AMERICAN UNIVERSITY OF BEIRUT

CONTRIBUTION OF ECOSYSTEM SERVICES TO REDUCING POVERTY VULNERABILITY: A CASE STUDY OF ONDO STATE, NIGERIA

by
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ABSTRACT
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Ecosystem services have gained attention as a potential tool for promoting sustainable development and natural resource management. Despite this, development agencies often overlook ecosystem services in their policies and plans. This study investigates the potential of ecosystem services to reduce poverty vulnerability in Ondo State, Nigeria. The study found that the study area is rich in multiple ecosystem services, including provisioning services such as crop production and water, regulating services such as carbon storage and crop pollination, supporting services such as habitat quality, and cultural services such as aesthetic quality and recreation & tourism. The mapping of these services provides a useful tool for decision-makers to incorporate ecosystem services into poverty vulnerability reduction plans. However, the study also identified hindrances such as oil spillage and lack of infrastructure to maximize the potential of ecosystem services to reduce poverty vulnerability in areas with high poverty especially in the coastal regions.

The study suggests that the success of the strategy to use ecosystem services to reduce poverty vulnerability depends on several factors, including governance, economic opportunities, and infrastructure. Therefore, there is a need for a comprehensive approach that considers multiple factors to reduce poverty vulnerability effectively. The findings have implications for sustainable development planning in Ondo State and other regions with similar ecosystems. It highlights opportunities that might not have been explored by development agencies and underscores the need for integrated approaches to natural resource management, considering the value of ecosystem services for sustainable development. It also provides valuable insights into how ecosystem services can be harnessed to promote sustainable development in Ondo State and beyond.

However, the study has some limitations, including model-based oversimplifications, the use of secondary data sources that may introduce errors and inaccuracies, and the lack of consideration of economic issues. Future research could address these limitations using more accurate and detailed data, incorporating economic considerations, and considering broader regional and national contexts.

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ABBREVIATIONS

ES – Ecosystem Services

LGAs – Local Government Areas

SDGs – Sustainable Development Goals

InVEST - Integrated Valuation of Ecosystem Services and Trade-offs

ARIES - ARtificial Intelligence for Environment and Sustainability

ANE - Akoko North East

ANW - Akoko Northwest

ASE - Akoko Southeast

ASW - Akoko Southwest

AKN - Akure North

AKS - Akure South

ESO - Ese-Odo

IDA - Idanre

IFD - Ifedore

ILJ - Ilaje

ILO - Ile-Oluji-Okeigbo

IRL - Irele

ODG - Odigbo

OKP - Okitipupa

ONE - Ondo East

ONW - Ondo West

OSE - Ose

OWO - Owo

CHAPTER I

INTRODUCTION

Ecosystem services refer to the benefits that humans derive from natural ecosystems, including provisioning services (e.g., food, water, and fiber), regulating services (e.g., climate regulation, water purification, and pest control), cultural services (e.g., recreation, spiritual, and educational), and supporting services (e.g., nutrient cycling and soil formation) (MEA, 2005). These services are critical for human well-being and are estimated to contribute trillions of dollars annually to the global economy (TEEB, 2010).

In the context of poverty, ecosystem services are particularly important as they can contribute to reducing vulnerability and enhancing resilience. Poverty is a complex subject that has multiple dimensions and various measurements (Wunder, 2001; Adams et al., 2004). Poverty can be defined as an unstable social condition due to the abnormal functioning of economic, ecological, cultural, or social systems, depriving people of the capability to adapt, live, and meet their minimum living needs (Opschoor, 2007). This research explored the contribution of ecosystem services to reducing poverty vulnerability in Ondo State.

Nigeria is a country with significant poverty challenges, with an estimated 40% of the population living below the poverty line (World Bank, 2021). Ondo State, located in the southwestern part of Nigeria, is no exception to this trend, with elevated levels of poverty and vulnerability among its residents. The state's dependence on natural resources, such as forests and agriculture, highlights the crucial role of ecosystem services in supporting livelihoods and reducing poverty vulnerability.

Previous research has shown that ecosystem services are essential for poverty reduction and sustainable development (Costanza et al., 2014; Dasgupta et al., 2015). The depletion of ecosystem services can lead to increased poverty levels and reduced human well-being (Braat & de Groot, 2012). Therefore, research on the contribution of ecosystem services to poverty vulnerability in Nigeria, particularly in Ondo State, is vital.

The study used InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) and ARIES (ARtificial Intelligence for Environment & Sustainability) to map key ecosystem services in Ondo State and assess their spatial distribution. These models are widely used in ecosystem services research and are considered robust tools for assessing the provision and value of ecosystem services (Sharp et al., 2020; Václavík et al., 2013).

Focusing on the spatial distribution of these key ecosystem services in Ondo State, the study then explored connections between these services and poverty vulnerability.

This research is a contribution to the growing body of literature on the role of ecosystem services in poverty reduction and sustainable development. By providing insights into the connection between ecosystem services and poverty vulnerability in Ondo State, this study will support policymakers in designing and implementing effective interventions aimed at improving the well-being of the most vulnerable populations.

A. Research Gap

Despite the potential opportunities provided by ecosystem services, development agencies in Ondo State rarely consider them when addressing poverty alleviation. Even when ecosystem services are considered in the vulnerability alleviation plan, they receive the least attention; according to (Akinmulegun, 2014), culture, sport, and tourism received the least expenditure with ₦ 166.3 million (0.075%) in the Ondo State Vision 2020 poverty alleviation plan. On the other hand, several authors working on ecosystem services focus on direct monetary value rather than sustainable development (Popoola et al., 2018) as a case study. This study seeks to explore how ecosystem services can reduce poverty vulnerability in Ondo State, Nigeria.

B. Research Question

Can Ecosystem Services contribute to reducing poverty vulnerability in Ondo State, Nigeria?

C. Research Objectives

- Explore links between SDG (Sustainable Development Goals) 1 (No Poverty) and Ecosystem Services
- Build a baseline map for Ecosystem Services in Ondo State, Nigeria based on available data.

CHAPTER II

LITERATURE REVIEW

A. Ecosystem Services and Poverty Reduction

The concept of ecosystem services has rapidly grown in influence across academic disciplines and amongst organizations at the boundary of science and policy (Chaudhary et al., 2015). Ecosystem services are the benefits that humans derive from the natural environment, such as clean air and water, fertile soil, and biodiversity (MEA, 2005). These services are critical for human well-being and may play an essential role in reducing poverty vulnerability. However, From the literature search on this work, only few papers have been published that links ecosystem services and poverty reduction. However, the few ones that were found are explained as case studies.

One way in which ecosystem services can reduce poverty vulnerability is by providing essential resources for livelihoods. For example, ecosystems such as forests, fisheries, and agriculture provide food, fuel, and materials for construction and crafts, which are essential for the livelihoods of the poor (Spash and Hache, 2022).

Additionally, ecosystem services can reduce poverty vulnerability by providing important ecosystem functions that support human well-being. For example, forests and wetlands can provide protection against natural disasters, such as floods and landslides, and regulate the local climate, reducing the risk of extreme weather events (Karanja, 2021). This can help to reduce the vulnerability of poor communities to these events, which can be particularly devastating for them.

Moreover, ecosystem services can also provide opportunities for income generation for the poor. For example, ecotourism can provide economic benefits to local communities, creating jobs and income streams (Ceballos-Lascurain, 1996). Additionally, the sustainable use of natural resources, such as fishery and forestry resources, can provide long-term income opportunities for the poor (Karanja, 2021).

However, Suich et al. (2015) found that much of the published research simply describes observed relationships, rather than providing evidence for causal links. Much research also still fails to examine bundles of ES, and regulating services remain underrepresented. Further, while the multidimensionality of poverty is increasingly recognized, analyses to date remain heavily focused on income and assets, rather than in combination with non-income dimensions of poverty.

In general, the supply of ES is often thought to contribute to poverty alleviation, particularly in developing countries' rural areas. However, it is unclear how these contributions are frequently made. Even when solely consumptive outputs (e.g., food, fuel, etc.) are examined, a variety of ecosystem services are crucial to the poor. The patterns of direct ES contributions to households described (for example, from direct consumption of natural resources) tend to sustain livelihoods and/or prevent households from falling further into poverty rather than actively contribute to a steadily improving situation for the household, as these ES are insufficient to lift people out of poverty (Barrett et al., 2011). This contribution is intended to reduce vulnerability rather than poverty, as greater reliance on environmental services frequently implies more vulnerable households. However, this is a matter of interpretation, because poverty alleviation can be defined as both poverty prevention and poverty reduction (Angelsen and Wunder, 2003; Daw et al., 2011). Fisher et al. (2013) also identified the same thing that it is important to acknowledge the limits of ecosystem services for poverty alleviation, given evidence that ecosystem services tend to be more associated with poverty prevention than reduction.

An instance of this is the findings of Deng et al. (2010) that perceptions of benefits derived from establishing a nature reserve in China differed depending on wealth, with more benefits appearing to go to the wealthy people. Another instance is in examining a forestry project in Bangladesh, Muhammed et al. (2008) concluded the program being studied was a financial success as a plantation-raising strategy. However, landless and poor people were not selected to participate, and gender equity issues were also identified. This is why Fisher et al. (2013) recommended that research on poverty alleviation must recognize social differentiation and be able to distinguish between constraints of access and constraints of aggregate availability of ecosystem services.

Overall, several authors have identified several cases showing that the provision of ecosystem services can significantly reduce poverty vulnerability in many regions of the world. For instance, in Madagascar, the country's forests provide essential ecosystem services such as water regulation, soil fertility, and biodiversity conservation, which support local livelihoods (Neugarten et al., 2020). The sustainable use of these resources through community-based forest management has provided income opportunities for the poor, reduced poverty, and improved their well-being.

Similarly, in Kenya, the Kakamega Forest ecosystem provides a range of ecosystem services such as carbon sequestration, soil conservation, and water regulation, which support local livelihoods (Nyang'au et al., 2020). The forest ecosystem has also provided income opportunities for the poor through ecotourism, which has created jobs and income streams for local communities.

In Indonesia, the provision of ecosystem services has also been linked to poverty reduction. The restoration of degraded mangrove ecosystems in the region has been shown to support local livelihoods by providing opportunities for fishing, salt production, and tourism (Quevedo et al., 2020). The restoration of these ecosystems has not only increased the provision of ecosystem services but also helped to reduce poverty and improve the well-being of local communities.

Ferraro et al. (2015) found that protected areas in Brazil, Costa Rica, Indonesia, and Thailand have stored at least an additional 1,000 Mt of CO2 in forests and have delivered ecosystem services worth at least $5 billion. In Costa Rica specifically, Ferraro and Hanauer (2014) found that two-thirds of the poverty reduction associated with the establishment of Costa Rican protected areas is causally attributable to opportunities afforded by cultural ecosystem service such as tourism.

These case studies highlight the importance of ecosystem services in reducing poverty vulnerability and promoting sustainable development. By supporting local livelihoods, providing income opportunities, and protecting against natural disasters, ecosystem services can play a critical role in poverty vulnerability reduction efforts.

B. Ecosystem Services and Sustainable Development Goals (SDGs)

The United Nations General Assembly adopted the Sustainable Development Goals (SDGs) in 2015 as a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity (UN, 2015). The UN specify 17 SDGs, which are further split into 169 targets and 232 indicators., that aim to address a range of social, economic, and environmental challenges (UN, 2015).

The SDGs are interconnected and recognize the importance of integrated and holistic approaches to development (UN, 2015). For example, Goal 1 (No Poverty) is linked to Goals 2 (Zero Hunger) and 3 (Good Health and Well-being) through the need for access to nutritious food and basic healthcare, while Goals 6 (Clean Water and Sanitation) and 14 (Life Below Water) are linked through the need to protect water resources and marine ecosystems (UN, 2015). SDGs represent a comprehensive and integrated framework for sustainable development that recognizes the interconnectedness of social, economic, and environmental challenges.

Ecosystem services are linked to several SDGs, including poverty eradication, food security, health, clean water, climate action, and biodiversity conservation. For example, several studies have demonstrated that ecosystem services are critical in providing food and water for human populations (Gao et al., 2019). The provision of ecosystem services, such as pollination, soil fertility, and water purification, is essential for ensuring food security and sustainable agriculture, which are key components of SDGs 1 and 2.

Moreover, ecosystem services also play a vital role in maintaining human health (Nieuwenhuijsen et al., 2018). For instance, natural environments can provide physical activity and recreation opportunities, improving mental and physical health. Additionally, exposure to green spaces has been shown to reduce stress and improve cognitive function, which can contribute to SDG 3 (Good Health and Well-being).

Another critical aspect of the relationship between ecosystem services and SDGs is the role of biodiversity conservation in promoting sustainable development. Biodiversity is essential for maintaining the resilience of ecosystems and providing a range of ecosystem services (Díaz et al., 2019). The loss of biodiversity can lead to reduced ecosystem services, negatively impacting human well-being, reducing food security, increasing the risk of diseases, and disrupting water cycles (IPBES (Intergovernmental Panel on Biodiversity and Ecosystem Services), 2018). Thus, SDG 15 (Life on Land) aims to promote the conservation, restoration, and sustainable use of terrestrial ecosystems and biodiversity.

