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Farmers' willingness to accept for attributes of soil and water Conservation technologies in Northern Ghana

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Abstract

The issues of soil and land degradation have attracted considerable attention and concern in Ghana and, in particular, the rural areas where livelihoods of the majority of the households heavily rely on farming and land resources. Motivated by environmental and public good nature of interventions designed for soil and land degradation, knowing the optimum rate of resources for conservation practices and technologies is of great importance in the face of limited public funds as is the case of Ghana and all other developing countries. The current study estimates farmers' willingness to accept (WTA) for the attributes of soil and water conservation technologies (SWCT), specifically soil and stone bunds, using the Bayesian approach and the mixed logit model on data collected from 305 smallholder farm households in northern Ghana using the Choice Experiment (CE) Method. Farmers' most valued attribute in terms of WTA was the environment quality attribute. Also important to farmers were the potential yield improvements they expected from the technologies. WTA/ hectare for "potential yield increase", "improved landscape quality" and "collective action" are GH¢98.52 or US$16.63, GH¢696.0 or US$117.11, and GH¢-650.34 or US$-109.78 respectively. Production factor requirements of the technologies were not significant attributes to farmers in Northern Ghana. The importance of institutions on preference formation is supported by the significance of the WTA of collective action. With limited public funds, including collective action in PES programmes may offer a low-cost way of supplying environmental services. For soil and water conservation programmes to be more effective, technologies with features for which farmers have high preference, reflected by those with higher marginal willingness-to-accept, such as high crop yield and high environmental service supply should be promoted.

Keywords: Soil and water conservation technology, choice experiment, Bayesian econometrics, mixed logit model, willingness to accept, Ghana.

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1. Introduction

Agriculture plays an important role in the Ghanaian economy, and provides the main source of food, income and employment to its rural populations. Traditionally, over 57% of the country's workforce are employed by the sector and its related activities and it contributes significantly to its gross domestic product (GDP). Between 2006 and 2010, for instance, agriculture contributed about 30% on average to the country's gross domestic product (GDP) and has provided between 45.40% and 63% of employment for the labour force of the country between 1991 and 2013 (World Bank, 2024; Ghana Statistical Service [GSS], 2015). However, agriculture's contribution to GDP has persistently declined since 2006. The sector's contribution to Ghana's GDP declined from 24.8% in 2012 to an average of about 19.5% between 2013 and 2023 (Statista, 2024; World Bank, 2024). The decline, among others, has been attributed to the negative consequences of land degradation and its resultant effect on productivity (Ahiale et al., 2020).

The issue of land degradation is critical in Ghana as livelihoods of the majority of Ghana's rural households heavily rely on land resources. In fact, soil and land degradation in Ghana have been recognized since the 1930s, and has attracted considerable attention and concern (Agyepong, 1987; Benneh & Agyepong, 1990, Senayah, et al., 2005; Nchanji et al., 2023, Awoonor et al., 2024). Land/soil degradation is caused by both natural and human-induced factors which among others include unsustainable farming practices, removal of vegetation cover (including deforestation and overgrazing), mining activities, and urbanization and industrial activities caused by increased population growth pressures (Ngaiwi et al., 2023; Blay and Abunyuwah, 2024). Key processes resulting in land degradation are soil erosion by water and wind; chemical changes such as acidification, salinization, and nutrient loss; and physical degradation through pressures such as compaction (Ahiale, et al.,2020; Eswaran et al., 2001; UNCCD, 2013). Land degradation in Ghana, which is mainly as a result of soil erosion and soil nutrient depletion, ultimately has negative effect on soil productivity (i.e. low crop yields) and environmental quality. Land degradation can seriously reduce land productivity and joepardise economic growth (Koiri et al., 2024, Farani et al., 2024).

While all regions in Ghana are experiencing land degradation, the most hit areas are in the northern Ghana located within the most vulnerable zones of the Guinea and Sudan Savannahs (Asiedu et al., 2016; World Bank, 2006; Nchanji et al., 2023, Awoonor et al., 2024). Thirty-five percent of Ghana's land was threatened by desertification particularly in the northern regions (Upper East, Upper West and Northern Regions) since the 1960s (Ahiale, et al., 2020; Adanu et al., 2013; Kenworthy, 1995). As a result of land degradation, grasslands, woodlands and forests are being lost while natural water bodies are drying up due to prolonged droughts and deposition of sediments into water courses (Adanu et al., 2013). Large areas of croplands in northern Ghana which were hitherto fertile have been made infertile by land degradation. This has led to depletion of farm income and food sources. Thus, while all parts of Ghana are prone to land degradation, the associated food insecurity, economic and social vulnerabilities are considerably felt in the northern regions of Ghana.

Recognizing the seriousness of land degradation and its impact, and in an effort to improve environmental conditions in rural Ghana as well as reduce poverty among smallholder farmers, soil and water conservation (SWC) has become a must livelihood and sustainable strategy for all stakeholders. In northern Ghana several soil management programmes have been introduced over the years where substantial resources and efforts have been devoted to promote SWC and other nutrient-enhancing technologies. These include physical structures such as soil and stone bunds (the technologies of interest in this study) to smallholder farmers aimed at reversing the trend of degradation, improving yields and protecting the environment simultaneously. However, adoption rates of soil and water conservation technologies (SWCT) remain low and the land degradation problem has persisted (Ahiale et al., 2020).

