local community household level is presented in Table 7. Those for gender, age and education levels mostly mirrored official district statistics (see Ghana Statistical Service 2014). The results confirm an appreciable distribution of sampled respondents across the various socio-demographic groups. Settlers, mostly nomadic miners, migrant farmers, migrant professionals like teachers, and non-native spouses, contributed around a third of the sample. Descriptive results also confirm Amansie West's status as both an active mining and farming district where smallholder farmers also provide casual labor in mines, mostly during the off-season, or scavenge abandoned mines for spoils and earnings used to obtain supplementary farm capital. Family land holdings are the commonest means of land access in these areas (70%), with a few cases of private, shared, rented and stool land tenure arrangements. Most of these land holdings are used to cultivate food crops and selected cash crops (mostly cocoa, coconut and oil palm), with the dominant farm sizes ranging from less than one acre to 20 acres. About a third of the respondents earn GH₵ 2000 or less yearly, which is well below the national yearly minimum wage (see Nyarko Otoo 2018). The table also shows the average yearly incomes among respondents who engage in mining, farming, and non-farming-non-mining activities to be GH₵ 10,216, GH₵ 3,855 and GH₵ 3,188 respectively. This confirms the importance of ASM in these local economies.

Table 7: Descriptive results

Socio-demographic variables	**Study sample (n=320)**	
	Count	***%***
Gender		
Male	166	51.9
Female	154	48.1
Age		
17-24 years	55	17
25-34 years	82	26
35-44 years	53	17

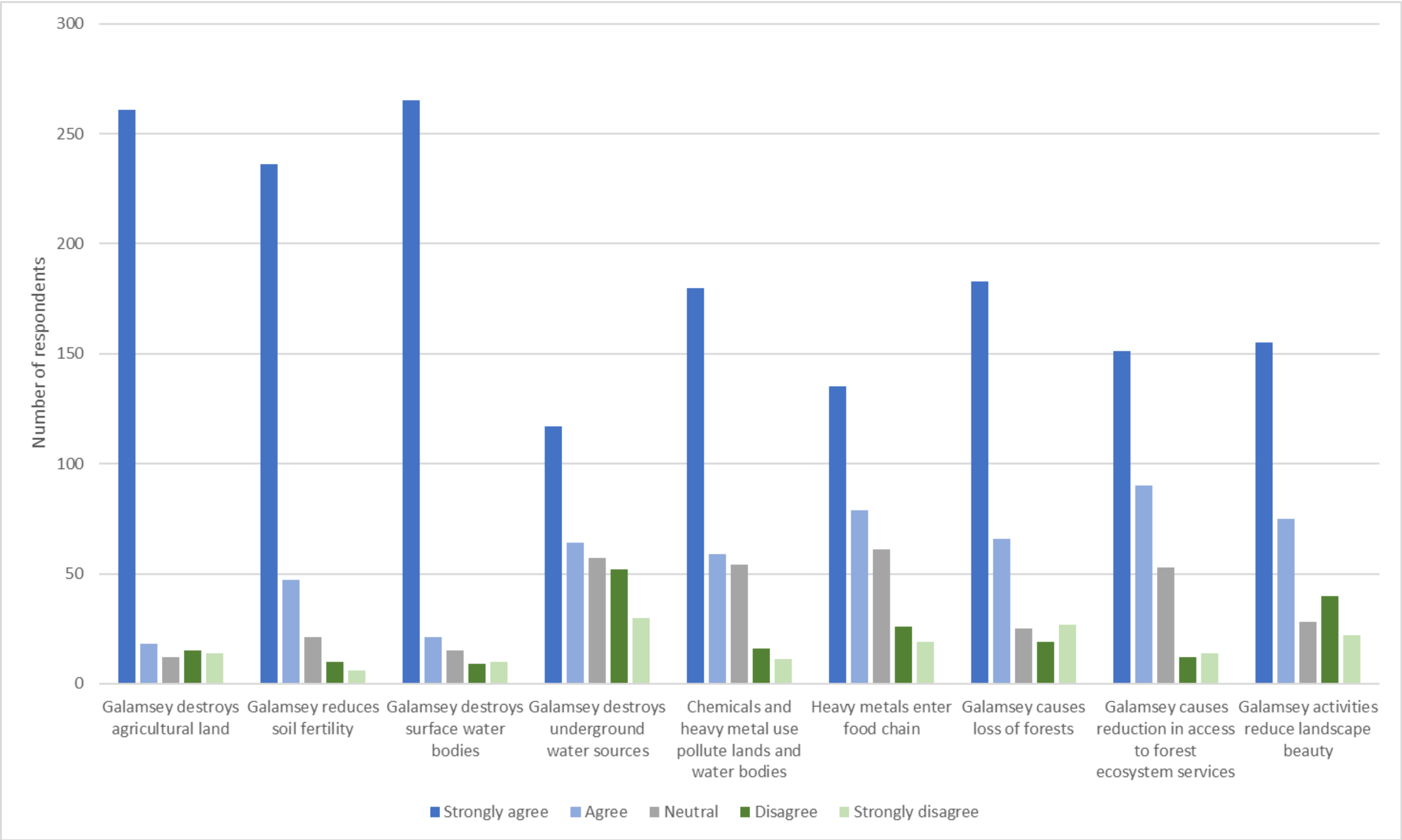
45-54 years	52	16
55-64 years	44	14
>=65 years	34	11
Education level		
None	59	18
Primary	52	16
Junior secondary/Middle school	134	42
Senior secondary/Secondary	48	15
Tertiary	16	5
Vocational/Technical/Commercial	11	3
Residence status		
Native	220	69
Settler	100	31
Mining engagement		
Yes	112	35
No	208	65
Mining engagement type (n=112)		
Digger	22	20
Concession owner	3	3
Casual laborer	54	48
Machine operator	22	20
Supervisor	8	7
Processor	3	3
Farming engagement		
Yes	202	63
No	117	37
Farm size (n=215)		
<=1 acre	16	8
2 acres - 5 acres	107	54
6 acres - 10 acres	51	25
11 acres - 20 acres	19	9
21 acres to 30 acres	3	1
>30 acres	3	1
Access to land		
Yes	215	67
No	105	33
Land accessed (total acres)		
Private land	252.75	13
Family land	1323.5	70
Rented land	142.5	7
State land	0	0
Customary/Stool land	47	2
Shared land	137.5	7
Annual income (GH₵)		