Furthermore, ecosystem services can also contribute to achieving SDG 13 (Climate Action). Natural ecosystems such as forests, wetlands, and oceans absorb carbon dioxide, helping to mitigate climate change. On the other hand, the loss of these ecosystems can lead to increased greenhouse gas emissions and exacerbate climate change.

The interlinkages between ecosystem services and SDGs imply the importance of adopting a holistic and integrated approach to sustainable development. The SDGs are interconnected, and achieving one goal can contribute to the achievement of others. For instance, promoting sustainable agriculture practices can reduce poverty, improve food security, and conserve biodiversity. Wood et al. (2018) found through an expert survey of 16 ecosystem services that individual ecosystem services could make important contributions to achieving 41 targets across 12 SDGs. The provision of food and water, habitat & biodiversity maintenance, and carbon storage & sequestration were perceived to each make contributions to >14 SDG targets, suggesting cross-target interactions are likely, and may present opportunities for synergistic outcomes across multiple SDGs. Although Wood et al. (2018) only found ES to contribute to over 12 SDGs, Yin et al. (2021) found ES to benefit all Sustainable Development Goals (SDGs); however, the author noted man-made pressures has led to degradation of ecosystems and their services. Furthermore, a missing link was between ES and SDGs identified by

Geijzendorffer et al. (2017) who found that there is a lack of information on social behavior, use, demand, and governance measures of ecosystem services.

In a bid to further establish the link between ES and SDGs, Yang et al. (2020) gathered information through a survey from experts from different countries by telling them to value SDGs and relate them with ES. Sixty six countries participated in the survey, and answers were grouped into three macro-regions: Asia; Europe, North America, and Oceania (ENO); Latin America, Caribbean and Africa (LA). The authors found that the most prioritized SDGs in the three macro-regions are usually those related to essential material needs and environmental conditions, such as SDG2 (Zero Hunger), SDG1 (No Poverty), and SDG6 (Clean Water), and that at a global scale, the number of prioritized synergies between SDGs and ES exceeded trade-offs.

A case study of the Volta basin in West Africa by Johnson et al. (2019) comparing the effectiveness of three alternative conservation prioritization approaches: (1) land cover-based, (2) topographic-based, and (3) an ecosystem service-based approach to minimize the impact of agricultural expansion is a good example of ES and SDGs. The authors discovered that an ecosystem service-based approach was the most effective.

Ondo State, Nigeria, is a region rich in natural resources and biodiversity, including forests, wetlands, and coastal ecosystems (Oluwole et al., 2017). However, the region faces significant challenges related to poverty, unemployment, and environmental degradation (Oluwole et al., 2017). The mapping of ecosystem services and their contributions to the SDGs in Ondo State, Nigeria, is important for several reasons.

First, it will provide a comprehensive understanding of the ecosystem services available in the region, including their spatial distribution and the benefits they provide to local communities (Kumar and Kumar, 2014). This information can inform land use planning and management decisions that promote sustainable development and the conservation of natural resources (Kumar and Kumar, 2014).

Second, mapping ecosystem services can help identify the trade-offs and synergies between different regional SDGs and ecosystem services (MEA, 2005). For example, the provision of clean water from forested watersheds can contribute to both SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land) (MEA, 2005). By mapping the spatial distribution of ecosystem services and their contributions to the SDGs, it will be possible to identify areas where these trade-offs and synergies are most prominent and develop strategies for managing these relationships to maximize the benefits to local communities and the environment.

Third, mapping ecosystem services can provide a basis for monitoring progress towards the SDGs in Ondo State, Nigeria (UN, 2017). By quantifying the contributions of different ecosystem services to the SDGs, it will be possible to track progress towards specific targets and to identify areas where additional action is needed to achieve the SDGs (UN, 2017). This information can inform policy development and allocate resources towards activities most likely to contribute to achieving the SDGs.

C. Poverty in Nigeria

Poverty is defined in diverse ways depending on who asks the question, how it is understood, and who responds. There’s no single definition for poverty. However, according to the United Nations, poverty entails more than the lack of income and productive resources to ensure sustainable livelihoods. Its manifestations include hunger and malnutrition, limited access to education and other basic services, social discrimination and exclusion, and lack of participation in decision-making.

The variation in what poverty means for different people in different societies necessitates an understanding of what poverty means in Nigeria. According to the National MPI 2022 in Nigeria, a comprehensive assessment of the extent of poverty across multiple dimensions has been tailored to four Dimensions which are; health dimension, education dimension, living standard dimension, and work and shock.

Health-related deprivations that the National MPI 2022 captures for each household include: severe food insecurity, undernutrition, and access to healthcare. It also revealed that half of all Nigerians are affected by severe food insecurity and that almost 3 in 10 (28.7%) of Nigerians are poor and have at least one undernourished household member.

Education-related deprivations that the National MPI 2022 captures for each household include: school lag; school attendance and years of schooling. It was also revealed that more than one quarter (26.3%) of Nigerians are multi-dimensionally poor and live in a household with a child between the ages of 6 and 15 that is not attending school. About 1 out of 6 (16.6%) Nigerians are multi-dimensionally poor and have at least one child (8-17 years of age) in the household who is educationally lagging at least two years (grades) behind.

Deprivations in the Living Standards dimension together contribute 33.6% to multi-dimensional poverty in Nigeria with about 4 out of 10 Nigerians experiencing deprivation in at least one of the Living standard related deprivations that the National MPI 2022 captures for each household. This includes water; sanitation; housing material; cooking fuel and; assets. Furthermore, half the Nigerian population (50.6%) use dung, wood, or charcoal as their main cooking fuel. In addition, almost 1 in 2 (46.5%) Nigerians are deprived of access to improved sanitation facilities.

Deprivations in the Work and Shock dimension together contribute 14.1% to multi-dimensional poverty in Nigeria. Work and shocks related deprivations that the National MPI 2022 captures for each household include unemployment, underemployment, and security shock. One in seven Nigerians (14.3%) live in a household where at least one person is unemployed, and more than 1 out of 5 (15.9%) are underemployed. A household is considered deprived if at least one household member aged 15 years and above is working fewer than 40 hours per week but is available and willing to do extra hours of work.

Data on poverty in Nigeria is not reported at local government levels. Instead, it classifies each local government into a senatorial district and assumes that poverty is evenly distributed within each senatorial district. Ondo State, which is the case study area for this research, has three (3) senatorial districts which are Ondo North, Ondo South and Ondo Central. According to the poverty map of Ondo state by senatorial district shown in Figure 9, Ondo South is the poorest followed by Ondo North and Ondo Central senatorial districts, respectively.

One thing to note in the assessment of multidimensional poverty in Nigeria is that it does not consider ecological and cultural indicators. This means, there are possibilities for a place to be rich in natural resources and still be classified as poor based on the dimensions considered in the MPI 2022. This study explores the opportunities provided by ecosystem services for reducing poverty vulnerability in Ondo State, Nigeria.

D. Mapping ecosystem services

Mapping ecosystem services involves identifying and quantifying ecosystem services' location, distribution, and value across a landscape. This approach provides a spatially explicit understanding of ecosystems' benefits to humans and can inform land-use planning, resource management, and conservation efforts. Mapping ecosystem services can be done using various methods, including biophysical models, remote sensing, and participatory mapping.

1. Biophysical Models for Mapping Ecosystem Services

Biophysical models quantify ecosystem services based on ecological data such as vegetation cover, soil properties, and climate. These models use mathematical algorithms to estimate the amount and distribution of ecosystem services across a landscape.

Biophysical models are commonly used for mapping ecosystem services, especially those related to regulating services, such as carbon sequestration, water regulation, and climate regulation. Biophysical models are based on ecological data such as vegetation cover, soil properties, and climate and use mathematical algorithms to estimate the amount and distribution of ecosystem services across a landscape (Mouchet et al., 2014). Biophysical models can be divided into two types: empirical models and process-based models.

Empirical models are based on statistical relationships between ecological variables and ecosystem services. These models are useful for areas with limited ecological data and can provide quick estimates of ecosystem services. However, they may not accurately reflect the underlying ecological processes that drive ecosystem services.

Process-based models are based on the underlying ecological processes that regulate ecosystem services. These models are more complex and require more detailed ecological data but can provide more accurate estimates of ecosystem services. Process-based models can be used to simulate ecosystem processes and predict changes in ecosystem services under different scenarios, such as land use or climate (Mouchet et al., 2014).

One example of a biophysical model for mapping ecosystem services is the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model. The InVEST model is a suite of tools that use biophysical models to map and quantify ecosystem services across various landscapes. The InVEST model can map ecosystem services such as carbon sequestration, water regulation, and biodiversity (Tallis et al., 2018).

According to Dong et al. (2015), InVEST model has been successfully applied to services and valuation of ecosystems in many countries and regions, such as the United States, California, Hawaii, southern Central America, Ecuador, Venezuela, Colombia, Central America, Belize coast, Asia and Africa, Indonesia, Amazon, and Tanzania. Quantitative ecosystem services assessment using InVEST also helped Kamehameha Schools to design and implement a plan that fulfils its mission to balance environmental, economic, cultural, educational, and community values (Goldstein et al., 2010).

The InVEST model was also experimented on by Arcidiacono et al. (2015) for the Habitat Quality and Carbon Sequestration functions. The survey area is the Municipality of Lodi in the south part of the Lombardy Region north of Italy due to the high accessibility to the database information and to attempt the software's adaptability to produce reliable output at a micro-scale.

Butsic et al. (2017) used InVEST toolset to quantify ecosystem services at the county scale. They investigated the provision of ecosystem services in Sonoma County, California, and addressed three related questions. First, do lands protected by the

Sonoma County Agricultural Preservation and Open Space District (a publicly funded land conservation program) have higher values for four ecosystem services — carbon storage, sediment retention, nutrient retention, and water yield — than other properties? Second, how do the correlations among the identified services differ across protected versus non-protected properties? Third, what are the strengths and weaknesses of using the InVEST toolset to quantify ecosystem services at the county scale? The only limitation the authors found was that while InVEST provided a low-cost, clearly documented way to evaluate ecosystem services at the county scale, there is no ready way to validate the results.

Another example is ARIES (ARtificial Intelligence for Environment & Sustainability (ARIES), an open-source technology capable of selecting and running models to quantify and map all ecosystem service provision aspects, including biophysical generation and flow and extraction by sinks and beneficiaries. This web-based technology can address a broad range of physical, social, and economic contexts, providing access to a library of sustainability models and spatial datasets at multiple scales ranging from global to local.

ARIES aims to improve existing methods by adopting a uniform conceptualization of ecosystem services, keeping model complexity low, and using computer learning and reasoning to specialize the model for each application context (Villa et al., 2014). The authors assume that the dominant "one model fits all" paradigm is often ill-suited to address the diversity of real-world management situations across the broad spectrum of coupled human-natural systems. However, Mullin (2019) shared concern about the ARIES model stating that it implies all ESs (Ecosystem Services) generated are converted into benefits for humans, not accounting for the depletion of goods and services before they reach the beneficiaries. Another concern with ARIES is its lack of outputs for some areas of the world when using it for some ecosystem services.

While biophysical models have proven useful for mapping ecosystem services, they do have limitations. Biophysical models require extensive ecological data, which may be lacking or unreliable in many regions. Additionally, biophysical models may not account for social and economic factors that influence the value of ecosystem services, such as cultural values or market demand (Pascual et al., 2017). Biophysical models are useful for mapping ecosystem services, especially regulating services. However, their limitations must be considered. They should be used with other methods, such as participatory mapping and remote sensing, to provide a more comprehensive understanding of ecosystem services.

2. Remote sensing method for mapping ecosystem services

Remote sensing is another commonly used method for mapping ecosystem services. Remote sensing uses satellite and aerial imagery to identify and quantify ecosystem properties such as vegetation cover, water availability, and land use. Remote sensing data can be used to estimate ecosystem services such as carbon storage, water regulation, and habitat provision (Maes et al., 2016).

One example of remote sensing-based mapping of ecosystem services is the Normalized Difference Vegetation Index (NDVI), which uses satellite imagery to estimate vegetation cover and biomass. NDVI has been used to estimate carbon storage, crop productivity, and water availability (Jia et al., 2018). Another example is the Water Yield Model, which uses remote sensing data and hydrological models to estimate water availability in a watershed. The Water Yield Model has been used to identify areas of high-water yield and prioritize these areas for conservation efforts (Kang et al., 2015).

Earth observation data can quantify the production capacity of forests and agro-ecosystems using biomass as an indicator. Narrowband and broadband vegetation indices such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Fraction of Photosynthetically Active Radiation (FPAR) and Leaf Area Index (LAI) can be used as indicators of productivity in a crop growing season, as they are able to characterize variation in phenology and photosynthetic potential of crops and help identify the cropping cycle and growth (Prabakaran et al., 2013).