Several economic incentives and constraints have been reported to encourage degradation and discourage conservation by farmers (Belayneh, 2023; Boufous et al., 2023; Irham et al., 2024; Antle & Diagana, 2003; Cohen, 2013; Lutz et al., 1994; Pender & Kerr, 1998; Platteau, 1990; Reardon et al., 1997; Reardon & Vosti, 1995). Particularly, poverty and market failures have been extensively cited as constraining investment by farmers in soil conservation (Cohen, 2013; Holden & Shiferaw, 1999; Holden, Shiferaw, & Wik, 1998; Pender & Kerr, 1998; Reardon et al., 1997; Scherr, 2000). Market failures, due among others, to the "public goods" nature of the environmental benefits of soil and water conservation measures causes decisions made at the farm household level in relation to conservation investments to be done in the setting of imperfect conditions of distorted signals, which may prevent the resource use pattern from following the socially optimal path (McConnell, 1983; Chen et al., 2023). The off-farm environmental benefits of on-farm conservation measures are in the public domain, however, there are no markets for such benefits or when there are, the market prices underestimate their social scarcity values because the public or consumers of such goods and services consider them as "free" and so farmers are not compensated by the market for reducing land degradation rates to the level which society wants (Yang et al, 2023; Wang et al., 2023).

The existence of some market failure is sufficient condition for government intervention, typically in the form of allocating public funds to, for instance, internalize land degradation. Payment for Environmental Services (PES) in which incentive payments are made to resource managers to adopt conservation practices/technologies is one such intervention which is increasingly becoming popular worldwide. The incentive payments are made on the basis of the positive environmental services (ES) expected to result from adoption of conservation practices and technologies (Asfew et al., 2023; Paudel et al., 2023). Under such interventions, knowing the optimum rate of resources to be invested from public funds is of importance in the face of limited public funds as is the case in developing countries. The current study uses the choice experiment method and the mixed logit model to value the attributes of SWCT, specifically soil and stone bunds, thus providing policymakers, government, and other interested donor agencies with a guide for decision-making and policy formulation on the adequate level of compensation payment that will encourage farmers to adopt SWCT and also give a basis for the cost implications of conservation. A knowledge of the economic value of the attributes does also help in the analysis of trade-offs between different attributes.

2. Materials and Methods

This section deals with the processes of the choice experiment conducted and the bases of selection of key production variables used. Study area and data collection procedures are also presented. It further details the econometrics models applied and justification upon which they were selected.

2.1 Choice experiment design (Experimental design)

Data were obtained from a designed CE in which farmers had the option to choose among alternatives/profiles representing SWCT, specifically soil and stone bunds in a hypothetical conservation plan. The attributes and attribute levels assigned to SWCT were informed by literature, discussions with experts and extension staff, and focus group discussions with farmers. We used seven attributes to characterize SWCT. They are: four attributes based on the needs and benefits of the technologies, one that is an ecosystem service attribute (this is a composite attribute) provided by the technology, one which is related to the institutional context, and finally a 'price' or compensation attribute. The attributes have different numbers of levels ranging from 2-6. The levels assigned are on per acre basis due to the fact that farm sizes are generally small, and farmers are more familiar with the measurement of acre than the conventional hectare. The chosen attributes and attribute levels are given in Table 01).

Table 01: Attributes and levels used in the choice experiment

Attribute	Levels
1. Labour (man-days)	126, 211, 296, 381
2. Area (proportions)	1/20, 1/10, 3/20
3. Time (years)	1, 2, 3, 4
4. Yield (proportions)	0, 1/10, 3/10, 2/5, ½
5. Landscape quality/features	Deteriorated landscape quality
	Maintained landscape quality
	Improved landscape quality
6. Collective action	Membership required
	Membership not required
7. Payment (GH¢) – WTA/acre	0, 850, 1200, 1550, 1900, 2250

Generally, farmers' preferences for, and adoption of resource conservation technologies are influenced by the characteristics of that technology, farmers' perception of its requirements and benefits, and availability and distribution of production factors (i.e., land, labour/time, capital, knowledge skills, etc) (Ortiz et al., 2023; Drechsel et al., 2005). Thus from the farmers' viewpoint, the choice of the appropriate technology is determined by the production factor requirements of the technology and the relative availability of these factors in the farm economy (Jung and Chung, 2024; Gregory et al., 2024; Barriviera et al., 2023; Drechsel et al., 2005). Others relate to the environmental services produced and the institution under which production takes place. In effect, critical attributes of SWCT from farmers' perspective, are environmental services produced and the institutional context under which adoption are used to describe the technologies. This section explains the attributes used in the experiment as summarised in **Table 01.**