Up to 500	24	8
500 to 1000	21	7
1000 to 2000	52	17
2000 to 5000	86	28
5000 to 10000	66	21
10000 to 20000	41	13
>20000	22	7
Average yearly household income	***Average income (GH₵)***	***%***
Mining	10,215.5	54
Farming	3,855.4	21
Non-farming & non-mining	3,188.2	17
Remittances	1,534.7	8
Total (overall average)	(7,141.5)	100

5.2.2. Respondents' perception of impact of illegal ASM (galamsey) on their immediate environments

Figure 4 shows that a significant majority of the respondents perceived galamsey to have a negative impact on local community environments and welfare, particularly, galamsey activities destroying agricultural lands, reducing soil fertility, destroying surface water bodies, destroying forests, limiting their ecosystem services and reducing landscape beauty. There were, however, interesting variations in the responses for statements like "Galamsey destroys groundwater", "Chemicals and heavy metals used pollute lands and water bodies", and "heavy metals enter the food chain and affects consumers", to which between 25 - 44% of respondents were either not sure or disagreed. These responses are indicative of the local communities' consciousness of the visible impacts illegal ASM activities have on the environment, and highlight how much more effort needs to be put into creating local awareness of those impacts that take time to manifest, like the ecological and health effects of heavy metals used during ore extraction.

Figure 4: Local communities' perceptions of impact of illegal ASM (galamsey) activities on their immediate environments and welfare



5.2.3. Respondents' preferences and WTP towards community land rehabilitation

Table 8 presents the mixed logit (MXL) results of the three models stipulated in section 5.3. Statistically significant standard deviation (SD) coefficients (see Annex) associated with high-level land reclamation, phytoremediation on 50% land, phytoremediation on 25% land and high canopy cover, revealed the presence of substantial unobserved respondent heterogeneity and were addressed as random coefficients in all models. The remaining attribute variables (with SD p-value >0.10) were kept as fixed coefficients due to the lack of evidence of heterogeneity. All three estimated econometric models were statistically significant (each having p-values = 0.000) with coefficients of selected variables showing expected signs. Relative to the base level, a positive (negative) sign of the coefficient for an attribute variable implies that there is an increase (a decrease) in derived utility. The negative sign associated with the household cost of land rehabilitation (in this case, the respondent's labor contribution), reveals its trade-off disutility.