Erosion control regulation can be measured with medium-resolution optical imagery (10- to 30-meter resolution) (e.g., Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper) by identifying the reflectance properties of the constituents of sediments (e.g., lithological composition, grain size and moisture content), potentially enabling the detection of eroded land and material deposition (Small et al., 2009). Vegetation indices and elevation data are suitable for predicting soil erosion risk, as mapping variability in vegetation cover and plant residue can help reveal areas prone to erosion. Remote sensing-based soil erosion models integrate NDVI, vegetation fraction cover, slope gradient and land use (from SRTM data) to estimate annual soil erosion rates (Wang et al., 2013b).

Remote sensing can also be combined with other data sources, such as ecological models, to provide more accurate estimates of ecosystem services. For example, remote sensing data can be used to parameterize biophysical models and improve the accuracy of ecosystem service estimates (Vogt et al., 2018).

One of the main advantages of remote sensing is its ability to provide data over large areas and at regular intervals, which is particularly useful for monitoring changes in ecosystem services over time. However, remote sensing also has limitations, including mismatch of scale and resolution of different data sources, dependence on weather conditions, sensor limitations, and extensive processing and analysis (Maes et al., 2016).

In summary, remote sensing is valuable for mapping ecosystem services, providing spatially explicit information over large areas. Remote sensing can be used to estimate ecosystem services such as carbon storage and water availability and can be combined with other methods, such as biophysical models to improve accuracy.

E. Applications of Mapping Ecosystem Services

Mapping ecosystem services has numerous applications in environmental management and policy. For example, mapping can identify areas of high ecological value that should be prioritized for conservation efforts. It can also be used to identify areas where land use changes may significantly impact ecosystem services, such as the conversion of forests to agriculture. Additionally, mapping can inform the development of ecosystem service markets, where ecosystem services are bought and sold based on their value (Pascual et al., 2017).

Another common application of mapping ecosystem services is in land use planning. By identifying areas of high value for ecosystem services, maps can be used to prioritize conservation and restoration efforts in these areas. For example, in the Brazilian Amazon, maps of ecosystem services were used to identify areas of high carbon storage and prioritize these areas for conservation efforts (Macedo et al., 2015).

Mapping ecosystem services can also inform natural resource management by identifying areas of high value for specific services, such as water regulation or habitat provision. This information can guide conservation efforts, inform restoration strategies, and support sustainable natural resource use. For example, maps of ecosystem services were used to support watershed management in California, where areas of high-water yield were identified and prioritized for conservation efforts (Kang et al., 2015).

Maps of ecosystem services can inform policy development by providing a spatially explicit understanding of the distribution and value of ecosystem services. This information can support policy development related to environmental protection, natural resource management, and land use planning. For example, maps of ecosystem services were used to inform the development of the European Union's Biodiversity Strategy for 2020, which includes targets for the conservation and restoration of ecosystems and their services (Maes et al., 2016).

Mapping ecosystem services can also support conservation efforts by identifying areas of high value for specific services and guiding the development of conservation strategies. For example, in Costa Rica's Osa Peninsula, maps of ecosystem services were used to identify areas of high carbon storage and prioritize these areas for conservation efforts (Leimona et al., 2015).

During the literature review, it was found that no studies have applied ecosystem service mapping to poverty vulnerability, both in general and in the specific context of Ondo State, Nigeria. This significant gap in the existing literature highlights the importance of current research in addressing this knowledge deficit and contributing to the field of ecosystem services research in the region. By filling this gap, the findings of this research can provide valuable insights into the relationship between ecosystem services and poverty, and inform policymakers, practitioners, and other stakeholders in developing effective strategies for poverty alleviation and sustainable ecosystem management in Ondo State, Nigeria.

F. Challenges in Mapping Ecosystem Services

While mapping ecosystem services offers numerous benefits, several challenges must be addressed. One of the primary challenges is data availability and quality. This can be particularly challenging in developing countries or regions with limited resources for data collection (Haines-Young et al., 2018). In addition, different ecosystem services require several types of data, which can further complicate the data collection process. Biophysical models require extensive ecological data, which may be lacking or unreliable in many regions. Cloud cover, atmospheric conditions, and sensor limitations may affect remote sensing data. Additionally, mapping ecosystem services may require expertise from multiple disciplines, including ecology, geography, and economics (Mouchet et al., 2014).

Another challenge is the lack of standardization in the methods used for mapping ecosystem services. This can make comparing results across different studies and regions difficult and limit the mapping effectiveness in informing decision-making (Bagstad et al., 2013).

There is also a challenge related to the complexity and interconnectedness of ecosystem services. Many ecosystem services are interdependent and influenced by numerous factors, such as land use change, climate change, and human activities. This complexity can make it challenging to accurately map and quantify ecosystem services and their values (Fisher et al., 2018). For instance, if a coastal region study is to be conducted, mapping ecosystem services of mangroves, seagrasses, and coral reefs will require considering factors such as species composition, habitat density, health status, hydrological and geomorphic conditions, as well as human activities. These cannot be directly mapped with the current tools, which therefore highlight the need for robust methods that account for the interdependencies and dynamics of ecosystem services.

Finally, there are challenges related to integrating social and cultural values into mapping ecosystem services. Ecosystem services are not only biophysical entities but also have social and cultural values that must be considered. This can be particularly challenging, as these values may vary across communities and cultures (Turnhout et al., 2013). This challenge can be addressed through interdisciplinary collaborations between social scientists, cultural experts, and ecologists as they will help bridge the gap between biophysical and social-cultural aspects of ecosystem services mapping, leading to more holistic and inclusive assessments. This can be through a comparison of biophysical values (tangible) to social-cultural ones (intangible).

CHAPTER III

METHODOLOGY

This section focuses on how the study addresses the primary research question about Ecosystem Services' potential to mitigate poverty vulnerability in Ondo State, Nigeria. The section explores the research methodology employed in the study, including the study area description, the data collection techniques, the analytical methods used to analyze the data, and the interpretation of the findings. By examining these aspects of the research, the section provides a better understanding of how the study addresses its research questions and contributes to the broader literature on mapping ecosystem services.

A. Study Area

Ondo State is one of the 36 states in Nigeria. It is in the geographical coordinates of 7°10N and 5°5E. It has a total land area of 15,500 km2 (6,000 sqm) (Adefolalu et al., 2014). It shares boundaries with Ekiti, Kogi, Edo, Ogun, and Osun States.

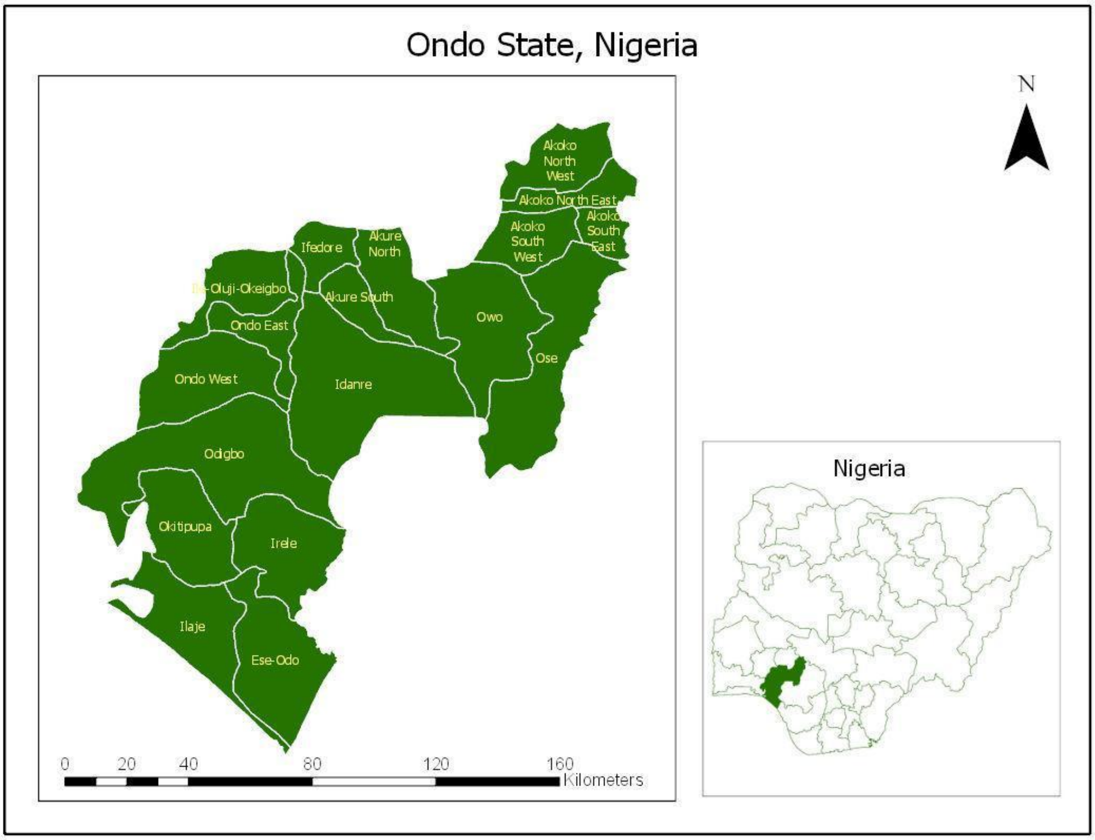


Figure 1. Map of Study Area, Ondo State, Nigeria

Ondo State, Nigeria is a key area for this study due to several reasons. Firstly, Ondo State is known for its rich natural resources, including forests, rivers, and agricultural lands, which contribute vital ecosystem services to local communities. Understanding and mapping these ecosystem services can provide valuable insights into their role in reducing poverty vulnerability in the region. Secondly, Ondo State is characterized by an extreme poverty rate, with a sizeable portion of its population living below the poverty line. This makes it a relevant context to investigate the relationship between ecosystem services and poverty vulnerability, and to identify potential strategies for leveraging ecosystem services to reduce poverty and improve livelihoods. Lastly, there is a lack of existing literature on ecosystem service mapping for poverty vulnerability in

Ondo State, Nigeria. Addressing this research gap can provide valuable knowledge and insights that can inform policy and decision-making at local, regional, and national levels.

1. Climate

The climate of Ondo State ranges from tropical wet- and dry climates with a mean annual rainfall of about 1,500 mm and 2,000 mm in the derived savanna and humid forest zones respectively (Adefolalu et al., 2014). The wet season starts in April and ends in October, and the dry season commences from November to March. However, the average annual rainfall mostly increased to 2,500 mm on the Southern coast and can reduce to about 1,220 mm in some years at the northern limit of the forest belt. The mean annual temperature is about 26.6°C with an average yearly humidity of 76.05%. The climate is monsoonal, contrasting well-defined dry and wet seasons (Adebekun, 1978; Agboola, 2005).

2. Geology and Soil

Ondo State comprises two distinct geological regions of sedimentary rocks in the Southern part and the pre-Cambrian basement complex rocks in the northern part of the state. The sedimentary rocks contain post-Cretaceous sediments from the Abeokuta formation of the Cretaceous. The basement complex rocks, conversely, contain medium-grained gneisses, strongly foliated rocks occurring as outcrops with alternating bands of dark and light minerals. The light bands color is rich in minerals such as feldspar and quartz, and the dark-colored bands are full of abundant biotic mica. A portion of the state in the northeast overlies the coarse-grained granites and gneisses

(Ekanade, 2007). The soil type of the study area ranges from medium-grained granitic rocks to medium-grained gneisses and schists, which support the development of low rainforests suitable for tree crops such as cocoa, kola, and oil palm (Ekanade, 2007). The relief of Ondo State is dominated by the plain that rises gently from the coast northwards to the area of crystalline rock where icebergs rise above the surrounding plains (Adebekun, 1978).

3. Landform and drainage

Ondo State is composed of lowlands in the southern part and in certain parts at the central. And rugged hills with granitic outcrops dominate several places, mostly in the northern part of the state. The land is rising from the coastal area in the south, i.e., less than 15 meters above sea level, to the rugged hills of the northeastern area of the Akoko region. The notable hills in Ondo State are found in Idanre and Akoko, which rise beyond 250 meters above sea level (Adebekun, 1978). The geomorphological units of the creek and riverine portions of the state contain sand ridges, lagoons, swamp flats, creeks, and distributaries of the western Niger Delta (Online Nigeria Community Portal, 2013). The major rivers found in Ondo State include Owena, Oluwa, Oni, Ogbese and Ose, and their drainage system is characterized by basement complex rocks (Olajide and Adeogun, 2006).

4. Vegetation

Ondo State falls within the evergreen tropical rainforest, a transitional zone between the fresh-water swamps along the coast and the Guinea Savanna belt in the north (Ekanade, 1990). The southern and central parts of the state contain natural vegetation of high forest rich in various hardwood for timber such as *Milicia excelsa*, *Antiaris africana*, *Triplochiton scleroxylon* , *Terminalia Superba*, *Lophira Procera*, etc. But in the northern part are found the woody savanna and grassland such as *Blighia sapida* and *Parkia biglobosa*, which dominate the Akoko area (Online Nigeria Community Portal, 2013). The swamp flats are the area of freshwater swamp forests dominating the interior and the units of mangrove vegetation near the coast. Worthy of notice in the state vegetation is the prevalence of tree crops plantation such as cocoa, kola, coffee, rubber, oil palms and citrus, with cocoa being the most vital tree crop in the state.

