



## Research article

# Impact of illegal mining activities on forest ecosystem services: local communities' attitudes and willingness to participate in restoration activities in Ghana



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## ABSTRACT

Understanding local communities' willingness to participate in environmental restoration activities can help assess the level of volunteerism that can be expected for restoration projects. This study ascertained local communities' perception of the importance of non-market ecosystem services, the impact of illegal mining on ecosystem services, and their likeliness to participate in restoration of degraded lands resulting from illegal mining. Fifty respondents each were purposefully selected from three mining communities (Ntakam, Asawinso No.1 and Nkatie) in a survey. Analysis of variance (ANOVA) tests results indicated there were no difference in views of respondents regarding the importance of forest for various non-market services. Illegal mining activities were identified as the cause of environmental problems such as water pollution, deforestation, poor soil fertility and limited access to land for agriculture productivity. Majority of respondents across the three communities indicated that forest is very important for non-market environmental services. Logistic regression results indicated that factors that affect likeliness to participate in restoration financing included income, embracing non-market ecosystem services as important, confidence in PES schemes and positive value motivation for restoration (altruistic, use and bequest values).

## 1. Introduction

Tropical forest ecosystems around the world are being wiped-out at a rate of 25 million acres per year (Bagyina, 2012). While agricultural activities and wood extraction are identified as major drivers of deforestation and forest degradation in terms of spatial coverage (Hosonuma et al., 2012), degradation caused by mining tend to have long-term adverse effects on flora and fauna (Cristescu et al., 2012). This is often due to the dumping of toxic chemicals and the severe mutilation of the earth's crust (Lei et al., 2016), the combined effects of which inhibit vegetation growth for a long time.

Alvarez-Berrios and Aide (2015) identified mining as an activity that causes significant change to the environment but often ignored in deforestation analysis, because it mostly covers small areas compared to agriculture or wood extraction activities. The rise in demand and prices of gold in the last two decades triggered a wave of intense mining

activities across the world (World Gold Council, 2012). Many of these mining activities were and are still being carried out by small-scale including illegal miners (Creek, 2009; Alvarez-Berrios & Aide, 2015), particularly in developing countries where regulatory capacities and institutions are weak.

The small-scale mining sector in Ghana is an important contributor to job creation for people in rural communities due to lack of sufficient-paying alternative jobs (Hilson and Banchirigah, 2009; Amponsah-Tawiah and Dartey-Baah, 2011). About 85% of the estimated one million people who are directly or indirectly employed in the small-scale mining sector are identified as illegal because they operate without license (Akabzaa and Darimani, 2001; Akabzaa et al., 2007; Ofosu-Mensah, 2010); a phenomenon popularly referred to as 'galamsey' in Ghana. The havoc caused by galamsey activities includes the destruction of forest cover and soils through introduction of toxic waste into soil and water bodies that often lead to health problems (Opoku-Ware, 2010).

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Restoration of mined areas is a necessary process after mining, to ensure that disturbed lands are returned to environmental conditions suitable for recommencement of the former use or for a new use (Tetteh, 2010). Fundamentally, the aim of restoring mined sites is to re-establish vegetal cover, stabilize the soil and water conditions and bring back ecosystem goods and services (Queensland DEHP, 2012; Aseidu, 2013).

The Minerals and Mining Act 2006, (Act 703) of Ghana requires all licensed operators to secure environmental impact assessment (EIA) which specifies the environmental safety for any intended mining projects in Ghana. The EIA should be accompanied by land reclamation plan which must indicate among others, how topsoil will be preserved, slopes will be stabilized and restored, progressive reclamation will be carried out, and how revegetation will be effected (Aseidu, 2013). Despite the existence of these legal items for protecting the environment, illegal mining and non-compliance remain the cause of mining-related environmental degradation in Ghana.

Even though the extent of environmental degradation caused by mining in Ghana is well documented (e.g. Aryee et al., 2003; Armah et al., 2011; Armah et al., 2013; McDonald et al., 2014; Mensah et al., 2015), little research has gone into ways by which the situation could be remedied. Studies that looked at solutions to mining-imposed environmental problems actually centered on the treatment of chemical-laden effluent usually discharged by mining companies (e.g. Babut et al., 2003; Armah and Gyeabour, 2013). For instance, Aseidu (2013) looked at reclamation of small-scale surface-mined lands in Ghana focusing on the restoration process, methods and costs. The study seeks to broaden the horizon of knowledge on the subject matter by looking at how local communities will accept the challenge and responsibility of maintaining degraded landscapes as defacto owners and prime beneficiaries of natural resources within the landscapes. To this end, the study will bring a better understanding to mining communities' perceptions and attitudes toward the impact of galamsey activities on forest ecosystem services and their willingness to participate in restoration programs that seek to improve ecosystem services to sustain rural livelihoods. The study therefore aims at contributing to how mining-imposed environmental degradation can be remedied using community-based approach. The feasibility (likely participation) of the concept of payment for ecosystem services (PES), a market-based compensatory program aimed at reducing the market imperfection brought by positive externalities associated with non-market ecosystem services (Engel et al., 2008; Obeng et al., 2018) is explored. PES programs encourage participation by providing monetary compensation to owners or managers for behaviors that protect and can enhance the flow and quality of non-market ES and ultimately well-being (Leimona et al., 2015; Wunder, 2015; Obeng et al., 2018). Specifically, the study assessed the level of importance that mining communities place on forest ecosystem services and determined the perception and attitudes towards the impact of galamsey activities on forest ecosystem services at the community level. It further assessed the factors influencing communities' willingness to participate in restoration activities for improved ecosystem services within a PES framework.

We premised that people who are motivated by personal values to cherish the natural environment (hypothesis 1) and those who attach much importance to non-market ecosystem services (hypothesis 2), would likely subscribe to a PES scheme for restoration of degraded lands. Also, we expected people involved in illegal mining activities to show less likeliness to subscribe to a PES scheme for restoration of degraded lands (hypothesis 3) and demographic factors (age, gender, family size, education, residential status, income level) to have no effect on likeliness to subscribe to a degraded-land restoration PES scheme (hypothesis 4).

## 2. Materials and methods

### 2.1. Description of study area

The study was conducted in three communities, Nkatieso, Ntakam

and Asawinso No.1 in the Bibiani Forest District (BFD) of the Western North Region of Ghana (Fig. 1). The BFD is located at approximately 6°27' latitude north and 2°17' longitude west and falls within the Equatorial Rain Forest Zone. The natural vegetation is moist-deciduous and serves as a habitat for important economic tree species such as *Milicia excelsa* and *Khaya anthotheca* (GSS, 2017). Two of the study communities, Ntakam and Nkatieso are with populations of about 300 inhabitants each, while Asawinso No.1 is relatively larger with population of about 500 inhabitants. Inhabitants are largely farmers and depend on the forest ecosystem for agricultural activities to support their livelihoods. Nearly 70% of the residents' livelihood depends on agriculture as either labourers or cultivators; many depend on hunting for non-timber forest products (NTFPs) (game, snails, collection of honey, firewood, fruits and seeds) as a livelihood activity (GSS, 2017). Gold mining is another predominant livelihood activity in the district (GSS, 2017).