Coefficients for land reclamation (both at moderate level and high level), and phytoremediation on 50% of the land were statistically significant (p-value <0.0001) in model 1. This implies that respondents, on average, prefer and are willing to contribute labor for land rehabilitation projects repair that reclaim degraded lands and integrate 50% of the rehabilitation area with phytoremediation species, to remove heavy metal contaminants, over the current situation option. Among these statistically significant land rehabilitation attributes however, moderate-level land reclamation had a fixed effect, suggesting that it was the more preferred and most important driver of WTP within the sample size. More specifically, respondents were 2 times more likely to prefer or opt for land rehabilitation initiatives with a medium-level land reclamation, relative to the status quo, ceteris paribus. The effects of both high-level land reclamation and phytoremediation on 50% of the land on WTP, however, had random coefficients, denoting some level of variance in how they influence choices. The coefficient values of the remaining attributes in Model 1 were statistically insignificant. Utility coefficients for vegetation structure were also statistically significant at a 10% Type-1 error level in Models 2 and 3 when individual-specific characteristics were controlled for. The relative importance (RI), which is the importance of an attribute relative to all other attributes conditional on the range of levels of that attribute, was also computed. The results again confirmed land reclamation and phytoremediation (on 50% of the land) as the top two relatively most important attributes for respondents when compared to labor and time costs as well as final vegetation outlook.

The effects of ASC-interacted-individual-specific (socio-demographic or/and perception) variables that indicate the probability of choosing the status quo option, ceteris paribus, were examined in Models 2 and 3. The signs of the coefficients of ASC-interacted-individual-specific socio-demographic variables, controlled for in Model 2, can hence be interpreted as, otherwise constant, the average probability of an individual choosing the status quo choice decreases (if negative) and increases (if positive) with the presence of/increase in the variable. None of the individual-specific variables in both models, however, had statistically significant effects.

Table 8. Results from mixed logit models explaining respondents' preferences for mined land restoration service options (n=320) (Number of Halton draws: 50)

Variable	Model 1		Model 2		Model 3	
	Attributes only		**Attributes + socio-demographic**		**Attributes + socio-demographic + perception**	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Fixed coefficients						
Cost	**-0.008*****	0.002	**-0.008*****	0.002	**-0.008*****	0.002
Medium vegetation cover	0.296	0.228	0.293	0.232	0.290	0.230
Implementation period (> 20 years)	-0.229	0.168	-0.225	0.169	-0.223	0.167
Implementation period (10 to 20 years)	-0.152	0.152	-0.122	0.153	-0.121	0.152
Moderate level land reclamation	**2.019*****	0.281	**2.021*****	0.281	**2.012*****	0.274
Mean of random coefficients						
ASC (Status quo)	**-30.76*****	11.487	-42.816	4154	-29.821	3956
High level land reclamation	**2.376*****	0.324	**2.351*****	0.324	**2.338*****	0.313
Phytoremediation on 50% land	**1.212*****	0.179	**1.149*****	0.178	**1.143*****	0.172
Phytoremediation on 75% land	0.049	0.179	0.080	0.174	0.081	0.173
High vegetation cover	0.288	0.191	**0.330***	0.192	**0.328***	0.191
Socio-demographic factors						
Female x ASC			-117.457	2496997	-82.109	15249.690
Age x ASC			-1.690	2.658	-1.361	2.165
Education x ASC			-36.967	59.577	-26.987	30.758
Income x ASC			-0.002	0.003	-0.001	0.001
Native x ASC			-27.128	46.271	-20.913	24.238
Mining engagement x ASC			87.865	4154.9	66.529	3956
Farming engagement x ASC			23.376	42.485	14.162	19.864
Land access x ASC			-112.768	1492206	-74.478	7542
Perception/attitudinal factors						
Perceptions of environmental impact of ASM					1.651	8.659
Log-likelihood	-535.229		-504.391		-504.386	
LR Chi^2(5)	75.500		44.000		43.66	
Prob > Chi^2	**0.000**		**0.000**		**0.000**	
AIC	1100.458		1054.783		1056.773	
BIC	1189.941		1191.408		1199.338	
Relative importance (%)						
Phytoremediation	72%					
Land reclamation	22%					
Implementation period	5%					
Vegetation cover	1%					
Cost to household	1%					

*****Statistically significant at 1%, *Statistically significant at 10%**

Marginal WTP estimated in Table 9 confirms the most preference for land reclamation. This was followed by phytoremediation on 50% of reclaimed lands, which was significantly higher than phytoremediation on 75% land with a WTP value of just GH₵ 6.01 household^{-1} month^{-1} – the least preferred among all the attributes. Average WTP for vegetation cover followed phytoremediation on 50% land with GH₵ 35.57 household^{-1} month^{-1} and GH₵ 36.65 household^{-1} month^{-1} for dense cover and medium cover respectively. The number of years required to fully restore degraded lands did not significantly influence land rehabilitation decision making, despite its negative WTP due to waiting time. In one of the FGD sessions, a respondent justified this with this quote:

"Most of our community lands have been destroyed from galamsey and restoring these lands will take a long time to complete… We will be doing this not for us but for our children and their children to benefit".