5. Poverty in Ondo State, Nigeria

Ondo state, like other states in Nigeria shared a proportion of the country's economic challenge, as the statistics from the NBS (National Bureau of Statistics) in 2013, indicated that about 45.7% of the inhabitants of the state is suffering from poverty. According to Akinmulegun (2014), the following poverty vulnerability reduction programs were adopted by government to better the lives of the people and drastically reduced the level of poverty in the state:

- **Abiye Safe Motherhood and the Mother and Child Hospitals:** Contributed to the reduction of maternal and infant mortality.
- **Mega Schools and free transport for students:** Contributed to bridging the gap between the poor and the rich in the state, so that every child has equal access to primary school education. Each of the 18 local government areas has its own mega school.
- **Ultra-Modern Markets:** Contributed new markets with modern facilities to all communities in the 18 local government areas of the state. These

markets allow women to buy and sell in a comfortable, modest, and clean environment. Moreover, the establishment of Automart buildings has reduced the cost of automobiles, especially in the state capital.

- **Micro-credit Schemes and Youth Empowerment Programs:** Contributed to the growth of small and medium scale entrepreneurs and the reduction of unemployment. Youths have been empowered by receiving assistance in cash and in kind and through sponsorship of technical careers.
- **Agric Villages and Centers:** Contributed to youth employment, and to the increase in agricultural produce in the state. Over 2,000 youths have been employed through these programs established in the 3 centers in the state's 3 senatorial districts.
- **Tourism and Sport Development**: Contributed to the creation of the "mare" festival in Idanre Hills, to the establishment of the first state to owned Olympic Standard swimming pool, and the formation of the first state football team ("Sunshine Football club").

B. Research Method

The research is a GIS-based ecosystem services mapping, and it relied on many available secondary data collected using remote sensing techniques. This study explored databases online and locally to gather data used. The method is divided into two, one of them is connecting ecosystem services to SDGs following the method of Citton et al. (2023), and the other is the mapping of the selected ecosystem services in the context of limited data availability.

1. Connecting Ecosystem Services to SDGs

Seven ecosystem services were selected for this study depending on data availability and their relevance to the sustainable development goals as researched by Wood et al. (2018). The selected ecosystem services are crop production, crop pollination, water provision, carbon storage, habitat quality, recreation and tourism, and aesthetic quality.

2. Mapping the Selected Ecosystem Services

The mapping of the selected ecosystem services was performed primarily using the InVEST toolkit from the Natural Capital Project (Integrated Valuation of Ecosystem Services and Trade-offs) (Sharp. et al. 2018). The data used included different resolutions depending on the sources from which they were obtained. However, there was no need for manual scaling because the InVEST model has the capability to adjust the resolution within its operations.

It was not possible to use InVest to map recreation and tourism and carbon storage for the following reasons. It was not possible to use InVEST for mapping recreation and tourism because the database it uses relies on Flickr data of visits to various sites and Flickr is not widely used in the study area. Instead, data on recreation and tourism was developed by identifying tourist sites in the state and displaying them as points within the study area polygon. With respect to carbon storage, local data is scarce. Instead, ARIES (ARtificial Intelligence for Environment and Sustainability, Villa et al., 2014, Bagstad et al., 2013a, b) was adopted.

The information displayed in table 2 below shows the categories of selected ecosystem services, the data sources used for their mapping and the adopted model.

Table 1. Indicators, Data Sources and Model adopted for mapping selected ecosystem services.

Ecosystem service	Indicators	Data sources	Model adopted
Provisioning Services			
Food	Area of local key crops	Sentinel 2 classification (10m res)	InVEST Crop production percentile yield (50 percentile)
Water	a) Renewable groundwater b) Surface water	WorldClim 2016 DEM (30m res) from (SRTM, 2010) Soil Map from HYSOG (250m res) (Ross et al., 2018) LULC of Ondo State (30m res) from (ESA, 2021)	InVEST Seasonal Water Yield (SWY)
Supporting Services			
Habitat Life cycle maintenance	Habitat quality	LULC of Ondo State (30m res) from (ESA, 2021) Threats and Sensitivity (Berta et al., 2020)	Habitat Quality InVEST
Regulating Services			

Climate regulation	Carbon storage	ARIES (Villa et al., 2014)	ARIES Carbon Storage
Pollination	Pollinators probability	LULC of Ondo State (30m res) from (ESA, 2021)	InVEST Crop Pollination
		Guild data adapted from (Williams et al., 2015, Winfree, 2007 and Steffan-Dewenter, 2002)	
		Biophysical data adapted from (Bartomeus et al., 2013, Winfree et al., 2009 and Kennedy et al., 2013)	
Cultural Services			
Recreation & Tourism	Tourism sites of Ondo State	Google Map	
Aesthetic	Viewshed of Ondo State	LULC of Ondo State (30m res) from (ESA, 2021)	InVEST Scenic Quality
		DEM (30m res) from (SRTM, 2010)	

a. Provisional Services

Provisioning ecosystem services included food provisioning based on crop yield in tons/hectares of local crops and water-related services including available local recharge (renewable groundwater) and quick flow (surface water).

In the case of food provisioning, crop yield data was modelled using InVEST crop production percentile model on a map of the crop types of Ondo State generated from remotely sensed data. The model uses existing data to map the crop yields for each crop's 25th, 50th, 75th and 95th percentiles. Like Van Ittersum et al. (2013) findings, only the 50th percentile maps were considered a proxy for the median of the yield production. The crop types of the Ondo State map were produced at 10 m resolution using Sentinel 2 reflectance data, averaging cloud-free images from all years of 2021. The bands selected were Band 2, Band 3, Band 4, Band 8, and Band 11, corresponding to Blue, Green, Red, Near Infrared, and short-wave infrared, respectively. A trained classification on the Sentinel 2 data was then performed using the Maximum Likelihood classification tool in ArcGIS Pro as used by Priyadarshini et al. (2018). The Training sample was created based on published reports on field data and main agriculture crop distribution in Ondo State.

For a more accurate classification, the Sentinel 2 images were masked for the area not indicated as agricultural in the LULC map from ESA 2021. The resulting crop distribution map was then used to run the InVEST crop production percentile model. The results derived for individual crops were combined into a single map by assigning an economic value to the crop yield in terms of (USD) per ton. The USD values assigned to each crop was sourced from the Producer Prices on the FAO (Food and

Agriculture Organization) Stat database for the Western African region, using the average of the available countries' data.

Water related services, namely available local recharge (renewable groundwater) and quick flow (surface water), were analyzed based on Climatic data, digital elevation model (DEM), soil groups, watershed, and land use. Both services were analyzed by the same InVEST model for Seasonal Water (SWY). Even though the model is considered an oversimplification by some authors (Scordo et al., 2018), it has been used to give a qualitative overview to point to areas that are important for the local recharge aquifers. The Water recharge indicator extracted from the model is the "sum of the Available Local Recharge," which consists of the contribution to the groundwater base flow of a pixel from the local water balance (Local recharge = Precipitation - Evapotranspiration - Runoff).

Similarly, the quick flow is the runoff component of the local water balance equation. Climate data for monthly precipitation was obtained from the climatic online database from WorldClim 2 (Fick et al., 2017); Soil types were extracted for Ondo State from the Global Soil Map of HYSOG (Ross et al., 2018); The digital elevation model is the SRTM 2010 at 30 m resolution, while the Land Cover unit from ESA 2021. The ET0 (Evapotranspiration) data was acquired from Global Aridity Index and Potential Evapotranspiration (ET0) Climate Database v3 prepared by Trabucco et al. (2019). The rainfall event data was acquired from World Meteorological Organization (WMO)'s World Weather Information Service. For KC Values, LAI was acquired from MODIS and the Allen et al. (1998) method was used for the estimation of KC from the LAI Value. Curve Numbers were adapted from Cronshey (1986), and the Threshold flow accumulation was determined using the DEM using the Flow Accumulation function in the spatial analyst tool of ArcGIS Pro. Then the raster calculator was used to handle the NODATA values before doing the zonal statistics with the zonal statistics as a table having the Maximum option checked.

b. Supporting Services

Supporting services assessed in the study consisted of Habitat Quality, which is based on the InVEST Habitat Quality model, and assumes that areas with higher habitat quality support a higher richness of native species and that decreases in habitat extent and quality lead to a decline in species persistence (e.g., Terrado et al., 201. Habitat quality in the InVEST model is estimated as a function of (1) the suitability of each LULC type for providing habitat for biodiversity, (2) the different anthropogenic threats impairing habitat quality, and (3) the sensitivity of each LULC type to each threat. In this case, the threat and sensitivity to threat data was adapted from Berta et al. (2020). The threat and sensitivity data are a parameter required by InVEST Habitat Quality Model. The threat data is a table mapping each threat of interest to its properties and distribution maps and the sensitivity to threat data is a table mapping each LULC class to data about the species' habitat preference and threat sensitivity in areas with that LULC. The two tables were exported as Comma-Separated Values (CSV) and imported into the model.

c. Regulating Services

Regulating ecosystem services included climate regulation and pollination and were mapped as follows: Climate Regulation, was assessed based on Carbon storage and was modelled using the ARIES Global Carbon Storage model (Martínez-López et al., 2019).

The global vegetation carbon storage model follows the Tier 1 Intergovernmental Panel on Climate Change (IPCC) methodology and quantifies above- and below-ground carbon storage in vegetation in physical units (T/ha), using a lookup table. The model's lookup table uses five datasets as inputs, following: 1. Landcover, 2. eco-floristic region, 3. continent, 4. frontier forests–a proxy for the degree of forest degradation (Potapov et al., 2008), and 5. presence of a recent fire (i.e., within the last 10 years). This model provides globally consistent estimates of the amount of carbon stored in above and below-ground vegetation (Ruesch and Gibbs, 2008).

Pollination was estimated using InVEST Crop Pollination Model. The model focuses on wild bees as a key animal pollinator. It uses estimates of the availability of nest sites and floral resources within bee flight ranges to derive an index of the abundance of bees nesting on each cell on a landscape (i.e., pollinator supply). It then uses floral resources, and bee foraging activity and flight range information to estimate an index of the abundance of bees visiting each cell. The required inputs include a land use/land cover (LULC) map, land cover attributes, guilds or species of pollinators present, and their flight ranges. The Guild data used were adapted from Williams et al. (2015), Winfree (2007), and Steffan-Dewenter (2002), while biophysical data used were adapted from Bartomeus et al. (2013), Winfree et al. (2009), and Kennedy et al. (2013).

d. Cultural Services

Cultural ecosystem services included recreation and tourism and aesthetic value. As indicated above, tourist sites were manually mapped and displayed as points within the study area polygon. It was not possible to use InVEST in this case because the program uses Flickr data of visits while Flickr is not widely used in the study area.

Aesthetic value of Ondo State natural landscape was determined using the InVEST Scenic Quality model and data inputs like SRTM 30 m DEM. The model also required a shapefile for the features that can have a negative impact on the scenic quality, such as unattractive landforms like roads and densely populated urban areas. Point data was produced by identifying and marking the locations of these negatively impacting features in the study area. Finally, the model generated a result in which each pixel represents the cumulative visual impact at that specific location.

3. *Poverty Map of Ondo State*

The Multidimensional Poverty Index (MPI) for 2022 was retrieved and examined in detail for this study. Upon thorough analysis, it was discovered that the report did not provide any information on poverty at the local government level. However, data on poverty at the senatorial district level was available in the report. Considering this finding, the data pertaining to senatorial districts was utilized to generate a poverty map using the ArcGIS Pro software. It was assumed that the poverty level of a given local government area was equivalent to that of the senatorial district to which it belonged, based on the available data.

4. *Data Transformation from Continuous to Discrete by Local Government Areas (LGA) level*

The data was transformed from continuous to discrete using the 'Zonal Statistics as Table' tool in ArcGIS Pro. The tool estimates the average pixel value within each LGA. This tool was personified by selecting the shapefile of Ondo State as the "zone map" and each ecosystem service map as the "raster." The generated output table for each ecosystem service was then exported into Google Sheets to have a CSV file that was subsequently uploaded into ArcGIS Pro for joining. The joining process involved using the join function on the LGA Administrative map shapefile of Ondo State and the aggregated ES table as the "join table." Finally, the new table containing the discrete value was then used to create the map of each ecosystem service by LGAs, thereby providing a clearer picture of areas with high and low provisioning of ecosystem services, as the discrete value of each ES was utilized as the basis for symbology.

