IMPLICATION OF LARGE-SCALE AGRICULTURAL INVESTMENT ON BIODIVERSITY: EVIDENCE FROM MIXED METHOD STUDY OF FARM HOUSEHOLDS IN NORTHERN GHANA

FINAL REPORT

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ACRONYMS

CO_2	Carbon Dioxide
DPSIR	Driver-Pressure-State-Impact-Response
EEA	European Environmental Agency
FAO	Food and Agriculture Organization
FAOSTAT	The Food and Agriculture Organization Corporate Statistical Database
FDI	Foreign Direct Investment
FGDs	Focus Group Discussions
FIAN	Foodfirst International Action Network
FOE	Friends of the Earth
GAEZ	Global Agro-Ecological Zones
GCAP	Ghana Commercial Agricultural Project
GHSL	Global Human Settlement Layer
GIS	Geographic Information System
GLSS	Ghana Living Standard Survey
GLSS7	Ghana Living Standard Survey round 7
GNDVI	Green Normalized Difference Vegetation Index
GPS	Global Positioning System
GRAIN	Genetic Resources Action International Network

GRUMP	Global Rural-Urban Mapping
GSS	Ghana Statistical Service
ICOUR	Irrigation Company of Upper Region
ILC	International Land Coalition
ITFC	Integrated Tamale Fruit Company
IWAD	Integrated Water and Agricultural Development
JCR	Joint Research Centre
KIIs	Key Informant Interviews
KIs	Key informants
LSAI	Large-Scale Agricultural Investment
MoFA	Ministry of Food and Agriculture
MSAI	Medium-Scale Agricultural Investment
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared
NPK	Nitrogen, Phosphorus, and Potassium
NRGP	Northern Rural Growth Project
MVP	Multivariate Probit
OLS	Ordinary Least Squares

RAI	Responsible Agricultural Investments
SAPs	Sustainable Agricultural Practices
USGS	United States Geological Survey
VIF	Variance Inflation Factor
WGS84	World Geodetic System 1984

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EXECUTIVE SUMMARY

Following the 2007-08 food, energy/fuel, financial, and climate change crises, most developing countries, witnessed an unprecedented escalation in large-scale acquisition of land by foreigners -foreign direct investment (FDI) in land - for large-scale agricultural investment (LSAI). This generated debate among development practitioners, who raised conflicting views about the implication of LSAI on local occupants. Whereas some highlight the potential benefits of LSAI, others highlight its potential threats to livelihoods, environment and ecological sustainability, ecosystem services, and biodiversity which is critical to people's health and planetary wealth. Such concerns attracted much attention in the empirical literature which examined LSAI and its implications for local occupants. However, the literature is unclear about how LSAI affects biodiversity in Ghana, even though information on the clearing of the vast area for such investment exists in Ghana. Also, much of the empirical literature has not benefited from methods that integrate quantitative and qualitative data to understand the biodiversity implications of LSAI, despite the strength of such methods in providing an in-depth understanding of complex phenomena such as LSAI and biodiversity.

By way of filling the aforementioned gaps, this study examined the effect of LSAI along with the effect of medium-scale agricultural investments (MSAI) on biodiversity in Ghana, using a mixed-method design. Specifically, the multiphase mixed method design was employed in gathering qualitative and quantitative data to (i) identify the processes of acquiring land for MSAI/LSAI, the size and actors involved (ii) examine the effects of LSAI and MSAI on biodiversity implied in species richness, evenness, diversity, EVI and SAVI (iii) analyse the effects of LSAI and MSAI on access to ecosystem services, and (iv) analyse the effects of LSAI and MSAI on biodiversity and ecosystem management practices in Ghana.

In the first phase of the multiphase mixed method design, qualitative data was gathered through key informant interviews with stakeholders selected through the purposive sampling technique. Content analysis was then used to identify key themes concerning the processes of acquiring land for MSAI/LSAI, the size and actors involved, the effects of MSAI and LSAI on biodiversity, ecosystem services, and strategies employed to manage biodiversity and ecosystem services in Ghana. In the second phase, a questionnaire instrument was developed based on the findings from the first phase study. This instrument was then administered in the 2021 cropping season to a sample of 1000 households selected through a multistage sampling technique. The information of a subsample of households from this dataset was combined with their information from a survey conducted in the 2018 cropping season to make a panel. The panel dataset was then augmented with a spatial dataset. Descriptive statistics, non-parametric techniques, and panel regression models were employed on this dataset to examine the effects of MSAI and LSAI on biodiversity, access to ecosystem services, and adoption of biodiversity and ecosystem management practices in northern Ghana. In the third phase, qualitative data was gathered from 140 participants selected through a purposive sampling technique. An interview guide with questions generated from the second phase findings was employed to interview these participants in 10 separate group discussions across 10 communities of the selected districts of northern Ghana. Content analysis was used to analysed the qualitative

responses. The third-phase results were integrated with first and second-phase findings to better explain the LSAI and its implications on biodiversity.

Results from the first phase qualitative study revealed that two main actors are involved in LSAI, namely, domestic and foreign actors and that the scale of land acquired in this category for investment is extremely large. However, processes involved in the acquisition of land on such a large scale for agricultural investment - as mirrored in the way it is described - appear complex and inconsistent to local people and thus, project some traces of inefficiencies in the acquisition process. Further, LSAI had both negative and positive effects on biodiversity, the negative consequences appear to outweigh the positive effects. Regarding the strategies employed to deal with the consequences of LSAI on the different aspects of biodiversity, the study revealed that tree planting and the application of sustainable agricultural practices have been introduced to help improve plant and soil biodiversity.

Regarding the second phase quantitative study. the regression analysis revealed that the effects of MSAI and LSAI on biodiversity, ecosystem services, and adoption of biodiversity and ecosystem management practices vary with model specification. For the effect of MSAI and LSAI on biodiversity, the results showed that increasing the district’s share of farms that are under MSAI (5-50ha) is associated with a decrease in biodiversity while increasing the district’s share of farms that are under LSAI (over 50ha) is associated with increase in biodiversity. The increase in some biodiversity due to LSAI was explained by knowledge possessed by LSAI investors in managing biodiversity in the area. For the effect of MSAI and LSAI on ecosystem services, the results showed that the district’s share of MSAI enhances access to economic trees and forests, while the district’s share of LSAI dissipates households’ chances of accessing forest for hunting and gathering, fuel wood, medicinal plants. The positive effect of MSAI on access to ecosystem services was attributed to existing agrarian relations between medium-scale investors and local farmers. Regarding the effect of MSAI and LSAI on biodiversity and ecosystem management practices, the study revealed that MSAI significantly dissipates the adoption of biodiversity and ecosystem management practices including SAPs, tree planting techniques, and improved seed varieties but LSAI does not. These results were attributed to a missing link between the investment farms and local farmers to share knowledge about the practices.

1 BACKGROUND

Biodiversity - genetic, species, and ecosystem diversity – is critical for agriculture and food security (FAO, 2018). Biodiversity plays a crucial role in influencing various aspects of crop production, livestock management, and overall agricultural resilience. Biodiversity plays a crucial role in agriculture, as it influences various aspects of crop production, livestock management, and overall agricultural resilience (Sumaila et al., 2017). Traditional crops and wild edible plants contribute to food security, especially for communities in remote or marginalized areas. Natural predators and beneficial insects thrive in diverse ecosystems. Thus, maintaining biodiversity in and around agricultural fields can help control pests and diseases and as well reduce the need for synthetic pesticides. Many crops rely on pollinators, such as bees, butterflies, and other insects, to produce fruits and seeds. Without plant species serving as habitat for these insects for sufficient pollination, crop yields will be affected and food security can be severely affected (Millennium Ecosystem Assessment, 2005). Different plant species and microorganisms in the soil improve soil structure, nutrient cycling, and organic matter content, leading to enhanced soil fertility and productivity (Teklewold, Kassie, Shiferaw, et al., 2013). Biodiversity buffer against extreme weather events, such as floods and droughts, and support adaptation to changing climate conditions. Sustainable agriculture practices that promote and maintain biodiversity are essential for building resilient and productive agricultural systems while preserving natural resources and ecosystems (Fletcher, 2021). Thus, biodiversity is central to agricultural transformation and development. This implies any issue concerning biodiversity will affect food security especially in areas that rely on agricultural transformation for development.

One such issue is large-scale agricultural investment (LSAI) (in ranges of 50ha or more) by foreigners. In the wake of the 2007-08 crises, most nations witnessed an upsurge in LSAI in which external governments financed land-based investments to strengthen bilateral trade or produce food and energy for export. This generated mixed concerns among development practitioners. Whereas some highlight the consequences of LSAI on local occupants (e.g., Anseeuw et al., 2012), others view LSAI as a development opportunity (e.g., Deininger et al., 2011). In response, empirical studies investigated LSAI and its implication on local occupants (e.g., Cotula et al., 2014; Schoneveld et al., 2011; Ayelazuno, 2019; etc.). However, as much of the debate sought to highlight LSAI and its implications for livelihoods with specific reference to investment by external governments or transnational corporations, the conversion of natural vegetation by LSAI into large-scale plantations is largely occurring in many developing countries. This is particularly true in Ghana and northern Ghana, in particular, where land with natural vegetation has been transferred on a large scale and converted to large plantations for food (Ayelazuno, 2019b; Kuusaana, 2017) and non-food (Boamah, 2014) crop production. Yet, information on such conversions and as well as the implication of such conversions on biodiversity is rare. In particular, the actors involved, the size of the investments, and their implications on biodiversity are rarely known. Moreover, little is known about the paths through which LSAI affects biodiversity despite the relevance of such information for land use and biodiversity policies. So far, existing studies focused on LSAI and its impacts on livelihoods, loss of water, forest destruction, or animal population with little regard for how LSAI affects species richness, evenness, diversity, and health. Moreover, results concerning the impacts of such investment are mixed and fall outside Ghana. Thus, we do not know whether such outcomes are also applicable in the case of plant species richness, evenness, diversity and health of vegetation in Ghana. Additionally**,** literature on LSAI uses mono-methods, which do not broaden the depth of understanding of complex phenomena such as LSAI and biodiversity.

Building on past studies (Koh & Wilcove, 2008; Mbaya, 2015; Noack et al., 2022) this study analyses LSAI and its impacts on biodiversity in Ghana using multiphase mixed-method design. Specifically, this study seeks to: (i) identify the processes in land acquisition, the size and actors involved in LSAI (ii) analyse the impact of LSAI on species richness, evenness, and diversity and (iii) analyse the implications of LSAI on access to ecosystem services and biodiversity management practices. Such information could be very useful for policy-makers in designing policies that regulate LSAI as trade, and improve the environment and biodiversity in Ghana. The findings will particularly be useful for the community-investor guidelines for large-scale land transactions for the Ghana Commercial Agricultural Project under Ghana's Ministry of Food and Agriculture (Ministry of Food and Agriculture, 2015). Further, there is an existing guideline for large-scale land transactions to minimise speculative acquisitions, protect the interest of local communities and genuine investors and as well as promote better land use and government development policy objectives (Lands Commission, 2016). Findings from the proposed study will provide relevant information for improving these guidelines. It is also argued that the purpose of financing LSAI by the external government is to strengthen trade relationships with host countries in Africa (see for instance, Hules & Singh, 2017). Thus, findings from this study may also help inform policy-makers in designing guidelines for LSAI by foreign governments. This may further strengthen trade ties between Ghana and foreign governments.

2 LITERATURE REVIEW

2.1 Review of Concepts and Measurement

2.1.1 Large-scale agricultural investment

Ideally, the main questions of research in the area of large-scale agricultural investment (LSAI) are the typology, drivers, and impact pathways of LSAI. However, analysis of answers to these questions depends on how LSAI is conceived. This is challenging because insights on the concept vary, and so there is no consensus on its precise meaning. Although studies concerning large-scale agricultural investments (LSAIs) have always been on the rise, there appears to be little hope of reaching any agreement on a common definition of the concept. A careful study of the literature shows that the definition comes from three dimensions. The first is the geographical dimension which places much emphasis on the location of the LSAI or investors' country of origin. A case in point is a report by GRAIN Briefing (2008) which defines LSAI as investments carried out by foreign entities. Another example in line with the definition by GRAIN Briefing (2008) comes from a report by VIVAT International (2015) in which LSAI is descried as investment by transnational corporations, private investors, and foreign governments through sale or lease contracts which sometimes can last for as long as 99 years and are highly detrimental to the interests of the affected communities. Other studies in line with the definitions of LSAI by the GRAIN Briefing (2008) include the FoodFirst Information and Action Network (FIAN International, 2010), Zoomers (2010), and Davis et al. (2014). The Land Matrix also defined it as any intended, completed, or unsuccessful initiative in low- and middle-income nations to acquire land through purchase, lease, or concession (Land Matrix Africa Regional Focal Point, 2020). However, while this definition may be true, it is worth pointing out that such investments are also initiated by domestic investors. As revealed in studies by Jayne et al. (2016) and Jayne et al. (2022), most of these investments – though described in these studies (e.g., Jayne et al., 2016, 2022) as medium-scale investments (i.e., farm investments of 5-100ha) - are carried out by citizens many of whom are successful graduates of small-scale investments (i.e., farm investments of 0-5ha).

The second is the scale dimension of LSAI which places much emphasis on the size of land acquired or capital involved in the investments. A case in point is Cotula et al. (2009) who described LSAI as an investment involving the outright purchase of 1000 hectares or more. Another example is Borras et al. (2012) who argued that LSAI involves significant transactions in two generally separate but related dimensions: the size of the capital invested and the size of the land acquired. On the other hand, Jayne et al. (2016) and Jayne et al. (2019), and Jayne et al. (2022) who further studied this investments category by comparing their data to that of the small-scale and medium-scale investments, argued that the operated land of such investment is over 100 hectares. However, in addition to the heterogeneity of definition, the scale dimension is regardless of any detail such as purpose, investor, or time length and also overlooked the processes engaged in establishing such investments. that are corrupt, non-transparent, non-consultative, and do not lead to compensation of farmers. Other literature in line scale with the scale dimension includes Friends of the Earth (2010), and Twene (2016) among others.

The third, which is known as the process dimension, focuses more on the approaches employed to regulate LSAI, describing LSAI as corrupt non-transparent, or non-consultative based on the principles presented by De Schutter (2009) for LSAI. Such a definition has been adopted by International Land Coalition's Tirana Declaration (ILC, 2011) to describe LSAI as investments that do not only disregard human rights, social, economic, and environmental impacts but are also non-transparent, non-consultative, and not based on a thorough assessment. This view of the concept of LSAI considers a variety of factors including the need to seek the consent of the affected people, respect human rights and consider environmental and social impacts assessment. This is extremely necessary because many conflicts that have arisen from such investments have often revolved around key issues raised. In addition, this definition also seeks to provide a holistic framework or criteria that can be used to justify whether such investments can be regarded as land grabs or not. Borras and Franco (2012) later extended and provided more insights into the process dimension arguing that LSAI involves (i) conversion of forest land or land previously devoted to food production for subsistence or domestic consumption to produce food or biofuels for export; (ii) transnational and driven largely by the Gulf states, Chinese and South Korean governments, and companies; (iii) land deals involving finance capital and partly leading to speculative deals; (iv) deals that are often shady and involve national and local governments; (v) deals which often lead to the displacement of local communities; and (vi) deals which require regulation, whether through the Responsible Agricultural Investments (RAI) or voluntary guidelines advocated by social movements and NGOs. Borras and Franco (2013) also argued that LSAI involves taking over relatively large swaths of land and other natural resources through a variety of methods and forms, carried out through extra-economic coercion involving large-scale capital. This often results in a shift in resource use orientation toward extraction, whether for domestic or international purposes, as capital's response to the convergence of the food, energy, and financial crises, climate change mitigation imperatives, and demands for resources from newer human populations. Based on the scale (e.g., Cotula et al., 2009) and process dimension of the concept of LSLA (De Schutter, 2009; von Braun & Meinzen-dick, 2009), the Lands Commission of Ghana described LSLA as acquisition that covers land area of about 20.23 hectares or more and on the other hand, a land acquisition that covers an area less than 20.23 hectares but triggers social, economic and/or environmental concerns that needs to be safeguarded. Further, such acquisitions must: (i) not violate human rights (ii) be based on free, prior, and informed consent of the affected, (iii) be based on a thorough assessment of social, economic, and environmental impacts (iv) be based on transparent negotiations and (v) be based on consultative planning (Lands Commission, 2016).

Despite the lack of consensus on how LSAI is defined, it is generally accepted that LSAI can involve an investment of significant resources, both financial and technological into land for agricultural activities. This can involve various practices such as industrial agriculture, commercial farming, or agribusiness operations (Anseeuw et al., 2012; Borras & Franco, 2012; Cotula et al., 2009; Deininger et al., 2011; Hall, 2011; Zoomers, 2010).

2.1.2 Approaches to Measurement of LSAI

Following the definitions, three approaches are common in literature for measuring large-scale land acquisition. The first and second approaches involve two distinct levels of self-reported indicators. The first is a binary indicator where an individual, household, or community is directly captured as affected and non-affected by LSAI. This has been employed in several studies (e.g., Jiao et al., 2015; Shete & Rutten, 2015; Aha & Ayitey, 2017; Bottazzi, Crespo, Omar, & Rist, 2018; Mabe et al., 2019). The second approach is similar to the first approach, but further captures the size of land loss by households through LSAI. This approach has been employed by Tuyen (2014). However, one obvious problem concerning the self-reported indicators is that farmers may report being affected, losing land through LSAI or inaccurate size of land loss especially if they detect that they will be compensated for the loss, or decline to report if they detect that providing such information might lead to further loss. Also, this approach fails to detect inaccurate responses as it does not give room for further questions. Further, the approach fails to justify why a particular deal is classified as LSAI. Unlike the first and second approaches, the third approach involves counting the number of deals and has been employed in national or multi-national studies (Arezki, Deininger, & Selod, 2013; Giovannetti & Ticci, 2016; Kareem, 2018; Pardo, 2017; Lay & Nolte, 2018; Santangelo, 2018). The final

approach is the indirect approach which is based on a set of core principles proposed by several researchers and think-tanks (De Schutter, 2009; von Braun & Meinzen-dick, 2009; Borras & Franco, 2012; International Land Coalition, 2012;) for large-scale land acquisitions and leases. In this approach, households are asked a series of qualitative questions regarding land loss by the supposed investors. Then, based on these responses, households are classified as exposed to LSAI and used in a reduced-form regression equation to analyze the household exposure to LSAI and its effects on livelihoods. What is more important in this approach is its recognition of the need to seek the consent of the affected people, respect human rights and consider environmental and social impacts assessment in all land deals. According to Twene (2016), this approach can provide a holistic framework or criteria that can be used to justify whether a land deal can be regarded as a land grab or not.
In this study, because we do not have the list of households and communities exposed to large-scale land acquisitions, we combined the first and final approaches, where the first approach is employed to identify households exposed to acquisitions covering 20.23ha or more whiles the final approach is adopted for further categorization of households into LSAI by domestic and foreign entities and as well as direct and indirect exposure to LSAI by domestic and foreign entities. A detailed methodology for satisfactory measurement is presented in chapter three of this study.

2.1.3 Biodiversity and Ecosystem Services

The terms "biodiversity" and "ecosystem services" are both not only complex but multidimensional. The term "biodiversity" represents the variety of lives on the planet, in a specific ecosystem, or elsewhere (FAO, 2018; Fletcher, 2021). It includes diverse biological, and genetic species, ecosystems, and ecological processes (Cardinale et al., 2012). Ecosystem health depends on biodiversity because it benefits both human society and the natural world in a variety of ways (Dalmazzone, 2008). The three primary parts of biodiversity are as follows. The first is the diversity of species, which describes the various species variety in a region. Both richness and evenness (the relative abundance of various species) of species can be used to quantify species diversity. The variance in genetic qualities within a species is referred to as the second concept, or genetic diversity (Cardinale et al., 2012). Since genetic variety supplies the building blocks for natural selection and evolution, it is important for adaptability to conditions and resilience of unstable environments (Fletcher, 2021). Ecosystem diversity is the third component of biodiversity and refers to the variety of different habitats in a given region. Ecosystem diversity can include forests, grasslands, wetlands, coral reefs, and many other types of habitats (Ibid.). Each ecosystem provides unique ecological services and supports specific assemblages of species (Cardinale et al., 2012; Mace et al., 2012). Biodiversity plays a vital role in maintaining ecosystem health and functioning (Wineman et al., 2022). Biodiversity is responsible for the provisioning services of the ecosystem including the production of food, fuel, fibers, hunting, gathering, and other valuable resources that support human well-being. Biodiversity is also noted for its role in regulating essential ecological processes, including climate regulation, water purification, pollination, pest control, and disease regulation (Wineman et al., 2022). It is also responsible for cultural services including cultural identity, aesthetic value, recreational opportunities, and spiritual significance for many societies. Biodiversity is also responsible for nutrient cycling, soil formation, and habitat creation, which are fundamental for other ecosystem services (Mace et al., 2012; Wineman et al., 2022).
On the other hand, "ecosystem services" refers to the benefits that humans derive from ecosystems (Mace et al., 2012). Most of these services fall into one of four categories. the ecosystem's supporting, regulating, cultural, and providing functions (Mace et al., 2012; Millennium Ecosystem Assessment, 2005). The ecosystem's provisioning services, which include the generation of renewable resources like food, wood, and fresh water, are the first of

these types. The second of these classes in this study is the regulating functions of the ecosystem, which are in charge of reducing environmental change, such as regulating the climate, controlling pests and diseases, etc. The third is cultural service, which is defined to include non-material benefits that support people's growth and cultural advancement. Examples include how ecosystems influence local, national, and international cultures; the development and dissemination of knowledge; creativity sparked by contact with nature; and leisure. The fourth category, referred to as supporting services, includes biological functions like photosynthesis, nitrogen cycling, soil formation, and the water cycle. Provisional, regulating, and cultural services would not exist without supporting services (Millennium Ecosystem Assessment, 2005). These services may also interact to provide the final services as some services may not be the final ecosystem services that provide goods and value to humans (Fletcher, 2021). For instance, it is well-known that the ecosystem provides grown-trees but the ultimate services including furniture may require more inputs on the trees to get it to the furniture required by humans. In the same vein, primary production is necessary for the existence of the maize plant, but flour which is the final good needed by humans may harvesting and preparation to get the flour.

2.1.4 Approaches to measuring biodiversity and ecosystem services

As shown previously, both biodiversity and ecosystem services are multidimensional as each is composed of multiple components. As a result, different methods and metrics have evolved to estimate biodiversity. However, the choice of an indicator depends on the focus of the study of the researcher. If the focus is biodiversity or ecosystem services in general, then assessment and quantification of various components of biological diversity or ecosystem services within a given area or across different ecosystems is necessary. For biodiversity, the first method is species richness which is considered the simple and widely used measure of biodiversity (Gotelli & Colwell, 2001). Species richness refers to the number of species that exist in a particular area or location (Magurran, 2021). The more species there are in an area, the higher the species richness (Magurran, 2004). The second of these methods is species evenness which measures the relative abundance of different species within a community. It also assesses how evenly or unevenly individuals are distributed among the different species present. Higher evenness indicates a more balanced distribution of individuals among species. The third method is the species diversity where various indices including the Shannon-Wiener index and Simpson's diversity index, are used to provide a more comprehensive measure of biodiversity by considering both species richness and evenness. These indices consider both the number of species present and their relative abundance to calculate a diversity value (Magurran, 2004). The fourth of these methods is referred to as genetic diversity which involves analyzing the genetic variation within species. This can be done by examining differences in DNA sequences, and genetic markers, or analyzing specific genetic traits. Genetic diversity provides valuable insights into the adaptability and resilience of populations to environmental changes. The fifth is the ecosystem diversity which represents to the variety of different ecosystems or habitat types within a region. It takes into account the range of ecological communities and interactions present. Ecosystem diversity can be assessed by mapping and categorizing different habitat types or using remote sensing techniques to identify landscape features (Reed, 1990). The sixth method is functional diversity which considers the range of ecological functions and traits that species perform within an ecosystem. It assesses the variety of roles and interactions among organisms, such as their feeding habits, reproductive strategies, and ecological functions. Functional diversity provides insights into ecosystem processes and resilience (Petchey & Gaston, 2006). The seventh is the phylogenetic diversity. Phylogenetic diversity focuses on the evolutionary relationships among species. It measures the amount of unique evolutionary history present in a given area or community. Phylogenetic diversity provides insights into the evolutionary distinctiveness and potential conservation value of different species (Díaz & Cabido, 2001).

Concerning ecosystem services, quantifying and valuing the contributions of ecosystems to human well-being, economic activities, and sustainable development are required. These involve the use of various approaches and methods to assess the benefits that ecosystems provide to humans. These approaches and methods include biophysical assessments, economic valuation, ecological production functions, remote sensing and GIS, surveys and social assessments, integrated assessment models, and composite indicators (Millennium Ecosystem Assessment, 2005; Nelson et al., 2009). The biophysical assessments quantify the physical attributes and functions of ecosystems that contribute to the provision of services. They include measuring parameters such as water quality, soil erosion rates, carbon sequestration, pollination rates, and habitat availability (Potschin-Young et al., 2018). The economic valuation assigns monetary values to ecosystem services to capture their worth in economic terms. These methods can include market-based approaches (e.g., determining the market price of a service) or non-market valuation techniques (e.g., stated preference surveys, contingent valuation, or choice experiments) (Liquete et al., 2015). The ecological production functions estimate the relationship between ecosystem characteristics and the provision of services. They involve quantifying the ecological processes and functions that underpin the production of services, such as carbon fixation, nutrient cycling, or water purification. Further, remote sensing techniques, such as satellite imagery and aerial photography, combined with geographic information systems (GIS), are used to map and assess changes in land cover, vegetation types, and ecosystem extent. This information helps estimate the spatial distribution and changes in ecosystem services. The surveys and social assessments involve gathering information directly from stakeholders and local communities to understand their perceptions, preferences, and reliance on ecosystem services. This qualitative and quantitative data can help assess the cultural, recreational, and social dimensions of ecosystem services. For the integrated assessment models, data from various sources, such as biophysical assessments, economic valuation, and social surveys are combined to estimate the supply, demand, and trade-offs associated with ecosystem services. These models provide a comprehensive framework for evaluating multiple services and their interactions (Grêt-Regamey et al., 2015). Lastly, the composite indicators combine multiple variables or metrics into a single index to summarize and compare the overall state or value of ecosystem services. These indicators often incorporate data from different sources and use weighting methods to account for the relative importance of different services (Millennium Ecosystem Assessment, 2005).

It is, however, important to note that no single metric can fully capture the complexity and dynamics of biodiversity. The choice of methods depends on the specific context and research objectives. Often, a combination of metrics and approaches is recommended to gain a more comprehensive understanding of biodiversity and ecosystem patterns and changes over time (Mace et al., 2012). It is also important to note that some metrics are not deducible with field surveys. As a result, multidisciplinary approaches including filed surveys, remote sensing, and statistical modeling are often combined to estimate biodiversity and benefits that ecosystems provide across different scales and contexts (Colwell & Coddington, 1994).