Table 9. Marginal willingness-to-pay estimated for community mined land rehabilitation

Land rehabilitation attributes	**WTP (GH₵ household^{-1} month^{-1})**	
	Moderate	**High**
Land reclamation	249.76	293.91
Phytoremediation	149.92	6.01
Vegetation cover	36.65	35.57
Implementation period	-18.74	-28.30
Aggregate WTP	**417.59**	**307.18**

USD 1 is equivalent to GH₵7.75

6. Discussions and Conclusion

Using a unique land restoration study case in Ghana, this paper has combined the use of both qualitative and quantitative methods to reveal the conditions and extent local communities could contribute to restoring community mined lands. We identify and analyze existing network of actors who have the potential of influencing restoration projects, as well as factors that enhance and hinder willing involvement by community members. This section discusses these findings and proposes strategies for the sustained success of community-based land restoration projects.

6.2. Which key actors could make community-based rehabilitation projects work?

A key research question, which is important for designing community-led restoration projects is, 'Which actors are key to its success'? Our findings show that social networks of actors, involving chiefs, unit committees, assembly men, local government institutions, environmental NGOs, miners, landowners, and community members, could interact to meet sustainable local land management outcomes. Of particular interest is the integral role traditional authorities still play in natural resource management and its impact on promoting local people's welfare in Africa, as highlighted by Shackleton et al. (2002). The study findings confirm this by revealing the impact traditional leadership has in defining local people's priorities – in this case, on community land use and management. This is primarily because, as community overlords, traditional authorities have the power to enact and enforce local laws, and sanction noncompliance while seeking to protect and increase the potential benefits of local community lands. Most actions and inactions of other relevant actors within the chain, including unit committees, community members, miners, landowners, and even other highly influential actors like NGOs and assembly men, were shown to be directly influenced by chiefs.

On the low end of the influence ladder, local community members and landowners were seen to be largely not organized, with different individual land use priorities and under both unregulated and insecure land tenure structures, which Chirwa and Mahamane (2017) and Deininger et al. (2008) argue are major threats to sustainable land resource use. Against much more organized, better resourced, and well-connected miners, whose primary goal is ore extraction rather than land rehabilitation, these actors need to work collectively, and under equitable local land access and tenure securities backed by specific and clear laws, to encourage land rehabilitation as a common practice within the ASM sector.

6.3. Which land rehabilitation attributes do local communities value most?

Empirical findings from the DCE suggest that there is community support for reclaiming and remediating degraded and contaminated ASM lands for future productive use, irrespective of differences in individual-specific characteristics among respondents. This can be inferred from the significantly low household cost disutility from the MXL results (see Table 8). Such cost, which is the opportunity cost of contributing communal labor for land rehabilitation, is, however, dependent on the land tenure arrangements associated with the land in question, as detailed in subsection 6.2.4. This is in line with the findings of Owusu, Kimengsi, and Moyo (2021) who identified that households' choices in community-based landscape restoration in Tanzania depend on existing land policies and customs.

Amongst the primary concerns about ASM highlighted in the literature, see Cao (2007), Abhilash (2021), Mantey, Nyarko, and Owusu-Nimo (2016), and during the research study, was the lack of land reclamation. It, therefore, comes as no surprise that land reclamation was consistently mentioned as the 'most preferred' among the mined land rehabilitation attributes considered during the DCE. Land reclamation requires heavy machinery, operational know-how and funding resources (confirmed in Mantey et al. 2016), and it is for this reason that concurrent reclamation (see Salati, Mireku-Gyimah, and Eshun 2016) during ore extraction by miners is recommended by authorities as a more cost-effective land management practice. Land reclamation was more commonly preferred at a moderate level by communities, probably due to the additional resources required to achieve its high-level alternative, despite both levels supporting agricultural activity and vegetation growth.

Even though local communities significantly supported using specialized plant species to remediate reclaimed areas, results indicated that – despite the soil being potentially contaminated – they commonly preferred phytoremediation on only 50% of the total reclaimed area, leaving the remaining half to farm either food or cash crops (see 6.3.3). This preference, together with its random choice effect due to substantial respondent heterogeneity, confirms the limitations of local communities' awareness of the health implications of heavy metal-contaminated agricultural soils and the need for increased sensitization efforts. These revelations should also encourage the promotion of concepts like sustainable phytoremediation (Pandey & Souza-Alonso, 2018), which takes advantage of commercial opportunities alongside the ecological benefits of using phytoremediation.