### 2.2. Sampling procedures and data collection

The three communities, Nkatieso, Ntakam and Asawinso No.1 (Fig. 1) were purposively selected for the study based on the relative extent to which illegal mining activities had been carried out. By observation, the three communities were noted as the most vibrant places where illegal mining activities were taking place in the entire district. In each of the three communities, 50 farmers were selected using the snowballing sampling technique for a total sample size of 150 respondents. This method was used because some categories of the target respondents such as illegal miners, landowners, farmers, hunters of NTFPs as well as other community members who play different roles along the galamsey value chain, could not be easily identified with random sampling.

Two rapid rural appraisal techniques were used for data collection. A focus group discussion (FGD) was held with traditional authority leaders, forest guards, youth groups and different stakeholders from the three studied communities. Following the FGD, face-to-face interviews were conducted using a three-part semi-structured questionnaire. The first part of the semi-structured questionnaire captured information relevant to the perception and level of importance that mining communities place on forest ecosystem services. The second part comprised of a scale of questions for: i) assessing attitudes towards the impact of galamsey activities on forest ecosystem services at the community level, and ii) assessing willingness to participate in restoration activities for improved ecosystem services within the context of an incentive mechanism such as PES. The final section captured the socio-demographic information of respondents. Based on the MEA (2005) categorization of ecosystem services (provisioning, supporting, cultural and regulation), a list of market and non-market ecosystem services were provided for respondents to express their level of importance as well as their perception on the impact of galamsey activities on these services. For provisioning forest ecosystem services, the questions mainly focused on non-timber forest products (NTFP), while the scope of the non-market ecosystem services captured questions on supporting, regulating and cultural services. Attitudes and impact ratings were mainly elicited using five-point agreement and three-point impact Likert scales respectively.

The questionnaire administration was held in all three communities in June 2018 after pre-testing in May 2018. Pre-testing provided useful feedback information which was used to improve the questionnaire design, understanding and simplicity. The survey interviews were conducted using the commonly spoken local dialect in Ghana (Twi) after informed consent to participate in the study was obtained from study respondents. Traditional community entry processes were also followed by seeking and obtaining approval of leaders (chiefs) of all three communities for the surveys to be conducted. The ethics of the study protocol was approved by CSIR-Forestry Research Institute of Ghana (CSIR-FORIG).

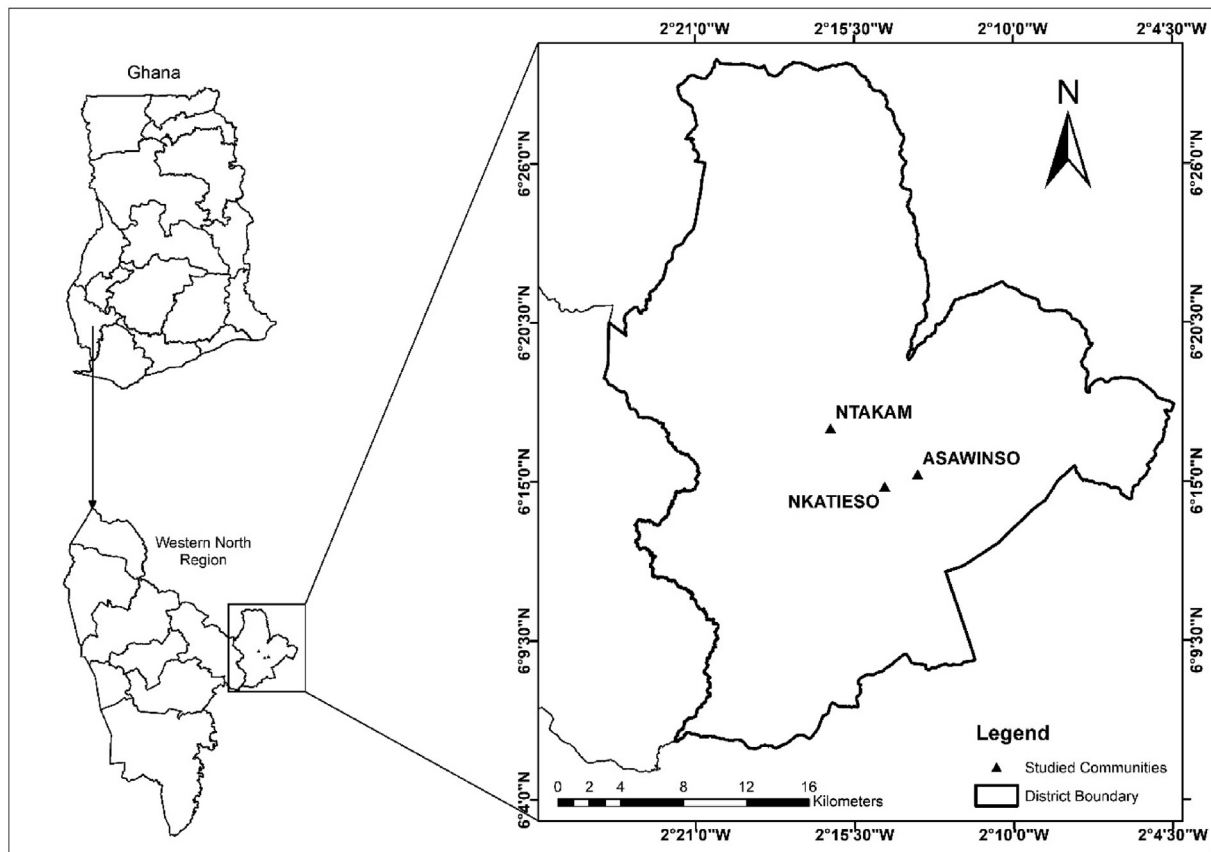


Fig. 1. Map of Ghana showing the study district and selected communities.

2.3. Analytical approach and model specification

Data analysis followed a two-step approach and was done using the Stata software version 13. The first approach covered descriptive summary statistics performed for the different parameters investigated under this study. Analysis of variance (ANOVA) was used to test for underlying differences in responses. The second approach comprised of logistic regression to understand the likelihood of participation and the underlying factors that would influence an individual's likeliness to participate in restoration activities. Test for multi-collinearity among the different variables used in the logistic regression was run. Interpretation of the influence of explanatory variables on the dependent variables was based on odds.