2.1.5 Biodiversity and Ecosystem Management Practices

Biodiversity and ecosystem management practices are essential to maintain the balance and health of natural systems and the services they provide to humans and the planet as a whole. These practices can be generally grouped into conservation, restoration, and sustainable land use strategies and can be used in isolation or combined to minimize or manage the loss of biodiversity or services provided by the ecosystems. Conservation efforts include implementing strategies to protect endangered and threatened species and establishing protected areas, such as national parks, wildlife sanctuaries, and marine reserves to preserve biodiversity and natural habitats. The restoration efforts include re-establishing native vegetation, reintroducing species, rehabilitation of degraded ecosystems and restoring damaged habitats, and creating suitable conditions for enhancing wildlife to thrive. Sustainable land use involves encouraging sustainable agricultural and forestry practices to minimize the negative impact of human activities on ecosystems and biodiversity. Practices like agroforestry, sustainable logging, and organic farming can promote biodiversity while providing for human needs. Sustainable land use can also involve the implementation of climate change mitigation and adaptation strategies to reduce greenhouse gas emissions and increase resilience to climate impacts to safeguard biodiversity and ecosystems.

2.1.6 Approaches to Measurement of Biodiversity and Ecosystem Management Practices

Biodiversity and ecosystem management practices are generally measured at the farm level through agrobiodiversity management practices - a subset of conservation and sustainable use practices of biodiversity and ecosystem management practices. These agrobiodiversity management practices strategies focused on conserving or sustaining diverse crops, livestock breeds, and traditional farming practices to enhance production systems. These practices include but are not limited to improved and indigenous seed varieties, soil fertility management practices, tree planting, agroforestry, sustainable agricultural practices, conservation practices, etc. To measure these practices some studies (e.g., Abdallah et al., 2023; Deininger & Xia, 2016; Liverpool- et al., 2023) employed binary indicators (i.e., whether or not agrobiodiversity management practices are adopted) in the absence of the actual values of such practices. Others (Pender & Kerr, 1998) employed a continuous variable (i.e., the value of labour time and cash expenses on each plot or size of plot devoted to agrobiodiversity management practices) to measure agrobiodiversity and ecosystem management practices.

Aside from these studies, other studies (e.g., Ma et al., 2017) measured these practices at two stages using binary variables in the first stage and continuous variables in the second stage. Ayamga (2012) in particular argued adoption of these practices exists in two distinct levels: a binary decision to adopt in the first stage and how much to invest in adoption in the second stage. Nonetheless, in this study, agrobiodiversity is measured as a binary indicator since the market for these practices is not well established.

2.2 Biodiversity-Ecosystem Service Relationship

A careful view of the literature revealed that the relationship between biodiversity and ecosystem services is complex and can be viewed from five perspectives that are narrowly different from each other. The first is the ‘ecosystem services perspective’ which equates biodiversity with ecosystem services and thus, argued that improving one will automatically improve the other (de Bourouill, 1895). In this perspective, values of biodiversity that are not based on its functional role in ecosystem processes are not reflected (Mace et al., 2012). The second is the ‘conservation perspective’ which argues that biodiversity itself is an ecosystem service and thus, measures ecosystem services without taking into consideration, the role of biodiversity in these services (Nelson et al., 2009). Rather, the ‘conservation perspective’ mostly focuses on a subset of biodiversity including species (Eigenbrod et al., 2009). The third, which this study refers to as the ‘multilayer perspective’ argued that there is a multilayer relationship between biodiversity and ecosystem services (Mace et al., 2012). In the first instance, biodiversity is considered a regulator of ecosystem processes (Wehn et al., 2018). Isbell et al. (2015), in particular, showed that biodiversity increased ecosystem resistance by stabilizing ecosystem productivity, and productivity-dependent ecosystem service. In the second instance, biodiversity contributes directly to some goods and their values in the ecosystem (UNEP Finance Initiative, 2008). In the third instance, biodiversity itself is considered as a good valued by humans (Cottingham et al., 2001; Mace et al., 2012). However, in all instances, biodiversity is seen as a strong influencer of the ecosystem (UNEP Finance Initiative, 2008). The fourth is the biodiversity science perspective where biodiversity - as noted in the definition of biodiversity - is seen as a broader entity that envelopes ecosystems, and their services along with biological, genetic species, and ecological processes (Cardinale et al., 2012; FAO, 2018; Fletcher, 2021; Millennium Ecosystem Assessment, 2005). Thus, the ecosystem and its services are seen as components of biodiversity, and a range of approaches are developed to support and protect all components of biodiversity.

2.3 Theoretical Review of the Effect of MSAI/LSAI on Biodiversity and Ecosystem Services

Generally, two main views guide studies on the effects of large-scale agricultural investments (LSAI) on the environment and biodiversity in particular. The first view, namely, the neo-colonialism view, argued that the acquisition of land and subsequent clearing to make way for LSAI can impact negatively on the environment and biodiversity including the destruction of forests, soil disturbance, and loss of services provided by the ecosystem. Cotula et al. (2009), in particular, have been very skeptical about the potential of such investment in sustaining soil and water in host communities and thus, highlight the (i) mining impacts of high water and nutrient-demanding crops to be cultivated with such investment; (ii) the pest or disease likely to be associated with production from such investments and (iii) the possible impacts on biodiversity of host communities. The Friends of the Earth (FOE) also warned that such investments can lead to deforestation and loss of habitat, soil degradation, pollution, and depletion of water resources (Friends of the Earth, 2010). The Foodfirst International Action Network (FIAN) also argues LSAI in the form of land deals is seriously threatening land, water, and forest resources (FIAN International, 2017). The view of the GRAIN – an international organization supporting farmers and social groups to gain control of communities and biodiversity – that such investment destroys the environment and biodiversity, and as well leads to pollution is not left out in this argument (GRAIN, 2008).

The second and contrasting view is the development optimism view. Despite acknowledging the potential negative impact of LSAI – as raised by the believers of neo-colonialism view - believers of the development optimism view still support LSAI arguing that such investment could be managed to minimize potential damages and as well benefit investors, host governments, and their populations alike (De Schutter, 2009; FAO et al., 2010; von Braun & Meinzen-dick, 2009). One such follower is De Schutter (2009), the UN Special Rapporteur on the right to food, who presents LSAI impacts through the lens of international human rights law. To the extent that opponents may still not accept LASI, De Schutter (2009) went on to propose some principles that must be followed for LSAI to benefit host States and investors alike. For investments to be beneficial, sustainable, and development-oriented, the Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Conference on Trade and Development, and other partners also developed seven principles that all parties involved should abide by (FAO et al., 2010). Zoomers (2010) also argued that the acquisition of land on a large scale is sometimes driven by the zeal to develop protected areas, ecotourism, and tourist complexes and conserve nature. In line with the development-optimism view, the followers of the land-use and cover change theory (e.g., Hepinstall et al., 2009; Liang et al., 2012; Pereira, 2020) provided valuable insights

into the drivers, processes, and impacts of land use change. While this group of followers acknowledged the potential impacts of land-use change on environmental systems including ecosystem services, biodiversity, and water resources, they also effective policies, governance, and land regulatory mechanisms can help steer land-use toward the conservation of environmental systems. Yet the principles, policies, governance, and land regulatory mechanisms soften the stands of opposers and intrusive intervention by the government, thereby making it possible for more investments (Borras & Franco, 2010). Cotula (2013), in particular, argued -through the lens of Polanyi's Great Transformation - that the law considers the land as a commercial asset and thus, facilitates MSAI/LSAI by investors. Another existing way of managing the negative land use changes that are consistent with the development-optimism view is the Driver-Pressure-State-Impact-Response (DPSIR) framework. The DPSIR framework (Brøgger-Jensen et al., 2018; Carr et al., 2007; EEA, 1999; Maxim et al., 2009) acknowledges consequences of environmental changes - as driven by demographic changes, economic activities, technological advancements, cultural and social factors, and policy decisions - on ecological and environmental indicators such as air and water quality, biodiversity levels, habitat degradation, climate change impacts, and ecosystem functioning. However, the framework also argues that the environmental issues identified can be address with policy measures, regulations and other initiatives.
Thus, generally, there is no consensus about the exact relationship between LSAI, biodiversity, and ecosystem services. Whereas LSAI is believed to have positive impacts by proponents, the opponents rather argued that LSAI can bring about negative impacts on the environmental systems including biodiversity and ecosystem services.

2.4 Theories on the Effect of LSAI on Biodiversity and Ecosystem Management Practices

Traditionally, the explanation of effect of LSAI on biodiversity and ecosystem management strategies can be traced to studies on the theoretical explanations of the spillover effects of Foreign Direct Investments (FDI) (e.g., Adenaeuer & Heckelei, 2011; Blomstrom et al., 1994; Blomström & Persson, 1983; Blomström & Sjöholm, 1999; Borensztein et al., 1998; Globerman, 1975b, 1975a, 1979; Santangelo, 2018; etc.). These studies view LSAI as FDI-related activity mostly carried out by foreign entities and thus, argued that foreign entities are superior in terms of technologies, experience, and knowledge. Within this context, these studies further argued that FDI and related activities by these entities can increase learning opportunities and enhance the knowledge of local firms and, as a result, contribute to the transfer of technologies to local firms. However, the focus of these studies is mostly the spillover effects from developed to host/developing country and foreign firm/industry to local firm/industry. Thus, in theory, the micro-level explanation of the effect of LSAI on biodiversity and ecosystem management strategies is missing in literature (i.e., to the best of our knowledge). The micro-level studies about the impact of LSAI on biodiversity and ecosystem management practices can only be deduced from studies that examined spillover effects or farmers' modernization efforts due to proceeds from MSAI/LSAI.

One of the central propositions of these studies is that the presence and high concentration of MSAI/LSAI can enhance smallholder access to agrobiodiversity management practices including improved inputs and new technologies thereby improving investment among smallholder farmers. Among these scholars is Dessy et al. (2012) who developed an occupational choice model to examine the mechanisms through which Foreign Direct Investments in Africa's Farmlands affect peasant welfare. In this model**,** Dessy et al. (2012) showed that if proceeds received from foreigners for LSAI by local authorities are invested in subsidizing the cost of inputs, investment in technologies will be improved among local farmers since these technologies will now be affordable to the local farmers. Based on Dessy et al. 's (2012) model, Kleemann, and Thiele (2015) also developed a theoretical model to study the mechanisms through which LSAI might affect rural populations in Sub-Saharan Africa. Again, the hypothesis of Dessy et al. (2012) on the effect of LSAI on households' investment in agrobiodiversity management practices was reinforced in Kleemann and Thiele's (2015) study. Liverpool- et al. (2023) extended the models of spatial knowledge spillovers to include MSAI. In the extended model, the effect of MSAI is implied in the effect of the presence of interaction through training received and purchase of inputs from MSAI. Based on this setup, Liverpool- et al. (2023) showed that the effect of interacting with a medium-scale farm on the small farm's input and output is mediated by how the interaction affects input costs and knowledge transfer.

2.5 Empirical Reviews

2.5.1 Effect of Large-Scale Agricultural Investment on Biodiversity

Although several empirical studies exist on LSAI (e.g., Chamberlin & Jayne, 2020; Davis et al., 2014; Jayne et al., 2019; Jayne et al., 2014, 2016, 2022; Kareem, 2018b; Kleemann & Thiele, 2015; Yengoh & Armah, 2015; Yengoh & Armah, 2014; etc.), studies on the relationship between LSAI and biodiversity is scanty in the empirical literature. This is despite the different views about the potential impact of such investments on the environment and biodiversity in particular (see for example, Cotula et al., 2009; De Schutter, 2009; FAO et al., 2010; FIAN International, 2017; Friends of the Earth, 2010; GRAIN, 2008; von Braun & Meinzen-dick, 2009; etc.). Moreover, the few studies on the relationship between LSAI and biodiversity did not focus much on how LSAI is explicitly related to plant species richness, evenness, diversity, and health.

In Brazil, Morton et al. (2006), for instance, studied whether LSAI, implied in cropland expansion, changes deforestation dynamics. Although the results revealed a new paradigm of forest loss with a growing conversion of forest to cropland, little can be said about the richness, evenness, diversity, and health of the species destroyed. Using land-cover data and bird and butterfly diversity data from the United Nations Food and Agriculture Organization, Koh and Wilcove (2008) also focused on the effect of large-scale oil palm plantation agriculture forest. The results suggest that 55%–59% of oil palm expansion in Malaysia, and at least 56% of that in Indonesia occurred at the expense of forests. Further, the results revealed that the conversion of either primary or secondary forests to oil palm may result in significant biodiversity losses, whereas the conversion of pre-existing cropland to oil palm results in fewer losses. In Cambodia, Davis et al. (2015) quantify the impact of LSAI on forest official records of concession locations and a high-resolution data set of forest cover between 2000 and 2012. The results from covariate matching showed that the annual rate of forest loss ranged from 29% to 105% higher than in areas with no concessions. Based on data from the World Bank, Land Portal, and FAOSTAT, Balehegn (2015) also studied the ecological consequences of LSAI in Sub-Saharan Africa, conceptualizing and highlighting only the potential effect of LSAI on habitat, biodiversity, and environmental degradation, among others. In Ethiopia, Ango (2018) studied the livelihoods and forest conservation impacts of medium-scale forestland grabbing suing data from interviews, discussions, and document review. The results indicate that the state transfer of forestland to investors for coffee production led to the loss of access to the forest. Meanwhile, a cross-country analysis by Zaehringer et al. (2021) on the consequences of LSAI for small-scale farmers and the environment shows that LSAIs contributed both directly and indirectly to deforestation in Mozambique, changes in small-scale farmers' agricultural land management in Kenya, and loss of access to grazing land in Madagascar. The results of Zaehringer et al. (2021) come after earlier evaluations by Carlson et al. (2012) in Indonesia where LSAI was found to facilitate the loss of 27% of forest cover, deforestation of 40% of peatland, 4% decline in intact forest cover, and 38% increase in carbon emissions from peatlands.

With the help of bird diversity data combined with land cover data, Noack et al. (2022) examined the mechanisms through which LSAI - as implied in farm size - affects biodiversity in Germany. The results indicate that the LSAI reduces bird diversity by 15% and that the decline is the result of land cover reduction. Using georeferenced data on locations of LSAI across 40 countries, Davis et al. (2023) also studied the extent to which LSAI affect forest and biodiversity across different ecosystems. The results revealed that forest cover decreased and deforestation varied between Africa and Asia due to LSAI. The results further revealed that biodiversity - as implied in relative species richness and evenness - will likely experience substantial losses due to LSAI. Nonetheless, the results of Noack et al. (2022) focused on bird diversity, and the results of Davis et al. (2023) on species richness and evenness focused on vertebrates and hence, not applicable to plant species. The study by Clough et al. (2020) also falls in the context of investment-biodiversity nexus. However, the focus of this study is on smaller field sizes. Other related studies are summarized in Table 2.1. However, the focus of these studies is not on plant species richness, evenness, diversity, and health.

Table 2.1: Studies on the impact of LSAI on biodiversity

Author (s)	Research definition	Study context	Indicators	Data type	Analytical framework	Observed impact of infrastructure
Meyfroidt et al. (2014)	Multiple pathways of commodity crop expansion in tropical forest landscapes	Multicountry case studies	Forestland	Case studies	Comparative analysis	Decrease in forest land
Ordway et al. (2017)	Deforestation risk due to commodity crop expansion in sub-Saharan Africa	sub-Saharan Africa	Deforestation risk	FAOSTAT data	Comparative analysis with Hierarchical and k-means clustering	Increasing pressure on tropical forests, Land-use changes
Ordway (2018)	Commodity Crop Expansion Pathways and Impacts in Tropical Forest Regions of Africa and Asia	Sub-Saharan Africa and Asia	Deforestation and ecosystem	Farmer surveys, and remote sensing data	Spatial and econometrics analysis	Increasing pressure on tropical forests, change forest structure and foliar characteristics, and shift in net ecosystem processes
Zaehringer et al. (2018)	Large-scale agricultural investments trigger direct and indirect land use change: New evidence from the Nacala corridor, Mozambique	Mozambique	Deforestation	Cross-sectional and Georeferenced/ spatial data	Descriptive statistics and remote sensing analyses	deforestation both directly and indirectly
Zaehringer, et al. (2018)	How do large-scale agricultural investments affect land use and the environment on the western slopes of Mount Kenya? Empirical evidence based on small-scale farmers' perceptions and remote sensing	Kenya	land use and the environment	Cross-sectional and Georeferenced/ spatial data	Descriptive statistics and remote sensing analyses	Increasing air pollution associated with agrochemicals sprayed
Dang et al. (2019)	An analysis of the spatial association between deforestation	Africa, Asia, and the Americas	Forest	Georeferenced/ spatial data	Linear mixed-effects models	Increasing forest loss

	and agricultural field sizes in the tropics and subtropics				and bootstrapping	
Rulli et al., (2019)	Interdependencies and telecoupling of oil palm expansion at the expense of Indonesian rainforest	Indonesia	Forest and fragmentation, CO_2 emissions, and freshwater pollution	Georeferenced/ spatial data	Remote sensing analyses	Decreased forest cover, increased forest fragmentation, CO_2 emissions, water scarcity, and pollution
Chiarelli et al. (2020)	Hydrological consequences of natural rubber plantations in Southeast Asia	Southeast Asia	Land use patterns and water resources	Georeferenced/ spatial data	Hydrological model and remote sensing analyses	increasing water scarcity, and green water consumption
Davis et al. (2020)	Tropical forest loss enhanced by large-scale land acquisitions	Multicountry	Tropical forest loss	Georeferenced/ spatial data	Remote sensing analyses	enhanced forest loss
Magliocca et al. (2020)	Direct and indirect land-use change caused by large-scale land acquisitions in Cambodia	Cambodia	Forest	Georeferenced/ spatial data	Remote sensing analyses	Decreased in total forest cover
Oberlack et al. (2021)	Why do large-scale agricultural investments induce different socio-economic, food security, and environmental impacts? Evidence from Kenya, Madagascar, and Mozambique	Kenya, Madagascar, and Mozambique	Environment	Household surveys, business model surveys, key informant interviews, and secondary data	Life-cycle assessments of farm production, analysis of remote-sensing data, and document analysis	Adverse to moderate impacts on the environment

Ahmed et al. (2022)	Land-Use Change Depletes Quantity and Quality of Soil Organic Matter Fractions in Ethiopian Highlands	Ethiopian	Soil Organic Matter Fractions	Field Experiment with soil samples	Acid hydrolysis technique	loss of carbon stock, depletion of Nitrogen stock
Chiarelli et al. (2022)	Competition for water induced by transnational land acquisitions for agriculture	Multicountry	Water scarcity	Agricultural statistics, and georeferenced data	Process-based crop and hydrological modeling	Exacerbated blue water scarcity
Wineman et al. (2022)	The Relationship Between Medium- Scale Farms and Deforestation in Sub-Saharan Africa: A Concept Note	Sub-Saharan Africa	Deforestation	Review	Descriptive statistics	forestland varies by type of investment

Source: Author’s illustration, 2022.

2.5.2 Effect of Large-Scale Agricultural Investment on Ecosystem Services

The impact of LSAI on ecosystem services has not been explicitly examined but can be inferred from the literature on LSAI. For instance, one of the explanations put forward by proponents for supporting LSAI is that there is abundant and underutilized land in some areas - especially in the global south - which can be utilized to close the potential and realized yield gap and as well as meet the food demands of the growing population in developing countries. The World Bank, in particular, estimated that out of the 446 million hectares of global land identified as suitable for cropping but unutilized, sub-Saharan Africa's share is represented by 46% - the highest compared to Latin America and the Caribbean (27.7%), Eastern Europe and Central Asia (11.8%), East and South Asia (3.2%), Middle East and North Africa (0.7%), and Rest of world (11.4%) (World Bank, 2010). These estimates are not only information about the location of land waiting for cultivation but the impetus for investors. According to the GRAIN database concluded land deals under LSAI ranged from 3 to 126 in Africa (GRAIN, 2016). However, what investors in such deals ignored is that the areas identified as 'unutilized' provide ecosystem services by serving as natural habitats and grazing land for some animals, allowing natural replenishment and regeneration of soil or land used for picking shea nuts, hunting, and gathering. In the northern part of Ghana, for instance, the land is naturally decorated with economic trees including acacia (*Acacia* species), mango (Mangifera *indica*), baobab (Adansonia *digitata*), shea (Vitellaria *paradoxa*), dawadawa (Parkia *biglobosa*), and neem (Azadirachta *indica*) (Abdallah et al., 2022). Land with these trees may not be used for cultivation but serve as a natural habitat for birds, insects, and soil micro-organisms or utilized by women in several ways including gathering shea nuts, mango fruits, and fuel wood for charcoal production (ActionAid International, 2009). Thus, even though no known empirical record exists for the explicit impact of LSAI on such services, the devastating implications for inhabitants are inevitable as the aforementioned ecosystem services are often lost through the conversion of land for LSAI. Donald (2004), for example, reviewed published and unpublished scientific evidence to assess the environmental implications of the production of agricultural commodities including cocoa and coffee. The study acknowledged the negative effects of such investments but also argued that production systems of such investment maintain soil structure, provide medicine, food and wood, enhance carbon sequestration, structural and biotic diversity, native flora and fauna, pollination and the biological control of pests and diseases.

2.5.3 Effect of Large-Scale Agricultural Investment on Biodiversity Management Practices

The literature on the impact of LSAI on biodiversity management practices has not been straightforward and can be inferred from studies on the impact of such LSAI on agrobiodiversity management practices. Using meta-analysis, Rudel et al. (2009), for example, revealed that ecosystems are less manageable under LSAI as compared to small-scale investment. Based on literature (e.g., Lin et al., 2011; Rudel et al., 2009), Balehegn (2015) argued that such investments are less efficient when it comes to using ecologically based methods for agricultural production, especially, when compared to small-scale investments but rather used more chemicals and hence causes pollution and other adverse effects on the environment.

In Mozambique, Deininger and Xia (2016) quantified the spillover effects of large land-based investments. The results showed positive short-term effects of LSAI on investment in agricultural practices including rotation, intercropping, improved seeds, fertilizer, and pesticides. A similar study was conducted by Ali et al. (2019) in Ethiopia but the results suggest that LSAI provided only modest benefits in terms of technology adoption. Meanwhile, in the southwestern highlands of Ethiopia, Ango (2018) investigated the impacts of investment in forestland on local livelihoods and forest conservation. The results indicate that the state transfer of part of the forestland to investors for coffee production disrupted conservation efforts by farmers.

Zaehringer et al. (2021) also assessed how LSAI influences land use, land management, and tree cover in Kenya, Mozambique, and Madagascar. The results revealed that farmers change their management of land with seed varieties, tillage, and irrigation due to LSAI.

Using information from 664 households in Ghana, Abdallah et al. (2023) study examined the relationship between LSAI and agrobiodiversity management practices including intercropping with nitrogen-fixing crops, minimum tillage, residue retention, NKP, Sulphate of Ammonia, and Urea. Their results show LSAI discourages the adoption of some of the practices.

Using Nigeria as a case study, Liverpool- et al. (2023) examine the spillover effects of MSAI on small farms, with a particular focus on the effect of training received and purchase of inputs from MSAI. Of particular interest to this study is the effect of training and purchases on the use of modern inputs. Specifically, the results showed that training from MSAI tends to increase the use of fertilizer, cereal, and cash crops seeds. The results also show that purchasing inputs from MSAI reduces the costs of accessing modern inputs but increases inorganic fertilizer use among small farms in Nigeria.

2.6 Limitations/gaps in the literature

From the ongoing discussions above, three issues are revealed as limitations and or gaps in the literature. First, existing studies have only looked at the impact of LSAI on biodiversity implied in loss of water, forest destruction, or animal population with little regard for how LSAI affects biodiversity implied in plant species richness, evenness, diversity, and health implied in vegetation indices. Moreover, the past studies either employed available remote sensing GIS spatial datasets or views of household respondents in examining the impact of LSAI on biodiversity. Meanwhile, combining households' responses with remote sensing Geographic Information System (GIS) spatial dataset can allow examination of the impact of LSAI on biodiversity with more precision and as well check for robustness. A similar gap exists for the effect of LSAI on ecosystem services implied in the use of land for livestock grazing, fallowing, picking shea nuts, and hunting and gathering. Second, when compared to other disciplines, there is a dearth of literature examining the effects of LSAI on biodiversity and ecosystem services in Ghana using a multiphase mixed-method design. The use of multiphase mixed methods research design can broaden the depth of understanding of complex and multidimensional phenomena such as LSAI and biodiversity. Yet past studies that examined the impact of LSAI on biodiversity used mono-methods.

Other gaps include an empirical strategy for analyzing the impact of LSAI on biodiversity. For instance, other factors - rather than LSAI - may affect biodiversity indicators. This is particularly true for medium-scale agricultural investment (hereinafter MSAI). The agricultural expansion reflected in smallholder expansion into MSAI - mostly owned by members of local rural communities, rural and urban duelers (Jayne et al., 2014, 2016) - has also been noted as a significant driver of deforestation (Jayne et al., 2019; Wineman et al., 2022). Therefore, omitting MSAI in the model for estimating the effect of LSAI on biodiversity and ecosystem services will have serious consequences for our results as the estimations will be inconsistent. Yet past studies did not focus on solving such a problem.

In the following sections, we develop a conceptual framework depicting the major channels through which LSAI is linked to biodiversity and ecosystem services and management practices based on the literature reviewed. We also present a framework of the multiphase mixed methods research design, and estimation strategies.

2.7 Conceptual framework

Our conceptual argument is that both biodiversity and ecosystem services (box 5) are influenced by biodiversity and ecosystem management practices (boxes 3 and 4), LSAI (box 2), and its drivers (box 1). As established in the literature reviewed, LSAI can involve investment in land on a large scale to establish industrial agriculture, commercial farming, or agribusiness operations (Anseeuw et al., 2012; Borras & Franco, 2012; Cotula et al., 2009; Deininger et al., 2011; Hall, 2011; Zoomers, 2010). This can have implications for biodiversity and ecosystem services. For instance, the followers of the neocolonialism narrative have hypothesized that LSAI (box 2) can involve conversion of forest land, land clearing**,** deforestation**,** habitat fragmentation**,** introduction of monoculture crops**,** removal of vegetation**,** agrochemicals use and intensive agricultural practices (box 3), thereby destroying the biodiversity and ecosystem services. The introduction of agrochemicals including pesticides, and fertilizer can impact negatively on less competitive plant and animal species, thereby reducing biodiversity (Geiger et al., 2010; Noack et al., 2022). Hautier et al. (2014), for example, showed that the use of fertilizers is not only a threat to grassland biodiversity but also to the ecosystem. If this argument holds, then our key proposition is that households or locations with MSAI or LSAI will exhibit a decline in biodiversity and ecosystem services as compared to areas without MSAI or LSAI. But LSAI can also involve industrial agriculture, commercial farming, or agribusiness operations (Anseeuw et al., 2012; Borras & Franco, 2012; Cotula et al., 2009; Deininger et al., 2011; Hall, 2011; Zoomers, 2010) involving land-use planning, irrigation methods, conservation measures, agroforestry approaches, agroecological approaches, sustainable agriculture, urban planning, land-use zoning (box 4). These activities may also be conducted in reaction to the detected consequences or to stop or lessen the negative impact on biodiversity and ecosystem services as depicted in the DPSIR framework (Carr et al., 2007; EEA, 1999; Maxim et al., 2009) and land-use change theory (e.g., Hepinstall et al., 2009; Liang et al., 2012; Pereira, 2020). Thus, LSAI (box 2) can have either positive or negative impacts on biodiversity and ecosystem services (box 5) through boxes [3] and [4] as recognized in Figure 2.1. However, the effect of LASI on the delivery services provided by the ecosystem will depend on its effect on biodiversity since ecosystem health depends on biodiversity (Cardinale et al., 2012; Cottingham et al., 2001; FAO, 2018; Fletcher, 2021; Mace et al., 2012; UNEP Finance Initiative, 2008). These ambiguous effects of LSAI on biodiversity and ecosystem services make it an empirical issue that is worth investigating.