One limitation of this study is that we do not have access to a national map of ecosystem services (ES) for Nigeria, which makes it difficult to compare the results with those from other regions. Therefore, to make sense of the values within the study area (Ondo state), the results were presented in percentage form instead of absolute values bearing in mind that high values of a particular ES in Ondo state may not necessarily indicate a high value at the national level and vice versa if national data becomes available.

5. Data Analysis

The study employed two main methods to investigate the relationship between ecosystem services and poverty vulnerability in Ondo State, Nigeria. First, a heatmap was generated to visualize the spatial distribution of different ecosystem services across the 18 local government areas (LGAs) of the study area. The heatmap was constructed using the "pheatmap" package in R programming language, with columns and rows representing the LGAs and different ecosystem services, respectively. The colors in the heatmap were scaled based on the standardized values of the ecosystem services, and the breaks in the color scale were chosen to show low, medium, and high values of the ecosystem services. The ecosystem services with positive value were taken to be in significant quantity in each LGA.

Second, the study analyzed the relationship between ecosystem services and poverty vulnerability in the study area. To do this, the 18 LGAs were classified into three categories of poverty vulnerability based on their poverty levels, which were obtained from the National Multidimensional Poverty Indicators (MPI) report. The poverty levels were defined as high poverty, medium poverty, and low poverty, with each LGA falling into one of these categories. The relationship between ecosystem services and poverty vulnerability was then analyzed using descriptive statistics and regression analysis techniques. The study used linear regression to examine the relationship between each ecosystem service and poverty vulnerability.

6. *Development of Ecosystem Services WebMap for Ondo State*

The development of WebMap was done in QGIS 3.28 using the QGIS2Web plugin. The output files are then hosted on GitHub to make it available for the public. The purpose of the WebMap is to serve as a tool that development agencies in Ondo State can use for decision support.

This research also sought to develop a WebMap of ecosystem services with the purpose of providing a decision support tool for development agencies in Ondo State. To achieve this, QGIS 3.28, a widely used open-source geographic information system software package, was used with the QGIS2Web plugin. The plugin was deemed suitable as it facilitated the creation of interactive and web-based maps to meet the specific needs of the target audience.

Subsequently, the output files of the WebMap were hosted on GitHub, a popular web-based hosting platform. This hosting option was deemed optimal as it provided a free, secure, and easily accessible platform for the public to utilize the WebMap without geographical limitations.

CHAPTER IV

RESULTS AND DISCUSSION

This section presents and discusses the outcomes of the mapping process and the contribution of ecosystem services to reducing poverty vulnerability in Ondo State. The study mapped seven ecosystem services, namely Crop Production, Crop Pollination, Habitat Quality, Aesthetic Quality, Water Provision, Carbon Storage, and Recreation & Tourism.

Poverty vulnerability in Nigeria is assessed based on senatorial districts, rather than at the level of local government areas, according to the available data. Consequently, it is assumed that all local government areas within a senatorial district have the same poverty level. Figure 2 highlights LGAs in the red zone as belonging to Ondo South Senatorial District, considered to have the highest poverty level. LGAs in the yellow zone belong to Ondo North Senatorial District and are considered a medium poverty level. Finally, LGAs belonging to Ondo Central Senatorial District are in orange color and have the lowest poverty level.

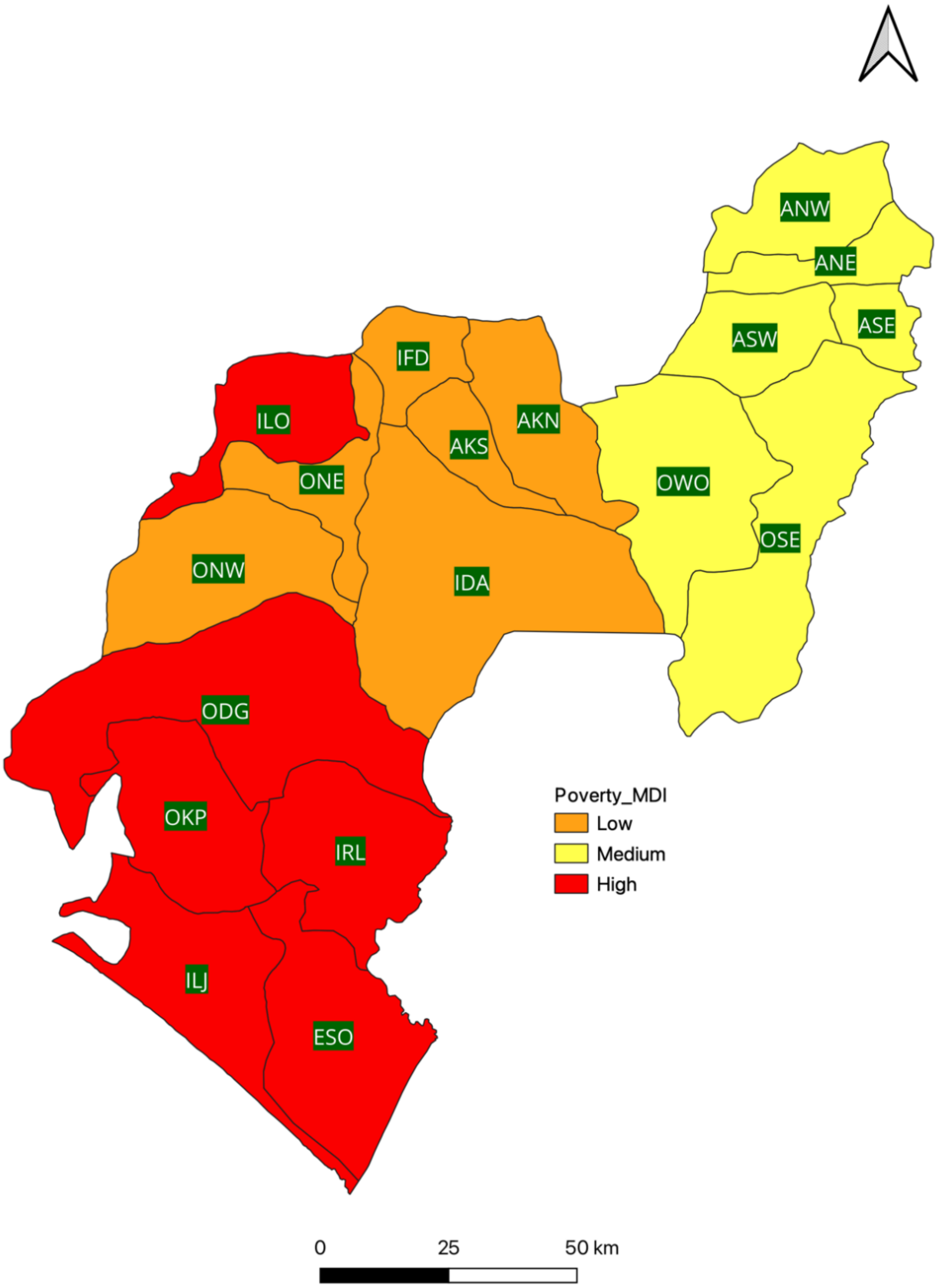
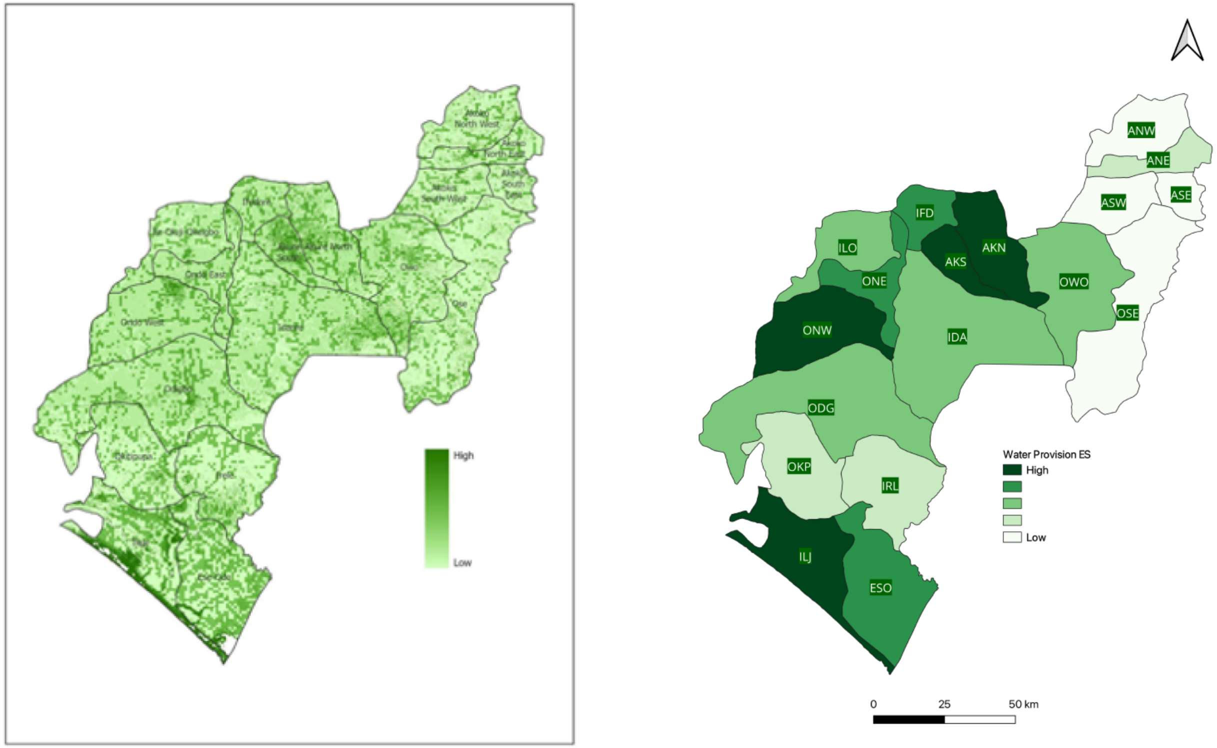


Figure 2. Poverty Vulnerability Map of Ondo State Nigeria by Senatorial Districts. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore(IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO). Note: Adapted from "The 2022 Multidimensional Poverty Index Report" (https://mppn.org/wp-content/uploads/2022/11/MPI_web_Nov15_FINAL.pdf). Copyright 2022 by MPPN

A. Provisional Services

The provision of water and crop production are two important ecosystem services that support human well-being and economic development. The results of this study indicate that there are significant variations in the provision of these ecosystem services across different regions in Ondo State, Nigeria.

The high-water provision levels in Akure South (6.85%) and Ilaje (6.56%) local government areas, as shown in Figure 4, suggest that these regions have a high availability of freshwater resources, which can support human water needs and contribute to the health of ecosystems. On the other hand, the lower water provision levels in Ose (4.54%) and Akoko Southeast (4.60%) indicate that these regions may face water scarcity, which can have negative impacts on human livelihoods and ecological systems.



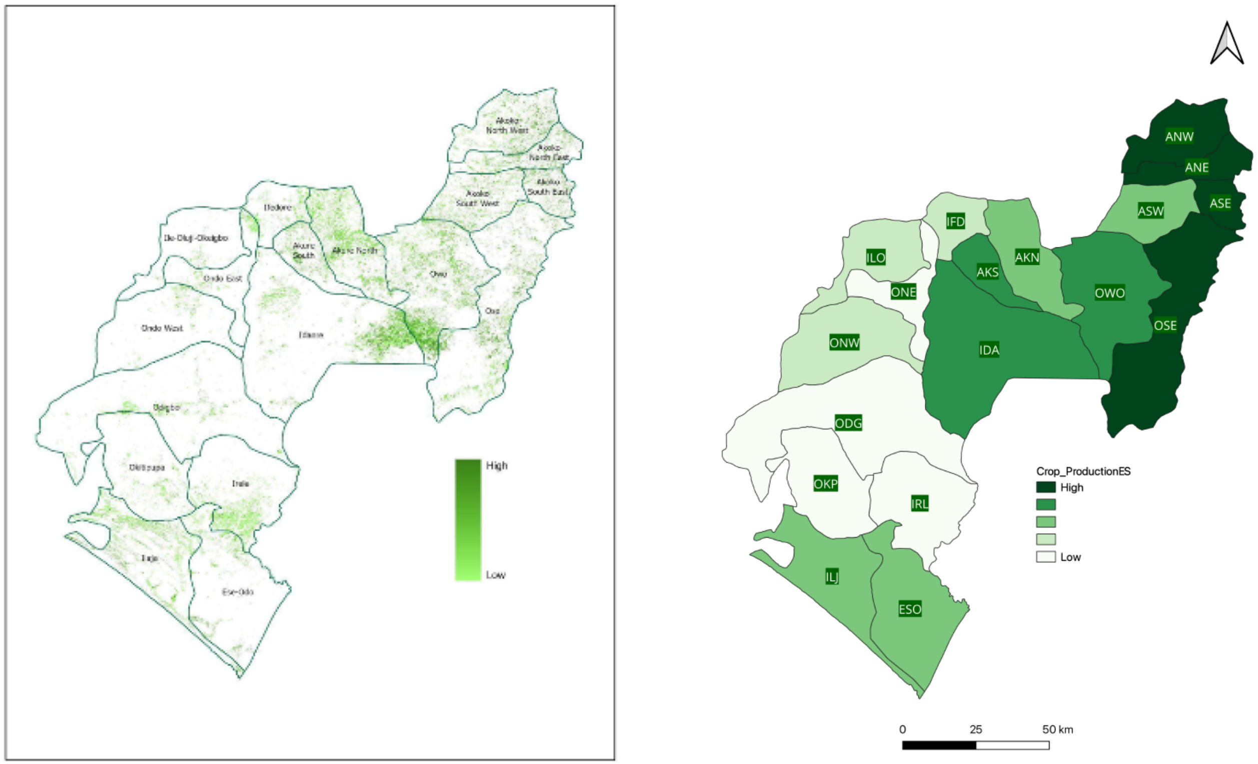
Continuous

Discrete

Figure 3. Water Provision by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore(IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

Water scarcity can lead to reduced crop yields, loss of biodiversity, and increased competition for resources, among other impacts. Therefore, targeted conservation efforts are needed to protect and enhance water resources in areas with low water provision levels. Watershed protection and restoration, improved water governance and management, and promotion of water-efficient technologies and practices can all contribute to the sustainable management of water resources in the region (Dziba et al., 2018).