Dense vegetation cover which provides habitat for increased biodiversity, wildlife activity and ecosystem service benefit, like fuel wood, wild fruits, game etc., was the next preferred attribute. This also had a random choice effect. The high degree of heterogeneity could be attributed to the already reduced forests in these communities, not only due to illegal ASM activities, but also expansion of farmlands and illegal logging activities in these traditional forest areas, as confirmed in Ghana Statistical Service (2014).

6.4. How can community-based mined land rehabilitation projects work?

Section 6.2.4 of our findings confirmed how informal permitting arrangements, just as direct radical state attempts at controlling resulting illegal mining operations, impact mine-land use and restoration outcomes, manifesting in the many scattered degraded and abandoned rural community mined-lands. Managing the significantly high direct costs, confirmed by Mantey et al. (2016), of reclaiming degraded and abandoned lands, calls for precautionary strategies to be enforced, particularly by community level stakeholders like traditional authorities, unit committees, assembly men, community members, and landowners, who could more effectively deal with miners on the ground. These strategies could consider:

1. Reviewing local land ownership laws to be more specific and clearer, with strict sanctions that hold landowners and community members accountable for lands customarily entrusted to them. Enforcing these laws should compel landowners to proactively secure management arrangements with prospective miners, which promote more sustained productive land uses while ensuring environmental stewardship.

2. Tasking miners to post some form of reclamation bond deposits at the community level, which should serve as collateral payment, indicating their commitment to rehabilitate lands after their operations. As is common with large-scale mines (see Adu-Baffour et al. 2021), these collateral payments can be returned to the miner after mine-operated lands have been transferred back to the landowner in their desired states.

3. Increasing sensitization and education programs within active mining communities on responsibilities of a miner, when it comes to community land use, before, during and after ore extraction, as well as the impacts illegal ASM actions and inactions have on community health, welfare, and environment.

4. Forming and working with active local organizations, like community-based organizations, civil society organizations, and farmer-based organizations. Such organized groups could support

weaker individual community members and landowners to identify and exercise their ownership rights, mobilize resources, and negotiate better benefits over their lands. They could also serve as an organized link to authorities at the local district and community governance levels, with the aim of ensuring sustained and rewarding community land management by miners.

Remediating and revegetating reclaimed lands are key follow-up processes in completing rehabilitation projects. The full impacts of these practices, which have been shown to include soil health enrichment, improvement, and decontamination, are realized only after years of proper application. The following strategies could be considered to encourage adoption of these practices:

1. Promoting experiential learning platforms, like Tropenbos Ghana's demonstration fields, where local communities are also involved in the processes of reclaiming, remediating (a concept which mostly sounded foreign to local community research participants), and revegetating degraded and contaminated mined lands and observing their transformative potential over time. The sustained success of such initiatives will, however, require combined active support from stakeholders from within the public, private and third sectors, including those relevant at the local community level.

2. Developing and promoting sustainable phytoremediation methods – using economically rewarding species, with potential for wood products, aromatic essential oils, biochar, energy or biodiesel, biofortification, ornamental purposes, phytomining purposes etc., as recommended by Pandey and Souza-Alonso (2018). Despite still being in its development stages, sustainable phytoremediation is seen as affordable in economic terms and particularly relevant for developing countries (Pandey & Bajpai, 2018).

These above-mentioned strategies, in combination, could be necessary steps to preventing irresponsible handling and abandonment of degraded community lands by miners while promoting the rare practice of contaminated land remediation which are key factors of sustainable land restoration. In situations where community lands have already been degraded and abandoned by miners and landowners, research findings revealed conditions under which community members could contribute willingly to restoration efforts. The use of communal labor was identified as their most preferred way of contributing towards restoring such lands. Community members were, however, only willing to contribute communal labor to restore lands if their ownership status was changed to community property, where post-restoration benefits could be used to support community-welfare projects that can be enjoyed by the entire community rather than just a few (see section 6.2.4). On such abandoned lands, support with land reclamation and technical services will still be needed from relevant stakeholders like local district assemblies, private sector and NGOs.

These views are in line with principles of Mentis (2020) who argues that the need for rehabilitation hangs more so on value judgement, as it does on cost-benefit, science and technology, to sustain natural capital for present and future generations. The success of rehabilitation activities, as emphasized by Chirwa and Mahamane (2017), depend on community-based natural resource management approaches with enabling policies in place to provide clear land tenure arrangements, full participation of communities and equitable benefit sharing. This case study reveals how social networks, together with social and cultural norms, rules and practices can influence sustainable community-based land restoration efforts.