But it must also be noted that the occurrence of economic activity like LSAI is not without drivers. These drivers can include medium-scale agricultural investments (MSAI), population increase, urbanization, industrialization, food production, agricultural expansion, consumer patterns, political choices, and cultural values as shown in box [1] of Figure 2.1. For instance, medium-scale agricultural investments (MSAI) sometimes fuel the surge in LSAI where medium-scale domestic investors offer their services to large-scale foreign investors or acquire land to partner with large-scale foreign investors (Anseeuw et al., 2012). The link between these drivers and LSAI is shown by a loop from box [1] to box [2] in Figure 2.1. Such drivers align with drivers of land-use change and human behaviour discussed, respectively, in the land-use change theory (e.g., Hepinstall et al., 2009; Liang et al., 2012; Pereira, 2020) and DPSIR framework (Brøgger-Jensen et al., 2018; EEA, 1999). But some of the drivers of LSAI may also influence management practices adopted within LSAI and can promote biodiversity conservation and enhance the provision of ecosystem services. For instance, the role of the population in input use intensification, especially fertilizer, has been shown in previous studies (e.g., Muyanga & Jayne, 2014). Further, much as food production and agricultural expansion influence LSAI, they also influence irrigation methods, conservation measures, agroforestry and agroecological approaches, sustainable agricultural practices, removal of vegetation, deforestation, and introduction of monoculture crops (Balehegn, 2015; Laurance et al., 2014).

Some of these drivers also influence biodiversity and ecosystem services. (Davis et al., 2020, 2023; Laurance et al., 2014). Thus, biodiversity, ecosystem services, and management practices are also influenced by the drivers of LSAI as depicted by an arrow from the box [1] to [3], [4], and [5] in Figure 2.1. However, previous studies examining the relationship between LSAI, biodiversity, ecosystem services, and management practices, rarely address these complex relationships between LSAI, biodiversity, ecosystem services, and management practices by the drivers of LSAI discussed here.

We employ this conceptual framework to gain a better understanding of the complex relationships between LSAI, biodiversity, and ecosystem services. In the next sections, we present the methods that help to explore the relationships between LSAI, biodiversity, and ecosystem services.

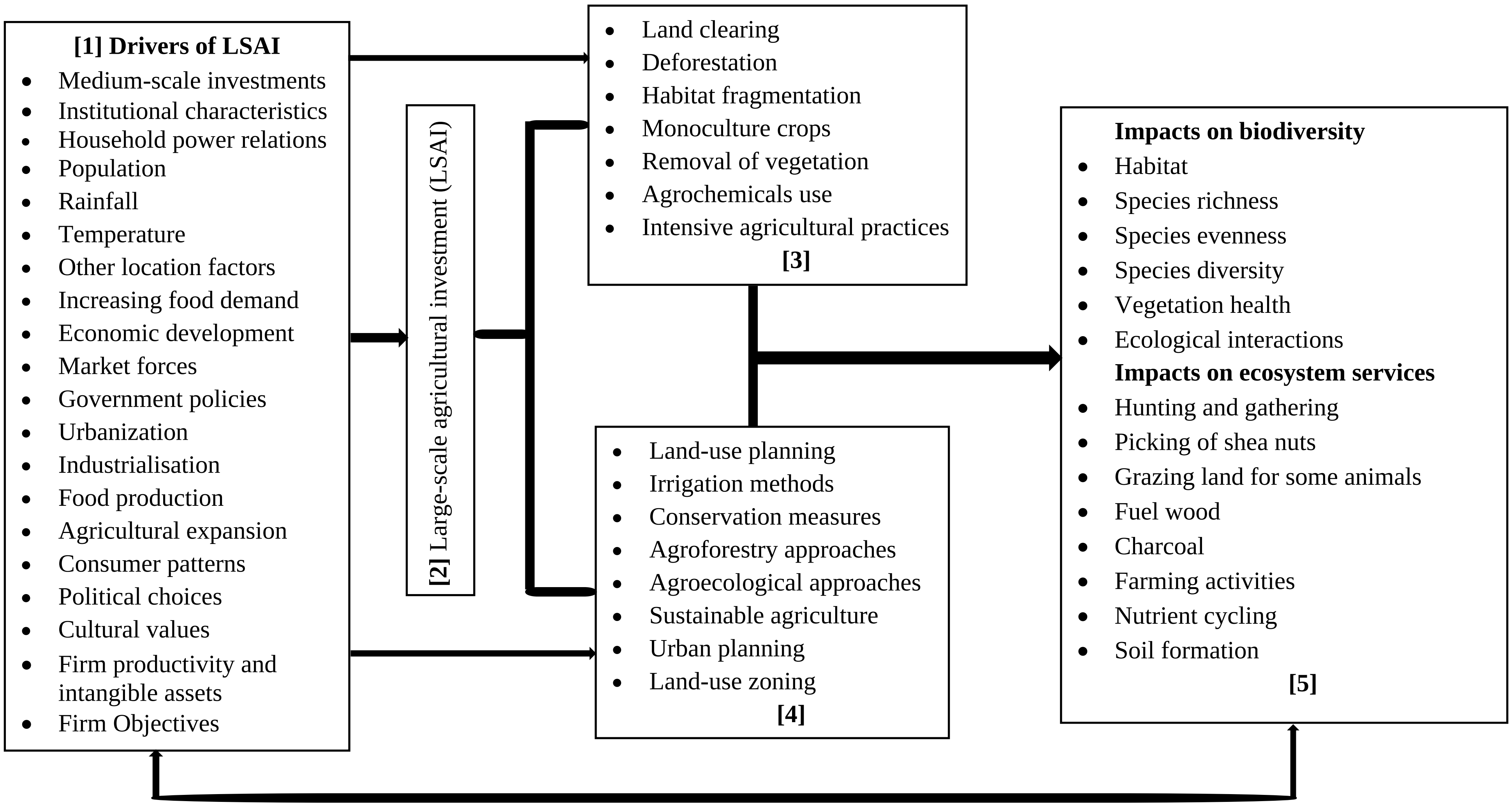


Figure 2.1: Conceptual Framework Linking LSAI to Biodiversity, Ecosystem, and Management Practices

Source: Author's conceptualization based on literature.

3. RESEARCH METHODOLOGY

3.1 Study Area

Northern Ghana refers to the northernmost part of the West African country of Ghana. It is composed of five regions: Northern Region, North East Region, Savannah Region, Upper East Region, and Upper West Region. Each region is subdivided into districts: 16 districts in the Northern Region, 6 districts each in the North East and Savannah Regions, 15 districts in the Upper East Region, and 11 districts in the Upper West Region. Each of the districts is further divided into several communities characterized by a distinct cultural landscape compared to those in the southern regions of Ghana. Geographically, Northern Ghana is located closer to the Sahel region, which influences its climate, vegetation, and agricultural practices. The region experiences a drier and hotter climate compared to the southern parts of the country, with a shorter rainy season and higher vulnerability to droughts.

The population of Northern Ghana is 5,825,919 people and consists primarily of different ethnic groups including Dagombas, Mamprusi, Gonjas, and Gurunsi, among others (Ghana Statistical Service, 2021). But land area including potential arable crop land is 97,700 square kilometers (MoFA, 2019) and thus, less dense. The major crops cultivated include millet, sorghum, maize, yam, and groundnuts (Ghana Statistical Service, 2020).

Despite its agricultural potential, Northern Ghana faces various development challenges. Poverty rates are generally higher compared to the southern regions, and access to basic infrastructure, healthcare, and education can be limited. The region also experiences food insecurity and periodic droughts, which can affect agricultural productivity and livelihoods (Ghana Statistical Service, 2014). Efforts are being made to address the development challenges in Northern Ghana. One such effort is large-scale agricultural investments promoted by the government and other stakeholders.

Large-scale agricultural investment in northern Ghana has been gaining attention in recent years because the area is assumed to abound with available cropland with a small population density. Investors, both domestic and foreign, have shown interest in acquiring land and establishing commercial agricultural operations in the region (Abdallah et al., 2022, 2023; Cotula et al., 2014). Between 2000 and 2019, concluded land deals in Ghana, including northern Ghana, grew from less than 5 to over 40 land deals with a cumulative land size ranging from less than 50,000 hectares to over 350,000 hectares (Land Matrix Africa Regional Focal Point, 2020). These investments aim to boost agricultural productivity, increase food production, create employment opportunities, and contribute to economic development. However, there are several considerations and challenges associated with large-scale agricultural investment in Northern Ghana. First, large-scale agricultural investments often involve acquiring large tracts of land, which can impact local communities and traditional land tenure systems (see for example, Cotula et al., 2009; De Schutter, 2009; FAO et al., 2010; FIAN International, 2017; Friends of the Earth, 2010; GRAIN, 2008; von Braun & Meinzen-dick, 2009; etc.). Second, while large-scale agricultural investments have the potential to create employment opportunities and stimulate economic growth, they can also have significant and complex relationships with the environment including biodiversity. The purpose of this study is to investigate the implication of LSAI on biodiversity using a multiphase mix method design.

3.2 Research Design

LSAI and biodiversity are difficult to study because the information provided can sometimes be scattered and difficult to understand. Given this caveat, the study employed a multiphase mixed-method design which involves an iteration of connected quantitative and qualitative phases sequentially aligned to address a set of research questions leading to the overall objective of the study. Thus, both qualitative and quantitative data were gathered from primary and secondary sources. The secondary data was obtained from the Ghana Statistical Service

(GSS), the United States Geological Survey (USGS) and NASA Landsat images, the WorldClim, the Global Rural-Urban Mapping (GRUMP), the Ministry of Food and Agriculture (MoFA), Lands Commission and Forestry Commission of Tamale - the lead agencies respectively in charge of food production, land registration, and forest conservation in northern Ghana - to help facilitate the attainment of the study objectives. The primary data was obtained from the first phase qualitative, second phase quantitative, and third phase qualitative study. These phases are explained in the following sections.

3.2.1 First Phase Qualitative Study

In the first phase, key informants with specialist knowledge of LSAI and plant biodiversity were interviewed. The informants included officials from MoFA, the regional Lands Commission and Forestry Commission, Ghana Commercial Agricultural Project (GCAP), traditional authorities, farmer leaders, Northern Rural Growth Project and Savannah Accelerated Development, and investors in LSAI. The purpose of the first phase of key informant interviews was to provide in-depth information on the context studied and as well identify elements for the development of instruments for the second phase of the quantitative survey. Ideally, the initial plan was to develop an interview guide for each of the key informants (KIs) including farmer leaders, chiefs, and elders; government officials including officials from Ghana's Ministry of Food and Agriculture, Land Commission, local government, Ghana Commercial Agriculture Project, Northern Rural Growth Project and Savannah Accelerated Development, and investors in LSAI. This was to be administered by the principal investigator (PI) and trained research assistants including the Co-researcher. However, the responses and preliminary analysis from our pretest revealed that our initial approach will not only introduce interviewer bias but may not also ease the triangulation of responses. As a result, the same interview guide - with a common set of guiding questions on perceptions of respondents about LSAI, actors, drivers, size of LSAI, biodiversity, and management practices, as well as the effect of LSAI on biodiversity - was developed, and administered to the KIs. Also, the interview guide included questions on changes in plant biodiversity (i.e., type of plants, variety of plants and species, diversification, access to ecosystem services of biodiversity, and adoption of biodiversity conservation or management practices). It is worth mentioning, here, that biodiversity includes plants and animals' life, their genetics, species, and ecosystem diversity. However, questions in the interview guide focused on plant species for two reasons. First, plants are directly affected by LSAI. Second, animals and other living organisms depend on plants for habitat and disappeared along with the loss of habitat. As a result, the interview guide contained general qualitative questions on changes in plants, types of plants and species, forests, access to provisioning services of the ecosystem, and conservation and management practices employed to maintain or respond to such changes. Also, question about how local people, government, and other institutions respond to changes in plants, types of plants and species, forest, etc., after LSAI in the area were asked. Analysis of these questions was help to generate insights into plants, types of plants, and species affected by LSAI in the area. Thus, at this phase, the focus was to reveal the plants affected by LSAI and how this can be generalized in a second phase quantitative survey where biodiversity indicators of such plants will be generated and their condition/situation under LSAI, assessed. The interview guide was administered in 2020/2021 cropping season to 60 KIs selected across the Northern, North East, Savannah, Upper East, and Upper West regions. These KIs were carefully selected based on their experience and special knowledge of LSAI and biodiversity. The KIs were recruited with the help of MoFA agents in contact with people of experienced and knowledge of LSAI and biodiversity. After the selection of the interview sample, phone contacts were made to respondents. In the phone conversation, and invitation letters sent, I introduced myself as a Researcher from University for Development Studies who had no affiliations with NGOs or government agencies. I also mentioned the research on the status of the impact of LSAI on biodiversity and other livelihoods, citing instances where LSAI has been very helpful in improving the biodiversity and livelihood in some areas in Ghana and the need to document how such investment can benefit local communities and biodiversity. This was to avoid suspicion and downplay gestures or actions that may raise suspicion.

Because I worked with a schedule, travel, and dates for the interviews were chosen in line with our timelines. Acceptance of invitations through phone calls was subsequently followed with formal letters of invitation (Please see attached for consideration). Most of the participants (50 of the 60 participants) accepted both phone calls and formal invitations with the scheduled dates. The rest of the initial sample (10) declined to participate in the interview, citing legal issues surrounding LSAI and fear of providing information that will subsequently lead to lawsuits. Efforts to convince them to participate turn out futile. To make up for the 60 KIs, I had to fall back on the MoFA agents who again helped in replacing those who declined. Similar contacts were made with the newly selected participants but dates for the interviews were scheduled to come after interviews with the 50 KIs who accepted earlier. Once the sample was ready, travels/visits to various communities began.

Ideally, I was completely an outsider in some of the study areas, especially, communities in Savannah, North East, Upper East, and Upper West. The characteristics of these communities including language, land tenure and use pattern, and cultural constructions appear completely different from that of the Northern region where I lived. My knowledge about these communities was based on second-hand information from news broadcasts and hearsay. As a result, I made a formal entry in each community where a KI was to be interviewed. The community entry involved formal contact with the assemblymen of each community. To familiarize myself and the work with the assemblymen, I showed each an introductory letter from the University for Development Studies confirming that I am a Lecturer and a Researcher at the University, conducting a study on the implication of LSAI on biodiversity in Northern Ghana including Northern, Savannah, North East, Upper East, and Upper West regions. One common issue I noticed is that each of the assemblymen not only becomes less suspicious after reading the letter but begins to open up, trying to find out how he/she might be of help. In all circumstances, I tell them of how I needed formal acceptance from chiefs to conduct interviews. Once, there is acceptance, I start interviews. There was no instance of rejection of my request to conduct interviews in any community. Thus, all interviews were conducted with the prior approval of the chiefs of the participants considered.

After community entry, interviews started using the interview guide developed previously. The interview guide was administered to the 60 selected KIs. It is worth noting that more than half (46) of the 60 participants had previously taken surveys on both LSAI and biodiversity in their respective communities and therefore had experience in issues articulated as research phenomena. For this reason, each discussion lasted less than 3 hours (180 minutes) and ranged between 1.75 hours and 2.5 hours with most of the time spent on probing the participants about the responses provided for the questions asked. The interview guide was complemented with a tape recorder, camera, and field notebook. Unfortunately, the tape recorder became faulty, compelling me to reconduct interviews in many instances. To circumvent such a problem, I quickly replaced the tape recorder with my phone. Overall, the interviews lasted for almost two months (5^{th} March – 24^{th} April 2022) with several reschedules of key informant interviews (KIIs) and a major reschedule lasting between 4^{th} and 8^{th} April 2022. Detailed information showing the distribution of participants by district and community is shown in Table S1 of the supplementary material to this report. While these interviews were being conducted, secondary data including information about GCAP and Northern Rural Growth Project (NRGP) was sourced from MoFA.

Data analysis and report generation: The plan to analyze and generate results was muddied by several challenges presented in the next section. Nonetheless, efforts were made to present the analysis and results of the first stage qualitative study. Regarding the analysis, we employed content analyses. Here, we searched for the pattern of words employed by our key informants in explaining the impact of LSAI and its implications on biodiversity. This is because the meanings attached to a particular phenomenon are mostly manifested in words used. Content analyses are particularly suitable for studying communications and answering classic questions of "who says what, to whom, why, how, and with what effect?"(Babbie, 2013). However, since the core of content analysis lies with the frequency distribution of individual words or texts, this study used word distribution and patterns in content analysis to study KI's views on LSAI and its implication on biodiversity. The application of words is based on the idea that a person's disposition or mood about material worlds and their content is conveyed through the words employed. The "***txttool***" command proposed by Williams and Williams (2014) for text analysis in Stata was employed since Nvivo was not readily available at the time of the analysis. Specifically, we mined the views of respondents on the impact of LSAI on biodiversity into phrases. Then, we employed the frequency distribution of words in content analysis, as proposed by Dicle and Dicle (2018), to summarize the responses into a word chart. From this chart, three themes including (i) knowledge of LSAI (iii) Implication (negative and positive) of LSAI on biodiversity, and (ii) farmers' strategies in dealing with its consequences (negative) of LSAI on biodiversity, were then formed from the words for discussion. In this chart, each word is presented with a corresponding frequency. Further, insights into the context of the use of each word are traceable in the KI's responses. Thus, when found relevant, responses of KIs are quoted directly by tracing the context of usage of each word to enhance/support our discussion. The three themes are presented in the results section.

3.2.2 Second Phase Quantitative Study

For the quantitative study, we draw data from multiple sources. First, a household survey was conducted on a total of 1,843 households that were selected using a multi-stage sampling technique. Since the study focused on land deals, Northern Ghana was selected for the study because the area is with a known record of several examples of large- or medium-scale land deals that are carried out by both domestic and foreign investors (see for example, Abdallah et al., 2022, 2023; Adams et al., 2019; Ahmed et al., 2018; Ayamga & Laube, 2020; Ayelazuno, 2019b, 2019a; Kuusaana, 2017; Nketiah et al., 2019). The area is also noted to abound in vast potential arable cropland that is unused and therefore likely to attract more investors. As noted previously, the land area including potentially arable cropland is 97,700 square kilometers (MoFA, 2019) yet occupants are less than six million people (Ghana Statistical Service, 2021). The area is divided into Northern Region, North East Region, Savannah Region, Upper East Region, and Upper West Region. Each of these regions is further divided into districts which are also subdivided into communities. Thus, our sampling consisted of a selection of districts in each region, communities in each district and households in each of the selected communities.

Regarding the selection of districts, and communities, we obtained information on the location of large- or medium-scale land deals from the Land Matrix database (Land Matrix, 2021) and the Lands Commission's branch in each of the regions under study. This information covered 25 out of the 54 districts in northern Ghana and consisted of 111 communities across the five regions under study. Using such information, we purposively selected 2 districts from each of the five regions (Bongo and Kassena-Nankana in Upper East Region, Mamprugu Moaduri and West Mamprusi in the North East Region, Central and North Gonja in the Savannah Region, Mion, and Savelegu-Nantong in the Northern Region, and Jirapa and Lawra in the Upper West Region) based on intensity of medium/large-scale land deals. Per the list obtained, the selected districts consisted of 59 communities with LSAI or MSAI. To select communities, we used a probability proportional-to-size (PPS) sampling approach in which 2-6 communities were selected from each district in proportion to the number of communities in the 10 districts selected. This made a total of 20 communities exposed to LSAI/MSAI. For the selection of households exposed to LSAI/MSAI, it was difficult to locate such households since there was no comprehensive list of agricultural households exposed to LSAI or MSAI. Again, we used a listing protocol to interview headmen, chiefs, and community leaders of selected communities to obtain a list of households exposed to LSAI or MSAI. In the listing we asked questions on land loss, number of members affected, current location of the affected members, and the origin of the acquirers. The final list consisted of 6,228 exposed households (4,124 MSAI and 2,104 LSAI) across 20 communities and 10 districts. Using the list, we conducted a random sample of 25 households exposed to LSAI and 25 households exposed to MSAI in each community. This made a total of 1,000 exposed households consisting of 500 and 500 households exposed to MSAI and LSAI, respectively (Table 3.1). Given that proper evaluation of the effect of such investments depends on counterfactuals (Cavatassi, et al., 2011), nonexposed households were also selected to serve as the control groups. To establish pure control groups for the exposed households, 20 non-affected communities were randomly selected to serve as a control group for the exposed communities. Then, from each of the 20 nonexposed communities, 50 nonexposed agricultural households were randomly selected to serve as a control group for the exposed communities.

Table 3.1: Households exposed to MSAI and LSAI by region, district, and village

Region	**District**	**Community**	**Number of households exposed to MSAI/LSAI**
Northern Region	Mion	Kpachaa	50
		Jimli	50
	Savelegu	Dipale	50
		Gushie	50
		Yapalsi	50
		Zoggu	50
	Total		**300**
Savannah Region	Central Gonja	Alipe	50
		Kusawgu	50
	North Gonja	Daboya	50
		Tudurupe	50
	Total		**200**
North East Region	Mamprugu Moaduri	Loagri	50
		Yagaba	50
	West Mamprusi	Guagbulga	50
	Total		**150**
Upper East Region	Kassena	Tono	50
	Talensi	Pawlugu	50
	Total		**100**
Upper West	Jirapa	Duori	50
		Guor	50
		Jirapa -Mile 5	50
	Lawra	Deboru	50
		Derkurayir	50
	Total		**250**

Total sample			**1,000**

Source: Field survey, November/December 2022.

This sum up to a total of 1,000 agricultural households that are nonexposed to both MSAI and LSAI. In all 2,000 households were sampled for the study. Figure 3.1 shows the household location, and districts in Ghana. The sampled households were then interviewed with a semi-structured questionnaire developed from the themes identified in the first phase of qualitative interviews. Kobo Toolbox loaded with questions from the questionnaire was used to elicit responses from households. The Kobo Toolbox is an online open-source suite of tools for field data collection developed by the Harvard Humanitarian Initiative. The Kobo Toolbox was installed in 10 Samsung Galaxy Tablets and questions from the questionnaire were then loaded. The questions covered households' characteristics, information on LSAI, drivers, and the size of LSAI. Also, questions leading to the construction of biodiversity indicators including species richness (measured as the number of crops planted by the farmer in the planting season), diversity (measured as the Shannon crop index), and evenness (measured as the ratio of Shannon crop index of diversity to crop richness) were asked in the survey. Specifically, questions on the number of plants planted by household, total area of plot, and area of plot covered by each plant/crop grown were asked. Also, questions on access to provisioning services of the ecosystem and biodiversity/ecosystem management practices were covered. Thus, questions on whether the household has access to provisioning services of the ecosystem (e.g., economic trees for shea nuts, mango fruits, dawadawa seeds, baobab leaves, moringa; grazing lands; forest for fuel wood, herbal medicines, water, hunting, and gathering, etc.) whether household adopted biodiversity/ecosystem management practices (e.g., sustainable agricultural practices such as conservation tillage, crop rotation, intercropping, cover cropping, integrated nutrient management, etc.; tree planting techniques such as agroforestry; and improved seed varieties, etc.) were asked. Aside from LSAI, other factors affecting indicators of biodiversity were captured in the questionnaire. For instance, medium-scale investments (i.e., investments with 5-50 hectares) are also noted to drive the conversion of forest/grasslands to farmland. Thus, questions on MSAI were also captured. Other questions captured were related to the perception of rainfall, climate, soil, and socioeconomic and agroecological variables. Faculty members were then employed to help review the questionnaire to ensure that the themes identified in the first phase were appropriately captured. Once the revision of the questionnaire was completed, enumerators were then trained for the survey.