Crop production was high in Akoko Southeast (10.61%) and Akoko Northeast (10.58%) suggesting that these regions have a higher potential for sustainable agricultural production, which can contribute to food security and economic development (Fig. 5). On the other hand, the low crop production levels in Irele (1.03%) and Ifedore (2.73%) indicate that these regions may face challenges related to soil fertility, access to inputs and markets, and climate variability, which can limit agricultural productivity and income generation (FAO, 2017).



Continuous **Discrete**

Figure 4. Crop Production by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

It is worth noting that Irele, an LGA in the Ondo South senatorial district which has highest poverty in the state, also has low crop production. One explanation for the link between this ecosystem service and poverty may be because farmers in Irele practice subsistence farming, productivity is low, and farming activities do not contribute to the overall economic development of the area. Investments in these areas with low crop production is needed in the form of support through agricultural research and extension services, and the development of supportive policies and institutions to enhance crop productivity and promote sustainable agriculture in these areas (Rockström et al., 2017).

Improving crop provisioning ecosystem services in both low and high provisioning areas of the state can contribute to the achievement of Sustainable Development Goal 2, which aims to create a world without hunger by 2030. However, while this ecosystem service offers benefits, there are issues to consider. This research reveals that areas with the highest crop production are not necessarily those with the lowest poverty rates. This suggests that although important levels of ecosystem services may be available in poverty-stricken areas, the benefits may be flowing to areas with lower poverty rates. To address this issue, it is recommended that the government of Ondo State strive to maintain a balance between ecosystem service provision and benefits in high poverty areas, particularly in areas where there is an important level of ecosystem service provision, such as crop production. This approach may help to reduce poverty vulnerability in these areas.

1. Regulating Services

The results of the study in Figures 6 and 7 regarding regulating services and their spatial distribution in Ondo State, Nigeria, are valuable for sustainable development and conservation efforts in the region. The study provides insights into the carbon storage and crop pollination potential of different areas in Ondo State, which can be used to prioritize conservation and sustainable agriculture efforts

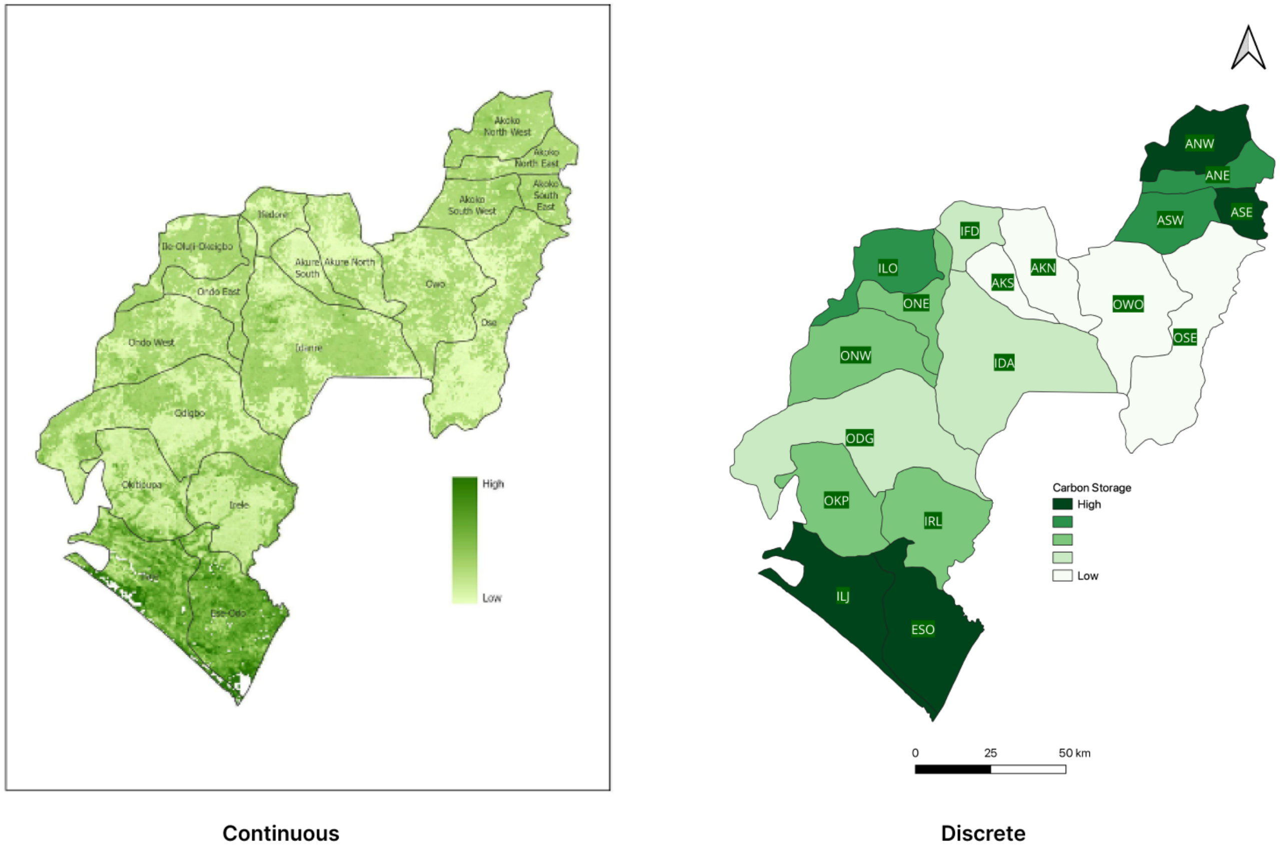


Figure 5. Carbon Storage by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

The study revealed that Ese-Odo and Ilaje have high carbon storage as they respectively contain 10.67% and 9.97% of total carbon stored in Ondo State as shown in Figure 5, while Ose (3.94%) and Akure North (3.97%) have low carbon storage. These findings are consistent with previous studies on the spatial distribution of carbon storage in Nigeria. For example, Alongi (2014) found that mangrove forests in the Niger Delta region, which includes Ese-Odo and Ilaje, have high carbon storage potential. On the other hand, areas with intensive land use, such as agriculture and urbanization, tend to have lower carbon storage potential than forest ecosystems as shown by Yu et al. (2010). This is consistent with the findings of this study which showed that areas with high crop production are not the same areas with high carbon storage.

Carbon storage is contributing to Sustainable Development Goal 13 which calls for urgent action to combat climate change and its impacts. It is intrinsically linked to all 16 of the other Goals of the 2030 Agenda for Sustainable Development. Mikunda et al. (2021) found that carbon storage is a sustainable option to combat climate change and does not prohibit the achievement of any other SDG.

In the areas with low carbon storage, Ondo State Government can invest in interventions like afforestation programs, landscape restoration, and sustainable forest management to increase carbon storage by promoting vegetation growth and healthy soils (Pan et al., 2011). The Ondo State Government can also invest in carbon capture and storage (CCS) technology for capturing carbon dioxide emissions from industrial processes and storing them in underground geological formations. While this technology is still in the initial stages of development, it can reduce greenhouse gas emissions (IPCC, 2018).

With regards to crop pollination, the findings of this research support the opinion of Akinwande et al. (2022) because areas with high pollinator probability such as Ile-Oluji-Okeigbo (6.58%) Ondo West (6.43%) are different from areas with high crop production.

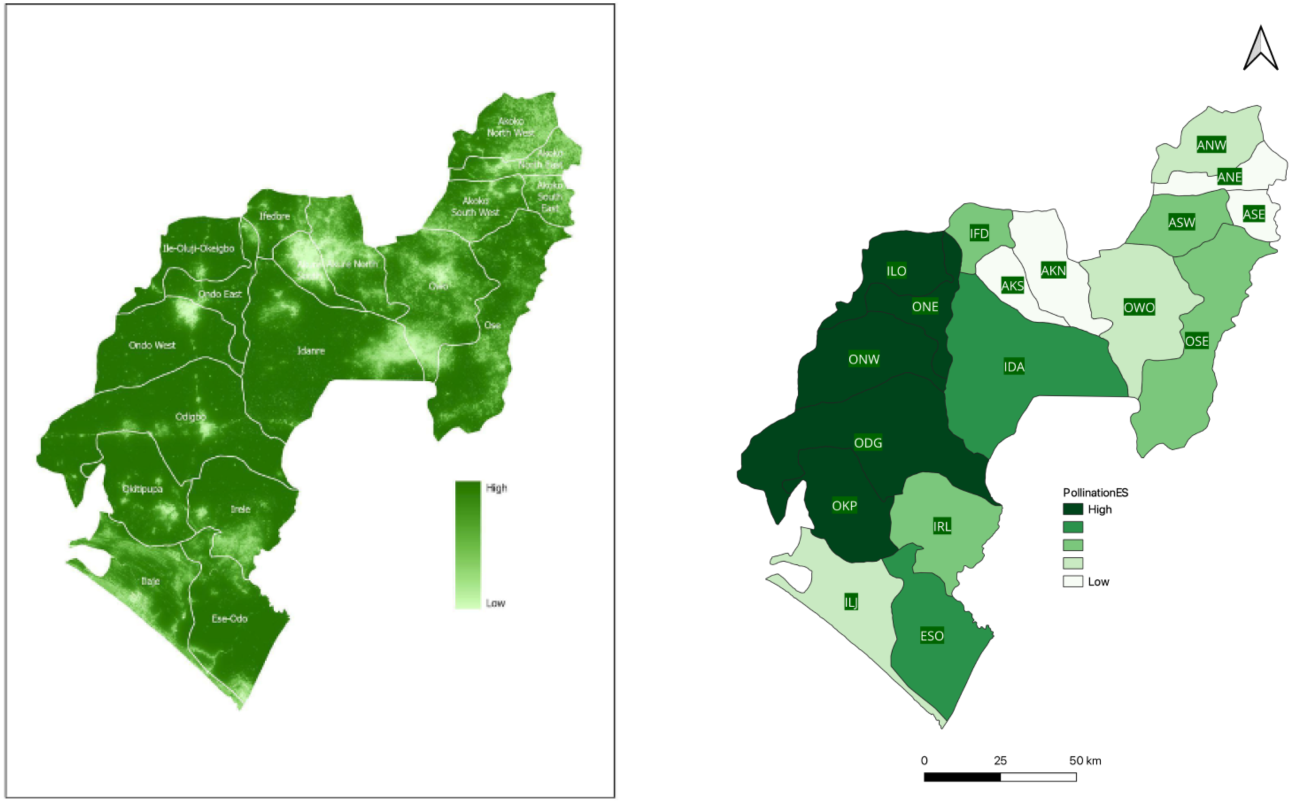


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Figure 6. Pollinator Probability by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

This therefore suggests that Crop production in the state is not taking the full advantage of crop pollination ecosystem services. It also suggests that there is heavy use of pesticides on the agricultural lands as pesticides has been found to decrease crop pollination just as Sponsler et al. (2019) found that pesticides can exert sub lethal and lethal effects on individual pollinators, and the type and extent of these effects vary with exposure level, duration, and route (ingestion, contact, inhalation). In this regard, to maximize the benefits of crop pollination in the agricultural lands of Ondo State, it can be advised that there should be reduced and regulated pesticide use. Another option could be increasing habitat diversity on farms by planting diverse native flowering plants and establishing hedgerows. Through improved crop pollination, increased crop yield can be achieved which would adversely be a considerable progress in the achievement of sustainable development goal 2: zero hunger.

The findings of the study have important implications for conservation and sustainable agriculture efforts in Ondo State. To preserve carbon sequestration and promote pollinator-friendly practices, conservation efforts can focus on protecting and restoring natural habitats such as mangrove forests, which have high carbon storage potential, and forests and woodlands, which provide important habitats for pollinators. In addition, sustainable agriculture practices such as crop diversification and reduced pesticide use can promote pollinator populations and enhance crop pollination.