The decision to participate in the restoration activities within the context of a PES scheme to prevent landowners from giving their lands for galamsey activities was modeled as a binary logistic function in Eq. (1).

$$Prob\text{ Restoration}_{PES}(0,1) = f(\text{socioeconomic factors, environmental attitudes, confidence in PES, values motivations}) \tag{1}$$

Eq. (1) can be expanded in Eq. (2) below:

$$Y(Prob\text{ Restoration}_{PES})(0,1) = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \dots + \beta_nX_n \tag{2}$$

And assuming the probability that an individual will likely participate in the restoration program (0,1) follows a linear function of predictors with a logistic link and random error ( $\alpha$ ), the coefficients  $\beta$  for predictors for each explanatory variable ( $X_1 \dots X_n$ ) can be estimated by maximum likelihood. Table 1 provides the definitions, descriptions and coding of all the variables used in the model.

3. Results

3.1. Demographic profile of respondents

The survey included information on gender, age, marital status, occupation, education, family size and monthly income. Out of 150 respondents, 28% were females and 72% males. The overall mean age of respondents across the study sites was 42 years with a standard deviation of 12.9 years and a range of 18–86 years. More than half of respondents (52.3%) were in youthful and active working age of between 18 and 40 years. Table 2 gives details of the demographic profile of respondents. The mean household size of Nkatieso was 6.4 with a minimum of 1 and a maximum of 17 members. There was no statistically significant difference ( $p\text{-value} = 0.29$ ) in the household size for the three communities. As high as 90% of respondents have had some level of formal education but only 14.5% and 5.1% reached secondary and tertiary education levels respectively. The average gross monthly income of respondents in the three study communities was GHS 864.88 with a standard deviation of GHS966.13 and a minimum and maximum income of GHS50.00 and GHS7,000.00 respectively.

3.2. Household participation in galamsey activities

Household members' involvement in galamsey activities is presented in Fig. 2. The results suggest that about 20.7% of respondents interviewed indicated they were directly involved in galamsey activities in their localities while majority (79.3%) reported they were not involved. However, more than half of the respondents (58.3%) had 1 to 3 members of their household involved in the galamsey activities (Fig. 2).

**Table 1**  
Definition of variables and descriptive summaries for the dependent and explanatory variables (N = 80 observations).

Variable Code	Variable Description	Mean	min	max	Stand. dev.
<b>Dependent Variable</b>					
Restoration_PES (Y)	Likelihood expressed as a binary variable: 1 = Yes, I am likely to subscribe to a PES scheme to pay land owners to prevent them from giving their lands for galamsey activities. 0 = if otherwise	0.51	0	1	0.50
<b>Explanatory Variables</b>					
Gender (X1)	Gender of respondent: 0 = male, 1 = female	0.28	0	1	0.45
Age (X2)	Age of respondents: 0 = >45 years 1 = between 18 to 45 years	0.67	0	1	0.47
Family_Size (X3)	Number of people in the family (binary): 0 = household size more than 6 1 = household size up to 6	0.53	0	1	0.50
HhIncome (X4)	Monthly household income (continuous) in GHC	785.60	50	7000	916.32
Residence_Status (X5)	Respondent residential status in the community: 0 = Settler 1 = Native of town	0.75	0	1	0.43
Education (X6)	Respondents education (binary): 0 = No formal education 1 = Formal education (primary school and beyond)	0.21	0	1	0.41
Involved (X7)	Involvement of respondents as an actor along the value chain: 0 = if respondent is not involved as an actor along the value chain 1 = if respondent is not involved as an actor along the value chain	0.25	0	1	0.44
Ecosys_Importance (X7)	Level of importance respondents attaches to non-market forest ecosystem services (Aggregated responses to 7 ecosystem services <sup>††</sup> ): 1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = Very important, 5 = Extremely important	4.30	1	5	0.62
Valuemotive (X7)	Respondents level of agreement to statements reflecting value motivation for participating in restoration activities on degraded mined sites for ecosystem benefits (Aggregated responses for three statements reflecting value motivation for willingness to pay for restoration activities <sup>†††</sup> ): 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree	4.31	1	5	1.13
PES_Confidence (X8)	Attitude towards PES (extent of agreement on desirability of paying landowners to protect and manage forests for ecosystem services) Binary: 0 = strongly disagree, disagree or neither agree or disagree 1 = Agree or strongly agree	0.61	0	1	0.49

<sup>††</sup> Environmental attitudinal statements used for the variable *Ecosys\_Importance*: forest help control disasters, e.g. flooding; enhances clean air and regulate temperature; provides habitat for diversity of plants and animal species; protect rives and streams from drying up; recreational purpose; landscape aesthetics; research and educational purposes; cultural and spiritual significance.

<sup>†††</sup> Attitudinal statements used for the variable *Valuemotive*: "I am willing to pay to restore the degraded galamsey sites, whether I currently benefit from it or not (altruistic values)", "I am willing to pay to restore the degraded galamsey sites, for my personal current and future use (use values)" and "I am willing to pay to restore the degraded galamsey sites for the benefits of future generation (non-use - bequest values)".

### 3.3. Level of importance attached to non-market forest ecosystem services

Fig. 3 presents findings on the level of importance attached to non-market forest ecosystem services in the study area. Nine non-market ecosystem services classified into cultural, regulating and habitat services based on ecosystem service classification (Hein et al., 2006; CICES, 2011; TEEB, 2010) were each rated on a 5-point Likert scale. The overall mean rating of attitudes toward the importance of forest in providing selected non-market ecosystem services on the 5-point Likert scale provides a clearer picture about the perceived importance associated with cultural, regulating and habitat services among the sampled population. All nine non-market ecosystem services except 'cultural and spiritual significance' recorded mean importance levels of greater than four, meaning that almost all the non-market ecosystem services were perceived to be 'very important' among respondents. 'Cultural and spiritual significance' of forest which recorded the least mean importance of 3.97 is still a positive perception but only trails behind the other eight services (Fig. 3).

Independent between groups (communities) ANOVA indicated there was no statistical significant difference between responses from the three communities for all nine services except 'landscape aesthetics' (*landscape aesthetics*,  $p$ -value = 0.016; 'help control disaster',  $p$ -value = 0.719; 'protect rivers and streams',  $p$ -value = 0.946; 'enhances clean air and regulate temperature',  $p$ -value = 0.906; 'provides habitat for plants and animals',  $p$ -value = 0.874; 'for research and education purposes',  $p$ -value = 0.247; 'cultural and spiritual significance',  $p$ -value = 0.487).