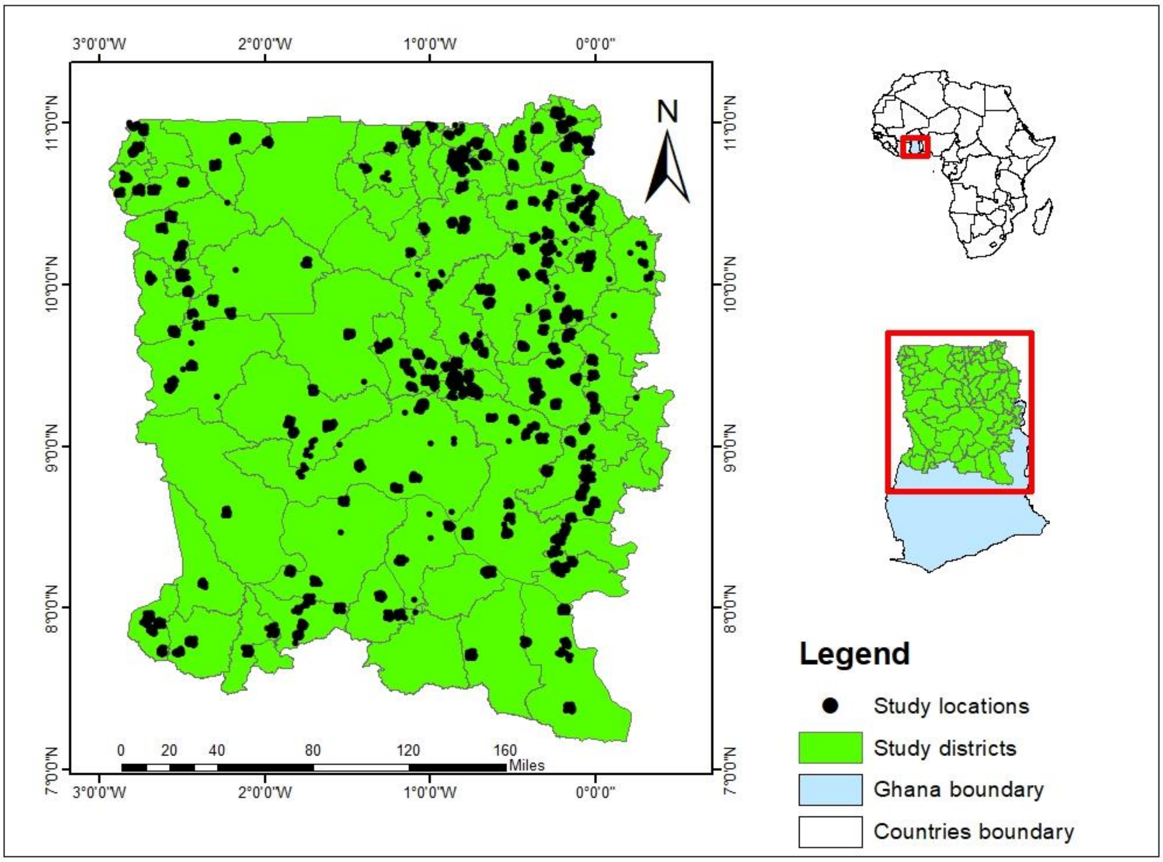


Figure 3.1: Study area map showing the study household location and districts
Source: Author, 2022

Enumerator Training: Enumerator training was an essential part of the survey so far as data quality is concerned. However, the success of such training depended on the resources needed for the training and the activities to be performed. Thus, before the training, resources and training activities were carefully organized and planned. The first and most important of the resources is the questionnaire for which enumerators are to be trained. Once the questionnaire was successfully loaded and reviewed, logistics were acquired for the training. The Lecture Hall 4 of the University for Development Studies, City Campus was designated as the venue for the training. A total of 20 potential enumerators were selected and the selection was based on the following factors; (1) familiarity with the districts, (2) understanding of the language, and (iii) previous participation in similar surveys. Because of the length and complexity of the questionnaire, five days (i.e., 24^{th}- 28^{th} of October, 2022) were allocated for the training to ensure that enumerators are comfortable with the questionnaire. Enumerators were trained on the following:

i. Introduction to the Kobo Toolbox environment, how to download and install "Global Positioning System (GPS) Coordinates"– the application software for tracking the sample household locations.
ii. The training focused mainly on the standardization of translations of questions in each module into various languages.
iii. The training also emphasized the use of the right instruments for the right job.
iv. The trainees were also shown how to locate sample households with GPS coordinates.

v. Other emphases at the training included community entry, proper introduction, and identification of correct respondents to ensure quality and as well as avoid duplicates and missing values.

vi. Much emphasis was also placed on clarifications and polite probing, interaction with the respondents, and paying attention to details.

The training was mainly facilitated by Mr. Abdullah Karim. However, Dr. Abdallah Abdul-Hanan was responsible for supervision and monitoring and as well stepped in to clarify some of the questions as and when the need arose. At the end of the training, 10 enumerators who speak the main respective languages in the selected communities were recruited for the survey. These enumerators resorted to face-to-face interviews to help interview the respondents. The participants were made to understand that participation in the survey is voluntary and information provided will only be used for research. Before the survey, the questionnaire was pretested with 20 households in Tamale. The pretesting resulted in feedback on the structure, and deficiencies of the questionnaire as well as the perceived time cost of administering the questions. All deficiencies regarding the structure of the questionnaire, deficiencies, and time cost were remedied before the main household survey. The household survey was conducted between 2nd November and 1st December 2022. The interviews were conducted based on the time scheduled by the respondents.

The data collected using Kobo Toolbox was then imported into Stata/MP 17 for cleaning and editing. Calculations of some of the survey-based biodiversity indicators such as species richness, evenness, and crop diversification were done at this stage. Cases with missing information and outliers were dropped to ensure the normality of data. Finally, a total sample of 1,843 households remained after cleaning. In Kassena-Nankana, North Gonja, and Jirapa, the enumerators delivered data on 157 households across six of the nonexposed communities. This data was difficult to use for the analysis and hence was dropped during the cleaning exercise. Thus, our total sample for the 2021 cropping season consisted of 843 nonexposed households, and 1000 exposed households (i.e., 500 households each under exposure to MSAI and LSAI) These represented a response rate of 84.3% for nonexposed households, 100% each for households exposed to MSAI and LSAI, respectively. To be able to estimate the effect of variation in MSAI and LSAI on our outcomes over time, we combined the data from a subsample of households in the 2021 survey with their information from the 2018 household survey. The 2018 survey consisted of 259 and 266 households exposed to MSAI and LSAI, respectively (see Abdallah et al., 2023; Ayamga et al., 2022 for details). These households formed part of the 2021 sample and were tracked using the 'My GPS Coordinates' application and the GPS coordinates of the households from the 2018 survey. Regarding the tracking of the households, the GPS points for the selected households in the 2018 survey were extracted and sorted according to districts. The extracted points of interest were converted into a GPS exchange format (GPX) using the DNR GPS software version 6.1. To ensure that enumerators were able to track the houses of interest even in the remote areas where internet connectivity was a challenge, we relied on the 'My GPS Coordinates' application downloaded from Google Play Store. 'My GPS Coordinates' is an offline application and can operate in areas without internet connectivity. Finally, the GPX file containing the house coordinates in a particular district was imported into 'My GPS Coordinates' for the enumerators based on where they were posted. And knowing their location in a particular community (town), they were able to navigate to the houses of interest. Figure 3.2 presents a pictorial view of the enumerator's location and houses to be tracked within the Tamale Metropolis.

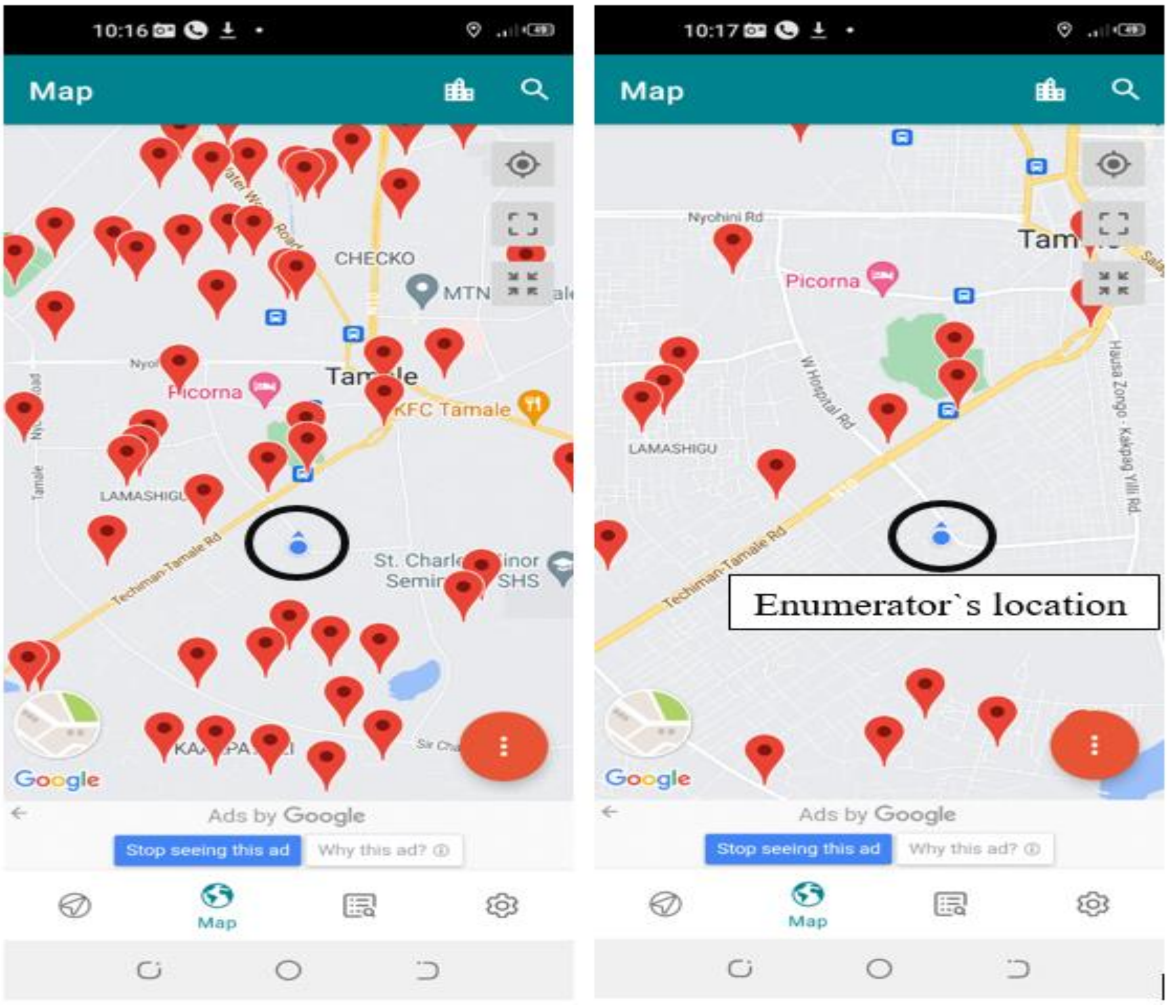


Figure 3. 2: Picture showing the enumerator's location and houses to be tracked within the Tamale Metropolis

Source: Authors, 2022.

Thus, the data to be used for this analysis is a panel dataset covering self-reported information on biodiversity, access to ecosystem services, biodiversity, and ecosystem management practices employed by households. The data also covered factors expected to influence the outcome variables which we generally categorized into MSAI and LSAI variables, household/plot-level, and location variables. The household/plot-level variables include gender, age, household size, education, remittances received, social group membership, leadership position, and perception of households about the soil properties of their plots. The location variables include population density, residential expansion measured by the proportion of building footprint area per 250-meter square grid cell, elevation, temperature, and precipitation. Reducing the influence of extreme outliers makes the data more suitable for statistical analyses, especially when assumptions of normality or equal variance are required. Following Billor et al. (2000), we performed a multidimensional outlier detection using 'bacon' – a user-written command we installed in Stata 17. Consequently, observations with large or low entries of variables were identified and removed leaving an unbalanced panel of 1,219 observations (606 observations in 2018, and 613 observations in 2021). This dataset is supplemented with information from other datasets. Specifically, we draw district-level measures of MSAI, LSAI, and infrastructural development from round seven of the Ghana Living Standard Survey (GLSS7) conducted by the Ghana Statistical Service (https://www2.statsghana.gov.gh/nada/index.php/catalog/97). The GLSS is a comprehensive survey conducted by the Ghana Statistical Service to gather data on living conditions and standards of living in Ghana. The survey provides important information for policymakers, researchers, and other stakeholders to understand the socio-economic situation of the country's population. GLSS7 is the seventh round of the survey, following previous rounds conducted at different intervals. The survey collects data on various aspects of household life, including agricultural production, income, expenditure, employment, education, health, housing, and access to basic services. It aims to provide an accurate representation of the living conditions of Ghanaians across different regions, rural and urban areas, and socioeconomic groups. To collect data, a two-stage sampling process is used in the GLSS: first, enumeration areas (EAs) are chosen based on the 2010 Population and Housing Census, with probability proportionate to size; and second, systematic household samples are taken from each of the selected EAs. Further, our household survey data captured the GPS coordinates of each household. This made it possible to complement the survey data with geographic information systems (GIS) data on population, weather, elevation, and vegetation indices from GRUMP, Landsat 8 images, and Shuttle Radar Topography Mission (SRTM) (https://earthexplorer.usgs.gov/) of the NASA/USGS, and WorldClim. Landsat 8 is a satellite mission operated by the United States Geological Survey (USGS) and NASA. It is part of the long-running Landsat program, which has been collecting Earth observation data since 1972. Landsat 8 carries two main instruments: the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). These sensors capture images of the Earth's surface across different spectral bands, allowing for a wide range of applications such as land cover monitoring, agricultural assessments, urban development studies, and natural resource management. Our data comes from the OLI sensor on Landsat 8 which captures data in nine spectral bands, including the visible, near-infrared, and shortwave infrared regions. It provides a high-ground resolution of 30 meters for most bands. On the other hand, the SRTM provides a high-resolution and detailed near-global coverage of topographic information about the Earth's surface. The elevation data from SRTM has a resolution of about 30 meters (approximately 98 feet) for most of the Earth's surface. The raw data underwent post-processing to remove errors, such as voids caused by radar shadows and interference. We also obtained precipitation and temperature data from WorldClim (https://www.worldclim.org/data/worldclim21.html). The WorldClim data provides gridded climate data at various spatial resolutions and time intervals, making it valuable for ecological, environmental, and climate research. The dataset is derived from weather station data and other sources, and it provides a range of bioclimatic variables that describe different aspects of climate. These variables include temperature, precipitation, solar radiation, wind speed, and other climatic parameters and are provided at different raster layers, with each layer representing a specific climate variable. The data is available at monthly, seasonal, and annual averages. The dataset covers the entire globe and is available at multiple spatial resolutions, ranging from 1 km to 10 km. We also sourced estimates of population density and urbanization data from the sixth version of Global Rural-Urban Mapping (GRUMPv1) (https://sedac.ciesin.columbia.edu/data/set/ghsl-population-built-up-estimates-degree-urban-smod). GRUMP provides high-resolution satellite imagery of estimates on urban and rural population distribution, settlement patterns, urbanization processes, and their spatial distribution across the globe. The dataset consists of multitemporal products (GHSL 1975-2014/15) available at a spatial resolution of 9 arc seconds and 30 arc seconds in the World Geodetic System 1984 (WGS84) Geographic Coordinate System. These products are part of the Global Human Settlement Layer (GHSL) and include the Built-Up grid (GHS-BUILT), Population Grid (GHS-POP), and the Settlement Model grid (GHS-SMOD) data packages (Joint Research Centre (JRC) et al., 2021). In this study, we made use of data on population, and built-up area with a spatial resolution of 9 arc seconds (approximately 250m grid cell). The data on population was transformed into population density before inclusion in our analysis. Although the GRUMP host population density dataset, it is of less fine resolution (about 30 arc seconds) which is also of far lower resolution than the resolution of the vegetation indices. For this reason, we resorted to using a finer resolution population data of the GRUMP to construct population density for the analysis. To generate the population density, we used estimates of the population from GRUMP with the estimates of arable land from Global Agro-Ecological Zones v4 (GAEZ v4) of the FAO. In addition to other input datasets, the GAEZ v4 contains information on artificial surfaces, cropland, grassland, tree-covered areas, shrubs-covered areas, herbaceous vegetation, aquatic or regularly flooded, mangroves, sparse vegetation, bare soil, snow and glaciers, and water bodies (Fischer et al., 2021). We divided the estimates of the population from GRUMP by the estimates of aggregated cropland, grassland, and tree-covered land from GAEZ to get population density. Thus, the population density variable is the number of persons per 250 square meters of grid cell.

Variable construction and descriptive statistics

In this section, we describe how key variables are constructed and as well present the definition/measurement and descriptive statistics of the key variables and other explanatory variables in Table 3.1.

Variables measuring MSAI and LSAI

We measure LSAI and MSAI using the GLSS7 dataset. Specifically, we constructed district-level MSAI (i.e., the share of operated farmland between 5 and 50 ha); and LSAI (i.e., the share of operated farmland over 50 ha). A common issue of the GLSS data, however, is that MSAI and LSAI are underrepresented (Jayne et al., 2019; Jayne et al., 2014). This problem persists in the GLSS7 as it contains only 26 out of 13,913 farm observations under MSAI and LSAI. To capture a more representative share of MSAI and LSAI, we employed the sampling weights generated in the GLSS7 data for each observation. Summarily, our final estimates showed that the share of land under MSAI and LSAI is 49.7% and 1.2%, respectively and thus, suggest the predominance of medium-scale investors over large-scale investors in northern Ghana (Table 3.1). These estimates are consistent with earlier studies that examined farm size distributions in Ghana (e.g., Jayne et al., 2019; Jayne et al., 2014, 2016; Jayne & Sanchez, 2022).

Outcome variables

Our outcome variables of interest include biodiversity, ecosystem services, and practices adopted by households for managing biodiversity and the ecosystem. As mentioned previously, biodiversity and ecosystem services are multidimensional concepts and cannot, therefore, be captured with a single indicator. For instance, for diverse taxa, more species will be recorded, but the gene pool is not necessarily expanded (Di Falco & Chavas, 2006; Gotelli & Colwell, 2001). Thus, using only indices for species richness will be inappropriate. To capture the different dimensions of biodiversity, we employed different metrics: (i) species richness (measured as the number of crops planted by the farmer in the planting season), (ii) diversity (measured by Shannon crop index H defined as $-\sum \left({\alpha_{ji}}/{\alpha_i}\right) * \ln({\alpha_{ji}}/{\alpha_i})$, where α_{ji} is the area of plot i planted with crop j and α_i is the total area of the plot i), (iii) evenness defined as ${H}/{\ln{(n_{ij})}}$ where H is the Shannon crop index n_{ij} is the species richness. These indicators are selected based on literature (e.g., Bozzola & Smale, 2020; Di Falco & Jean-paul, 2009; Di Falco & Perrings, 2005) and are constructed from the household survey which captured all information needed for the construction of such biodiversity indicators. However, a common issue with these indicators is the use of self-reported or recall data from households in construction. Generally, self-reported or recall data is commonly known to suffer from errors due to misreporting or misclassification (i.e., true negatives or false positives) (Abay et al., 2019, 2022; Wossen et al., 2022). Such errors may bias estimates of the biodiversity effect of MSAI and LSAI. We address this gap using spatial indicators of vegetation to check for the robustness of the results. Healthy vegetation often supports a diverse array of life - including organisms, birds, insects, and small mammals (Zhang et al., 2011) - which is sensitive to changes in vegetation conditions (Bonthoux et al., 2018; Holdridge et al., 2017; McFarland et al., 2013; Nieto et al., 2015; Sutherland et al., 2014; Zeng et al., 2017). Thus, the use of vegetation indices for measuring biodiversity is based on the idea that alterations in vegetation cover and structure may reflect shifts in habitat quality, disturbance levels, or ecological processes and biodiversity.

The first of these indicators is the enhanced vegetation index (EVI) which is commonly used in remote sensing and vegetation analysis to assess the health and vigor of vegetation (Weng et al., 2004). EVI is calculated with the values of near-infrared and red-light wavelengths obtained from satellite imagery (Avdan & Jovanovska, 2016). Mathematically, the EVI is expressed as:

$$EVI = \frac{G(NIR-Red)}{(NIR+C_1 Red-C_2 BLUE+L)} \qquad (3.1)$$

Where NIR represents the reflectance value of near-infrared light; Red represents the reflectance value of red light; BLUE is the blue reflectance; L the canopy background adjustment, C_1 and C_2 are coefficients used to reduce atmospheric influences; and G is the gain factor to normalize the values. $G = 2.5$, $C_1 = 6$, $C_1 = 7.5$, and $L = 1$. The EVI typically ranges from -1 to +1.

The second of these indicators is the soil adjusted vegetation indix (SAVI) expressed as:

$$SAVI = \left(\frac{(NIR-Red)}{(NIR+Red+L)}\right) \times (1+L) \qquad (3.2)$$

Where NIR and Red are as defined earlier; and L is the soil brightness correction factor with value of 0.5 in this study. SAVI values typically range from -1 to 1. Negative values represent non-vegetated areas, values close to zero represent sparse or stressed vegetation, and values approaching 1 represent healthy and dense vegetation. Higher positive values indicate denser and healthier vegetation, while lower or negative values indicate less vegetation or non-vegetated areas.

The use of EVI and SAVI in checking for robustness is based on the principle that any alterations of species richness, evenness, and diversity by MSAI and LSAI are likely to reflect in the density and health of vegetation as implied by EVI and SAVI. Compared to the normalized difference vegetation index (NDVI), EVI considers the atmospheric and canopy background effects while SAVI considers soil visibility on vegetation. A higher positive EVI and SAVI value indicates dense and healthy vegetation, while a lower or negative value indicates less to no vegetation. We employed EVI because of the low mountainous nature of northern Ghana. On the other hand, the SAVI is useful in this study since high temperature, intense grazing and farming in the north have rendered the vegetation visible.

The EVI and SAVI were both constructed from Landsat 8 images of the NASA/USGS (https://earthexplorer.usgs.gov/) as mentioned previously. Specifically, bands 4 and 5 were employed in this study for the construction of EVI and SAVI. These bands existed in Tag Image File Format (TIFF) and were downloaded, mosaic, and/or clipped to our area shapefiles using ArcGIS 10.8.2. except few, all the images were already projected to EPSG: 4326 - WGS 84. Thus, there was no geometric correction required as the study area falls under this coordinate system. The vegetation indices including EVI, and SAVI were then calculated using a raster calculator in ArcGIS 10.8.2. The cell values of a raster were finally extracted to the point location of the households for analysis. The statistics in Table 3.1 showed that the mean value of the crop count richness index is 2.88, suggesting that about three (3) different crop species are planted by households per season. Further, mean crop evenness is low and stood at 1.2 and thus, suggesting a less balanced distribution of individual crop species planted. These estimates are reflected in the low Shannon index of crop diversity (1.2) and thus, suggest a low number of species present and poor relative abundance in the area. Similarly, the mean EVI and SAVI values of 0.49 and 0.45 point to the presence of healthy and dense vegetation in northern Ghana. These values therefore generally point to the presence of little vegetation in northern Ghana and thus, seem to correlate positively with the previous findings on species richness, evenness, and diversity.

As mentioned previously ecosystem services refer to the benefits derived from the ecosystem. These benefits are categorized into provisioning, supporting, regulating, and cultural services (Eigenbrod et al., 2009; Mace et al., 2012; Millennium Ecosystem Assessment, 2005). In this study, however, our focus is on the ecosystem's provisioning services because they provide direct benefits to households and could be the immediate impact felt in the presence of MSAI and LSAI. In addition, these services are directly inferable from responses in a household survey. We specifically focused on access to grazing land for grazing livestock, access to forest for hunting and gathering, fresh water, medicinal plants and gathering of fuel wood for charcoal production, and access to economic trees including acacia (*Acacia* species), mango (Mangifera *indica*), baobab (Adansonia *digitata*), shea (Vitellaria *paradoxa*), dawadawa (Parkia *biglobosa*), and neem (Azadirachta *indica*) for picking shea nuts, mango fruits, dawadawa seeds and baobab fruits and leaves. The statistics in Table 3.1 indicate that about 33% of the exposed households have access to economic trees for picking shea nuts, mango fruits, dawadawa seeds, and baobab fruits and leaves. Also, about 56% have access to grazing land for grazing livestock, and 32% have access to forest areas for hunting and gathering, fuel wood, and charcoal production.

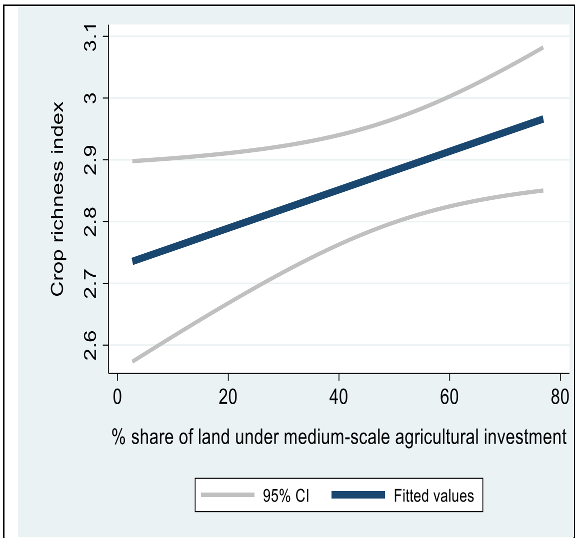
In this study, our management practices of biodiversity and ecosystem services, are strictly agrobiodiversity management practices - a subset of conservation and sustainable use practices of biodiversity and ecosystem management practices (Bezabih, 2008). Agrobiodiversity- a component of biodiversity (Bezabih, 2008) - refers to the variety and variability of plants, animals, and microorganisms that are used in agriculture and food production (Jacksonn et al., 2013). It includes not only crop species but also livestock breeds, fish varieties, and other organisms that contribute to agricultural systems (Jacksonn et al., 2007). Agrobiodiversity management practices focus on the strategies that conserve and sustain the use of diverse crops, livestock breeds, and traditional farming practices to enhance agricultural resilience, food security, and ecosystem health. These practices include improved and indigenous seed varieties, soil fertility management practices, tree planting, agroforestry, sustainable agricultural practices, conservation practices, etc. However, this study specifically focused on adoption of sustainable agricultural practices (SAPs) including fertilizer application, crop rotation, intercropping/residue retention or zero/minimum tillage; tree planting techniques including agroforestry; and improve seed varieties. The importance of on-farm adoption of these practices has been underscored in many studies (Abdallah et al., 2020; Teklewold, Kassie, Shiferaw, et al., 2013). However, the possibility of households' adoption of these practices in the presence of MSAI and LSAI has recently drawn a lot of attention (Abdallah et al., 2023; Ali et al., 2019; Ango, 2018; Deininger & Xia, 2016; Dessy et al., 2012; Kleemann & Thiele, 2015; Liverpool- et al., 2023; Liverpool-tassie et al., 2020; Zaehringer et al., 2021). As shown in Table 3.1, about 35%, 26 and 17% of the sampled exposed households employed SAPs, tree planting, and improve seed varieties for production.