References

Abhilash, P. C. (2021). Restoring the unrestored: Strategies for restoring global land during the un decade on ecosystem restoration (un-der). Land, 10(2), 1–17. https://doi.org/10.3390/land10020201

Adu-Baffour, F., Daum, T., & Birner, R. (2021). Governance challenges of small-scale gold mining in Ghana: Insights from a process net-map study. Land Use Policy, 102. https://doi.org/10.1016/j.landusepol.2020.105271

Aguilar, F. X., Obeng, E. A., & Cai, Z. (2018). Water quality improvements elicit consistent willingness-to-pay for the enhancement of forested watershed ecosystem services. Ecosystem Services, 30, 158–171. https://doi.org/10.1016/j.ecoser.2018.02.012

Ahirwal, J., Maiti, S. K., & Singh, A. K. (2016). Ecological Restoration of Coal Mine-Degraded Lands in Dry Tropical Climate: What Has Been Done and What Needs to Be Done? Environmental Quality Management, 26(1), 25–36. https://doi.org/10.1002/tqem.21481

Ahirwal, J., & Pandey, V. C. (2020). Restoration of mine degraded land for sustainable environmental development. 29(4), 2–5. https://doi.org/10.1111/rec.13268

Akpalu, W., & Normanyo, A. K. (2017). Gold Mining Pollution and the Cost of Private Healthcare: The Case of Ghana. Ecological Economics, 142, 104–112. https://doi.org/10.1016/j.ecolecon.2017.06.025

Awuah, A. O. (2021). Presence of heavy metals in the agricultural and forest landscape of some mining plagued districts in the Ashanti and Eastern region of Ghana. Kwame Nkrumah University of Science and Technology.

Bansah, K. J., Dumakor-Dupey, N. K., Kansake, B. A., Assan, E., & Bekui, P. (2018). Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. Journal of Cleaner Production, 202, 465–475. https://doi.org/10.1016/j.jclepro.2018.08.150

Bitsch, V. (2005). Qualitative Research : A Grounded Theory Example and Evaluation Criteria. American Journal of Agricultural Economics, 1(Spring), 75–91.

Börger, T., Hattam, C., Burdon, D., Atkins, J. P., & Austen, M. C. (2014). Valuing conservation benefits of an offshore marine protected area. Ecological Economics, 108, 229–241. https://doi.org/10.1016/j.ecolecon.2014.10.006

Bradshaw, A. (1997). Restoration of mined lands - using natural processes. Ecological Engineering, 8, 255–269. https://doi.org/10.1023/a:1005177815154

Cao, X. (2007). Regulating mine land reclamation in developing countries: The case of China. Land Use Policy, 24(2), 472–483. https://doi.org/10.1016/j.landusepol.2006.07.002

Carson, R. T., & Louviere, J. J. (2011). A Common Nomenclature for Stated Preference Elicitation Approaches. Environmental and Resource Economics, 49(4), 539–559. https://doi.org/10.1007/s10640-010-9450-x

Chaikaew, P., Hodges, A. W., & Grunwald, S. (2017). Estimating the value of ecosystem services in a mixed-use watershed: A choice experiment approach. Ecosystem Services, 23(November 2016), 228–237. https://doi.org/10.1016/j.ecoser.2016.12.015

Chirwa, P. W., & Mahamane, L. (2017). Overview of restoration and management practices in the degraded landscapes of the Sahelian and dryland forests and woodlands of East and southern Africa§. Southern Forests, 79(2), 87–94. https://doi.org/10.2989/20702620.2016.1255419

Datta, D., Chattopadhyay, R. N., & Guha, P. (2012). Community based mangrove management: A review on status and sustainability. Journal of Environmental Management, 107, 84–95. https://doi.org/10.1016/J.JENVMAN.2012.04.013

Deininger, K., Ali, D. A., Holden, S., & Zevenbergen, J. (2008). Rural Land Certification in Ethiopia: Process, Initial Impact, and Implications for Other African Countries. World Development, 36(10), 1786–1812. https://doi.org/10.1016/j.worlddev.2007.09.012

Ent, A. Van Der, & Baker, A. J. M. (2013). Hyperaccumulators of metal and metalloid trace elements : Facts and fiction. 319–334. https://doi.org/10.1007/s11104-012-1287-3

Ferring, D., Hausermann, H., & Effah, E. (2016). Site specific: Heterogeneity of small-scale gold mining in ghana. Extractive Industries and Society, 3(1), 171–184. https://doi.org/10.1016/j.exis.2015.11.014

Festin, E. S., Tigabu, M., Chileshe, M. N., Syampungani, S., & Odén, P. C. (2019). Progresses in restoration of post-mining landscape in Africa. Journal of Forestry Research, 30(2), 381–396. https://doi.org/10.1007/s11676-018-0621-x

Ghana Statistical Service. (2014). 2010 POPULATION AND HOUSING CENSUS. DISTRICT ANALYTICAL REPORT. AMANSIE WEST DISTRICT. Accra.