### 3.4. Perception and attitudes towards the impact of galamsey on forest ecosystem services and agricultural productivity

To understand differences in perception and attitudes towards the impact of galamsey activities on forest ecosystem services, respondents were asked to state their opinions on the degree of impact on a 3-point Likert scale (1 = low impact; 2 = moderate impact; 3 = high impact). The means recorded for perceived impact of galamsey on all forest resources and services considered (Fig. 4), were between 2 and 3, indicating moderate to high impact. 'Flooding leading to destruction of farms' was ranked the highest impact of galamsey by respondents in all three communities (Nkatieso 2.67(SD = 0.90); Ntakam, 2.49 (SD = 0.91); Asawinso No.1, 2.66 (SD = 0.98))The impact of galamsey on 'water availability' was perceived as the least with mean scores of 2.37 (SD = 0.86) for Nkatieso, 2.20 (SD = 0.79) Ntakam and 2.00 (SD = 0.92)Asawinso No.1 for, and (Fig. 4). Table 2 gives details of the responses to impact of galamsey on forest resources and ecosystem services.

### 3.5. Impact of galamsey activities on provisioning ecosystem services (non-timber forest products (NTFPs))

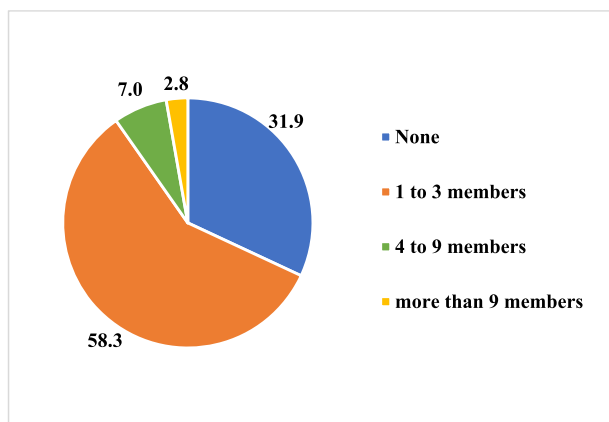
Respondents reiterated the impact of galamsey on a number of NTFPs that support rural livelihoods in their communities. Majority of respondents alluded to the abundance of several NTFPs prior to galamsey activities in their communities (Table 3). For instance, almost all



**Table 2**  
Communities' perception of impact of gamamsey activities on resources and ecosystem services.

Ecosystem services/land issues	Communities									P-value
	Ntakam			Asawinso 1			Nkatieso			
	1	2	3	1	2	3	1	2	3	
Water availability	33.33	14.58	52.08	46.94	6.12	46.94	27.78	7.41	64.81	0.162
Water quality	25	4.17	70.83	29.17	2.08	68.75	27.78	5.56	66.67	0.911
Land availability for farming	20.83	22.92	56.25	24.49	10.2	65.31	20.75	13.21	66.04	0.483
Land accessibility	20.83	22.92	56.25	20.83	14.58	64.58	26.42	13.21	60.38	0.67
Land productivity (fertility)	21.28	17.02	61.7	30.61	12.24	57.14	23.4	14.89	61.7	0.844
Flooding leading to destruction of farms	14.89	21.28	63.83	6.38	21.28	72.34	6.52	19.57	73.91	0.586

Scale of assessment: 3-point Likert scale (1 = low impact; 2 = moderate impact 3 = high impact).



**Fig. 2.** Percentage distribution of respondents' household members involved in gamamsey activities.

respondents (93%) indicated snails, a delicacy in Ghanaian cuisines, were highly abundant prior to gamamsey activities in the area. However, less than 1% rated snails as highly abundant prior to the ban on gamamsey (current status). More than half (56%) of the respondents rated the current status of snail availability in the community as totally scarce. This trend can be described for almost all the NTFPs assessed; namely, mushrooms, chew-sticks, pestles, poles, herbs and medicines (Table 3)

### 3.6. Willingness to participate in restoration activities of degraded mined sites for improved ecosystem services

#### 3.6.1. Level of concern of gamamsey impacts and likeliness to participate in restoration activities

Due to the impact of gamamsey at the various communities, the study attempted to investigate how likely respondents would be willing to participate in restoration activities for improved ecosystem services. Respondents were asked on whether there are presently environmental challenges which require remedy, the level of concern of these challenges and the importance of halting gamamsey and restoring the degraded mined sites. Nearly all respondents admitted that there is presently an environmental challenge which requires remedy. Table 4 shows an overview of the percentage distribution of respondents' rating of their level of concern. It is noticeable majority of respondents were extremely concerned about the impact of gamamsey activities on ecosystem services, in particular quality and availability of water resources in the communities. Approximately, 85% and 77% were extremely concerned about the quality of water resources and the drying up of streams and rivers respectively. More than half of the respondents interviewed were similarly extremely concerned about declined soil fertility, recurring flooding, erosion and open pits on farm lands and degraded landscape aesthetics. Fig. 5 further shows the mean rating of the level of concern of the impact of gamamsey on environmental resources among respondents and reflects the most concerned resources or ecosystem services

impacted by gamamsey activities.

To halt gamamsey activities at the various communities, peoples' willingness to participate is vital. Therefore, we ascertained likeliness of respondents to participate in incentive-based conservation program that seeks to restore degraded mined sites in their respective communities for improved ecosystem services as well as addressing the environmental challenges confronting them. Participation was articulated within the context of a PES mechanism using two separate approaches. First respondents were asked to indicate their likeliness in willingness to subscribe to a local conservation scheme that offer incentive to landowners to protect forest from degradation by adhering to sustainable on-farm forest management practices if they were landowners. The second approach further asked respondents to state their likeliness to be willing to participate in a restoration scheme that would require committing financial resources and or in-kind services to (i) prevent landowners from giving out their land for gamamsey activities through an incentive mechanism such as PES and (ii) to purposely commit to a watershed restoration management that seeks to enhance the water qualities of destroyed water bodies that the communities depend on.

The results suggest more than half of respondents (62.3%) are extremely likely or very likely to subscribe to an incentive mechanism such as PES to protect forest as landowners based on the impact of gamamsey activities on ecosystem services. Approximately 27% responded "not very likely" to "not at all likely" to the question on willingness to subscribe to a potential community-based PES scheme as a landowner whereas 10% were somewhat likely to subscribe to (Fig. 6). Similarly, approximately 52% were very likely or extremely likely to be willing to pay landowners under a PES scheme to prevent them from giving their lands for gamamsey activities in order to keep the forest and agricultural landscapes intact in their communities. Specific to how likely they are to subscribe to a PES scheme to pay to restore and protect waterbodies (rivers and streams) destroyed by gamamsey activities in their communities, about 60% were very likely or extremely likely to do so under a PES scheme. Fig. 7 suggests the mean rating of respondent's likeliness to be willing to participate under the three different environmental attitudinal statements in the three studied communities were all beyond "somewhat likely" and statistically non-significantly different from "very likely". The SD values also reveal responses for individual communities were symmetrical.