Table 3. 2: Variable definition/measurement and descriptive statistics

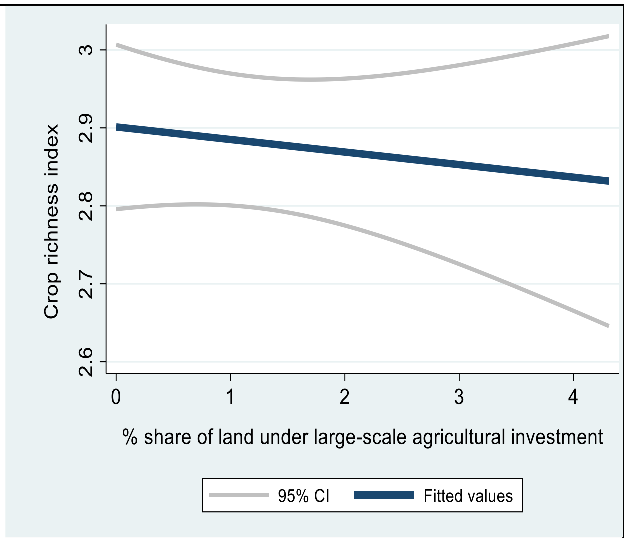
Variable	Definition	Mean	Std. dev.
MSAI	Medium-scale agricultural investment (district-level share of operated farmland under 5-50 ha)	49.658	28.399
LSAI	Large-scale agricultural investment (district-level share of operated farmland over 50 ha).	1.191	1.572
EVI	A score indicating the density, health, and greenness of vegetation.	0.493	0.106
SAVI	A score indicating the health and density of vegetation.	0.448	0.099
Crop count richness index	Number of crops planted by the farmer in the planting season	2.882	1.488
Shannon index of crop diversity (H)	Defined as $-\sum \left({}^{\alpha_{ji}}/_{\alpha_i}\right) * \ln({}^{\alpha_{ji}}/_{\alpha_i})$, where α_{ji} is the area of the plot i planted with crop j and α_i is the total area of the plot i	1.500	1.016
Index of crop evenness	Defined as ${}^{H}/_{\ln\,(n_{ij})}$ where H is the Shannon crop index and n_{ij} is the species richness	1.244	0.962
Trees	Dummy (1 if the household has access to economic trees such as acacia, mango, baobab, shea, dawadawa, and neem trees and 0 if otherwise)	0.331	0.471
Grazing land	Dummy (1 if the household has access to grazing land for grazing livestock and 0 if otherwise)	0.561	0.496
Forest	Dummy (1 if the household has access to forest areas for hunting and gathering, fuel wood, charcoal production and 0 if otherwise)	0.322	0.468
Sustainable agricultural practices	Dummy (1 if the household adopted the use of fertilizer, crop rotation, intercropping/residue retention or zero/minimum tillage, etc., and 0 if otherwise)	0.351	0.478
Tree planting	Dummy (1 if the household adopted tree planting or agroforestry and 0 if otherwise)	0.264	0.441
Improved seeds	Dummy (1 if the household adopted the use of improved seeds varieties and 0 if otherwise)	0.171	0.377
Population density	Number of persons per 250 meters grid cell	0.186	1.426
Built-up area	The proportion of building footprint area per 250 square meters grid cell	0.781	7.067
Elevation	Meters above sea level	179.858	54.900
avtemperature (mini)	Average minimum temperature (°C)	23.258	0.345
avtemperature (max)	Average maximum temperature (°C)	34.711	0.634

Precipitation	Total precipitation (mm)	94.057	7.073
Gender	Dummy (1 if household head is male, 0 if otherwise)	0.911	0.285
Age	Age of household head (years)	47.528	12.864
Household size	Number of people residing in a household	12.572	7.262
Education	Number of years spent in formal education	3.221	5.182
Remittances receive	Dummy (1 if household head is received remittance, 0 if otherwise)	0.194	0.395
Social group membership	Dummy (1 if the household head is a member of a social group; 0 if otherwise)	0.399	0.490
Govern. leadership position	Dummy (1 if the household head holds a leadership position in the government; 0 if otherwise)	0.212	0.409
Traditional leadership	Dummy (1 if household head holds traditional leadership position; 0 if otherwise)	0.387	0.487
Good fertile	Dummy (1 if the fertility of the soil is good; 0 if otherwise)	0.351	0.478
Moderately fertile	Dummy (1 if the fertility of the soil is moderate; 0 if otherwise)	0.468	0.499
Poorly fertile	Dummy (1 if the fertility of the soil is poor; 0 if otherwise)	0.166	0.372
Deep depth	Dummy (1 for deep soil depth; 0 if otherwise)	0.128	0.334
Moderate depth	Dummy (1 for moderate soil depth; 0 if otherwise)	0.551	0.498
Shallow depth	Dummy (1 for shallow soil depth; 0 if otherwise)	0.306	0.461
Flat slope	Dummy (1 for flat slope plot; 0 if otherwise)	0.473	0.499
Moderate slope	Dummy (1 for moderate slope plot; 0 if otherwise)	0.451	0.498
Steep slope	Dummy (1 for steep slope soil; 0 if otherwise)	0.061	0.239
Drought	Dummy (1 if the community ever experiences droughts; 0 if otherwise)	0.145	0.352
Flood	Dummy (1 if the community ever experiences flood; 0 if otherwise)	0.789	0.408

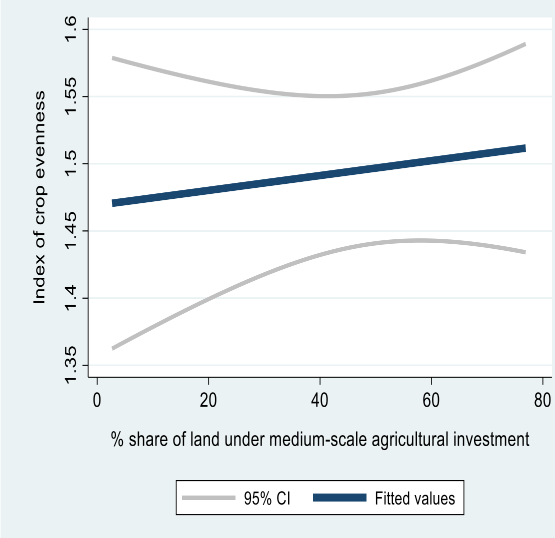
Figure 3.1 (Panels 1-10) further presents a non-parametric towaway linear prediction of the relationship between LSAI, MSAI, and biodiversity in northern Ghana. The x-axis on the left panel represents the weighted share of land under medium-scale agricultural investment (MSAI) while the x-axis on the right panel represents the weighted share of land under large-scale agricultural investment (LSAI) estimated at the district level. Further, the y-axis in each shows the variable of interest. In all the graphs, the thick middle curve shows the bivariate relationship between variables of interest and fitted values of share of agricultural investment. Thus, the thick middle curve on the left panels shows the bivariate relationship between variables of interest and share of land under medium-scale agricultural investment (MSAI) while the thick middle curve on the right panels shows the bivariate relationship between variables of interest and share of land under large-scale agricultural investment (LSAI) estimated at the district level. Each of the relationships was plotted along a 95% confidence interval depicted by the curves below and above curve representing the relationship between agricultural investment and the variables of interest. In Panel 1, the index of the richness of crop species is an increasing function of the district's share of land under MSAI and thus, appears to increase as the district's share of land under medium-scale agricultural investment increases. This suggests that the number of different species planted by a farm household exposed to MSAI/LSAI is enhanced by the increase in a district's share of land under MSAI. On the other hand, the crop species richness appears to decrease with a district's share of land under large-scale agricultural investment. This is like the results in panel 10 in which SAVI dcreases with increasing share of land under LSAI. Similarly, crop species evenness, and Shannon index of crop diversity are increasing functions of the district's share of land under MSAI and appear to increase with increasing share of land under MSAI but decrease as the district's share of land under LSAI increases (Panels 3-6 of Figure 3.1). Also, EVI and SAVI are both decreasing functions of MSAI up to a certain threshold, about 45% of MSAI, and increases thereafter (Panels 7 and 9). This finding is similar LSAI-EVI nexus in panel 8.



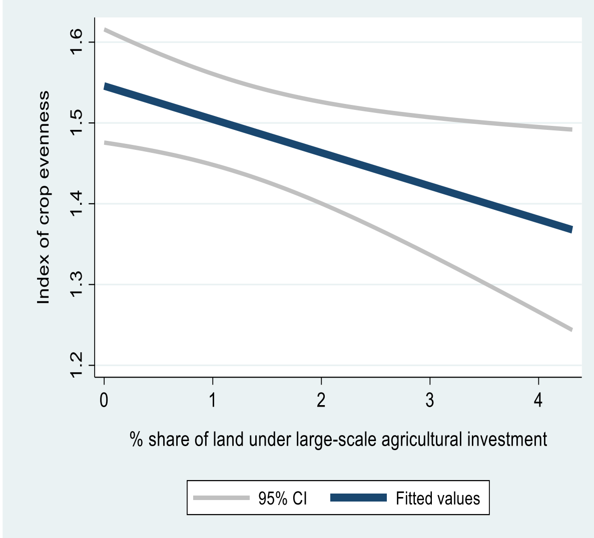
Panel 1: Crop richness by MSAI



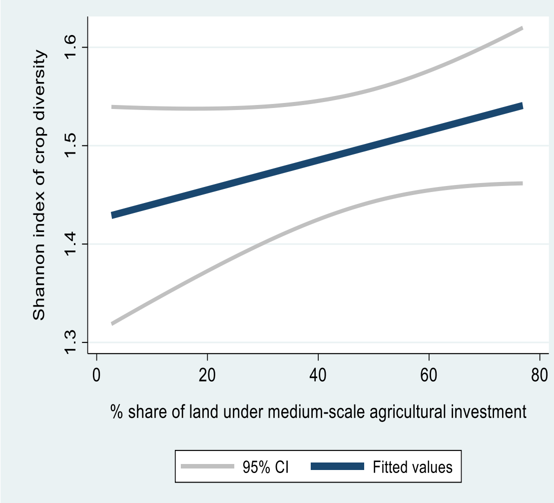
Panel 2: Crop richness by LSAI



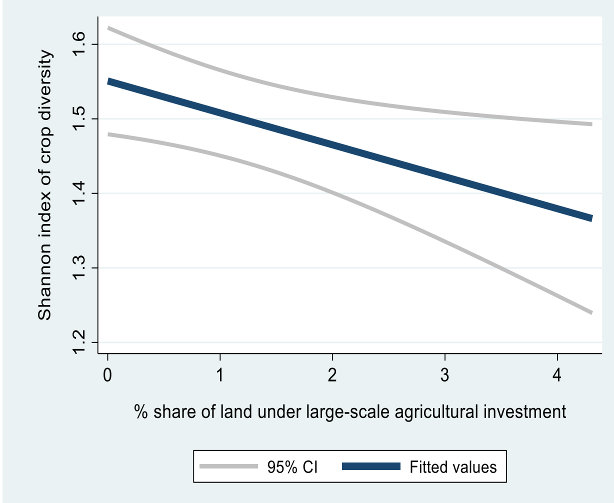
Panel 3: Crop evenness by MSAI



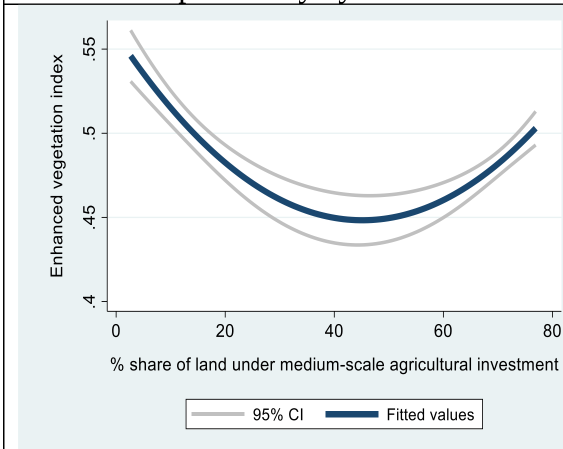
Panel 4: Crop evenness by LSAI



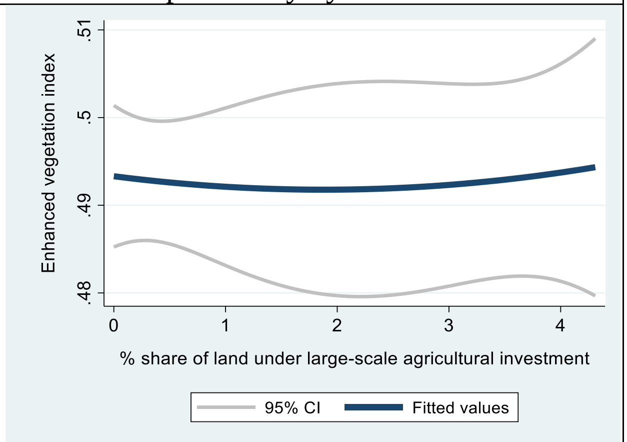
Panel 5: Crop diversity by MSAI



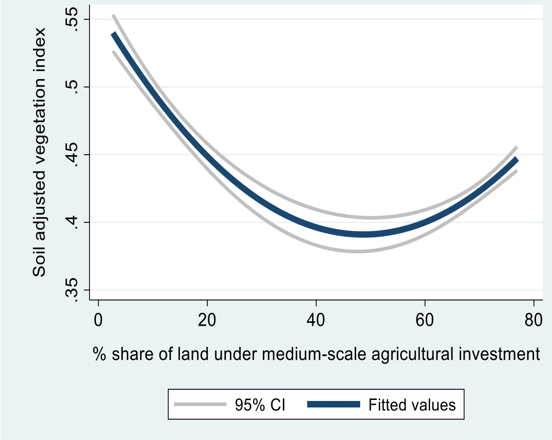
Panel 6: Crop diversity by LSAI



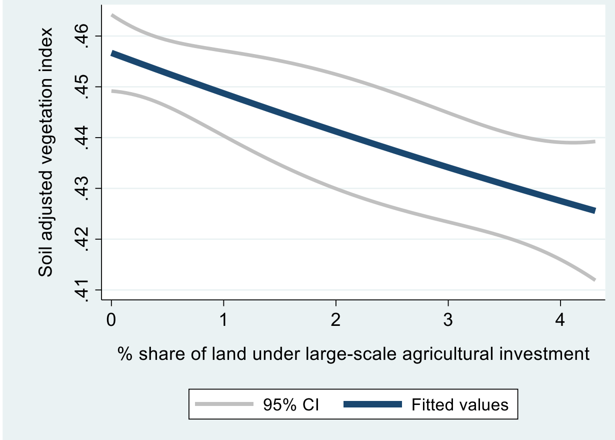
Panel 7: EVI by MSAI



Panel 8: EVI by LSAI



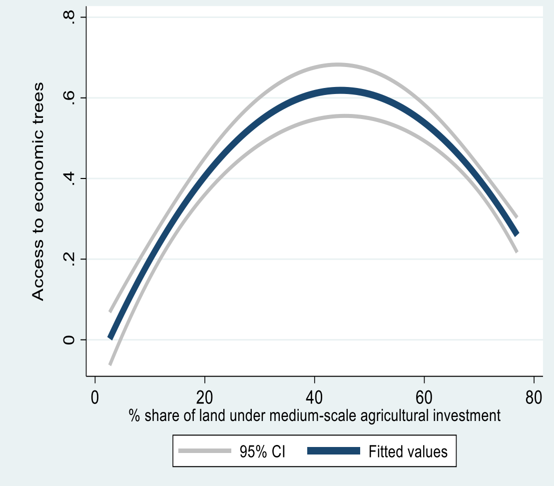
Panel 9: SAVI by MSAI



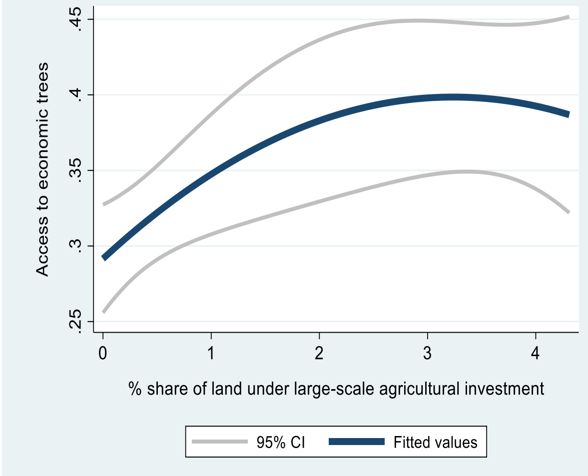
Panel 10: SAVI by LSAI

Figure 3.3: Biodiversity indicators by agricultural investment

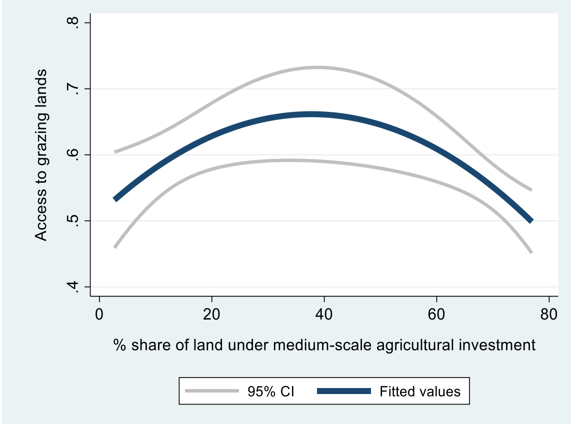
Further, Figures 3.4 present a non-parametric towaway quadratic prediction of the relationship between LSAI, MSAI, and ecosystem services in northern Ghana. The left panels of Figure 3.4 represent the relationship between MSAI and ecosystem services while the right panels represent the relationship between LSAI and ecosystem services The relationships on the left panels of Figure 3.4 shows that household likelihood of accessing economic trees, grazing land,, and forests increases with increasing district's share of land under medium-scale agricultural investment and start to fall when the district's share of MSAI is above 40%. Similar results are established with the right panels for the LSAI. Thus, household access to ecosystem services is an increasing function of both MSAI and LSAI in northern Ghana. These further suggest households' access to ecosystem services is influenced by both MSAI and LSAI. The number of different species planted by a farm household exposed to MSAI/LSAI is enhanced by the increase in a district's share of land under MSAI.



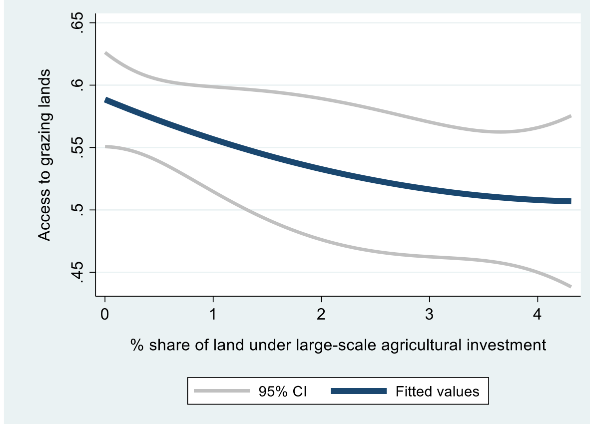
Panel 1: Access to economic trees by MSAI



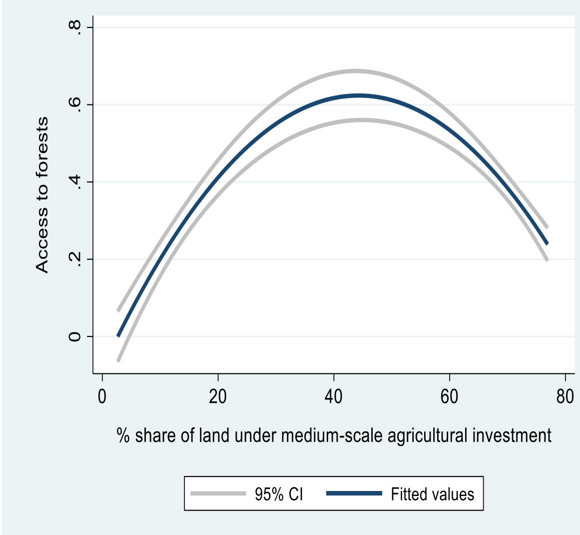
Panel 2: Access to economic trees by LSAI



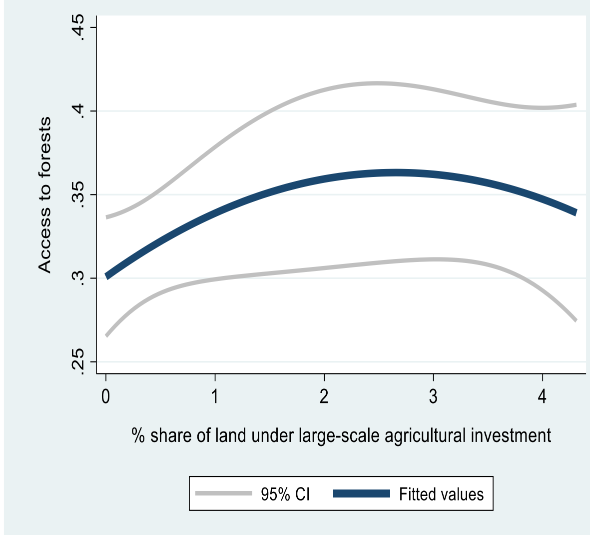
Panel 3: Access to grazing lands by MSAI



Panel 4: Access to grazing land by LSAI



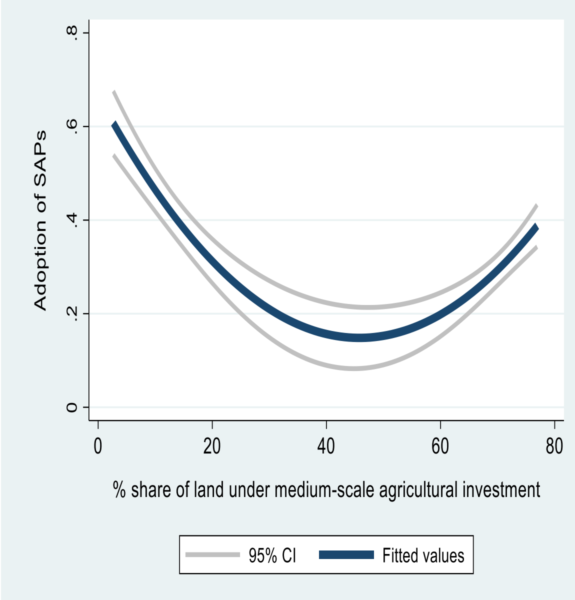
Panel 5: Access to forests by MSAI



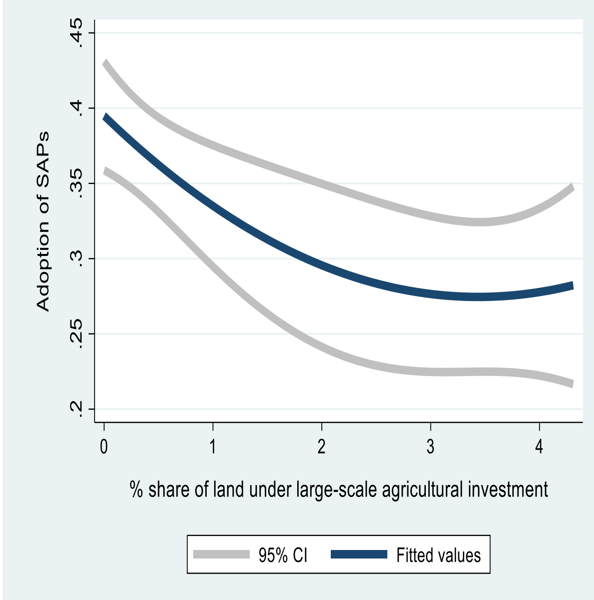
Panel 6: Access to forests by LSAI

Figure 3.4: Access to Ecosystem Services by agricultural investments

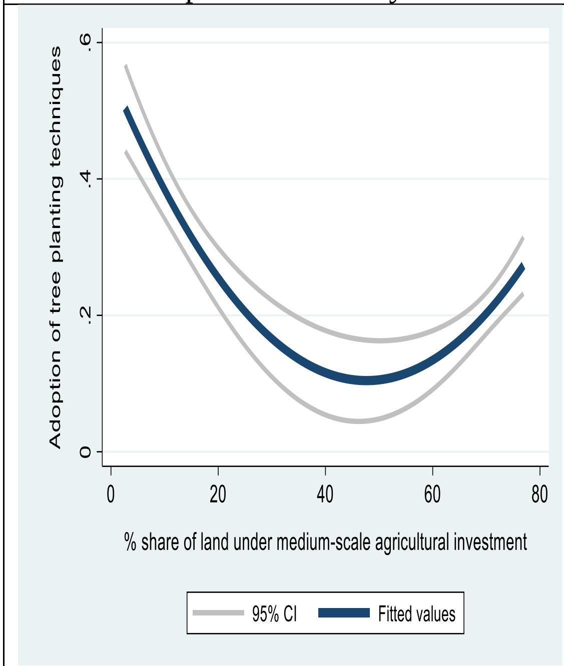
Figures 3.5 present a non-parametric towaway quadratic prediction of the relationship between LSAI, MSAI, and biodiversity and ecosystem management practices in northern Ghana. The relationships on the left panels of Figure 3.5 shows that the probability of adopting SAPs, tree planting techniques, and improved seed varieties increases as the district's share of land under medium-scale agricultural investment increases and starts to rise when the district's share of MSAI is around 45%. On the right panels, however, the probability of adoption of SAPs and improved seed varieties decreases with increasing the district's share of land under LSAI and stabilizes when the district's share of land under LSAI reached 3%. For the adoption of tree planting strategies, the probability of adoption decreases until the district's share of land under LSAI reached 2.5% where it starts to rise. These further suggest both MASI and LSAI influence households' adoption of biodiversity and ecosystem management practices in northern Ghana.



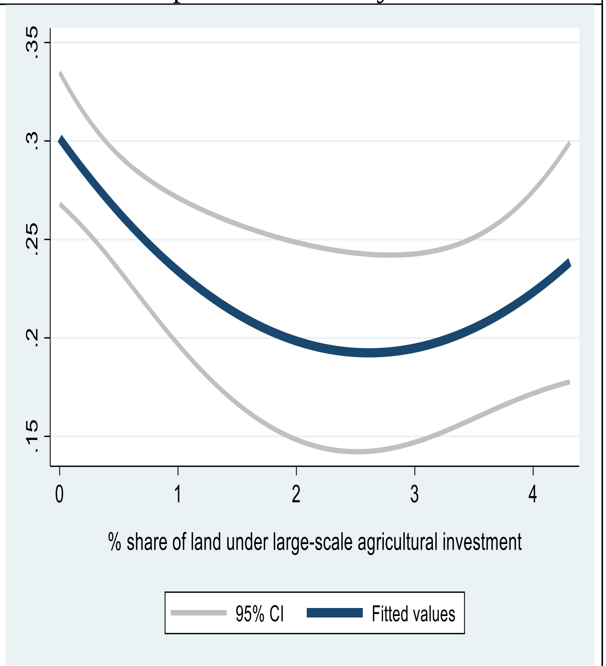
Panel 1: Adoption of SAPs by MSAI



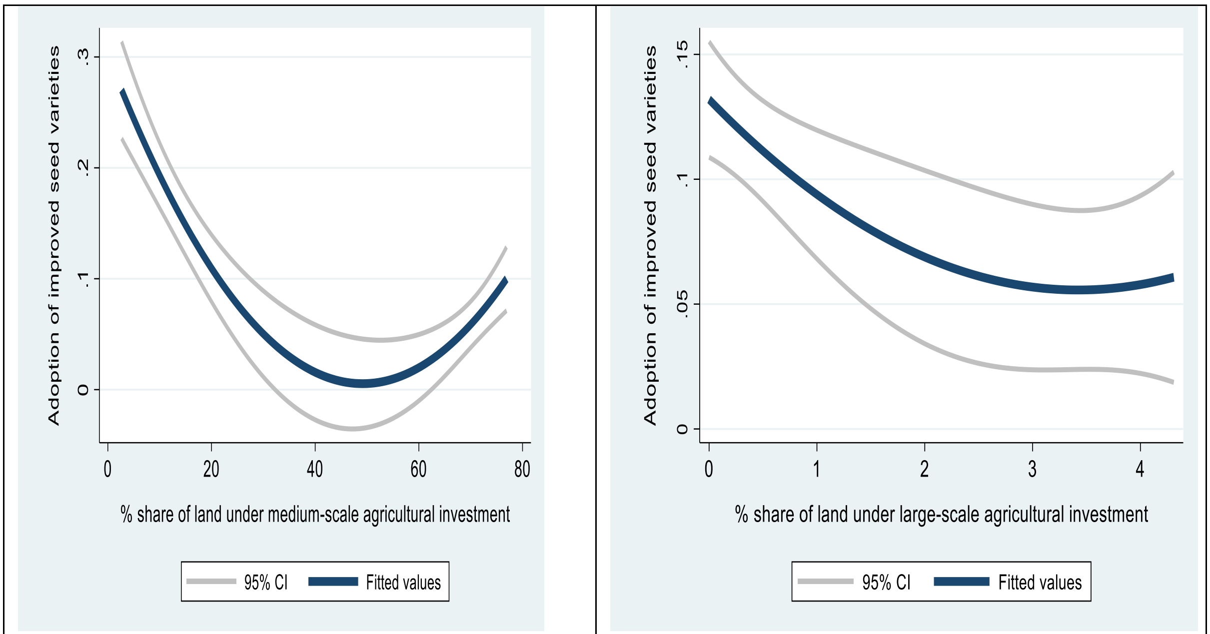
Panel 2: Adoption of SAPs by LSAI



Panel 3: Adoption of tree planting techniques by MSAI



Panel 4: Adoption of tree planting techniques by LSAI



Panel 5: Adoption of improved seed varieties by MSAI

Panel 6: Adoption of improved seed varieties by LSAI

Figure 3.5: Biodiversity and Ecosystem Management Practices by agricultural investments

These bivariate relationships generally showed that biodiversity, ecosystem, and management practices are affected by MSAI and LSAI. However, because the non-parametric methods do not control for the effects of other variables affecting our outcomes, these relationships cannot be regarded as the effect of MSAI and LSAI. Ideally, other variables may be contributing to the change in the outcomes rather than MSAI and LSAI. In the next section, we present more rigorous methods that control other factors and as well allow an econometric analysis of the effects of MSAI and LSAI on biodiversity, ecosystem, and management practices.