2.2 Labour Requirement

Conservation methods require resources, mainly additional labour for construction and annual maintenance (Uz and Mamkhezri, 2024; Shiferaw & Holden, 2001; Stocking & Abel, 1989). Stocking & Abel (1989) noted that inadequate consideration of labour could cause a failure in soil and water conservation schemes. This attribute is the extra/additional labour in man-days that the farm household would require in order to construct any conservation technology on an acre of farm land. This amount does not include the labour requirement for other farm activities like clearing, planting, harvesting, etc. It is often erroneously supposed that farmers' (family) own labour input is a free resource. The amount of farm work self-employed farmers are willing to do depends on factors such as the potential benefit of doing extra work, other (on- or off-farm) job opportunities and his/her own motivation and personal need for regeneration or social time (Jung and Chung, 2024; Gregory et al., 2024;). The opportunity cost of labour is the possible return to labour that would have been earned if that labour had been used for an alternative activity. Different SWC structures have different labour input requirements (Herweg & Ludi, 1999). The number of man-days depends on the type of technology (Drechsel et al., 2005), the slope of the land, and the availability of the construction material (i.e., earth or stone). In comparison, soil/earth bund requires less amount of labour than needed for stone bund. In Ahiale et. al. (2020), it was observed that construction of bund required as much as 100 man-days for construction works on a small quarter-hectare plot (see also Shiferaw & Holden, 1998; Stocking & Abel, 1989). Herweg and Ludi (1999) indicate that maintenance requires high labour inputs. A case study by Drechsel et al. (2005) estimated that 97 man-days/ha of labour was required for construction and maintenance of stone bund. Based on FAO's (1986) and Shiferaw and Holden's (2001) estimation of direct labour requirements from the engineering features of conservation technologies, labour requirement ranged, depending on the slope of the field, between 28 and 280 man-days/hectare for soil bund and from 60 to 600 man-days/hectare for construction of stone bund. The focus groups discussions revealed that the amount of labour required per acre ranged from 60 -120 man-days for stone bund and an average of 30 man-days for soil/earth bund.[1] Though periodic maintenance of the structures is required after construction, this is not included in the hypothetical plan, however, some minimal provision for maintenance was included in the number of man-days. Four levels of this attribute were assigned.

2.3 Land loss

The installation of new SWCT is associated with loss of cultivable land. Farmers have argued that mechanical SWC structures do occupy valuable cropping area (Ludi, 1997; Wyatt, 2002). In areas where land is scarce, loss of cropping land due to construction of new SWCT presents an important issue (Shiferaw & Holden, 2001). Apart from the area taken up by the structures, farmers have reported that they also make some traditional farm operations difficult to undertake. The area lost therefore imposes revenue loss to farmers. The proportion of land loss to conservation structures depends on the slope of the land: the steeper the slope, the shorter the spacing between structures, and the more productive land occupied by the structures (Arrueta, et al., 2022; Ellis-Jones & Tengberg, 2000). In their estimation, Shiferaw and Holden (2001) concluded that conservation structures could reduce the effective area cultivated by up to 20%, similar to Wubshet (2004) and Kruger (1994) who estimated that bunds take up 10-20% of cultivated area and even more on steep land (Kassie et al., 2009). Based on these values and the information collected from farmers and experts, three levels were assigned to the area loss attribute.

2.4 Time

Time attribute considers the number of years after construction of structures that a certain level/proportion of yield increase is achieved. Resource poor farmers would expect benefits from SWCT to accrue within a cropping season (Duke et al., 2013; Ellis-Jones & Tengberg, 2000). It has been indicated that poverty and liquidity constraints or scarcity have vital implications on the actions of smallholders (Holden et al., 1998). They may result in high rates of time preference or a situation where farmers are said to have a short time horizon, so that present rather than future consumption informs decisions about technology adoption/investment (Holden et al., 1998). Any technology that gives long-term rather than short-term benefits is deemed undesirable. Therefore, it is important for farmers that any SWC technology reaps benefits of improved yields, from their perspective, in a reasonably short time after adoption or construction. Evidence shows that it is possible for yield improvement to be obtained just after a year of construction (Cofie et al., 2002). Loeffen et al. (2008) argue that for most SWCT, there is a time-lag between their initial adoption and felt impacts or productivity gains. In their study in Niger, farmers reported that on average, they had to wait 3 years to see the effects of stone bund, stone lines, and wood barriers, however, for technologies such as soil bund and small dikes, they had to wait for a year only. From the focus group discussions, farmers reported that increased yield is observed normally a year after adoption/construction and that about the fourth year and onwards, the maximum of about 50% is achieved. Four levels were assigned to the time attribute.

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[1] A man-day in Ghana is 8 hours.