#### 3.6.2. Underlying factors influencing likeliness of participating in restoration activities

Results of the logistic regression model predicting the underlying factors influencing an individual's likeliness of participating in a gamamsey restoration program within a PES context is presented in Table 5. This include coefficients, standard errors, Type-I error significance and odds ratios. Relative to the socio-economic factors, all the attitudinal factors showed stronger statistically significant effects ( $p < 0.01$  or  $p < 0.001$ ) on likeliness to participate in an incentive-based restoration mechanism to improve ecosystem services. The negative and statistically significant coefficient of *involved* suggests that, on average, people who were involved in gamamsey activities were 81.1% less likely to subscribe

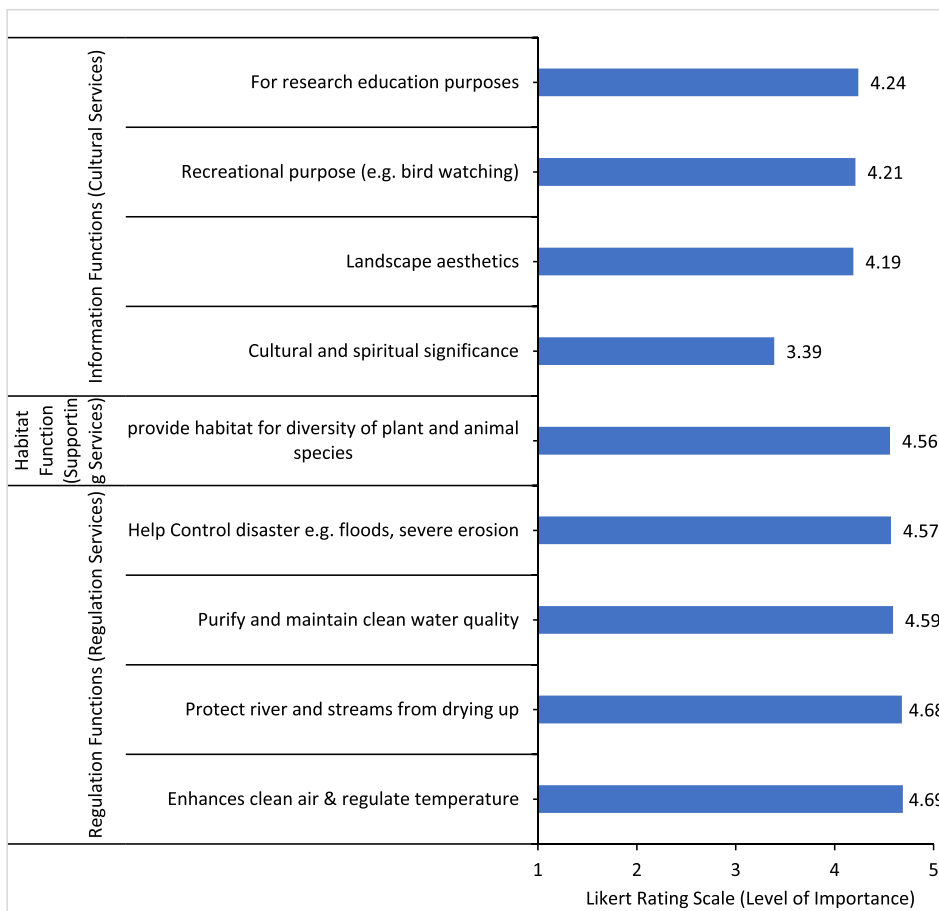


Fig. 3. Mean rating of attitudes toward the importance of forest in providing selected non-market ecosystem services on 5-point Likert scale.

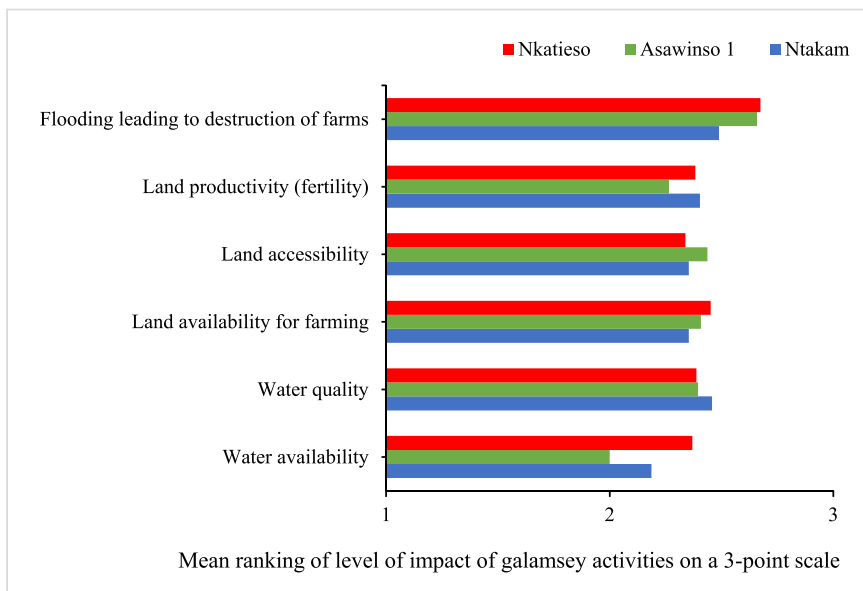


Fig. 4. Mean ranking of perception of impact of galamsey activities on different ecosystem services and resources. Likert scale: 1 = low impact; 2 = moderate impact; 3 = high impact.

to an incentive program that pays landowners to prevent them from giving their lands for galamsey activities than not who were not involved, *ceteris paribus*. On average, an increase in the level of importance attached to non-market forest ecosystem services is associated with 6.8

times more likelihood to subscribe to the proposed restoration program, *ceteris paribus*.

With regards to values associated with forest ecosystem services, a unit increase in respondents' level of agreement to statements reflecting

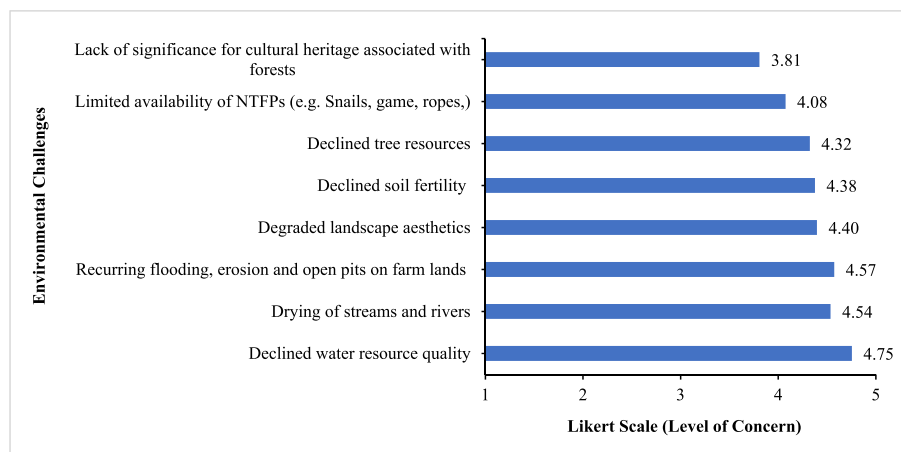
**Table 3**  
Perception of impact of galmsey activities on NTFP availability.