2. Supporting Service

As shown in Figure 8, the finding that Ese-Odo (6.01%), Ile-Oluji Okeigbo (6.05%), and Odigbo (6.02%) have high habitat quality while Akure South (3.85%) and Akure North (4.84%) have lowest habitat quality is an important contribution to our understanding of the spatial distribution of supporting services in Ondo State, Nigeria. Supporting services, such as habitat quality, is essential for the survival and well-being of all living organisms, as it provides the necessary resources for them to thrive.

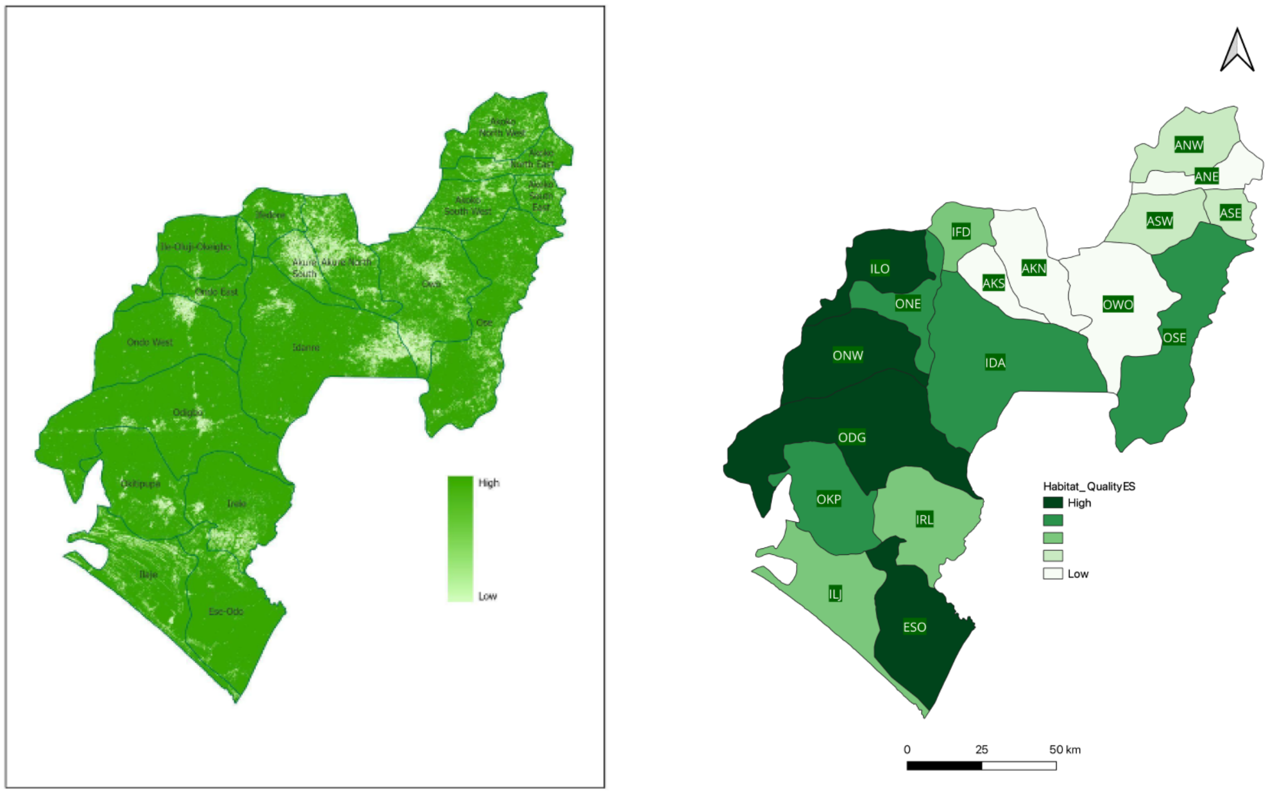

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Figure 7. Habitat Quality by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

Habitat quality refers to the suitability of an area to support a particular species or community of species (Fahrig, 2003). High habitat quality is associated with areas that have a diversity of vegetation types, a variety of microhabitats, and low levels of disturbance. The finding that Ese-Odo, Ile-Oluji Okeigbo, and Odigbo have high habitat quality is consistent with their high carbon storage and crop pollination potential, which suggests that these areas have intact ecosystems that support a diverse range of species.

On the other hand, the finding that Akure South and Akure North have low habitat quality is consistent with their elevated levels of urbanization and intensive land use, which are known to be detrimental to biodiversity (McKinney, 2008). Urbanization and land use change are major drivers of habitat loss and fragmentation, which can result in reduced habitat quality and biodiversity (Xu et al., 2019).

High Habitat Quality is a significant contribution to SDG 15 titled Life on Land, which requires targeted efforts to protect, restore and promote the conservation and sustainable use of terrestrial and other ecosystems. Goal 15 focuses specifically on managing forests sustainably, halting and reversing land and natural habitat degradation, successfully combating desertification, and stopping biodiversity loss. All these efforts combined aim to ensure that the benefits of land-based ecosystems, including sustainable livelihoods, will be enjoyed for generations to come (UNEP (UN Environment Programme), n.d.).

The implications of the findings for conservation and sustainable development efforts in Ondo State are significant. Areas with high habitat quality should be prioritized for conservation efforts to maintain biodiversity and ecosystem services. This can involve protecting natural habitats such as forests, wetlands, and mangroves, and promoting sustainable land use practices like agroforestry and conservation agriculture (Simelton et al., 2021).

In addition, efforts to enhance habitat quality in areas with low habitat quality can promote biodiversity conservation and support sustainable development. Especially in a place like Akure South with extremely low habitat quality due to increasing urbanization, improving the habitat quality can involve restoring degraded habitats, promoting green infrastructure such as urban parks and gardens, and adopting sustainable land use practices in urban and peri-urban areas (McKinney, 2008).

3. Cultural Services

The findings of the study on cultural services, particularly aesthetic quality, and recreation & tourism, provide valuable insights into the spatial distribution of these services in Ondo State, Nigeria. Cultural services are defined as the non-material benefits that people obtain from ecosystems, including aesthetic experiences, recreational opportunities, and cultural heritage (MEA, 2005). These services are important for human well-being and play a significant role in tourism development and cultural preservation.

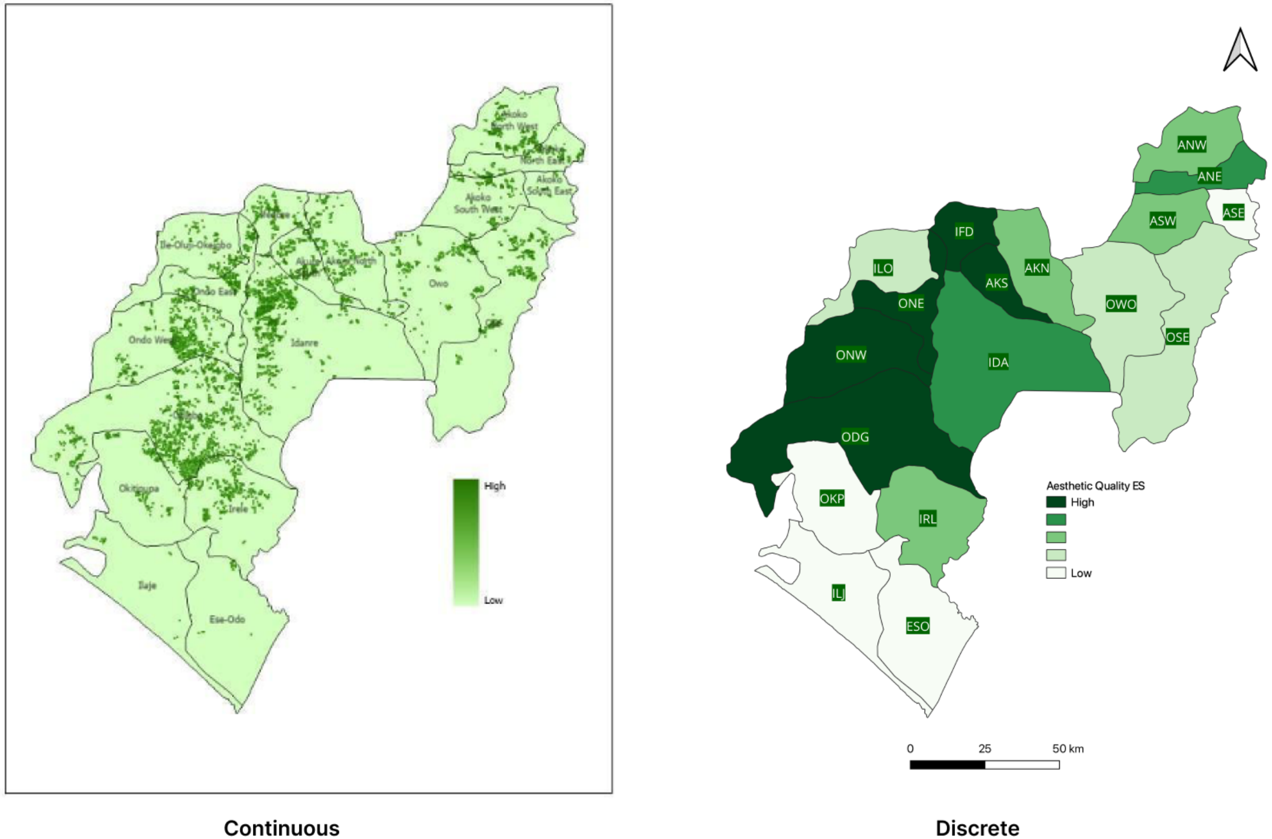

Figure 8. Aesthetic Quality by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

The finding in Figure 8 that Akure South (12.89%), Ondo East (9.62%), and Ondo West (9.12%) have high aesthetic quality while Ese Odo (0.27%), Ilaje (0.31%), and Akoko Southeast (1.33%) have low aesthetic quality is significant for several reasons. Aesthetic quality is a key component of cultural services, and areas with high aesthetic quality are often associated with scenic landscapes, natural features, and cultural heritage sites (MEA, 2005). The presence of high aesthetic quality areas in Akure South, Ondo East, and Ondo West suggests that these areas have significant cultural and tourism potential.

On the other hand, the finding that Ese Odo, Ilaje, and Akoko Southeast have low aesthetic quality may indicate a lack of scenic landscapes or cultural heritage sites in these areas. These findings however negate the common knowledge that one of the indicators of scenic landscape is presence of natural features because Ese Odo and Ilaje which have found to be of low aesthetic quality from the InVEST model have good natural features than the areas found to be high aesthetic quality. This may be one of the inaccuracies or limitations with the InVEST Scenic Quality model since one of the parameters of the model is the Digital Elevation Model (DEM) which does not account for trees.

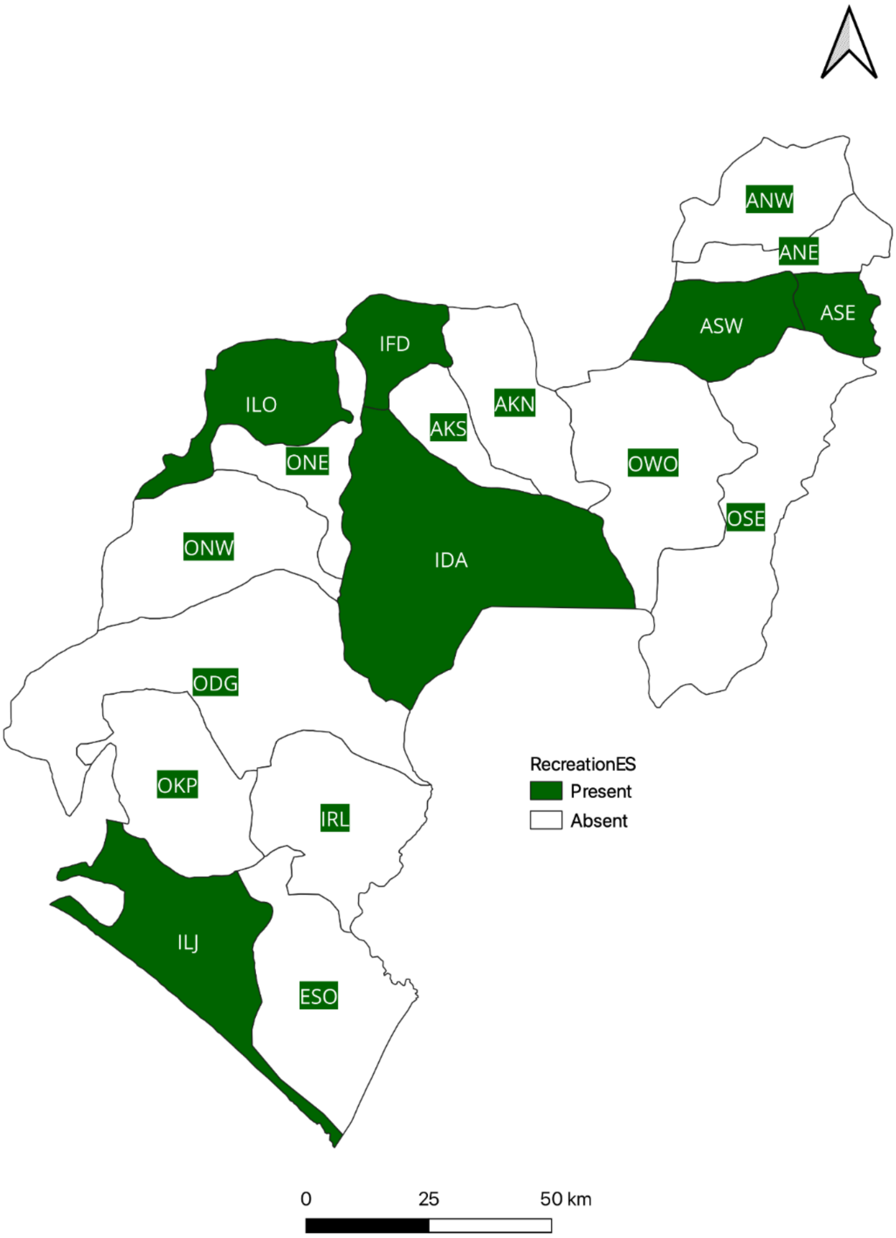

Figure 9. Recreation and Tourism by LGAs. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

Regarding recreation & tourism ecosystem services, the findings in Figure 9 reveal that several local government areas have nature and cultural tourist sites. This therefore underscores the tourism potential of Ondo State. Places such as Araromi Beach in Ilaje, Idanre Hills in Idanre, Igbo Olodumare in Ile-Oluji-Okeigbo, Cave of Ashes and Elizade Smoking Hills Golf Resort Ifedore, Oke Maria Sacred Hill Top in Akoko Southwest, Ebomi Lake in Akoko Southeast. These sites offer opportunities for recreational activities and cultural experiences and can contribute to local economic development through tourism (UNEP, 2015).