2.5 Potential yield increase

Considering the fact that soil and stone bund occupy precious space and their construction is labour intensive, an important issue for the farmer is whether their yield impacts are significant enough to merit the investments in labour and land. The expectation of higher yields and its associated returns obtained by adopting SWC measures are the key drivers of SWC technologies adoption (Etsay et al., 2024; Loeffen et al., 2008). Farmers with limited resources, would expect to see benefits from SWC investments (Ellis-Jones & Tengberg, 2000). Both soil and stone bunds are built to control runoff, thus, reducing soil erosion, conserving soil moisture and soil organic matter, and any added nutrients. All things being equal, crop yields with conservation in the initial years depend on the effect of conservation on soil erosion and the effective area planted (Shiferaw & Holden, 2001).The effectiveness of soil and stone bund at reducing erosion varies, with stone bund being more effective, though it occupies more land. Increased soil moisture and improved soil fertility are important for crop growth and yield, so that, yields may not decline but rather increase under conservation (Duke et al, 2013; den Biggelaar at al., 2003; Lal, 1998). However, the impact or the performance of the technologies on yield also depends on other factors like location, soil type, pattern and amount of rainfall, whether nutrients are added to the soil in the form of fertilizers, seed type, etc. Though there is opposing evidence, improved crop response is the general consensus. In high-rainfall areas, most soil conservation technologies appear to have positive effects on reducing production risk, with some variation by region. Evidence from several studies has also shown that the impact of SWCT in low-rainfall regions is particularly significant. For example, Kato et al. (2009) found that soil and stone bund have considerable positive mean impacts on crop production on plots in low-rainfall areas in Ethiopia. Their observations were consistent with previous studies in Ethiopia (Bekele, 2005; Gebremedhin et al., 1999; Kato et al., 2009). Kassie et al. (2008) and Bekele (2005) both found stone bund to have favourable impacts on production in low-rainfall areas. Graff (1996) also found that stone bund could increase sorghum yields on very degraded soils by 47% in Burkina Faso. In northern Ethiopia, plots with stone bund ranging in age between 3 and 21 years recorded an average increase in grain yield of 53% in the lower parts of the plots (Nyssen et al., 2007). Vancampenhout et al. (2006) also estimated an overall increased crop response of 18.5% (ranging from 5% - 57.4%) in the presence of stone bund compared to the hypothetical yield in absence of stone bund in the Ethiopian highlands. The increase in crop yield was recorded for all crop types and for most soil types (Gebrernichael et al., 2005; Vancampenhout et al., 2006). These evidences are particularly significant for the study areas which are low rainfall regions. From the focus groups and expert discussions, it was reported that yield improvements of 20% to 50% of the main cereal crops of maize, millet, and sorghum on fields with soil and stone bund compared to fields without them have been recorded. Based on the literature, focus groups and expert advice, 4 levels, in proportions, were assigned to the yield increase attribute.

2.6 Landscape quality and attribute

This attribute refers to the ecosystem services provided by SWCT at the local level. There is considerable evidence that SWCT can provide a wide range of benefits to the environment and wildlife. Soil and stone bund have been proposed to reduce land degradation and to improve the quality of the natural resource base (Fenta et al., 2024; Gebremedhin et al., 1999; Herweg & Ludi, 1999; Nyssen et al., 2000). Soil/stone bunds provide various ecosystem services, both on and off-site. On and off-site effects/ecosystem services are definitely positive (Li et al., 2024; Haregeweyn et al., 2005), manifesting themselves at the local, regional/national and global scales (Newcome et al., 2005). These benefits include substantial flood and erosion control, substantial reduction in sedimentation of water bodies and its consequent improvement in water quality and aquatic life; reduction in leaching and deposition of fertilizers, herbicides and pesticides in water bodies, and aesthetic improvements (Lóczy etal., 2024; Bingham et al., 1995; FAO, 2007; Holland, 2004; Webb et al., 2001). SWC therefore can halt land degradation leading to maintenance of the status quo or improved landscape quality (Lóczy et al., 2024; Seid et al., 2024). Absence of conservation deepens land degradation resulting in further deterioration of the landscape quality. Three levels associated with the environmental services from soil and water conservation were thus assigned.

2.7 Collective action

Many natural resource management practices require cooperation among individuals (Zhu, Wang, 2024; Knox & Meinzen-Dick, 2001). Collective actions include collective decision-making, setting rules of conduct of a group and designing management rules, implementing decisions, and monitoring adherence to rules (Li et al., 2024; Meinzen-Dick et al., 2004, p.5). In this study, collective action is mainly concerned with implementing contracts and monitoring adherence to rules and contracts by the participating farmers. It also implies collective punishment in the event of free-riding by group members, as well as sharing of skills, labour, etc. This attribute is assigned two levels: membership required (means collective required) and membership not required (no collective action).

2.8 Payment/compensation level

The price attribute is required to estimate welfare changes. Initial and continuous investments in cash and labour are normally required for SWC technology implementation (Byungyul et al., 2023; Ellis-Jones & Tengberg, 2000). The payment vehicle is payment by government to farmers for providing environmental services. From the conservation plan, payment is to be disbursed in two parts, 50% before construction and the remaining 50% made half-way through construction. Six payment levels were assigned to this attribute.

2.9 Choice set

The choice experiment included three versions consisting of six choice sets, each choice set containing two designed and a 'status quo' alternatives, the 'status quo' was included to offer respondents the opportunity to choose 'no change' or 'do nothing' situation (Alpizar et al., 2001) so that respondents are not forced to either choose between alternatives they regard as unimportant (i.e., with negative utility) or causes non-participation (Kjaer, 2005; Lockwood, 1999). After the first two choice sets, respondents were asked to indicate attribute(s), if any, they ignored when they were making their choices so that non-attendance can be accounted for in the econometric estimation. Pictures representing landscape quality/feature levels were also included in the questionnaire in order to help respondents have the same understanding of the levels. Alternatives were created by optimally combining the attributes and attribute levels and the alternatives combined into choice sets. For environmental valuation, it is better to use shifted designs because of the absence of good quality *a priori* information (Glenk et al., 2024; Mariel et al., 2021; Ferrini & Scarpa, 2007). Shifted design is derived by modifying a conventional fractional factorial main effect orthogonal design and uses an orthogonal fractional factorial to provide the "seed" alternatives for each choice set (Ferrini & Scarpa, 2007; Bunch et al., 1996). Shifted design was used to generate choice sets in this study.