NTFPs	Highly abundant		Moderately abundant		Less abundant		Totally scarce	
	Prior to Galmsey	Current Status	Prior to Galmsey	Current Status	Prior to Galmsey	Current Status	Prior to Galmsey	Current Status
Mushrooms	87.5	1.48	5.88	11.11	2.94	31.85	3.68	55.56
Snails	92.65	0.74	2.94	12.59	2.21	30.37	2.21	56.3
Ropes	83.5	2.86	9.71	20.95	1.94	40	4.85	36.19
Bamboo	81.74	7.63	10.43	24.58	1.74	31.36	6.09	36.44
Rattan	82.18	1.00	10.89	30.00	0.99	31.00	5.94	38.00
Canes	82.18	2.00	8.91	28.00	0.99	29.00	7.92	41.00
Pestles and Poles	79.82	2.78	11.01	22.22	-	30.56	9.17	44.44
Chewsticks	71.91	3.49	17.98	22.09	0	32.56	10.11	41.86
Herbs and medicines	78.1	8.26	12.38	30.28	0.95	28.44	8.57	33.03
Climbers	74.73	1.11	15.38	28.89	2.2	33.33	7.69	36.67
Other plant group collections	60.23	1.14	29.55	27.27	0	28.41	10.23	43.18

**Table 4**  
Percentage distribution of respondents' level of concern of galmsey impacts.

Environmental Challenges	Not at all concerned	Slightly concerned	Moderately concerned	Very much concerned	Extremely concerned
Declined water resource quality	1.99	0.66	1.99	10.60	84.77
Drying of streams and rivers	5.96	1.99	1.99	12.58	77.48
Declined soil fertility	5.80	0.72	5.07	26.81	61.59
Degraded landscape aesthetics	2.94	1.47	5.88	32.35	57.35
Recurring flooding, erosion and open pits on farm lands	2.21	0.00	5.88	22.06	69.85
Limited availability of NTFPs (e.g. Snails, game, ropes)	4.11	4.79	15.07	31.51	44.52
Lack of significance for cultural heritage associated with forests	4.79	33.56	21.92	7.53	32.19
Declined tree resources	0.70	2.11	11.97	34.51	50.70

5-point Likert scale (1 = Not at all concerned; 2 = slightly concerned; 3 = moderately concerned; 4 = Very much concerned; 5 = extremely concerned).



**Fig. 5.** Mean rating of level of concern about the impact of galmsey on different environmental resources. (5-point Likert Scale: 1 = Not at all concerned; 2 = slightly concerned; 3 = moderately concerned; 4 = Very much concerned; 5 = extremely concerned).

an individuals' value motivation (bequest, existence, altruistic and use values) for their willingness to engage in restoration activities is associated with 1.58 times more likeliness to subscribe to the proposed restoration program. Similarly, a unit increase in the level of agreement to statements reflecting confidence in PES applicability as a conservation mechanism was associated with 7.4 times more likeliness to subscribe to the proposed restoration program. None of the socio-economic variables showed statistically significant impact except for *income*. On average, for a unit increase in respondents monthly income, the odds of being likely to subscribe to the proposed program increased by a factor of 1.0, controlling for all other variables. Overall, it can be noted that controlling for all variables and respondents have no attributes based on the estimated model, the odds of subscribing to the proposed program will decreased

by a factor of 12.6.

#### 4. Discussion

##### 4.1. Level of importance communities place on forest ecosystem services

Ecosystems have both market and non-market values that provide human welfare (Page and Bellotti, 2015; Obeng et al., 2018). Respondents in all three communities were unanimous in recognizing the importance of the non-market values of forest. Among nine non-market ecosystem services, respondents across the three communities expressed similar views (mostly identifying the forest ecosystem services as 'very important'), except for the aesthetic value of forest where

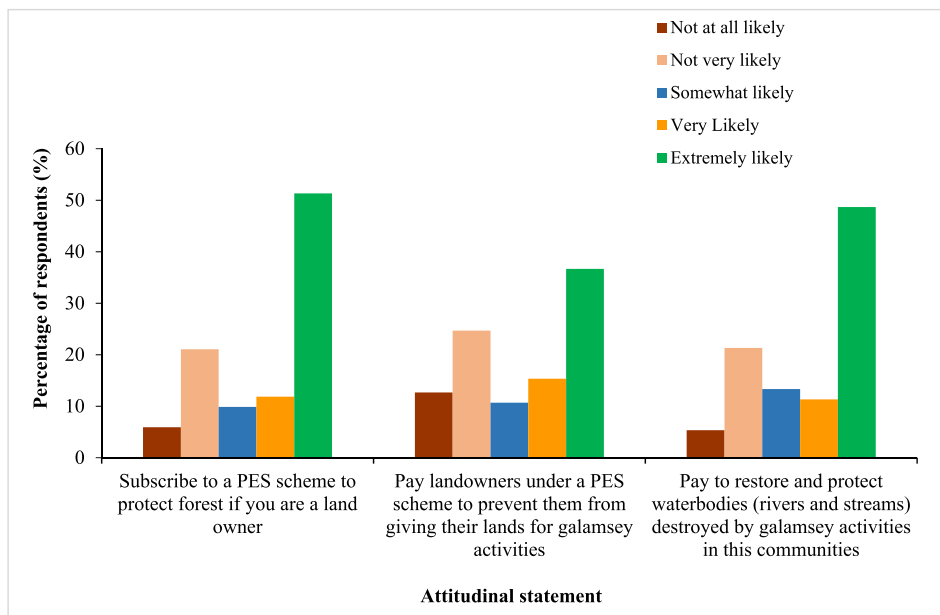


Fig. 6. Percentage distribution of respondents' likeliness to subscribe incentive conservation mechanism to protect forest from illegal mining activities.