Hensher A., D., Rose M., J., & Greene H., W. (2005). Applied Choice Analysis: A Primer. Retrieved from https://books.google.de/books?hl=en&lr=&id=8yZrtCCABAgC&oi=fnd&pg=PR13&dq=hensher+applied+choice+analysis&ots=RGMP7Wncu5&sig=kM0vIL63h_IHGS8vDCZYbmhDnTQ#v=onepage&q&f=false

Hilson, G. M. (2002). The future of small-scale mining: Environmental and socioeconomic perspectives. Futures, 34(9–10), 863–872. https://doi.org/10.1016/S0016-3287(02)00044-7

Hole, A. R. (2007). Fitting mixed logit models by using maximum simulated likelihood. Stata Journal, 7(3), 388–401. https://doi.org/10.1177/1536867x0700700306

Hole, A. R. (2013). Mixed logit modelling in Stata - An overview (pp. 1–43). pp. 1–43. Sheffield.

Hu, W., Woods, T., & Bastin, S. (2009). Consumer Acceptance and Willingness to Pay for Blueberry Products with Nonconventional Attributes. Journal of Agricultural and Applied Economics, 41(1), 47–60. https://doi.org/10.1017/s1074070800002546

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF). (2018). GLOBAL TRENDS IN ARTISANAL AND SMALL-SCALE MINING (ASM): A REVIEW OF KEY NUMBERS AND ISSUES. Retrieved from http://pubs.iied.org/pdfs/G04266.pdf

Jennifer, G. (2013). Analyzing the Social Web (E. Steve, Ed.). Retrieved from https://books.google.de/books?hl=en&lr=&id=XP8jc2cDNrwC&oi=fnd&pg=PP1&dq=Analyzing+the+Social+Web&ots=eiUfZ-pT7W&sig=d-35iM9keJUzQM_NI3hoOfZTqaE&redir_esc=y#v=onepage&q=Analyzing the Social Web&f=false

Kuhfeld, W. F. (2005). Methods in SAS. Techniques.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated Choice Methods: Analysis and Applications. Retrieved from http://www.amazon.com/Stated-Choice-Methods-Analysis-Applications/dp/0521782759

Mansuri, G., & Rao, V. (2004). Community-based and-driven development: A critical review. The World Bank Research Observer, 19(1), 1–77. https://doi.org/10.1093/wbro/lkh012

Mantey, J, Nyarko, K. B., Owusu-nimo, F., Awua, K. A., Bempah, C. K., Amankwah, R. K., … Appiah-effah, E. (2020). Mercury contamination of soil and water media from different illegal artisanal small-scale gold mining operations (galamsey). Heliyon, 6(June), e04312. https://doi.org/10.1016/j.heliyon.2020.e04312

Mantey, Jones, Nyarko, K., & Owusu-Nimo, F. (2016). Costed reclamation and decommissioning strategy for galamsey operations in 11 selected MDAs of the Western region , Ghana.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In Frontiers in Economics (pp. 105–142). New: Academic Press.

McIntyre, T. C. (2003). Databases and Protocol for Plant and Microorganism Selection: Hydrocarbons and Metals. In S. C. McCutcheon & J. L. Schnoor (Eds.), Phytoremediation: Transformation and Control of Contaminants (Vol. 1). New York: Wiley.

Mcquilken, J., & Hilson, G. (2016). Artisanal and mining in Ghana Evidence to inform an 'action dialogue.'

Mentis, M. (2020). Environmental rehabilitation of damaged land. Forest Ecosystems, 7(1). https://doi.org/10.1186/s40663-020-00233-4

Nyarko Otoo, K. (2018). MINIMUM WAGE FIXING IN GHANA. Accra: Friedrich-Ebert-Stiftung Ghana.