2.10 The survey

The survey was conducted in the northern regions of Ghana due to the severity of land degradation in that area of Ghana. A multi-stage stratified sampling procedure was employed in this study in 2021, following a similar one conducted in 2010 by Ahiale et al. (2020). First, a district was selected from each region based, among others, on their levels of land degradation as compared to other districts, then a purposive selection of a total of 25 villages with the presence of SWC structures of interest in this study was done.[2] A purposive random sampling was again employed to select a total of 305 farm households bringing the total number of completed choice sets to 1830. One-on-one interviews with respondents were conducted by trained interviewers. Because of the high level of illiteracy among respondents, stones, sticks and diagrams were used to explain proportions in the choice experiment to respondents. Completed questionnaires were inspected for errors and omissions and enumerators sent back to respondents to make the necessary corrections.

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[2] ***Physical evidence of SWC structures is important because for stated preference studies, knowledge and familiarity of the good being valued is helpful.***

Table 02: Example of a choice set

Attribute	Alternatives		
	Option 1 - Status quo	Option 2	Option 3
1. Additional Labour	0	125	210
2. Area loss	0	3/20	3/20
3. Time	0	4	4
4. Increase in millet yield	0	½	1/10
5. Landscape quality	Deteriorating landscape quality	Improved landscape quality	Deteriorating landscape quality
6. Collective action	Group Membership not required	Group Membership required	Group Membership not required
7. Payment	0	850	2100

Option 1 ☐ Option 2 ☐ Option 3 ☐ Don't know ☐

2.11 Econometric model - random coefficient/mixed logit lodel

The mixed Logit (ML) or Random Parameter Logit (RPL) model is one of the popular models for the analysis of CE data (Hensher & Greene, 2003). Its increased use for analysing stated preference data is because it: eliminates the restrictive assumptions of conventional logit and probit models; is uncomplicated, very flexible, can be equated to any random utility model (RUM); and it is not limited to normal distributions (McFadden & Train, 2000; Train, 2003). Also, unlike the standard logit model, random variation of the taste parameters, unrestricted substitution patterns, and correlations in unobserved factors over time are permitted by the ML (Hensher & Greene, 2003; Train, 2003). To illustrate the ML, the utility associated with an individual n, who chooses alternative i in choice situation or set (or time) t, is represented in a discrete choice model by a utility expression of the general form:

$$U_{nit} = g(\beta_n')x_{nit} + \varepsilon_{nit} \tag{1}$$

where $g(.)$ may take any form (Train, 2003), and is a transformation of the utility coefficients, x_{nit} is a vector of observed variables which in the present study are the attributes of technology, β_n is unobserved coefficient, ε_{nit} is an unobserved random term which is assumed to be identically and independently distributed.

The β_n parameters vary over decision makers in the population with density $f(\beta_n|\theta)$, where θ is described, for example, by the mean and covariance of the β_ns in the population (Train, 2003). The ML choice probabilities are expressed as the integral of the logit probabilities evaluated over the density of distribution, mathematically written as:

$$P_{nit} = \int L_{nit}(\beta_n) f(\beta_n|\theta_n)\, d\beta_n \tag{2}$$

where $L_{nit}(\beta)$ is a logit probability evaluated at the vector of parameter estimates β that are random realizations from the density function $f(\beta)$. For a particular realization of β, the ML probability is:

$$L_{nit}(\beta_n) = \frac{exp(V_{nit})}{\sum_j \exp(V_{njt})} = \frac{e^{g(\beta_n')x_{nit}}}{\sum_j e^{g(\beta_n')x_{njt}}} \tag{3}$$

The estimation of θ with the assumption that some or all of the β_ns vary in an unspecified and therefore "random" pattern is the interest.

Concerns associated with using this model include: which parameters to model as being randomly distributed across individuals; the statistical distribution for the coefficients; and the economic interpretation of the randomly distributed coefficients (Uz and Mamkhezri, 2024; Hess et al., 2005b). Misspecification of the model is a real threat. This threat could come from choosing a wrong mixing distribution which consequently affect model performance, behaviour, and interpretation (Hess, 2005, 2007; Hess et al., 2005b) so a priori choice of distribution to represent the $\beta_n s$ must be done with theoretical or intuitive biases vis-à-vis what is reasonable variation in parameter values across a population (Hess et al., 2005a). For example, it would be inappropriate to use a normal distribution, which is both positive and negative for a positive coefficient such as WTA. For complexities on biases related to choice of the right mixing distribution, readers are referred to Train (2003); and Train and Sonnier (2005). We utilized the mixed logit model specification with Bayesian estimation framework following Balcombe et al., 2009; Rigby et al., 2009; and Train and Weeks, 2005.