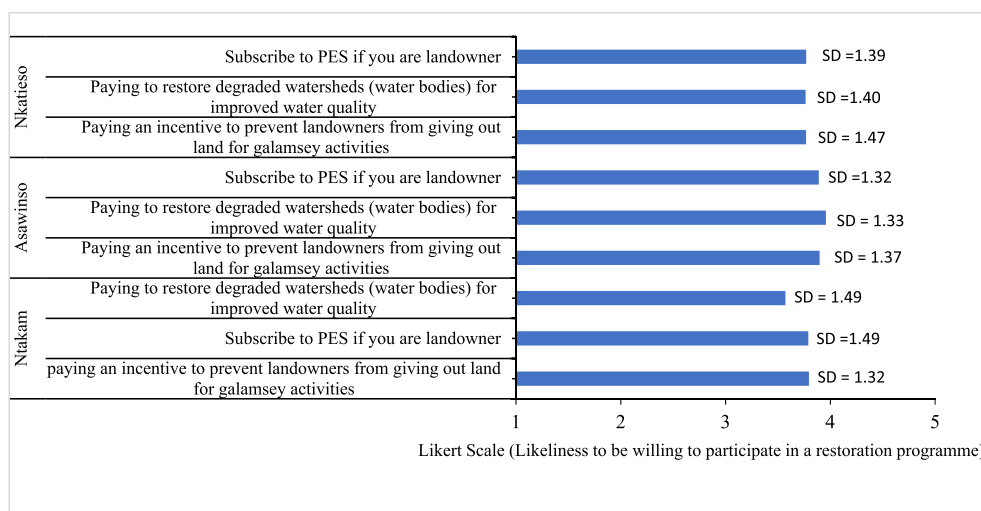


Fig. 7. Mean rating of likeliness to be willing to pay for a restoration program that seeks to protect degraded mined sites for enhanced ecosystem services (Likert scale: 1 = not at all likely, 2 = not very likely 3 = somewhat likely, 4 = very likely, 5 = extremely likely).

Table 5

Logistic regression for determinants or likeliness to participate in restoration activities.

Variable	Coefficient	Odds ratio	Standard error	p-value
Gender	-0.081	0.922	0.564	0.885
Age	0.087	1.090	0.569	0.879
Family_size	0.307	1.360	0.504	0.542
Income	0.001	1.001	0.000	0.014**
Residence_status	0.858	2.359	0.629	0.173
Education	0.289	1.335	0.624	0.644
Involved	-1.665	0.189	0.598	0.005**
Ecosys_importance	1.920	6.823	0.521	0.001***
Valuemotive	0.462	1.587	0.225	0.040**
PES_confident	2.004	7.417	0.529	0.001***
Constant	-12.622	0.000	2.789	0.001***

NB: Log likelihood function = -56.428; LE Chi2 (11) = 64.557; McFadden's R2 = 0.364; McFadden adjusted R2 = 0.240: statistically significance at 95 % confidence interval (P > z 0.05\*\*); 99% (P > z 0.01)\*\*\*; 90% (P > z 0.1).

respondents differed in their opinions. Similar findings reported by Meijaard et al. (2013) whose study found that villagers in Borneo (in Malaysia and Indonesia) regard non-market forest ecosystem services to be very important for their health. As noted by Meijaard et al. (2013) such recognition of importance of non-market values of forest could be due to positive social desirability. Thus, people could be responding affirmatively mainly to show good knowledge of environmental issues and functions of the forest.

The role of forest as disaster control agent was very well recognized by respondents as very important. This is probably because residents noticed severe flooding and erosion in areas where there is little or no vegetation cover, as this is a common occurrence in Ghana during rainy seasons. Through ocular observation, the researchers noticed large gullies resulting from erosion in places denuded of vegetation within the study communities. However fast vegetation growth and the topography of the area makes it less susceptible to natural flooding. A study by Dave



et al. (2016) on forest ecosystem services derived by smallholder farmers in North-western Madagascar showed a similar trend where 46.7% of his respondents were of the view that forest ecosystem reduces flooding, while 64.1% stated that forest ecosystem reduces sediments/debris. Also, studies by Maass et al. (2005) and Meijaard et al. (2013) provides insights on how forest edge communities in small catchment areas view the role of forests in reducing storm hazards as important.

Safeguarding and improving air quality has been a necessity of environmental policies during the course of the 20th century. In studies on people perception and value placed on forest ecosystem by communities by McPherson et al. (2006) on importance of urban trees, respondents mentioned that trees clean the air by absorbing nitrous oxides, sulphur dioxide, carbon dioxide and other pollutants, and also provide shade in car parking lots and decrease ozone emissions from vehicles. This study reveals that not only are residents in the study area conscious of the role of trees in maintaining air quality and low temperature; they are also willing to support community-based restoration initiatives to re-establish vegetation in denuded areas within their communities. Mtoka (2015) studied impacts of land cover changes on the provisioning ecosystem services at Goaso-Ghana, and asserts that 50% of the study respondents' emphasized importance of forest to be provision of habitat for animals, while 15% were of the view that forest ecosystem serve as habitat for fishes. The response that galamsey facilitates the drying up of water bodies did not come as a surprise, as evidence abound in the study communities. Unlike farmers who do not cultivate areas surrounding water bodies, illegal miners rather target water bodies and their environs, clearing the surrounding vegetation and exposing the water bodies to accelerated evaporation and siltation. This has serious consequences on the environment. Local people's knowledge of importance of forests in water protection, as revealed in this study, agrees to broader scientific understanding of the importance of forests in helping to maintain hydrological balance (Bruijnzeel, 2004; Brauman et al., 2007). The results on the importance placed on forest by respondents on galamsey forest clearing and its associated impacts on rivers and streams protection are substantiated by Wilk (2000) who found similar locally held knowledge of the linkages between forest and two watersheds in rural Thailand and India.

Forest ecosystems provide unique recreational enjoyment, which cannot be obtained in other environments. Such recreation has the potential of improving overall quality of life. Respondents in this study identified forests as very important source of recreation. The forest serves as both a working field and a recreational ground for rural dwellers in Ghana. It is common to find people (particularly the elderly) on their off-work days, take a stroll in the forest to enjoy the ambience and serenity. Konijnendijk et al. (2005) who studied people's perception on forest and environmental benefits alluded to peoples' affinity for natural architectural characteristics provided by trees that give inspiration and contribute to human wellbeing. Individuals' perceptions of the beauty of their neighborhoods, pleasure in their surroundings, and pride in their community have been shown to be closely related to features of forest ecosystem (Konijnendijk et al., 2005).

Forest ecosystems provide important spiritual, cultural and emotional experiences and play a significant role in providing residents with a sense of place, community, and home (Elmendorf, 2008; McPherson et al., 2006). Although spiritual significance was rated the least important by respondents in this study, in rural Ghana, some of the traditional and spiritual activities are carried out in the forest in line with beliefs and norms (Asante et al., 2017; Myren and Andel, 2011). Most rural settings see the forest as an abode of the ancestors and a repository of healing powers for human afflictions, as such much respect is placed on the forest. Disturbing the forest is linked traditionally to disturbing the home of the ancestors.