Obeng, E. A., Dakurah, I., Oduro, K. A., & Obiri, B. D. (2021). Local communities' preferences and economic values for ecosystem services from Mole National Park in Ghana: A choice experiment approach. Global Ecology and Conservation, 32(November), e01904. https://doi.org/10.1016/j.gecco.2021.e01904

Owusu, R., Kimengsi, J. N., & Moyo, F. (2021). Community-based Forest Landscape Restoration (FLR): Determinants and policy implications in Tanzania. Land Use Policy, 109(November 2020), 105664. https://doi.org/10.1016/j.landusepol.2021.105664

Pandey, V. C., & Bajpai, O. (2018). Phytoremediation: From Theory Toward Practice. In Phytomanagement of Polluted Sites: Market Opportunities in Sustainable Phytoremediation. https://doi.org/10.1016/B978-0-12-813912-7.00001-6

Pandey, V. C., & Souza-Alonso, P. (2018). Market Opportunities: In Sustainable Phytoremediation. In Phytomanagement of Polluted Sites: Market Opportunities in Sustainable Phytoremediation. https://doi.org/10.1016/B978-0-12-813912-7.00002-8

Raabe, K., Sekher, M., Schiffer, E., Birner, R., & Shilpi, A. (2010). How to Overcome the Governance Challenges of Implementing NREGA Insights from Bihar Using Process-Influence Mapping. IFPRI Discussion Paper, 00963(April).

Saier, M. H., & Trevors, J. T. (2010). Phytoremediation. Water, Air, and Soil Pollution, 205(SUPPL.1), 2008–2010. https://doi.org/10.1007/s11270-008-9673-4

Salati, L. K., Mireku-Gyimah, D., & Eshun, P. A. (2016). Proposed mining and processing methods for effective management of Artisanal and Small-scale gold mining in Nigeria. International Journal of Scientific & Engineering Research, 7(12), 951–970.

Schiffer, E. (2007). Manual - Net-Map toolbox. Influence Mapping of Social Networks (pp. 1–6). pp. 1–6. IFPRI.

Shackleton, S., Campbell, B., Wollenberg, E., & Edmunds, D. (2002). Devolution and Community-Based Natural Resource Management: Creating Space for Local People to Participate and Benefit? Natural Resource Perspectives, 76(76), 1–6.

Sharma, P., & Pandey, S. (2014). Status of Phytoremediation in World Scenario. International Journal of Environmental Bioremediation & Biodegradation, 2(4), 178–191. https://doi.org/10.12691/ijebb-2-4-5

Singh, S. N., & Tripathi, R. D. (2007). Environmental Bioremediation Technologies (S. Singh & R. Tripathi, Eds.). Berlin Heidelberg: Springer.

Tetteh, E. N., Logah, V., Twum-Ampofo, K., & Partey, S. T. (2015). Effect of duration of reclamation on soil quality indicators of a surface – Mined acid forest Oxisol in South – Western Ghana. West African Journal of Applied Ecology, 23(2), 63–72.

Tibbett, M. (2010). Large-scale mine site restoration of Australian eucalypt forests after bauxite mining: soil management and ecosystem development. In L. C. Batty & K. B. Hallberg (Eds.), Ecology of Industrial Pollution. Retrieved from https://books.google.de/books?hl=en&lr=&id=t4yauYHrCRoC&oi=fnd&pg=PA309-IA8&dq=large+scale+mining+land+restoration&ots=DyuyLIg8M3&sig=pTFTwcHuWi0m5T1Ss-1WYwS4_Bk&redir_esc=y#v=onepage&q=large scale mining land restoration&f=false

Tischew, S., & Kirmer, A. (2007). Implementation of basic studies in the ecological restoration of surface-mined land. Restoration Ecology, 15(2), 321–325. https://doi.org/10.1111/j.1526-100X.2007.00217.x

Veisten, K. (2007). Willingness to pay for eco-labelled wood furniture: Choice-based conjoint analysis versus open-ended contingent valuation. Journal of Forest Economics, 13(1), 29–48. https://doi.org/10.1016/j.jfe.2006.10.002

Velásquez Ramírez, M. G., Vega Ruiz, C. M., Gomringer, R. C., Pillaca, M., Thomas, E., Stewart, P. M., … Torres, D. del C. (2021). Mercury in soils impacted by alluvial gold mining in the Peruvian Amazon. Journal of Environmental Management, 288(March). https://doi.org/10.1016/j.jenvman.2021.112364

Worlanyo, A. S., & Jiangfeng, L. (2021). Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. Journal of Environmental Management, 279, 111623. https://doi.org/10.1016/J.JENVMAN.2020.111623

World Bank. (2019). 2019 State of the Artisanal and Small-Scale Mining Sector. 85. Retrieved from https://www.pactworld.org/download/4210/nojs/Delve-2019-State-of-the-Artisanal-and-Small-Scale-Mining-Sector.pdf

World Bank. (2020). Ghana Country Environmental Analysis.

World Bank, & IFPRI. (2010). Gender and Governance in Rural Services. https://doi.org/10.1596/978-0-8213-7658-4

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