2.12 Model specification and estimation

In this section the modelling framework and notations used in Balcombe et al. (2009) and Rigby et al. (2009) in particular are adopted. From equation (1), the β_ns are organized to have fixed parameters, c'_n in the first block, and random coefficients, b'_n in the second, so that $\beta'_n = (c'_n,\ b'_n)$, $c_n = Z'_n\alpha_c$ and $b_n = Z'_n\alpha_b + u_n$, where α_c is the fixed mean and α_b the fixed population means assumed to vary across the population, $Z_n = I_k \otimes z_n$, and z_n is a $(h \times 1)$ vector determining preferences and describing the characteristics of the nth individual, $h = 1$ and $z'_n = 1\ \forall n$ if no characteristics exist. The errors, u_n which signifies the level of deviation of each respondent's utility function b_n from the population mean is an independently and identically normally distributed vector with zero mean and variance covariance matrix Ω and are assumed to be uncorrelated across individuals. $\Omega = \mathrm{LL}'$, L is the lower triangular Choleski factor of Ω which allows the parameters to be freely correlated, have an unrestricted scale and ensures that the estimated Ω is positive finite at all times. The function $g(.)$ may take many forms (Train & Sonnier, 2005).

If $\{y_{nit}\}_{nit}$ is the set of all stated choices by respondents; $Z = \{z_n\}_n$, the set of characteristics describing all respondents; $X_n = \{x_{nit}\}_{it}$ the set of choices given to the nth individual, and $X = \{X_n\}_n$ is the set of all choice sets given to all respondents, and the data is denoted by D, then the collection, $D = \{Y, Z, X\}$.

The nth individual faced with a set of choices will prefer x_{it} if $U_{nit} > U_{njt}\ \forall j \neq i$. The group of all parameters describing the model will be indicated as $\Theta = (\alpha, \Omega)$, where $\alpha' = (\alpha'_c, \alpha'_b)$. The set $\{b_n\}_n$ is denoted as B the 'latent data' and $\int_B dB$ is the denoted expression for the multiple integral $\int_{\beta_n} \ldots \ldots \int_{\beta_1} db_1 \ldots \ldots . . db_n$ which is finite, and tacitly assumed to be a specified set for B. The probability of respondent n's observed order of choices can be formalized as:

$$p_n = \prod_{t=1}^{T}\prod_{j=1}^{J}\left(\frac{e^{g(\beta_n)'}X'_{nit}}{\sum_{j=1}^{J} e^{g(\beta_n)'}X'_{nit}}\right)^{y_{nit}} \tag{4}$$

The likelihood function for the observed choices is given as:

$$L(\Theta|D) = \int_B \left(\prod_{n=1}^{N} p_n\right) dF(B|\Theta, Z) \tag{5}$$

The marginal likelihood, given priors on the parameters $P(\Theta)$ is

$$M(D) = \int_\Theta L(\Theta|D)P(\Theta)\mathrm{d}\,\Theta \tag{6}$$

The larger the marginal likelihood, the greater the support for a particular model (Koop, 2003). For Bayesian estimation, the posterior distribution of the parameters $P(\Theta|\mathrm{D})$ is:

$$P(\Theta|\mathrm{D}) \propto L(\Theta, D)P(\Theta) \qquad 7)$$

where $\pi(\Theta)$ is the prior distributions for the parameters.

For Bayesian estimation, priors for α and Ω should be specified, and for the current study, the proper prior for α which allows for the estimation of marginal likelihood values (Balcombe et al., 2009) is specified to be normally distributed with mean μ, and variance A_0:

$$(\alpha'_c, \alpha'_b)' = \alpha \sim N(\alpha|\mu, A_0\,) \tag{8}$$

A_0 is a diagonal matrix containing the diagonal blocks $A_{0,c}$ and $A_{0,b}$. For models containing both fixed and random coefficients, the associated means for α_c and α_b are μ_c and μ_b respectively. A normal prior on α is expedient because it affords a conditional posterior on α that is normal and thus easy to draw from (Train & Sonnier, 2005). The variance is specified to be sufficiently high so that the prior has minimal influence on the posterior (Train & Sonnier, 2005; Train & Weeks, 2005). The prior for Ω is distributed inverse Wishart:

$$\Omega \sim IW(\Omega | T_0, v_0) \tag{9}$$

with T_0 degrees of freedom and parameter v_0. The inverted wishart prior implies that it is easy to draw from the conditional posterior on Ω which is also inverted wishart (Rigby & Burton, 2006; Train & Sonnier, 2005). The hyperparameters μ, A_0, T_0, v_0 are set a priori. The priors employed here are set more informatively with $A_0 = 10Ik$, $\mu = 0$, $T_0 = v_0 I/10$, and $v_0 = k(k+1)/2$. The prior for $\beta_n \forall n$ is specified to be normal with mean α and variance Ω, and the prior on each β_n is proportional to this density times the prior on α and Ω (Train, 2003; Train & Sonnier, 2005).

Draws from the posterior are obtained using the M-H (Metropolis-Hastings) and Gibbs sampling algorithms. Model estimation was done with code written by Kelvin Balcombe in Gauss 7.0. One thousand iterations occurring prior to convergence were discarded (i.e., the 'burn in'). After convergence, every 100th draw ('skip') was kept from 100,000 interactions, leaving 10,000 values from which to summarize the posterior. Convergence was monitored visually using trace plots and modified t-tests. Over 30 models were estimated, each in both preference and WTA spaces and the best performing model chosen based on the logged marginal likelihood calculated using equation (6). Larger values of the logged marginal likelihood indicate greater support for a given model. For in-depth literature on model selection for the mixed logit with Bayesian estimation and preference and WTA spaces (see Balcombe et al., 2009; Rigby et al., 2009; and Train and Weeks, 2005). The attribute coefficients were allowed to be fixed, normal, lognormal, or censored normal, except the price coefficient which was assumed to be triangular as well. "Don't Know" responses were excluded from the estimation.