#### 4.2. Perception and attitudes towards the impact of galamsey on forest ecosystem services

The perceived impacts of galamsey on forest ecosystem services in the study area cannot be overemphasized. Responses from all three communities pointed to the fact that water availability and quality are increasingly being jeopardized. This is because while activities of galamsey cause drying up and inaccessibility of water bodies, it also pollutes the few ones that are accessible. Inaccessibility becomes a problem due to huge pits that have been dug by illegal miners around water bodies. Also, when vegetation near water bodies are cleared to make way for mining activities, evaporation increases and causes water bodies to dry quickly (Barlow and Clarke, 2004). The introduction of dangerous chemicals such as mercury and cyanide into water bodies through galamsey activities is leading cause of water pollution in the studied communities. These chemicals kill aquatic organisms and make water unsafe for human use. The clearing of vegetation and subsequent digging of areas around water bodies cause siltation and turbidity thereby compromising the quality of the water (Mensah et al., 2015; Aryee et al., 2003).

Owusu-Koranteng (2005) argues that environmental challenges associated with galamsey have deprived rural communities of potable water. Anane-Acheampong et al. (2013) tested some water quality parameters ( $P^H$ , total dissolved solids –TDS, total Arsenic, total Cyanide, Iron, conductivity) in various water sources in the study district and reported all of them (except  $P^H$ ), to be above levels recommended by the Ghana EPA (Environmental Protection Agency) and the World Health Organization. It is therefore not surprising that water quality was rated as above moderate impact by respondents in all three studied communities. Mining has affected land availability in the study communities as land meant for agricultural activities are being used for mining operations. In addition, the activities of mining through topsoil removal have rendered some areas unproductive for agricultural activities. This has dire consequences on residents in mining communities, as most of them are farmers (Table 1) and depend hugely on the land for their livelihood activities. Consequences of this phenomenon are food shortage, poverty, crime and migration.

Respondents in this study have found galamsey to affect their communities negatively by contributing to a reduction in land availability for agricultural productivity. Similarly, Armstrong (2008) found that increasing gold mining activities in Ghana is claiming agricultural lands and rubbing forest dependent communities of their livelihoods resources. Agricultural lands are not only degraded in the study area but loss of land for farming activities has also led to reduction of the fallow period from around 12 years to less than five years (Bagyina, 2012). Deforestation resulting from galamsey has long-term impacts even when mine sites are properly decommissioned. It could take ten to fifteen years for a restored mine site to become ready for agricultural activities (Akabzaa and Darimani, 2001). In general, soil fertility loss, soil erosion and large-scale deforestation are partly responsible for the low level of agricultural productivity, especially crop production (Armstrong, 2008; Bagyina, 2012).

Galamsey-related degradation of the environment in rural communities has debilitating effect on rural livelihood strategies. The livelihood strategies of rural households vary enormously. However, a common strategy is for household members to undertake a range of activities that may have significant impact on the households and in some way contributes to one or more of household needs. The harvesting and consumption of NTFPs have high significant livelihood dimensions by means of providing essential components of rural livelihood needs. The degree of dependence on NTFPs is not only restricted to local usage but have over the years, shifted from local subsistence to an all year-round commercial venture. Additionally, NTFPs often have important cultural ideals which are valued by rural communities. The impact of galamsey on NTFP seems to threaten this very essential dependable rural livelihood

strategy.

Respondents across the three communities were very much concerned about the mining-related degradation of their environment – water bodies, forests and soils. Showing concern about the environmental problems is a sign of positive attitude towards the environment, which can result in willingness to participate in solving the problems. In as much as galamsey seem to be the quickest income generating venture in the mining communities, agriculture remains the backbone of their subsistence and sustainable income generating activity. It is therefore not surprising that respondents showed concern about the destruction of their livelihood resource base. The mere proximity of residents to sources of environmental problems (galamsey operations) could account for their high level of concern for the environment. A study conducted by Gifford and Nilsson (2014) showed that people who live near sources of environmental problems tend to develop pro-environmental concern. Environmental concern hinges on positive attitude towards the environment, which is an important ingredient in efforts to rehabilitate degraded lands.

#### 4.3. Factors influencing communities' willingness to participate in restoration activities for improved ecosystem services

The success of community-based forest restoration activities have been proven to rely heavily on a pivotal role given to local communities (Appiah, 2001; Blay et al., 2006). The high level of concern and willingness expressed in this study is a major advantage that can be capitalized upon to design appropriate community-centered restoration programs. Environmental attitudes and involvement in galamsey activities helped explain much variability in the likeliness to participate in restoration activities, but attitudes toward PES programs as a forest conservation initiative and acknowledgment of the importance of non-market forest ecosystem services had the strongest effects. This trend is also consistent with Obeng et al. (2018) where environmental attitudes predicted willingness to pay for conservation initiative than socio-economic variables. These arguments are also reiterated by Stern et al. (1995), Johansson-Stenman (1998) and Obeng and Aguilar (2018) that perceptions, beliefs and environmental attitudes have relatively stronger predictive impact on willingness to pay for conservation than socio-demographics. In this study, income was the only socioeconomic variable that showed statistically significant impact on likeliness of participation however, the effect was very marginal. With such determining underlying factors, it is important to focus on sensitization programs that appeals to people's conscience and attitudes towards the holistic importance of forest including both market and non-market ecosystem benefits.

## 5. Conclusion

The result from this study is an indication that simple methods and questions can be used to elicit useful information for policy or decision-making. Although limited in terms of coverage and robust statistics, it extends boundaries of knowledge by providing deeper insights into the perceptions of mining communities on ecosystem services and their willingness to support restoration efforts. It demonstrates that when bottom-up approach is adopted and local communities are made principal actors in restoration projects, success levels may be higher than otherwise. Mining communities are aware of the importance of forest ecosystem services and how it affects their livelihoods and general well-being. Forest ecosystem services which are of much importance to respondents include disaster control such as flood and severe erosion; enhancement of clean air and temperature regulation; and protection of rivers and streams from drying up. Respondents are also conscious of the impact of galamsey activities on their soil and water availability and quality. With these knowledge and recognition of the gravity of environmental problems resulting from galamsey, the studied mining communities were willing to embrace and participate in restoration projects. Determining factors of likeliness of participation included income,

embracing non-market ecosystem services as important, confidence in PES schemes and positive value motivation for restoration (altruistic, use and bequest values). This study demonstrates that restoration of galamsey-degraded lands in Ghana is possible if a bottom-up approach is adopted where local communities are put at the center of affairs and made to own restoration processes through a community-based PES-like scheme. The feasibility and opportunities of market-based incentive mechanism such as PES should be explored further. A more potent approach to sensitization programs that focus on importance of non-market forest ecosystem services besides provisioning goods remain key.

## Declarations

### Author contribution statement

Elizabeth Asantewaa Obeng, Kwame Antwi Oduro, Beatrice Darko Obiri, Joseph Appiah-Korang, Haruna Abukari, Reginald Tang Guuroh, Gloria Djaney Djagbletey, Mark Appiah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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The authors declare no conflict of interest.

### Additional information

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