Data Analysis

Estimating the Effects of MSAI and LSAI on Biodiversity

To estimate the influence of MSAI and LSAI on biodiversity, we specify the following equation:

$$Y_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 MSAI_{it} + \beta_3 LSAI_{it} + \beta_4 C_{it} + \beta_5 T + \eta_{it} + \varepsilon_{it} \qquad (3.3)$$

Where Y_i is the vector of the outcome variables including biodiversity indicators for unit i. Our key variable of interest is a large-scale agricultural investment $LSAI_i$; and β_2 is the coefficient representing the effect of LSAI on biodiversity, ecosystem service, or practices that manage biodiversity and ecosystem services. However, LSAI and biodiversity may be jointly driven by unobserved factors. For instance, the majority of land acquisitions from customary authorities are medium-scale agricultural investment $MSAI_i$ by local investors or emergent farmers (i.e., local elites, urban-based people, civil servants, retirees, other wealthy people, etc.) who, in the aggregate, have acquired considerably more land than LSAI (Jayne et al., 2014). Such acquisitions may also drive biodiversity. For this reason, we included $MSAI_i$ to capture the impacts on biodiversity occurring from nearby land acquisitions by local/medium-scale investors. Thus, our key variables are now MSAI and LSAI. This allows for testing whether the differences between the effects of LSAI and MSAI are equal to zero, i.e., $\beta_3 - \beta_2 = 0$.

Significant differences from zero indicate that effect of LSAI is more pronounced on biodiversity than MSAI. But the inclusion of $\mathrm{MSAI_i}$ in equation (3.3) may lead to a potential correlation with $\mathrm{LSAI_i}$. Local investors' interest in LSAI is sometimes fueled by the surge in foreign interest in land. Anseeuw et al. (2012), argued that foreigners in LSAI build a partnership with domestic entities to reduce transaction costs caused by the complexity of administrative legislation. The surge in foreign interest in the land also inspire acquisitions by nationals who acquired land to then agree with foreign companies (Anseeuw et al., 2012). Such cases exist in Ghana where LSAI by local actors is influenced by LSAI by foreigners. Ayamga and Laube, (2020), for instance, argued that the withdrawal of foreign actors from LSAI due to the outcry of peasants and strong opposition from civil society groups created spaces that are almost immediately filled by MSAI by domestic actors. Thus, while MSAI by locals may affect biodiversity, it may also correlate with LSAI by foreigners. Such potential correlation of LSAI by foreigners with MSAI by locals may affect the estimation of the pure effect of LSAI by foreigners on biodiversity, especially, when both are included in a regression model. Going forward, multicollinearity checks were conducted with the variance inflation factor (VIF) based on pooled OLS results. However, the results showed that multicollinearity is not a problem for the regression models as the maximum VIF is less than 10. The VIF for MSAI and LSAI, in particular, were found to be 1.90 and 1.62, respectively, and thus, suggest that redundancy is not an issue for the inclusion of both LSAI and MSAI in equation (3.3). We also included detailed information about household/plot-level factors $\mathrm{H_i}$ and community-level variables C, respectively, to minimize potential bias from other unobserved factors. The parameters β_1 and β_4 are the respective coefficients of households/plot factors $\mathrm{H_i}$ and community level variables C. T is a year dummy that takes a value of 1 for 2021 and 0 for 2018; β_5 is the coefficient; and η_{it} is the unobserved heterogeneity. Although these actions are likely to reduce unobserved heterogeneities, we cannot claim to have accounted for all unobserved heterogeneities.

Because of the unbalanced nature of our data, we are restricted in terms of the panel model to use. For biodiversity, if we use the fixed effects estimator, some observations will be lost and we may not achieve consistent estimates (Wooldridge, 2002). Besides, results of model diagnostics with Hausman tests - when a balanced panel is assumed - showed that random effects are more appropriate than the fixed effects model. Moreover, the role of time-invariant variables like population density, averages of precipitation, minimum and maximum temperatures on biodiversity, and other outcomes are very important in this study yet the fixed effects model dropped them from the estimations. The random effects and pooled OLS can therefore be used in this situation as both allow cross-sectional and the variation of the variables over time and as well permit examination of the role of time-constant variables. However, the random effects and pooled OLS models assume that unobserved variations across households are uncorrelated with the predictor or independent variables to be included in equation (3.3). This assumption may not hold as all variables (e.g., innate ability and other unobservable covariates) were not observed/measured in this study (omitted variable problem). To avoid any problem of potential correlation of unobserved variations across households with the predictor variables, the Mundlak approach (Mundlak, 1978a) has been applied in many studies (Bozzola & Smale, 2020; Di Falco & Jean-paul, 2009; Muyanga & Jayne, 2014; Ricker-gilbert et al., 2014). These studies assumed that the endogeneity bias is due to time-invariant unobserved factors, such as household heterogeneity (Wooldridge, 2002). In this model, household-level averages of all time-varying variables are included in a random effect or pooled OLS estimations to control for unobserved time-constant heterogeneity that is likely to correlate with other households' characteristics. In this study, however, the choice of random effect or pooled OLS and the use of the Mundlak method (Mundlak, 1978a) with random effect or pooled OLS for the estimations was made with due consideration of the outcomes of additional tests. First, we run a diagnostic test with the null hypothesis that variances across entities are zero using the Breusch-Pagan Lagrange multiplier. Second, we run a test for using the Mundlak device with our model of choice. In all, the results favour the use of the random effects model without the Mundlak device. The results of model diagnostics with Hausman tests, the Breusch-Pagan Lagrange multiplier, and the Mundlak test can be provided upon request.

Our estimation of the random effects model without the Mundlak device was then conducted for each outcome using a multi-stage model. As mentioned previously, we employed both self-reported or recall data from households and data from remote sensing GIS. In the first stage, only the key variables (i.e., district-level shares of operated farmland under 5-50 ha; and share of operated farmland over 50 ha) are entered into each of the outcome specifications. In the second stage, the key variables are entered into the model along with only household/plot-level covariates and a time dummy to check the behavior of the coefficients MSAI and LSAI with self-reported or recall data from households over time. In the third stage, the key variables are entered into the model along with only location covariates and a time dummy. In the final stage, the key variables are entered into the model along with household/plot-level covariates, location variables, and a time dummy. The purpose of the third and final stage models is to check the precision with which coefficients MSAI and LSAI are measured when the remote sensing GIS spatial dataset is used in isolation or combined with self-reported or recall data from households over time.

Similar steps were employed to estimate the effect of MSAI and LSAI on the ecosystem services, and biodiversity and ecosystem management practices (BEMPs). But the ecosystem services, AND BEMPs were captured as binary variables, so the specifications were switched to nonlinear models. The type of nonlinear model selected also depended on a few issues discussed below. Specifically, we considered two salient issues in our choice of a nonlinear model for these estimations. First, we considered the possibility of interrelations among (i) the services provided by the ecosystem services and (ii) BEMPs. In the former case, we argued that time spent harvesting the products of economic trees can affect the time spent in hunting and gathering services provided by the forest. Further, more fuel wood harvested from economic trees could imply less fuel wood needed from the forest for cooking. Further, grazing in the forest may not be necessary with access to grazing lands. Additionally, it may be economically sensible for a household to access all these services from the ecosystem. In the latter case, an increase in the use of fertilizer could imply less income for the adoption of crop rotation, intercropping, minimum tillage, and residue retention. Further, the application of fertilizer could imply less labour for these practices. Second, we consider the possibility of endogeneity bias due to time-invariant unobserved factors, such as household heterogeneity. To deal with the issue of potential interrelationships among ecosystem services and BEMPs, multivariate probit (MVP) model is employed. For the endogeneity bias, we employed the Mundlak device in which household-level averages of all time-varying variables are included in pooled MVP model estimations to control for the unobserved time-constant heterogeneity. The detailed strategy for estimation of the access to ecosystem services and adoption of BEMPs using the MVP with the Mundlak device is presented below.

Effect of MSAI/LSAI on Ecosystem Services, and BEMPs

To avoid biased estimates, we augment a multivariate probit (MVP) model with the correlated random effects (CRE) model where mean values of age and formal schooling years of the head, household size, assets, remittances received, membership to social groups like farmer-based organization, NGO, etc., leadership, and plot information is included in an MVP model along with the district's share of land under MSAI and LSAI, and other explanatory variables to minimize unobserved heterogeneity. The inclusion of the mean values of these explanatory variables in the MVP model is the correlated random effects (CRE) (Chamberlain, 1984; Mundlak, 1978; Wooldridge, 2002) which has been employed in controlling unobserved heterogeneity (Chamberlin & Jayne, 2020; Kassie et al., 2015; Muyanga & Jayne, 2014; Teklewold, Kassie, & Shiferaw, 2013). Specifically, the MVP model estimates the relationship between explanatory variables and the choice of adoption, allowing for the correlation between unobserved disturbances, and the different adoption choices (Cappellari & Jenkins, 2003). The MVP model is specified as:

$$A_{ikt} = \delta_0 + \delta_1 I_{it} + \delta_2 X_{it} + \delta_3 \bar{X}_i + \varepsilon_{it} \quad k = \text{a, b, c} \qquad (3.4)$$

$$A_{ik} = \begin{cases} 1 \; if \; A^*_{ik} > 0 \\ 0 \; if \; A^*_{ik} \leq 0 \end{cases} \qquad (3.5)$$

Where A_{ik} is access or adoption decision related to the latent variable A^*_{ik} for each of the ecosystem services or biodiversity and ecosystem management practices k for household i at time t; X_i is a vector of exogenous covariates of household/plot i; I_i is the vector of potentially endogenous investment (i.e., MSAI and LSAI). $\bar{X}$ is the index of the averages of household/plot varying explanatory variables that help account for time-invariant unobserved heterogeneity; δ_is are the coefficients of X_i, I_i, and $\bar{X}$; and a, b, and c represent the alternative ecosystem services including economic trees, grazing lands, and forests, or the biodiversity and ecosystem management practices including SAPs, tree planting techniques, and improved seed varieties. If the ε_i in equation (3.4) jointly follow a multivariate normal distribution with 0 as the mean and 1 as the variance, then the covariance matrix $\sum$ can be stated as:

$$\sum = \begin{bmatrix} 1 & \rho_{ab} & \rho_{bc} \\ \rho_{ba} & 1 & \rho_{ac} \\ \rho_{cb} & \rho_{ca} & 1 \end{bmatrix} \qquad (3.6)$$

Where the off-diagonal elements $[rho(\rho)]$ in equation (3.6) represent the unobserved correlation between the stochastic components of the different types of SAPs. The specification in equation (3.6) allows for correlation across the unobserved components of the error terms that affect the choice of alternative SAPs in the several latent equations. A positive correlation is interpreted as a complementary relationship, while a negative correlation is interpreted as a substitute. This assumption means that equation (3.4) generates an MVP model that jointly represents access to ecosystem services or decisions to adopt a particular component of biodiversity and ecosystem management practice (Greene, 2002).

On the other hand, the CRE controls for endogeneity due to time-constant unobserved heterogeneity (Chamberlain, 1984; Mundlak, 1978). Fixed effects procedures could be used for solving such problems. However, the fixed effects would require the estimation of single equation models and can lead to incidental parameter problems. The CRE approach assumes that if explanatory variables, influencing the access to ecosystem services or adoption of the practices, are correlated with unobserved variables (ε_{it}), they are correlated only with the time-invariant component of the unobserved variables (e_{it}) which is a linear function of averages of the household/plot-varying explanatory variables i.e., $e_{it} = \pi_i \bar{X}_i + \omega_{it}$ with $\omega_i \sim IID(0, \sigma^2)$, $E(\omega_i | \bar{X}_i) = 0$ and $\bar{X}_i$ is the vector of the mean values of time-varying explanatory variables and π_i is the corresponding index of coefficients, and ω_i is a normally distributed error term (Chamberlain, 1984; Mundlak, 1978). It is, however, worth noting that the CRE does not control for time-varying unobserved heterogeneity. Thus, if the unobserved plot/time-varying heterogeneity is correlated with access or adoption or other observed explanatory variables, our estimate of the effect of MSAI and LSAI will be inconsistent. We minimize potential bias from unobserved plot-varying heterogeneity by including detailed information about household/plot level factors and community level variables, respectively, to minimize potential bias from other unobserved factors. Although these variables are likely to correlate positively with the unobserved heterogeneities and might help reduce unobserved heterogeneities, we cannot claim to have accounted for all unobserved heterogeneities.

Based on the methods and dataset presented, the effect of MSAI and LSAI on biodiversity, ecosystem services, and BEMPs were examined. The results are presented in section 4.

3.2.3 Third Phase Focus Group Discussions (FGDs)

To explain the results of the second phase, a third phase of focus group interviews was conducted. In the third phase, FGDs were conducted to help explain the second phase's quantitative results. Specifically, one focus group discussion was conducted in each of the 10 districts. Following Babbie (2013) and Twumasi (2001), 14 participants exposed households consisting of both men and women were selected into each group to generate meaningful discussions. Since the homogeneity of participants allows a free flow of conversations (Babbie, 2013), participants with low livelihood security index were selected into each group. In all, 140 exposed households were selected to participate in 10 different focus group discussions. Based on the results of the second phase, an interview guide was developed for the group discussions. The questions were generated from the findings of the second phase quantitative study and generally contain questions whose answers led to explaining the second phase quantitative results. Before the start of each interview, participants were informed about the second phase results so that they could use them as a reference point to offer their explanations. The EVISTR Digital Voice Recorder was used for recording the conversations. However, the responses from the interviews were written in a notebook as backup information. After the interviews, all discussions in the audio recorder were carefully transcribed following the procedure in the first phase of qualitative interviews. Content analysis was then employed to analyse transcribed information. Specifically, the distribution of words and their frequencies was employed because the core of content analysis lies with the frequency distribution of words. Moreover, the meanings attached to a phenomenon are mostly manifested in the words used (Babbie, 2013). The Nvivo, "*txttool*" (Williams & Williams, 2014), and *wordfreq* and *wordcloud* commands (Dicle & Dicle, 2018) in Stata were employed to generate words and their corresponding frequencies. These were integrated with the second phase study to explain the survey results. When found relevant, quotations were presented to support the findings.

3.3 Ethical Considerations

Ideally, the main concern about studies of large-scale acquisition and associated agricultural investment is the concept apply in labelling. The development optimism view, inspired by managerial discourse, recognizes dangers in the foreign direct investment in the land but still insists that there are considerable opportunities that could benefit investors, host governments, and their populations. This school of thought, therefore, prefers terms like 'large-scale land acquisition', 'large-scale agricultural investment', or 'foreign direct investment in the land'. On the other hand, the neo-colonialism view, inspired by the populace discourse, highlights the potential negative livelihood impacts of LSAI in poor countries and therefore calls for support to disallow any entity involved in such practices. This school of thought prefers the term 'land grabbing'. However, in this study, labeling such investment under consideration as land grabbing will mean that such investment is associated with negative impacts on biodiversity and the livelihood of local occupants. This can raise a wide range of legal and ethical questions leading to a possible halt of the study. Such labeling can also deny the researchers access to respondents that matter in this study. As a result, the term large-scale agricultural investment by foreign entities or foreign direct investment in land was adopted throughout this study.

Also, information on land can be considered sensitive by respondents. Thus, respondents may provide shady and scattered information that is difficult to understand. For instance, for fear of being evicted or providing information that might lead to further dispossession, disgruntled victims may be less inclined in sharing their stories. Similarly, actors involved in LSAI, key informants including traditional authorities, officials from Lands Commission, Forestry Commission, etc., may decline to participate in the interviews for fear of violation of laws governing information access. All these issues can make it difficult to get precise information for this study. Similarly, the multidimensional nature of LSAI and biodiversity makes it complex as it is difficult to gather complete information from only one group of participants. Given these nuanced issues and the need to piece together information, the research team employed different strategies to secure sensitive information from respondents. First, the team sought the consent of all participants through the authorities of the University for Development Studies. Thus, introductory letters were acquired from the university for each interviewer served to each participant. For smooth elicitation of information, it was stated in the letters that information will only be used for research. Second, we employed enumerators who reside or have ever resided in the sampled communities for the interviews since most respondents appear comfortable working with people they know. As mentioned previously, these personnel were trained for the translation of questions to participants. Third, LSAI is based on large-scale land acquisitions which are mostly contested by the affected victims. This implies publication of unverified and sensitive information from such investments may put investors and their investments at risk. Thus, all participants, investors, and their investments are anonymized to allow for the publication of this study.

4. RESULTS AND DISCUSSIONS

4.1 Results of First Phase Qualitative Study

Knowledge of LSAI: Table 4.1 presents the word chart generated from views of KIs regarding their understanding of LSAI. The results show that knowledge of LSAI in northern Ghana is not straightforward and mixed with different connotations (see Table 4.1). Specifically, words like 'transparent', 'informed', 'development', 'employment', 'beneficial', and 'win-win' were employed and thus, show positive connotations while words like 'forceful', non-compensative', 'non-consultative', 'nontransparent', 'nonbeneficial', 'hunger', 'underdevelopment', 'unemployment', displacement, illegal were employed and therefore show negative connotation (Table 4.1). The words with positive connotations including 'development', 'employment', 'beneficial', and 'win-win' seem to suggest that land acquired for LSAI leads to the welfare improvement of farmers in the area. Mr. Robert Kwame is the Chairman of the Water Users Association under ICOUR- one of the LSAI located in the Upper East region of Ghana and responsible for providing irrigation to farmers for the production of rice (Figure 4.1). He argues: *"As for the benefits of the ICOUR project, you cannot say it all.*

Even the nation is benefitting from it. At the household level, we can pay the school fees of our children, and the crime rate in the area has been reduced since most youths are getting employment from the project".

Figure 4.1: Interview with the Chairman of the Water Users Association of ICOUR in the Upper East Region of Ghana
Photo: Author, 2022

Mr. Fatawu Issifu is a Field Officer in the Northern region of Ghana under MoFA – a lead agency of food production in Ghana tasked with the implementation of the Ghana Commercial Agricultural Project (GCAP) (Figure 4.2). He argues that "*despite several challenges faced, GCAP identified and developed rice valleys for investors (nucleus farmers) and their farmers, helped them with grants, linked them to agricultural inputs and output market"*. He further argues that: *"those who took such intervention serious benefited in terms of employment and paying back the loan on time*".

Figure 4.2: Interview of MoFA Field Officer in Northern Region
Photo: Author, 2022

However, some of the KIs have a different opinion about the project in the area. Mr. Danumin Subiniman, the CEO of DANSMAN COMPANY which benefited from the GCAP and is located in Tamale, argues that the project did not fulfill its duties as advertised in the call for proposals. According to him, GCAP specified in the call that USD50,000 was to be given to each beneficiary but only 30% of the funds were released to them ever since the project started. This according to him has led to low performance, lay-out of some workers of the company, and unemployment. Sensing doubt on my part about his narration, he asked that I take a closer look at his empty shop where the interview is being conducted. He believes that the emptiness of the shop is caused by the GCAP project which did not fulfill the promises made during the call.

Figure 4.3: Interview of CEO of Dansman Company in the Northern Region
Photo: Author, 2022

Further, words or phrases including 'chiefs and elders', 'home government', 'foreign governments', 'financial institutions', 'large-scale industries', 'agro-processors', 'public', 'private', 'domestic' and 'foreign' investors were also employed in describing LSAI (Table 4.1). Mr. Alhassan Issah, a native of the Gushie community in the Savelegu District of the Northern Region believes that land under Integrated Tamale Fruit Company (ITFC) is a joint project between several actors including the Nanton, Dipale, and chiefs, Wienco Ghana Ltd and some white men and therefor large. A closer view of the words employed also appears to reveal three key issues in this study. First, not only do the words employed by the KIs appear directly opposite to the attributes of the processes outlined in Ghana for acquiring land for LSAI but they appear with the greatest frequency. This is evidenced in the dominant use of words such as forceful, non-compensative, non-consultative, nontransparent, hunger, underdevelopment, unemployment, and displacement. This, therefore, casts doubt on the processes employed by actors in acquiring land in the area for LSAI. For instance, throughout the interviews, it was repeatedly mentioned how chiefs forcefully take land from farmers in the name of LSAI. In support of this point, one of the interviewees explained: *"Our chiefs have power over land and can therefore sell land to investors without obtaining prior consent or informing anyone. If you complain, the chief will threaten you with banishment"*. Another said: "*We have no idea of how the land was acquired for such large-scale investment, we were informed about it and we were never involved in the negotiations process or compensated for the loss of crops on the land***".** These further highlight the fact the way land is being released to investors may have fallen out of the due processes for acquiring land for LSAI and thus, trigger the use of such words in describing LSAI. Second, the words employed also mirrored the different actors involved in the acquisition of land for LSAI. This is reflected in the use of words such as 'chiefs/elders', 'home government', 'foreign governments', 'big financial institutions', 'large-scale industries', 'large-scale agro-processors', 'public', 'private', 'large domestic' and 'foreign' investors in describing LSAI. Third, the connotations also revealed that the scale of land involved in LSAI may be large. This is reflected in the use of 'big financial institutions', 'large-scale industries', 'large-scale agro-processors', 'large domestic', and 'large foreign' investors.

Table 4.1: Word Chart showing the frequency of terms in KIs responses to the impact of LSAI on biodiversity

Word	**Frequency**
Consented	21
Unconsented	72
large-scale agro-processors	32
big financial institutions	60
Borrowed	50
chief-elders	100
non-compensative	56
Development	25
Displacement	2
Dispossessive	2
large domestic investors	36
Employment	10
Forceful	130
foreign governments'	40
large foreign investors	56
Foreigners	60
Gifted	33
Government	5
home government	80
Hunger	20
Illegal	44
Uninformed	32
Large	18
large-scale industries	21
Nonbeneficial	81
Nontransparent	66
Politicians	40
Poverty	16
Private	22
Purchasing	11
Secrete	21
Speculative	7
Stolen	7
Transparent	128

Underdevelopment	2
Unemployment	1
Uninformed	7
Informed	132
win-win	5

Source: Field Work, 2022

The implication of LSAI on biodiversity: Table 4.2 (projected in Figure 4.4) presents the implication of LSAI on biodiversity in northern Ghana. The results revealed that LSAI in the area has affected biodiversity in several ways. Specifically, soil fauna, fertility, soil organic carbon density, silt content of the soil, plant distribution, crops, animals, forest, vegetation, food production, fiber, fuel wood, herbal medicines, shea nuts, pure water, hunting, and gathering has been affected. However, the effect is mixed and resonated in the words employed by the KIs in describing the implication of LSAI on biodiversity. Whereas words such as poor, loss, low, floods, erosion, degradation, deforestation, infertile, and destruction represent negative connotations, words such as improved, good, enhance, and high represent positive connotations employed in describing the effect of LSAI on biodiversity. A closer view of the words employed by the KIs points to two opposing views about the effect of LSAI on biodiversity and thus, add to the debate about the implication of LSAI on the environment. The positive connotations may be highlighting the potential positive benefits of LSAI, while negative connotations may be highlighting the potential dangers of LSAI. However, the frequency with which the negative connotations appear is higher than that of the positive connotations. This is reflected in our interviews where it was continuously mentioned that LSAI undermines different aspects of biodiversity in the area.

Table 4.2: Word Chart showing the frequency of terms in KIs responses to the impact of LSAI on biodiversity

Word	**frequency**
Poor	80
Loss	50
Low	33
Floods	28
Erosion	20
Degradation	26
Deforestation	100
Infertile	90
Destruction	37
Improved	18
Good	18
Enhance	15
High	10

Source: Field Work, 2022

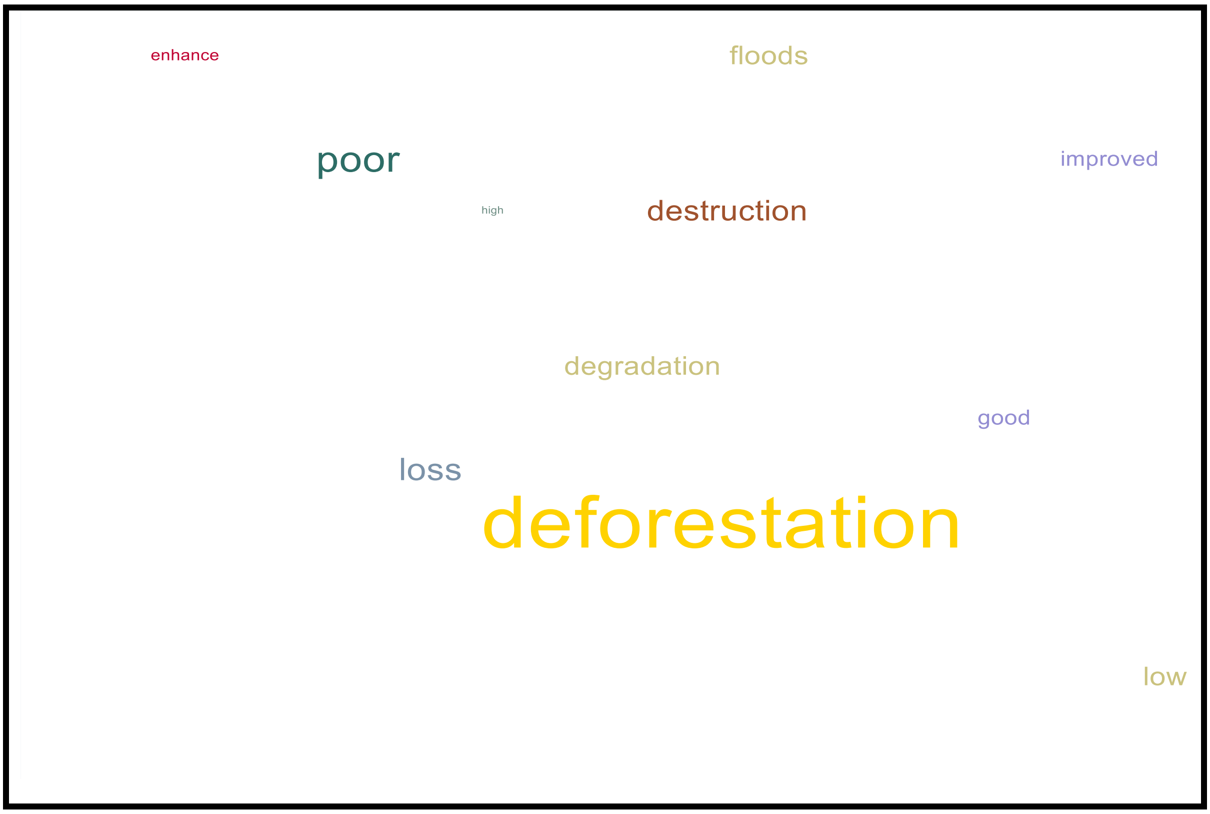


Figure 4.4: Word Cloud of KIs' Views on Consequences of LSAI

Source: Field Work, 2022

To further substantiate the impact of LSAI on biodiversity, we present in Table 4.3 the perception of KIs on the effect of LSAI on biodiversity in the area. The results revealed that LSAI has adversely affected biodiversity in the area. Whereas 7 (11.7%) are of the view that LSAI led to an increase in biodiversity, 36 (60%) argued that LSAI decreased biodiversity in the area. On the other hand, about 17 (28.3%) maintained that no changes in biodiversity are observed in the area.