The marginal utilities of ignored attributes are shrunk in the direction of zero by multiplying the latent variables by a shrinkage factor, which is bounded on the lower side by 0 and upper side by 1. This multiplication is done so that bigger shrinkage of the marginal utilities towards zero are obtained when lower shrinkage values are used (Balcombe et al., 2011). Specifically, if the original marginal utility of individual n, for an attribute j is β_{nj}, then if a person claims to have ignored that attribute, their estimated marginal utility is $\rho * \beta_{nj}$, where ρ is the estimated shrinkage coefficient. If ρ was 1 and 0, then the person would retain their original or be assigned zero marginal utilities respectively.

3. Results and Discussion

3.1 Household and socio-economic characteristics of households

We present descriptive and summary statistics of major socio-economic and demographic characteristics of the farmers in the study area in this section. Farming organization and institutional characteristics of the households interviewed are also presented in this section. The results indicated that 78% of the 305 survey respondents were males. This observation of male-headed household dominance in the survey area is not unexpected, as many studies of the area recorded similar results (Abunyuwah et al., 2024; GSS, 2021; Nanii et al., 2019; GLSS5, 2008). Majority of the respondents (67%) were over 40 years of age. In all, about 36% of farmers reported that they were 51 years or above, and 31% aged between 41 and 50 years. On education, about 77% of respondents had no formal education and only 8% and 15% of the farm household heads have respectively had secondary/higher level and basic education. Household sizes in the study area were generally large, with an average family size of nine (9) persons, reflecting the large household sizes typical of African villages and farming households in Ghana (Ahiale, et al., 2020). Notwithstanding the large household sizes in the study area, majority of the households (71%) did not have enough own or household labour to perform farm production activities.

The results indicated that average of four (4) persons per household did provide on-farm labour. This observation constrains decision making options on subsistence production strategies and adoption of labour-intensive technologies such as soil and water conservation (stone and soil bunds). Ahiale et al. (2020), assert that lack of adequate household labour is one of the reasons why adoption of conservative technologies is low in the study area. Land holdings in the study area were generally on small scale, with average total farm size of 2 hectares, ranging between minimum and maximum of 0.40 and 6.20 hectares respectively. Majority of the respondents

(96%), agreed that land degradation was prevalent in their areas of operation. On soil erosion, while almost all respondents (95%) noted it to be a problem in the study area, only 22% of them indicated that it was not severe one. The results indicated that 25%, 26% and 27% of the farmers rated erosion in the study area as fairy severe, severe and very severe respectively. Membership to associations and previous adoption experience recorded fairly low responses of 51% and 57% respectively. The findings of the study also show that income levels in the study area were relatively low. About 29% of the respondents' households earned less than ($100) per annum, while only 17% of the households earned more than ($450) per annum.

3.2 Econometrics results

In this section, we present the results of the models presented in section 3.3 in Tables 03, Table 04 and Table 05. The best performing model is estimated in WTA space with all the attribute coefficients distributed normally except the price attribute which is distributed lognormally. The WTAs, signifying the choices between alternatives as a function of the attributes are shown in Table 03. The means indicate the WTA, i.e., the marginal willingness-to-accept of the attributes. Identical mean and median specify a normal distribution of WTA. For all attributes except 'potential yield increase', the means and medians are fairly dissimilar. The WTAs for 'additional labour' and 'payment level' are larger than their standard deviations, indicating robust estimates. 'Additional labour', 'area loss', 'time', and 'improved landscape quality' have zero medians, indicating indifference for the attributes by half of the respondents. The marginal WTA for 'potential yield', maintained landscape quality', 'improved landscape quality', 'collective action' and 'compensation level' are significant at 5% based on pseudo t-values.

Negative WTA implies that the attribute contributes negatively to utility and therefore need to be compensated for and vice versa. Farm households are willing to accept GH¢206.90/acre (US$34.95/acre) or GH¢649.90/hectare (US$109.78/hectare) not to act collectively under a compensation scheme for adopting a technology.[3] The negative sign means that farmers who do not act collectively would demand higher compensation. This is consistent with Ahiale (2020), Kaczan et al. (2017) and Swinton (2000). Swinton (2000) studied Peruvian farmers and found that social capital, measured by group membership and collective action constitute a low cost means of contributing to natural resources sustainability. This is because the cost of endogenous monitoring to each participant (Ostrom et al., 1994) and the possible collective punishment due to free-riding is less than the gain provided by, for example, collective labour and skill sharing (Satama-Bermeo, 2024; Villamayor-Tomas et al., 2021; Carrere, 2001; Schachhuber, 2004; Swinton, 2000). For any technology providing a 1% increase in yield, farm households are willing to accept an average of GH¢39.40/acre (US$6.65/acre) or GH¢99.00/hectare (US$16.63/hectare) to adopt it. The higher the proportion of yield increase, the less the compensation that would be demanded.