Table 4.3: KIs views on the effect of LSAI on biodiversity

Perception	Frequency	Percentage
Significantly increased	3	5
Increased	4	6.67
No change	17	28.33
Decreased	24	40
Significantly decreased	12	20

Source: Field Work, 2022

We further present in Table 4.4 the plant species destroyed by LSAI in the area. The responses revealed tree destruction during the land preparation stages for LSAI. However, the majority confirmed that shea nut (33.3%), neem (20%) and dawadawa (16.7%), acacia (10%), and baobab (8.33%) trees were the major trees destroyed by the activities of the LSAI. The remaining plant species including citrus, moringa, and mango were not highly destroyed because these three are mostly grown at homes for shade, medicinal and aesthetic purposes. The destruction of trees affected businesses and ecosystem services provided by the trees in the area. For instance, out of the 60 KIs interviewed, 76.4% were of the view that access to shea nuts declined as a result of the destruction of shea trees for LSAI, while the rest of the

23.6% attributed the reduction to other activities that prevent women from picking shea nut. Similarly, about 80.3% attributed a decline in charcoal production to LSAI while 19.7% attributed it to other farming activities. Madam Asana Alhassan, a shea butter producer in Yagaba, a community in the Mamprugu-Moagduri district complained as follows: "*Now shea butter, charcoal, and firewood businesses which use to fetch regular income for me and my family have all collapsed due to the destruction of shea and other local trees in this community*". Concerning access to grazing land, 56% admitted that grazing is restricted in the land acquired for LSAI while 44 said grazing is not. Mr. Alhassan Amin, a herder and a farmer in Tumu in the Upper West region, also complained as follows: *"The Augustine farms did not take away only our farmlands, but also restricted us from grazing our animals in the area"*.

Table 4.4: Plant species destroyed by activities of LSAI

Plant species	**Frequency**	**Percentage**
Shea nut (Vitellaria *paradoxa*) trees	20	33.33
Neem (Azadirachta *indica)* trees	12	20.00
Baobab (Adansonia *digitata*) trees	5	8.33
Acacia (*Acacia* species) rees	6	10.00
Mango (Mangifera indica)	3	5.00
Dawadawa (Parkia *biglobosa*)	10	16.67
Moringa trees	2	3.33
Citrus trees	2	3.33
Total	60	100.00

Source: Field Work, 2022

Mr. Daniel Akansake is an agronomist under the Irrigation Company of the Upper Region (ICOUR). He admitted that while the project promoted all-year-round farming, it also led to the loss of soil fauna, fertility, soil organic carbon density, silt content of the soil, loss of grazing land, forest loss (deforestation), and loss of vegetation due to continuous cropping. He also admitted that the introduction of herbicide has led to the loss of microorganisms, panicum maxima, and soil flora. However, Richard Derbile – a farmer under ICOUR – argued that the variety of vegetation that existed on the land is rather replaced by single crops including rice.

Figure 4.5: Interview with the Agronomist of ICOUR in the Upper East Region of Ghana
Photo: Author, 2022

Strategies for dealing with the consequences of LSAI on biodiversity: Because the acquisition of land on a large scale and the subsequent establishment of LSAI had led to the destruction of trees, the Environmental Protection Agency of Ghana encouraged the planting of trees to quickly replace the trees destroyed. As a result, attempts were made by managers of LSAI in collaboration with some farmers to plant fast-growing plants to replace the lost trees. In the Kpachaa community where BioFuel Africa Ltd operated, mango trees were intercropped with maize to serve multiple purposes of food production, provision of fuel wood for cooking, and charcoal production. Moringa trees were later planted in between the mango trees intercropped with maize. However, because the leaves of mango trees also serve as food for livestock, the mango trees were destroyed by animals. To make it worst, protests over the acquisition of land for such a project emerged leading to the project being halted and subsequently abandoned. This subsequently affected the growth of the mango and moringa trees. Thus, the objective of maintaining biodiversity failed. In the Gushie community, the Integrated Tamale Fruit Company produced mango for local and international markets. Reports from some KIs indicated that the owners of the company took large hectares of their land despite not being able to use all for the mango plantation. However, one of the key informants narrates the following: "*As part of the lease agreement, logistical assistance, 100 mango trees per acre, technical advice, and a ready market were provided to farmers under the nucleus farm operated by the company. Aside from this effort, the company also preserved a portion of the land acquired as a biodiversity zone*". It was also revealed that the company encouraged out-growers through the purchase of their produce. All these efforts were aimed at increasing tree crop plantation, reducing poverty, and environmental degradation, and as well as improving biodiversity in the area. Thus, the agronomist for ICOUR, Mr. Robert Akansake also revealed that continuous cropping and application of agrochemicals by farmers under ICOUR is leading to loss of soil nutrients, land degradation, and loss of some plant species. As a result, ICOUR in collaboration with Savanah Agriculture Research Institute teaches sustainable agricultural practices including manure, crop rotation, integrated, minimum tillage, residue retention, and zero use of petroleum-based products are introduced to help improve soil biodiversity.

Regarding the findings, the study revealed that different actors including domestic and foreign entities participate in LSAI and the land involved is mostly large. However, it was clear from the interviews that complexities exist in the processes involved in acquiring land for LSAI. Whereas words including 'transparent', 'informed', 'development', 'employment', 'beneficial', and 'win-win' point to efficiencies in the acquisition processes, words including 'forceful', non-compensative', 'non-consultative', 'nontransparent', 'nonbeneficial', 'hunger', 'underdevelopment', 'unemployment', 'displacement' and 'illegal' mirrored some inefficiencies in the processes. This calls for an investigation into the process involved in LSAI. Further, the KIs' views of the impact of LSAI on biodiversity provided a novel perspective on the biodiversity implications of LSAI. This is mirrored in the different concepts resulting from analysis of their descriptions of the impact of such investment on the loss of soil fauna, fertility, soil organic carbon density, silt content of the soil, loss of grazing land, forest (deforestation), and vegetation in the area of study. Regarding the strategies employed to deal with the consequences of LSAI on the different aspects of biodiversity, the study revealed that tree planting and the application of sustainable agricultural practices have been introduced to help improve plant and soil biodiversity. These findings are all robust themes necessitating further investigation. The second phase of this study will therefore focus on delving deeper into the impact of LSAI on biodiversity, ecosystem services, and management practices.

4.2 Results of the Second Phase Quantitative Study

4.2.1 Effects of MSAI and LSAI on Biodiversity

The results of the effects of MSAI and LSAI on biodiversity indicators including species richness, diversity, evenness, EVI, and SAVI, are presented in Table 4.5. As mentioned previously, a multi-stage estimation was conducted to examine the effects of the MSAI and LSAI on biodiversity, and to check the robustness of the results in the presence and absence of other factors. The biodiversity indicators consisted of indicators from self-reported or recall data from households and indicators from remote sensing GIS data. Thus, our model specifications differ not only in terms of the variables we controlled for but also in terms of the outcome indicators employed. Columns 1-5 (i.e., the basic model) show the effect of MSAI and LSAI on richness, diversity, evenness, EVI, and SAVI respectively, when no household/plot-level covariates or location covariates are controlled for. Columns 6-10 show the effect of MSAI and LSAI after accounting for the effects of only household/plot-level covariates in the model. Further, columns 11-15 show the effects of MSAI and LSAI on biodiversity when we accounted for only location covariates (otherwise known in this study as spatial controls), and columns 16-20 (i.e., full model) showed the effects of MSAI and LSAI on biodiversity after accounting for the effect of both household/plot and spatial controls in the model. These alternative specifications were estimated to test the robustness of our findings regarding the effects of MSAI and LSAI.

Generally, more variations are noted in the specifications for biodiversity indicators derived from self-reported data from the household survey. Thus, the results from models with outcomes derived from remote sensing GIS spatial dataset appear consistent and unlike results from specification with outcomes derived from self-reported or recall data from households which vary between the different specifications. When these results are pieced together, the emerging picture is that the self-reported indicators of biodiversity changed with model specifications with coefficients MSAI and LSAI increasing as household/plot level covariates and spatial controls are accounted for. This, therefore, points to downward bias if household/plot level covariates and spatial controls are not controlled. On the other hand, the coefficients of MSAI and LSAI in the specification with biodiversity indicators from remote sensing GIS remain almost the same across all specifications. Thus, even though the district-level share of both MSAI and LSAI generally affects biodiversity, the effects depend on the outcome employed. Whereas the effects of MSAI and LSAI on biodiversity outcomes derived from self-reported data are highly dependent upon the covariates accounted for, the effects of MSAI and LSAI on EVI, and SAVI derived from remote sensing GIS do not. Further, the parameter differences between LSAI and MSAI are significant across all the specifications, suggesting that the intensity of the household's exposure to investment in land acquisition matters in biodiversity.

For the basic model, LSAI is found to exert a positive effect on all the indicators even though it is significantly related to only EVI, SAVI, diversity, and evenness with a 0.35 percentage point decrease in EVI, 0.34 percentage point decrease SAVI, 5.10 percentage point decrease in diversity, and 5.56 percentage point decrease in evenness. On the other hand, MSAI is found to exert a negative influence on all the outcomes even though it is significant for only EVI, and SAVI and decreased them by 0.04 and 0.05 percentage points, respectively. Thus, whereas biodiversity is strongly enhanced by increasing the district's share of land under LSAI, the same cannot be said about biodiversity under MSAI as EVI, and SAVI decrease significantly under MSAI. When we account for the effect of household/plot level variables, no further insights are gained on the effect of LSAI and MSAI on biodiversity indicators except that some of the coefficient in the basic model varied from the coefficient in the model controlling for household/plot level covariates. Specifically, we note a 0.03-0.24 percentage point decrease in biodiversity indicators for 10 percentage point increase in district's share of land under MSAI. For LSAI, we note a 0.37-5.82 percentage points increase in biodiversity indicators for 10 percentage point increase in share of land under LSAI. When our indicators are regressed against the MSAI and LSAI along with the spatial controls, the magnitude of the coefficients of MSAI and LSAI differed again. For MSAI, we found a 0.03-0.33 percentage point decrease in the indicators of biodiversity if land under MSAI is increased by 10 percentage points in a district. On the other hand, a 0.36-6.31 percentage point decrease is observed for a district with 10 percentage point increase in land under LSAI. In the full model, similar results are obtained as in the specifications controlling for only households or spatial variables. Specifically, we note a 0.02-0.33 percentage point decrease in biodiversity indicators as district's share of land under MSAI is increased by 10 percentage point. On the other hand, the increase in biodiversity indicators is 0.38-6.66 percentage points for 10 percentage point increase in land under LSAI in a district. These results generally suggest that LSAI enhances biodiversity while MSAI leads to its destruction.

The decrease in biodiversity due to MSAI is plausible since vegetation destruction is commonly associated with the expansive attribute of MSAI (Wineman et al., 2022). The surprising result, however, is increase in biodiversity due to LSAI. In an attempt to explain such findings, we explored responses from focus group discussions. However, the responses from FGDs showed that the LSAI investors possessed biodiversity-relevant knowledge on how to safeguard biodiversity, ecosystems, and other natural resources and have not destroyed much vegetation (FGDs, July 20, 2023).

Aside from the key variables of interest, the results also show a significant role in some of the household/plot and spatial controls. We, however, refrained from a detailed discussion of households/plot level and spatial controls, because the focus here is primarily on the effect of MSAI and LSAI on biodiversity. But jointly, the household/plot and spatial controls significantly derive the biodiversity and thus, confirm other studies which noted that household/plot variables, weather and climate (as implied in precipitation, temperature, and elevation), urbanization (implied in the built-up area measured the proportion of building footprint area), and population density affect biodiversity (e.g., Bozzola & Smale, 2020; Wineman et al., 2022).

Table 4.5: Estimates of the effects of MSAI and LSAI on biodiversity indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	EVI	SAVI	richness	diversity	evenness	EVI	SAVI	richness	diversity	evenness
MSAI	-0.0004***	-0.0005***	-0.0000	-0.0014	-0.0007	-0.0003*	-0.0005***	0.0000	-0.0024*	-0.0008
	(0.0001)	(0.0001)	(0.0003)	(0.0011)	(0.0012)	(0.0001)	(0.0001)	(0.0003)	(0.0013)	(0.0012)
LSAI	0.0035**	0.0034***	0.0019	0.0510***	0.0555***	0.0038*	0.0037***	0.0041	0.0567***	0.0582***
	(0.0016)	(0.0012)	(0.0054)	(0.0164)	(0.0170)	(0.0023)	(0.0014)	(0.0058)	(0.0180)	(0.0135)
gender						-0.0012	-0.0018	0.0000	0.0633	0.0708
						(0.0059)	(0.0032)	(0.0381)	(0.0759)	(0.0945)
age_hhh						-0.0004**	-0.0001	0.0011*	0.0014	0.0010
						(0.0002)	(0.0002)	(0.0006)	(0.0018)	(0.0020)
schooling_yrs						0.0004	0.0002	-0.0009	0.0037	0.0024
						(0.0005)	(0.0004)	(0.0011)	(0.0042)	(0.0039)
hhsize						-0.0001	-0.0001	-0.0012	0.0072**	0.0061*
						(0.0003)	(0.0002)	(0.0010)	(0.0032)	(0.0033)
asset						0.0070**	0.0045	0.0058	0.0108	-0.0099
						(0.0031)	(0.0028)	(0.0082)	(0.0221)	(0.0264)
remittances						-0.0030	-0.0020	0.0114	0.0323	0.0480
						(0.0057)	(0.0043)	(0.0203)	(0.0592)	(0.0592)
social_group						0.0039	-0.0004	-0.0185	-0.0428	-0.0296
						(0.0060)	(0.0043)	(0.0130)	(0.0476)	(0.0521)
floods						-0.0032	-0.0001	0.0444**	-0.0898*	-0.0457
						(0.0064)	(0.0052)	(0.0202)	(0.0486)	(0.0627)
drought						0.0076	-0.0027	-0.0122	0.1208**	0.1116*
						(0.0078)	(0.0045)	(0.0263)	(0.0592)	(0.0650)
fertilizer						0.0004	-0.0001	0.0007	0.0025*	0.0016
						(0.0003)	(0.0001)	(0.0006)	(0.0013)	(0.0014)
tenure_security						-0.0069	0.0069	0.0359	-0.0776	-0.0938
						(0.0088)	(0.0061)	(0.0341)	(0.0901)	(0.0936)
good						0.0066	0.0052	-0.0439*	0.0020	-0.0253
						(0.0067)	(0.0039)	(0.0234)	(0.0671)	(0.0764)
moderate						-0.0028	-0.0010	-0.0105	0.0064	0.0035
						(0.0064)	(0.0035)	(0.0258)	(0.0731)	(0.0779)
deep_depth						-0.0007	0.0037	-0.0341	0.0911	-0.0174
						(0.0065)	(0.0043)	(0.0359)	(0.0942)	(0.0848)
moderate_depth						0.0079	0.0037	-0.0180	0.1181***	0.0827
						(0.0057)	(0.0040)	(0.0211)	(0.0440)	(0.0572)
flat_slope						0.0079	0.0001	-0.0418	0.1026	-0.0233
						(0.0063)	(0.0042)	(0.0353)	(0.1232)	(0.1033)
moderate_slope						0.0057	0.0017	-0.0306	0.0939	0.0219
						(0.0068)	(0.0044)	(0.0323)	(0.1217)	(0.1130)
Elevation										
values_built										
Avgmaxtemperature										

Avgmintemperature										
AvgPPT12										
Pop_dens										
sqpop_den										
year_01						-0.0065	0.0029	-0.0184	0.0973**	0.0107
						(0.0042)	(0.0027)	(0.0162)	(0.0446)	(0.0422)
Constant	0.5072***	0.4674***	1.5211***	-1.4893***	-1.2664***	0.5143***	0.4650***	1.4905***	-1.7916***	-1.4130***
	(0.0068)	(0.0071)	(0.0317)	(0.0548)	(0.0571)	(0.0150)	(0.0114)	(0.0772)	(0.2051)	(0.2202)
MSAI vs. LSAI	5.34**	9.13***	0.12	9.29***	9.92***	2.88*	7.33***	0.47	9.73***	17.62***
Observations	1,219	1,219	1,219	1,219	1,145	1,219	1,219	1,219	1,219	1,145
Number of hhid	618	618	618	618	603	618	618	618	618	603

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.5 continued.

VARIABLES	(11) EVI	(12) SAVI	(13) richness	(14) diversity	(15) evenness	(16) EVI	(17) SAVI	(18) richness	(19) diversity	(20) evenness
MSAI	-0.0003**	-0.0005***	0.0003	-0.0033***	-0.0017	-0.0002**	-0.0005***	0.0001	-0.0033***	-0.0018
	(0.0001)	(0.0001)	(0.0003)	(0.0011)	(0.0013)	(0.0001)	(0.0001)	(0.0003)	(0.0012)	(0.0013)
LSAI	0.0036**	0.0036***	0.0000	0.0589***	0.0631***	0.0039**	0.0038***	0.0030	0.0620***	0.0666***
	(0.0018)	(0.0014)	(0.0051)	(0.0137)	(0.0159)	(0.0018)	(0.0013)	(0.0062)	(0.0144)	(0.0181)
gender						-0.0016	-0.0017	0.0002	0.0679	0.0726
						(0.0057)	(0.0029)	(0.0396)	(0.0746)	(0.1019)
age_hhh						-0.0004**	-0.0001	0.0010*	0.0018	0.0014
						(0.0002)	(0.0002)	(0.0006)	(0.0019)	(0.0022)
schooling_yrs						0.0004	0.0002	-0.0010	0.0049	0.0036
						(0.0005)	(0.0003)	(0.0012)	(0.0043)	(0.0045)
hhsize						-0.0001	-0.0001	-0.0012	0.0079***	0.0067**
						(0.0003)	(0.0002)	(0.0011)	(0.0029)	(0.0028)
asset						0.0068**	0.0042	0.0061	0.0097	-0.0098
						(0.0028)	(0.0028)	(0.0082)	(0.0228)	(0.0251)
remittances						-0.0034	-0.0022	0.0118	0.0305	0.0473
						(0.0062)	(0.0041)	(0.0156)	(0.0545)	(0.0702)
social_group						0.0041	-0.0001	-0.0185	-0.0431	-0.0277
						(0.0051)	(0.0042)	(0.0140)	(0.0473)	(0.0553)
floods						-0.0031	0.0001	0.0465**	-0.1002*	-0.0604
						(0.0064)	(0.0049)	(0.0195)	(0.0556)	(0.0592)
drought						0.0078	-0.0026	-0.0108	0.1076*	0.0979
						(0.0070)	(0.0047)	(0.0283)	(0.0584)	(0.0699)
fertilizer						0.0004*	-0.0001	0.0007	0.0025*	0.0016
						(0.0002)	(0.0001)	(0.0006)	(0.0013)	(0.0015)
tenure_security						-0.0076	0.0061	0.0349	-0.0694	-0.0811

						(0.0094)	(0.0059)	(0.0368)	(0.0942)	(0.0814)
good						0.0071	0.0054	-0.0442**	-0.0008	-0.0273
						(0.0071)	(0.0040)	(0.0208)	(0.0733)	(0.0800)
moderate						-0.0028	-0.0009	-0.0102	0.0042	0.0017
						(0.0076)	(0.0042)	(0.0239)	(0.0680)	(0.0797)
deep_depth						-0.0006	0.0036	-0.0335	0.0846	-0.0245
						(0.0083)	(0.0048)	(0.0383)	(0.0821)	(0.0894)
moderate_depth						0.0079	0.0038	-0.0181	0.1165**	0.0807
						(0.0051)	(0.0036)	(0.0203)	(0.0516)	(0.0628)
flat_slope						0.0080	-0.0002	-0.0425	0.1013	-0.0236
						(0.0068)	(0.0046)	(0.0358)	(0.1351)	(0.1414)
moderate_slope						0.0057	0.0013	-0.0307	0.0929	0.0231
						(0.0066)	(0.0054)	(0.0352)	(0.1341)	(0.1377)
Elevation	-0.0001	-0.0002**	0.0043***	-0.0063***	-0.0039***	-0.0001	-0.0002**	0.0043***	-0.0064***	-0.0041***
	(0.0001)	(0.0001)	(0.0009)	(0.0010)	(0.0010)	(0.0001)	(0.0001)	(0.0009)	(0.0010)	(0.0011)
values_built	0.0008	-0.0006	0.0084	0.0017	0.0010	0.0008	-0.0006	0.0087	0.0023	0.0023
	(0.0031)	(0.0009)	(0.0165)	(0.0129)	(0.0394)	(0.0034)	(0.0010)	(0.0172)	(0.0129)	(0.0118)
Avgmaxtemperature	0.0245**	0.0427***	0.3188***	-0.5753***	-0.4380***	0.0243**	0.0413***	0.3162***	-0.5772***	-0.4342***
	(0.0097)	(0.0114)	(0.0787)	(0.1143)	(0.0932)	(0.0106)	(0.0105)	(0.0753)	(0.1058)	(0.0950)
Avgmintemperature	-0.0372***	-0.0471***	0.5368***	-0.5331***	-0.3666**	-0.0346***	-0.0451***	0.5412***	-0.5598***	-0.4063**
	(0.0143)	(0.0108)	(0.1602)	(0.1647)	(0.1822)	(0.0127)	(0.0110)	(0.1653)	(0.1628)	(0.1633)
AvgPPT12	0.0027**	0.0033***	0.0220***	-0.0596***	-0.0410***	0.0027**	0.0032***	0.0218***	-0.0602***	-0.0415***
	(0.0011)	(0.0012)	(0.0065)	(0.0100)	(0.0088)	(0.0013)	(0.0011)	(0.0058)	(0.0090)	(0.0092)
Pop_dens	0.0087	-0.0011	-0.1597	0.1938**	0.1417**	0.0088	-0.0013	-0.1640*	0.1930**	0.1337***
	(0.0170)	(0.0068)	(0.1126)	(0.0805)	(0.0570)	(0.0141)	(0.0060)	(0.0913)	(0.0763)	(0.0498)
sqpop_den	-0.0008	0.0002	0.0051	-0.0094	-0.0074	-0.0008	0.0002	0.0052	-0.0094	-0.0072
	(0.0020)	(0.0006)	(0.0112)	(0.0076)	(0.0240)	(0.0016)	(0.0005)	(0.0082)	(0.0089)	(0.0056)
year_01	-0.0050	0.0024	-0.0157	0.1014***	0.0158	-0.0068**	0.0028	-0.0204	0.1176**	0.0303
	(0.0040)	(0.0023)	(0.0110)	(0.0342)	(0.0424)	(0.0035)	(0.0030)	(0.0151)	(0.0471)	(0.0510)
MSAI vs. LSAI	4.40**	7.41***	0.00	18.55***	15.17***	5.06**	9.03***	0.20	18.44***	13.08***
Constant	0.2883	-0.2026	-24.8708***	37.6353***	27.0464***	0.2401	-0.1984	-24.8914***	38.0659***	27.7539***
	(0.4475)	(0.4815)	(4.0995)	(5.3917)	(4.4337)	(0.5178)	(0.4679)	(4.0673)	(5.4944)	(5.0274)
Observations	1,219	1,219	1,219	1,219	1,145	1,219	1,219	1,219	1,219	1,145
Number of hhid	618	618	618	618	603	618	618	618	618	603

Bootstrap standard errors with 100 replications are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Effects of MSAI and LSAI on Ecosystem Services

Table 4.6 presents the estimates of the effect of MSAI and LSAI on ecosystem services including access to economic trees for picking shea nuts, mango fruits, dawadawa seeds, and baobab fruits and leaves; access to grazing lands for grazing livestock, and access to forest for hunting and gathering, fresh water, medicinal plants and gathering of fuel wood for charcoal production. We run five pooled MVP models to check the robustness of the results to inclusion and exclusion of households, community level, and averages of the time-varying covariates. In the lower part of Table 4.6, we report joint tests of zero correlation between the error terms in each of the MVP specifications of the ecosystem services. However, the results indicated that the null hypothesis of zero correlation between the error terms must be rejected. This suggests that a household's access to ecosystem services is interrelated. The lower part of Table 4.2 also reports the correlation matrix indicating the type of interrelationship between the ecosystem services accessed by exposed households. Interestingly, each of the correlation coefficients is positively signed, suggesting that access to ecosystem services is considered complements by the exposed household in northern Ghana. This result is plausible because it is economically sensible for a household to access all these services from the ecosystem.