Table 03: Estimates of transformed WTA

Attribute	Mean	Stdv.	Median	Quartile	
				Lower	Upper
Additional labour (man-days)	0.520	0.252	0.000	-0.570	1.926
Area loss (percentage)	0.005	0.019	0.000	0.000	0.000
Time (years)	-0.072	0.709	0.000	-0.454	0.279
Potential yield (percentage)	0.094*	0.076	0.094	0.043	0.144
Maintained Landscape quality	1.820*	2.195	1.643	0.000	3.361
Improved Landscape quality	0.662*	1.174	0.000	0.000	1.360
Collective action	-0.494*	2.061	-0.001	-1.683	0.383
Compensation/payment level GH¢)	210.000*	93.060	190.690	141.874	257.988

*Note: * pseudo t-value significant at 5%; Within Bayesian inference, the coefficient's confidence interval excludes zero if the ratio of the estimate of the mean to the standard deviation exceeds 2.*

The two levels of the 'landscape quality' attribute have relatively high marginal WTAs as respondents would need to be compensated at a rate of GH¢770.00/acre (US$128.79/acre) or GH¢1925.00/hectare (US$321.96/hectare) to adopt a technology in order to maintain landscape quality and GH¢280.00/acre (US$46.84/acre) or GH¢699.00/hectare (US$117.11/hectare) to improve landscape quality, showing that farmers would have to be compensated more in order to supply environmental services. Table 04 presents estimates of

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[3] The average exchange rate in 2021 was GH¢5.924 to US$1 (BoG, 2021).

the mean (α) and the variance (Ω) together with their standard deviations.

Table 04: Parameter estimates of the utility coefficients

Attribute	Mean (α)	Variance (Ω)
Additional labour	0.068 (0.060)	0.084 (0.026)
Area loss	0.324 (0.222)	0.397 (0.239)
Time	-0.091 (0.098)	0.643 (0.208)
Potential yield	0.923 (0.102)	0.568 (0.174)
Maintained landscape quality	2.115 (0.400)	4.928 (1.960)
Improved landscape quality	1.186 (0.414)	1.863 (1.267)
Collective action	-0.648 (0.269)	5.513 (1.999)
Compensation/payment level	0.799 (0.103)	0.195 (0.073)

Note: within Bayesian inference, the coefficient's confidence interval excludes zero if the ratio of the estimate of the mean to the standard deviation exceeds 2.

The correlation among the WTAs of the attributes of the model is presented in Table 05. Four attributes/levels each are negatively ('additional labour', 'area loss', 'time', and 'maintained landscape quality') and positively ('yield', 'improved landscape quality', and 'collective action') correlated to compensation level. The negative correlations between the WTAs imply that households which are willing to accept less than average amounts for one attribute are also willing to accept less for the other attribute. The correlation between "improved landscape quality' and 'additional labour', 'area loss', and 'time' indicates that farm households concerned about improving the environment do not care much about the additional labour they require to adopt a conservation technology, area taken up by the conservation structures, and the number of years taken for yield benefits to start accruing to them. This is a reasonable result for any environmental conscious household.

Table 5: Correlations between WTAs (Estimated Utility Coefficient Correlations)

	Labour	Area	Time	Yield	Maint. ldscape quality	Improv ldscape quality	Coll. action	Payment
Labour	1.000	0.062	0.076	-0.187	0.969	-0.069	-0.086	-0.219
Area		1.000	0.250	-0.264	0.076	-0.118	-0.146	-0.156
Time			1.000	-0.705	0.298	-0.155	-0.092	-0.264
Yield				1.000	-0.243	0.116	0.029	0.125
Maint.landscape quality					1.000	-0.455	-0.620	-0.574
Improv.landscape quality						1.000	0.425	0.368
Collective action							1.000	0.523
Payment								1.000

There is a strong correlation of -0.705 between "time" and "potential yield" meaning that farm households that consider the number of years after which yield benefits are obtained after adoption important do not, on the other hand, consider the proportion of potential yield increase as important. While this result appears inconsistent with economic reasoning, it is also possible that for farm households, as far as some yield benefits accrue shortly after adoption of a technology, the amount of benefit is of no importance. Also, the positive correlation of 0.425 between the WTAs of 'improved landscape quality' and 'collective action' implies that farm households who are willing to accept more than the average WTA for landscape improvement are also willing to accept more than average WTA for acting collectively with other farm households.

4. Conclusion

This paper employed Bayesian methods and the mixed logit model to obtain WTA for attributes of soil and stone bunds in Northern Ghana using choice experiment data. ‘Potential yield increase’, ‘maintained landscape quality’, ‘improved landscape quality’, ‘collective action’ and ‘compensation level’ were found to be the most preferred attributes of farmers. The environment quality attributes are the most valued by farmers. Except “collective action” whose influence on utility/WTA is negative, all preferred attributes influenced WTA in a positive manner. The significance of collective action highlights the influence of institutions on preferences. The results also indicate that the production factor requirements of the technology in terms of the labour and land needed as well as the period of time lapse before yield increases are realised were not important to farmers in Northern Ghana, as long as they expect benefits to accrue.

With limited public funds, incorporating collective action in policy strategies of PES to address environmental degradation could offer a cost-effective or low-cost way of providing maximum environmental services. For soil and water conservation programmes to be more effective, technologies with features for which farmers have high preference, reflected by those with high marginal willingness-to-accept, such as high crop yield and high environmental service supply technologies should be promoted.

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