Regarding the main results, some variables from household/plot and community level have significant effects on the outcomes but these results are not discussed since they are not the focus of this study. For the effect of MSAI and LSAI on access to these services, columns 1-3, where only MSAI and LSAI are controlled in an MVP model, showed that the effect of the district's share of MSAI is positive and significantly related to exposed households' access to economics trees and forest but not land for grazing animals. On the other hand, the effect of LSAI is not significant for access to any of the services in the area. When we controlled for household/plot covariates, we note slight changes in the coefficients of the district's share of MSAI but the results remained the same in terms of sign and level of significance. On the other hand, the effect of LSAI on access to trees, grazing land, and forest changed slightly but the effect is significant for only forest access. Similar changes are noted after accounting for community-level variables in isolation and combination with household/plot and averages controlling for unobserved heterogeneity. We noted a negative coefficient of LSAI on access to trees, grazing land, and forest. This only became significant for access to the forest after we started controlling for other covariates and increased thereafter as more variables are controlled for. The maximum increase is then observed when the MVP accounted for the unobserved heterogeneity by introducing the means of all time-varying covariates (i.e., the Mundlak fixed effects). For MSAI, the coefficients changed slightly but remained positive and significant at 1% for access to trees and forest even when the Mundlak fixed effects is applied. We further conducted a test of the null hypothesis that all coefficients of the mean of the time-varying covariates are jointly equal to zero. However, the null hypothesis is not rejected and thus, suggests that unobserved heterogeneity is not an issue. But, in any case, the results underline the role of the district's share of MSAI in enhancing access to economic trees and forests, and the role of the district's share of LSAI in dissipating households' chances of accessing forests for hunting and gathering, fuel wood, medicinal plants. However, these results should be interpreted with some caution because of possible selection bias. Nonetheless, the effect of

LSAI is plausible and confirms other studies (e.g., ActionAid International, 2009; Donald, 2004) while that of MSAI is surprising and contradicts other studies which argued that the expansive attribute of MSAI and LSAI can affect biodiversity, ecosystems, and services provided (Guerrero-Pineda et al., 2022; Wineman et al., 2022). A further probe into why MSAI affect enhances access to ecosystem services like economic trees, grazing land, and forest revealed that MSAI is mostly owned by friends and people they know. Because of these relations, their women can still access the forest, grazing land, and economic trees like shea nuts from these farms without any restrictions. One participant explained the following to clarify their point: *"We know and have been with these people before they start this kind of investment. Some of them are our friends and some, our relatives, so they will not deny us access to lands they have acquired if we want to graze animals or pick shea nuts, fuel wood from it"* (Focus Group Discussions, July 4, 2023).

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Table 4.6: Pooled MVP estimates of the effects of MSAI and LSAI on ecosystem services

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VARIABLES	Trees	Grazing land	Forest	Trees	Grazing land	Forest	Trees	Grazing land	Forest	Trees	Grazing land	Forest	Trees	Grazing land	Forest
MSAI	0.007***	-0.001	0.007***	0.005***	-0.002	0.007***	0.006***	-0.001	0.008***	0.004**	-0.002	0.007***	0.005***	-0.002	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LSAI	0.002	-0.043	-0.037	0.000	-0.042	-0.051*	-0.006	-0.043	-0.059**	-0.006	-0.045	-0.065**	-0.012	-0.045	-0.070**
	(0.028)	(0.028)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)	(0.030)	(0.029)	(0.030)	(0.030)	(0.030)	(0.031)
gender				-0.141	-0.008	-0.114				-0.159	-0.019	-0.143	-0.157	0.001	-0.125
				(0.133)	(0.128)	(0.135)				(0.137)	(0.128)	(0.135)	(0.137)	(0.130)	(0.140)
age_hhh				0.002	0.002	-0.000				0.001	0.001	-0.001	-0.002	0.001	0.003
				(0.003)	(0.003)	(0.003)				(0.003)	(0.003)	(0.003)	(0.013)	(0.012)	(0.013)
schooling_yrs				-0.003	0.010	-0.006				-0.001	0.009	-0.003	-0.024	0.012	-0.016
				(0.008)	(0.007)	(0.008)				(0.008)	(0.007)	(0.008)	(0.032)	(0.026)	(0.036)
hhsize				0.005	0.002	0.008				0.001	0.001	0.005	-0.001	0.030	-0.005
				(0.005)	(0.005)	(0.005)				(0.005)	(0.005)	(0.005)	(0.021)	(0.022)	(0.022)
asset				-0.231***	-0.091***	-0.220***				-0.213***	-0.090***	-0.194***	-0.014	-0.140	0.039
				(0.038)	(0.034)	(0.037)				(0.038)	(0.034)	(0.038)	(0.128)	(0.120)	(0.138)
remittances				0.024	0.063	-0.090				0.074	0.062	-0.027	0.092	-0.085	-0.243
				(0.099)	(0.095)	(0.103)				(0.101)	(0.095)	(0.105)	(0.309)	(0.307)	(0.338)
social_group				-0.013	0.075	0.001				-0.044	0.071	-0.064	-0.202	-0.131	0.225
				(0.079)	(0.076)	(0.080)				(0.082)	(0.076)	(0.084)	(0.285)	(0.283)	(0.284)
floods				0.234**	-0.021	0.057				0.200*	-0.024	0.019	0.138	-0.035	-0.010
				(0.099)	(0.094)	(0.098)				(0.103)	(0.095)	(0.102)	(0.348)	(0.347)	(0.391)
drought				-0.157	0.055	-0.121				-0.129	0.070	-0.140	-0.130	0.067	-0.130
				(0.126)	(0.118)	(0.128)				(0.127)	(0.119)	(0.134)	(0.127)	(0.120)	(0.134)
fertilizer				0.004*	0.003	0.008***				0.005**	0.003	0.009***	0.008	0.011	-0.010
				(0.002)	(0.002)	(0.003)				(0.002)	(0.003)	(0.003)	(0.015)	(0.015)	(0.016)
tenure_security				-0.163	0.085	-0.543***				-0.115	0.079	-0.505***	0.236	0.557	0.462
				(0.130)	(0.131)	(0.127)				(0.133)	(0.132)	(0.129)	(0.491)	(0.478)	(0.484)
good				-0.121	0.100	-0.126				-0.115	0.114	-0.161	-0.306	0.586	-0.251
				(0.112)	(0.109)	(0.114)				(0.115)	(0.110)	(0.118)	(0.413)	(0.428)	(0.447)
moderate				-0.067	0.026	-0.064				-0.087	0.025	-0.077	-0.496	0.229	-0.002
				(0.110)	(0.107)	(0.113)				(0.112)	(0.108)	(0.115)	(0.416)	(0.414)	(0.443)
deep_depth				-0.055	0.022	0.043				-0.092	0.040	0.031	-0.527	-0.271	-0.058
				(0.135)	(0.129)	(0.138)				(0.141)	(0.130)	(0.141)	(0.471)	(0.492)	(0.535)
moderate_depth				-0.130	0.005	-0.054				-0.153	0.008	-0.062	-0.147	0.106	-0.207
				(0.093)	(0.091)	(0.095)				(0.095)	(0.091)	(0.099)	(0.334)	(0.325)	(0.353)
flat_slope				-0.035	-0.111	-0.023				-0.007	-0.101	0.029	-0.232	-1.230**	-0.117
				(0.154)	(0.151)	(0.160)				(0.164)	(0.151)	(0.169)	(0.465)	(0.514)	(0.504)
moderate_slope				-0.054	-0.088	-0.088				-0.022	-0.084	-0.050	-0.314	-0.424	-0.054
				(0.158)	(0.155)	(0.164)				(0.168)	(0.156)	(0.173)	(0.490)	(0.532)	(0.548)
Elevation							0.006***	0.002*	0.005***	0.006***	0.002*	0.005***	0.005***	0.002*	0.004***
							(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
values_built							0.023	-0.019	0.020	0.022	-0.019	0.016	0.025*	-0.022	0.019
							(0.015)	(0.017)	(0.019)	(0.014)	(0.017)	(0.022)	(0.015)	(0.016)	(0.023)
Avgmaxtemperature							-0.568***	0.052	-0.929***	-0.539***	0.067	-0.919***	-0.527***	0.052	-0.929***
							(0.134)	(0.111)	(0.121)	(0.133)	(0.112)	(0.118)	(0.131)	(0.114)	(0.117)

Avgmintemperature							0.775***	0.222	1.031***	0.729***	0.185	0.985***	0.631***	0.243	0.967***
							(0.196)	(0.202)	(0.207)	(0.204)	(0.205)	(0.214)	(0.209)	(0.213)	(0.223)
AvgPPT12							-0.052***	0.012	-0.083***	-0.050***	0.013	-0.084***	-0.052***	0.011	-0.088***
							(0.012)	(0.010)	(0.012)	(0.012)	(0.010)	(0.012)	(0.012)	(0.010)	(0.012)
Pop_dens							-0.091	0.076	-0.312***	-0.064	0.093	-0.292**	-0.069	0.106	-0.276**
							(0.087)	(0.098)	(0.120)	(0.096)	(0.099)	(0.123)	(0.096)	(0.099)	(0.128)
sqpop_den							-0.002	0.003	0.009	-0.003	0.002	0.008	-0.004	0.001	0.006
							(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.008)	(0.007)	(0.006)	(0.008)
year_01				-0.054	0.120	-0.068	-0.088	0.120	-0.166**	-0.050	0.111	-0.060	-0.058	0.099	-0.046
				(0.087)	(0.084)	(0.088)	(0.081)	(0.077)	(0.082)	(0.088)	(0.084)	(0.090)	(0.095)	(0.091)	(0.095)
Constant	-0.787***	0.241***	-0.787***	-0.557**	0.040	-0.165	4.708	-8.264	14.379**	4.919	-8.123	15.961**	7.100	-8.914	17.074**
	(0.078)	(0.074)	(0.077)	(0.268)	(0.266)	(0.269)	(6.927)	(5.981)	(6.679)	(6.928)	(6.015)	(6.751)	(6.947)	(6.207)	(6.848)
atrho21	0.260***			0.261***			0.271***			0.268***			0.266***		
	(0.048)			(0.049)			(0.050)			(0.051)			(0.051)		
atrho31	1.453***			1.470***			1.435***			1.467***			1.518***		
	(0.077)			(0.080)			(0.081)			(0.085)			(0.087)		
atrho32	0.194***			0.189***			0.221***			0.212***			0.201***		
	(0.048)			(0.049)			(0.050)			(0.051)			(0.052)		
The likelihood ratio test of all correlation coefficients jointly equals zero	638.57***			607.56***			573.94***			553.43***			557.79***		
Joint significance of mean of time-varying covariates - $\chi^2(57)$															
Observations	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,194	1,194	1,194

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4.2.3 Effects of MSAI and LSAI on Biodiversity and Ecosystem Management Practices

We estimated several models with the three biodiversity and ecosystem management practices using the pooled MVP model. Because of the absence of spatial indicators of biodiversity and ecosystem management practices our model specifications vary only in terms of the variables we accounted for. First, we estimated a basic model with the district's share of land under MSAI and LSAI as the only variables to observe the effect of these key variables in the absence of other confounding factors. Next, we introduced household/plot variables to see how sensitive the effects of MSAI and LSAI are to the introduction of household/plot variables. Then we introduced only the community-level variables to observe the behavior of the effects of MSAI and LSAI under community-level variables. Recall that the household/plot and community level variables were respectively, measured using self-reported data from household surveys and spatial datasets. Thus, the introduction of these variables into the model is also to check for the sensitivity of the results to the self-reported dataset from surveys and spatial controls from the spatial dataset in the model. Next, we introduce both household/plot and community-level covariates to observe the sensitivity of the coefficients of MSAI and LSAI to the presence of household/plot and community-level covariates or self-reported data and spatial controls. Finally, we introduced household/plot and community level covariates along with mean values of all time-varying variables to check the behaviour of the results after accounting for household/plot, community, and unobserved heterogeneity. The results are presented in Table 4.7 along with the correlation matrices and the likelihood ratio tests. The likelihood ratio test is a joint test of zero correlation between the error terms in each of the MVP specifications for the practices adopted to manage biodiversity and ecosystem while the correlation matrix shows how the practices are related. In our case, the results indicated that the null hypothesis of zero correlation between the error terms is rejected in each specification. This suggests that household's choice of adoption of SAPs, tree planting techniques and improve seed varieties are interrelated. Further, the correlation coefficients in each model are positively signed, suggesting that households employ the practices in a complementary manner. This finding is plausible since households deal with multiple on-farm constraints that require the use of different strategies.

Regarding the main results, we focused on discussing the effects of MSAI and LSAI since the effect of households/plots, community-level, and mean values of time-varying variables are not the focus of this report. In the basic model (columns 1-3), the coefficients of MSAI are all significant and negatively related to the adoption of all the practices considered. On the other hand, the coefficients of LSAI are mixed in terms of signs but none of these is significant. In the next model, where we accounted for household/plot covariates (columns 4-6), the coefficients of MSAI changed but remained negative and significantly related to the adoption of all the practices under consideration. When the community-level variables are accounted for, the coefficients of MSAI on the adoption of SAPs and tree planting techniques remained the same as in the model controlling for households/plot covariates. On the other hand, the coefficient of MSAI on adoption improved seed varieties increased slightly and remained significant. For LSAI, the coefficients increased but remained insignificant for the adoption of all the practices. In the model controlling for both household/plot and community variables, the coefficients of MASI decreased across all the practices but remained significant and negative. Although the coefficients of LSAI changed, they are not significant. For the specification controlling for household/plot, community, and unobserved heterogeneity, the coefficients of MSAI are all significant but showed slight changes. On the other hand, LSAI remained insignificant even though some changes are noted in the coefficients. Thus, in any case (i.e., whether we controlled for both observed and unobserved covariates), we found that MSAI is negative and significantly related to the adoption of SAPs, tree planting techniques, and improved seed varieties while LSAI is not. This suggests that the adoption of SAPs, tree planting techniques, and improved seed varieties is only high for a district with an increasing share of land under MSAI and not LSAI. The results on the effect of LSAI on the practices are surprising given the potential spillover effects of such investments. Exploration of the responses from focus group discussions revealed that not many farmers get employed by investment farms. For instance, in the communities visited for the focus group discussions, about 2-5 members were found to be employed by LSAI. This implies that not many farmers have an established link with the investment's farms. Such a low number of employment has implications for knowledge spillover and the adoption of biodiversity and ecosystem management practices. Recall that technology transfer from investment farms to local farmers and subsequent adoption is strongly linked with knowledge spillovers which do not exist on a missing link between the investment farms and local farmers. The fewer number of people employed therefore implies low adoption of biodiversity and ecosystem management practices. Other participants also argued that the focus of these investors is currently not on managing biodiversity and ecosystem but to increase yields and exporting to large markets. Another explanation revealed that protection of the investment areas from encroachment appears more important to large-scale investors than managing biodiversity and ecosystem in the area. These explanations showed that exposed households to LSAI do not appear to benefit from LSAI in terms of biodiversity and ecosystem management practices and hence the insignificant relationship between LSAI and the adoption of the practices considered.

Table 4.7: Pooled MVP estimates of the effects of MSAI and LSAI on strategies for managing biodiversity and ecosystem

VARIABLES	(1) SAPs	(2) Tree planting	(3) Improved seeds	(4) SAPs	(5) Tree planting	(6) Improved seeds	(7) SAPs	(8) Tree planting	(9) Improved seeds	(10) SAPs	(12) Tree planting	(13) Improved seeds	(14) SAPs	(15) Tree planting	(16) Improved seeds
MSAI	-0.004***	-0.008***	-0.009***	-0.004**	-0.007***	-0.008***	-0.004**	-0.007***	-0.010***	-0.003*	-0.006***	-0.008***	-0.004**	-0.007***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
LSAI	-0.033	0.031	-0.001	-0.028	0.028	-0.016	-0.029	0.033	0.019	-0.020	0.034	0.008	-0.012	0.036	0.003
	(0.030)	(0.032)	(0.043)	(0.031)	(0.033)	(0.043)	(0.031)	(0.033)	(0.044)	(0.032)	(0.034)	(0.044)	(0.032)	(0.034)	(0.044)
gender				-0.098	0.302*	-0.198				-0.073	0.330**	-0.214	-0.086	0.343**	-0.209
				(0.141)	(0.159)	(0.176)				(0.142)	(0.167)	(0.181)	(0.145)	(0.168)	(0.182)
age_hhh				0.001	0.004	-0.000				0.003	0.004	0.001	0.015	-0.014	-0.006
				(0.003)	(0.003)	(0.004)				(0.003)	(0.003)	(0.004)	(0.013)	(0.013)	(0.015)
schooling_yrs				0.014*	0.001	-0.010				0.014*	0.000	-0.013	0.045*	-0.022	0.061*
				(0.008)	(0.008)	(0.011)				(0.008)	(0.009)	(0.011)	(0.027)	(0.028)	(0.032)
hhsize				-0.007	-0.019***	-0.008				-0.005	-0.018***	-0.005	-0.000	0.008	0.009
				(0.005)	(0.006)	(0.008)				(0.006)	(0.006)	(0.008)	(0.023)	(0.024)	(0.024)
asset				0.158***	0.121***	0.130***				0.146***	0.109***	0.131***	-0.133	0.164	-0.176
				(0.034)	(0.036)	(0.044)				(0.035)	(0.036)	(0.044)	(0.128)	(0.128)	(0.144)
remittances				0.061	-0.028	0.080				0.063	-0.024	0.033	0.497	0.187	-0.395
				(0.097)	(0.101)	(0.124)				(0.100)	(0.105)	(0.127)	(0.303)	(0.308)	(0.352)
social_group				-0.090	0.045	0.041				-0.067	0.067	0.071	0.378	0.283	0.143
				(0.079)	(0.083)	(0.103)				(0.081)	(0.086)	(0.106)	(0.285)	(0.284)	(0.305)
floods				0.040	-0.098	-0.242**				0.090	-0.037	-0.238*	-0.207	-0.140	-0.627
				(0.096)	(0.098)	(0.118)				(0.100)	(0.099)	(0.122)	(0.355)	(0.357)	(0.404)
drought				-0.007	0.179	0.350**				-0.074	0.103	0.291*	-0.092	0.072	0.283*
				(0.123)	(0.127)	(0.159)				(0.125)	(0.128)	(0.163)	(0.126)	(0.130)	(0.161)
fertilizer				-0.002	-0.005	-0.009				-0.002	-0.005	-0.008	-0.011	-0.016	-0.017
				(0.002)	(0.003)	(0.005)				(0.002)	(0.003)	(0.005)	(0.014)	(0.012)	(0.013)
tenure_security				0.265*	0.480***	0.216				0.192	0.416**	0.135	0.125	1.047*	-0.587
				(0.137)	(0.156)	(0.186)				(0.141)	(0.167)	(0.193)	(0.496)	(0.539)	(0.602)
good				0.064	0.006	0.033				0.032	-0.042	-0.006	0.012	-0.307	0.495
				(0.112)	(0.122)	(0.144)				(0.116)	(0.128)	(0.150)	(0.427)	(0.440)	(0.480)
moderate				0.006	0.093	0.052				0.002	0.096	0.032	0.141	0.042	0.555
				(0.112)	(0.119)	(0.141)				(0.116)	(0.125)	(0.155)	(0.424)	(0.430)	(0.458)
deep_depth				0.050	0.274*	0.263				0.053	0.282*	0.268	-0.188	0.410	0.019
				(0.135)	(0.140)	(0.169)				(0.137)	(0.144)	(0.171)	(0.515)	(0.509)	(0.615)
moderate_depth				0.005	0.083	-0.151				0.018	0.090	-0.145	0.284	0.285	0.442
				(0.094)	(0.099)	(0.125)				(0.096)	(0.102)	(0.129)	(0.337)	(0.334)	(0.427)
flat_slope				-0.011	0.259	-0.192				-0.012	0.282	-0.155	-0.429	-0.027	0.054
				(0.160)	(0.178)	(0.198)				(0.164)	(0.190)	(0.204)	(0.516)	(0.563)	(0.556)
moderate_slope				0.005	0.203	0.053				-0.022	0.195	0.080	-0.442	-0.202	-0.053
				(0.164)	(0.182)	(0.203)				(0.169)	(0.196)	(0.211)	(0.537)	(0.582)	(0.588)
Elevation							-0.007***	-0.006***	-0.008***	-0.007***	-0.006***	-0.008***	-0.006***	-0.006***	-0.009***
							(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
values_built							-0.205***	-0.122*	-0.127	-0.224***	-0.108	-0.114	-0.224***	-0.100	-0.119
							(0.057)	(0.066)	(0.140)	(0.080)	(0.077)	(0.139)	(0.063)	(0.066)	(0.137)
Avgmaxtemperature							0.727***	0.703***	0.368**	0.686***	0.654***	0.329*	0.644***	0.579***	0.354**
							(0.143)	(0.155)	(0.170)	(0.143)	(0.157)	(0.168)	(0.143)	(0.155)	(0.176)
Avgmintemperature							-0.831***	-0.420**	-0.722***	-0.788***	-0.348	-0.733***	-0.729***	-0.287	-0.845***

							(0.212)	(0.206)	(0.268)	(0.216)	(0.213)	(0.276)	(0.225)	(0.223)	(0.286)
AvgPPT12							0.050***	0.047***	0.037***	0.046***	0.044***	0.034**	0.047***	0.041***	0.032**
							(0.012)	(0.013)	(0.014)	(0.012)	(0.013)	(0.014)	(0.012)	(0.013)	(0.014)
Pop_dens							-0.332**	0.153	1.473*	-0.336	0.065	1.685*	-0.357**	0.070	1.670*
							(0.158)	(0.266)	(0.870)	(0.255)	(0.302)	(0.921)	(0.179)	(0.284)	(0.868)
sqpop_den							0.065***	-0.020	-0.898**	0.068*	-0.009	-1.056**	0.071***	-0.010	-1.042**
							(0.022)	(0.037)	(0.454)	(0.035)	(0.042)	(0.487)	(0.026)	(0.040)	(0.462)
year_01				0.205**	0.021	0.078	0.191**	0.055	0.109	0.218**	0.005	0.074	0.226**	-0.008	0.049
				(0.089)	(0.093)	(0.125)	(0.083)	(0.086)	(0.112)	(0.092)	(0.096)	(0.129)	(0.099)	(0.103)	(0.132)
Constant	-0.137*	-0.283***	-0.835***	-0.480*	-1.290***	-0.589*	-9.587	-18.374***	1.065	-9.276	-19.120***	3.244	-9.380	-17.916**	5.299
	(0.072)	(0.073)	(0.088)	(0.278)	(0.312)	(0.352)	(6.809)	(6.763)	(7.913)	(6.819)	(7.000)	(8.106)	(6.992)	(7.030)	(8.512)
atrho21	0.688***			0.686***			0.630***			0.636***			0.631***		
	(0.057)			(0.058)			(0.059)			(0.060)			(0.060)		
atrho31	0.366***			0.354***			0.305***			0.300***			0.308***		
	(0.062)			(0.063)			(0.064)			(0.066)			(0.067)		
atrho32	0.285***			0.263***			0.226***			0.213***			0.242***		
	(0.064)			(0.065)			(0.069)			(0.071)			(0.070)		
Likelihood ratio test of all correlation coefficients jointly equal to zero	212.12***			199.52***			165.42***			161.12***			155.97***		
Joint significance of mean of time-varying covariates - $\chi^2(57)$													72.89*		
Observations	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,219	1,194	1,194	1,194

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. CONCLUSION

In this section, we conclude this report with a summary of the study's key findings. The main focus of the study was to examine the implication of large-scale agricultural investment on biodiversity in northern Ghana using a mixed-method research approach. The recent upsurge in medium- and large-scale agricultural investment in the form of land acquisition, and the expansive attribute associated with such investments affect biodiversity. Yet empirical studies examining the effect of such investments on biodiversity are missing in the literature despite the policy relevance of such information. In an attempt to fill such gap, this study (i) identifies the processes of acquiring for MSAI/LSAI, the size, and actors involved (ii) examines the effect of LSAI along with the effect of MSAI on biodiversity implied in species richness, evenness, diversity, EVI and SAVI (iii) analyse the effect of LSAI along with the effect of MSAI on access to ecosystem services, and (iv) analyse the effect of LSAI along with the effect of MSAI on biodiversity and ecosystem management practices in Ghana.

We used qualitative data from key informant interviews and focus group discussions, and quantitative data from household surveys and remote sensing GIS. The collection of the datasets and analysis followed a multiphase mixed method research approach consisting of first, second, and third phase data collection and analysis. In the first phase, we interviewed farmer leaders, investors, and key officials from institutions in charge of land and agricultural production in Ghana. Content analysis with the frequency distribution of texts and patterns was then employed to analysed the data. A second-phase households survey was then conducted in the 2021 cropping season based on the findings of the first phase of key informant interviews. The 2021 survey data was augmented with remote sensing GIS dataset. Then a subsample of the 2021 households was combined with their information in the 2018 household survey to make a panel dataset. This dataset was then analysed using descriptive, non-parametric techniques, and panel regression analysis. Using third-phase data from focus group discussions, we explained unexpected or surprising results from the second-phased quantitative study.

The findings of the data analysis can be summarised as follows:

1. The results revealed that actors including domestic and foreign entities participate in LSAI and processes employed by these actors are not clear to local farmers. Thus, in terms of origin, investors are classified into two main actors who do not make clear to farmers the process followed in acquiring land on a large scale for agricultural investments.
2. Both MSAI and LSAI affect biodiversity but the effects vary with biodiversity indicators employed. Specifically, the effects of MSAI and LSAI on biodiversity indicators derived from self-reported data vary with model specification but remained the same for biodiversity indicators derived from remote sensing GIS data. Furthermore, increasing the district's share of farms that are under MSAI (5-50ha) is associated with a decrease in biodiversity while increasing the district's share of farms that are under LSAI (over 50ha) is associated with a increase in biodiversity. The enhanced biodiversity indicators due to LSAI were attributed to biodiversity-relevant knowledge possessed by LSAI investors.

3. The effects of MSAI and LSAI on ecosystem services also vary with model specifications. But, in any case, the results underline the role of the district's share of MSAI in enhancing access to economic trees and forests, and the role of the district's share of LSAI in dissipating households' chances of accessing forests for hunting and gathering, fuel wood, medicinal plants. The positive effect of MSAI on access to ecosystem services was attributed to relations established with medium-scale investors who happen to be people they know.
4. The effects of MSAI and LSAI on biodiversity and ecosystem management practices also vary with model specification. However, whether both observed and unobserved covariates are accounted for in a model specification, MSAI is negative and significantly related to the adoption of SAPs, tree planting techniques, and improved seed varieties while LSAI is not. This is attributed to the missing link between the investment farms and local farmers to share knowledge about the practices.

5. POLICY RECOMMENDATIONS

Based on the above findings, the following policy recommendations are presented:

1. Relevant authorities including the state and traditional authorities can enhance transparency in the land market. Guidelines that support LSAI and MSAI are likely to enhance transparency, and avoid protests from local people and should be made available and accessible to both actors (i.e., local people and investors) by these authorities.
2. The loss of biodiversity to MSAI can have implications for livelihoods in Ghana. Thus, policies that can regulate such investment or reverse the observed decline in biodiversity should be designed and promoted.
3. Policies that will address the negative impacts of MSAI and LSAI on access to ecosystem services should be promoted.
4. Appropriate policies are needed to address the observed decline in the adoption of biodiversity and ecosystem management practices among households exposed to MSAI. In particular, policies that encourage the growth of MSAI and the adoption of biodiversity and ecosystem management practices in the same environment are needed.

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