B. Distribution of Ecosystem Services in Ondo State

The display of assessed ecosystem services in a matrix that groups LGAs by poverty status revealed that there are no specific patterns linking levels of ES services to poverty reduction (Figure 11). Instead, the findings highlighted opportunities where ecosystem services could contribute to reducing poverty vulnerability.

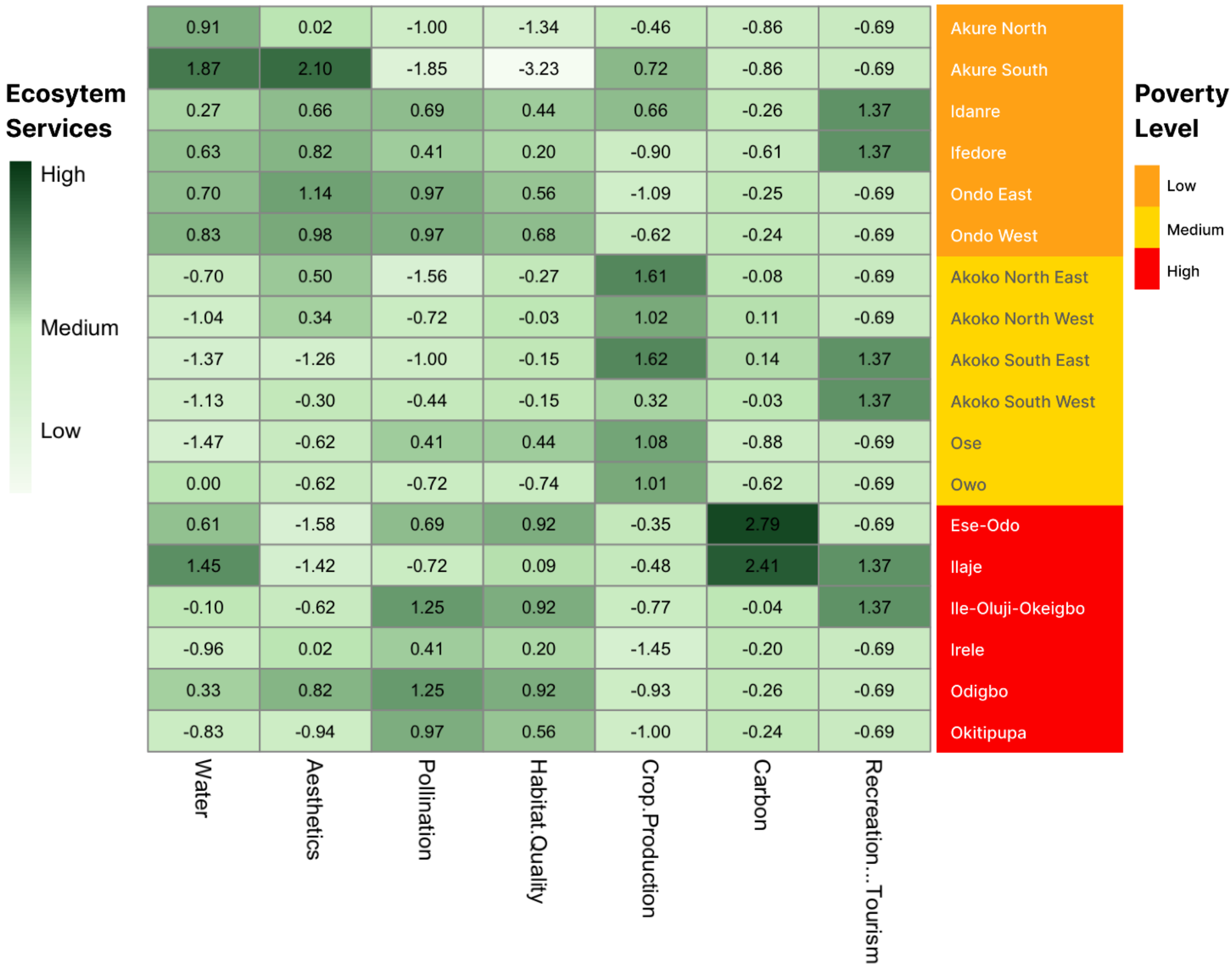

Figure 10. Distribution of Mapped Ecosystem Services in Ondo State By LGA and Poverty. Names of LGAs have been abbreviated as follows for easy labelling of the maps. Akoko Northeast (ANE), Akoko Northwest (ANW), Akoko Southeast (ASE), Akoko Southwest (ASW), Akure North (AKN), Akure South (AKS), Ese-Odo (ESO), Idanre (IDA), Ifedore (IFD), Ilaje (ILJ), Ile-Oluji-Okeigbo (ILO), Irele (IRL), Odigbo (ODG), Okitipupa (OKP), Ondo East (ONE), Ondo West (ONW), Ose (OSE), Owo (OWO).

From Figure 10, in terms of recreation and tourisms, the results show equal opportunities for benefiting from this type of cultural ecosystem services regardless of poverty status since two LGA in each poverty category presented high ES scores. In the case of high poverty areas, the impact of tourism may benefit residents more by providing revenue that can help prevent poverty vulnerability. This has been proven to be correct through the work of Scheyvens and Hughes (2018) who found that tourism can contribute to poverty, but the multidimensional nature of poverty must be considered. The author also noted structural inequalities must be addressed to make tourism more equitable and sustainable. Tourism has also been found to have positive effect on poverty reduction in China (Zhao and Xia, 2019). The findings of Folarin and Adeniyi (2020) confirmed that tourism development has also been found to contribute to poverty reduction in Sub-Saharan African countries and policies that increase the attractiveness and awareness of existing SSA tourism sites should be promoted because such interventions have considerable poverty reduction potential. A unidirectional causality relationship from international tourism towards the reduction of poverty was found in Mexico as 1% increase in international tourism leads to a 0.46% increase in household consumption per capita (a decrease in poverty) in the long-term (Garza-Rodríguez, 2019). However, the contribution of tourism to poverty reduction can only be made possible through government intervention. In China, Ji et al. (2022) identified that government intervention plays a key role in promoting forward local linkages, enabling residents to participate in the tourism value chain and increase their income.

The findings revealed that in terms of carbon, there are opportunities in the impoverished areas of Ondo State, as they have the potential to store more carbon because of the mangrove forest ecosystem and benefit from carbon credits. In China, the pilot carbon emissions trading schemes (ETS) resulted in increases in rural residential income and employment. According to Zhang and Zhang (2020), the estimated effects correspond to an increase of approximately 752.6 yuan in annual rural residential income and 2.35% in the ratio of rural employed population to the total employed population. The implementation of ETS was found to be beneficial to income growth and job creation for rural areas of China, which mean the ETS policy may be conducive to poverty alleviation in affected provinces. However, in India, Forest carbon projects have adversely affected the livelihoods of all three categories of farmers, with small and marginal farmers being the most distressed (Aggarwal and Brockington, 2020). The author found the issue to be a result of the project design such as binding land use, delayed accrual of benefits, static opportunity costs and displacement of existing economic activities have serious livelihood and equity implications. Unless these issues are addressed and strong safety nets are provided, forest carbon projects might create more poverty than wellbeing for marginal communities.

Regarding crop production, high-poverty areas have low crop production because they are subsistence-based, while medium-poverty areas engage in commercial farming, resulting in higher crop production. Low-poverty areas also have low crop production due to urbanization. Nevertheless, smallholder farmers have been found to be a key to ending hunger and malnutrition worldwide, but they are increasingly facing barriers to profitability (Fan and Rue, 2020 and Mbatha et al., 2021). Strategies to promote smallholder agriculture as a business in the extreme poverty areas of Ondo State can help to overcome these obstacles and move smallholders with profit potential towards greater prosperity. The findings of Fan and Rue has also been proven true by Saridakis et al. (2021) who confirmed that engaging in agribusiness and nonfarm entrepreneurship

(NFE) boosts household income and economic well-being, especially in rural areas with extreme poverty rates. Fan and Rue (2020) further opined that supporting smallholders to move out to seek non-farm employment opportunities can also contribute to the achievement of multiple Sustainable Development Goals (SDGs).

Concerning habitat quality, opportunities exist for both high-poverty and low-poverty areas, but maximizing habitat quality in high-poverty areas will contribute more to the sustainable development of the area. Although there is high habitat quality now, there are chances that if poverty does not reduce in the extreme poverty areas, the habitat quality will be adversely affected as there is there is a mutual causality between poverty and environmental degradation (Kassa et al., 2018). Kassa et al. opined that poverty worsens environmental degradation by leaving the poor with no alternatives other than degrading their environment and environmental degradation exacerbates poverty by deteriorating the poor's livelihood, income, and health. The high habitat quality in the extreme poverty areas can also contribute to reducing poverty as identified by Ferraro et al. (2011) that protected areas in Costa Rica and Thailand, on average, reduced deforestation, and alleviated poverty.

Pollination is high in high-poverty areas, indicating sustainable farming practices. However, in medium-poverty areas, there is high crop production and low pollination, suggesting a lack of sustainable farming practices. Pollination can be used to boost crop productivity in the high poverty areas. Animal pollination is essential for 87 of the leading global food crops, while 28 crops do not rely upon animal pollination and 60% of global production comes from crops that do not depend on animal pollination, 35% from crops that depend on pollinators, and 5% are unevaluated (Klein et al., 2007).

For aesthetics, it is challenging to draw conclusions as the InVEST model relied on elevation data for mapping, giving areas of higher elevation high aesthetic value instead of areas rich in nature. This limitation of the InVEST model placed high aesthetic value in low-poverty areas as they are located in the elevated part of the state. Just as tourism benefits the poor, good aesthetic quality will also support tourism as many people visit a place based on the scenery. Also, there may be an overlap of aesthetics with recreational, educational, and inspirational aspects of cultural ecosystem services (Smardon, 2021). Cultural and spiritual values like the aesthetic quality ecosystem service are important drivers of nature conservation and ecosystem management. However, these values are often intangible and difficult to represent in decision-making processes (Verschuuren, 2007). Bratman et al. (2012) found that exposure to nature can positively impact cognitive function and mental health. Diverse types of natural experience may have different effects on cognitive function and mental health. Preferences for nature may play a role in the environment's impact on psychological functioning. This can therefore contribute to reducing poverty vulnerability from the health and wellness dimension.

For water resources, there is high water provision in low-poverty areas, and impoverished areas are not deprived of water. However, the findings only assessed water in relation to its availability and not its quality. Therefore, even if there is high water provision in impoverished areas, they may not benefit from it if the water quality is poor meaning that there is a need for water intervention in these areas if high water provision will contribute to reducing poverty vulnerability. In the work of Ahmed et al. (2022) done in Sub-Saharan Africa and South Africa, water interventions were found to be essential for poverty reduction. Major water interventions identified include improving rainwater management, facilitating community-based small-scale irrigation schemes, developing, and managing groundwater irrigation, upgrading, and modernizing existing irrigation systems, facilitating, and improving livestock production, and promoting multiple uses of water. Investment in these water interventions will help to break the poverty trap across diverse rural communities. Another way that high water provision can contribute to reducing poverty vulnerability is through payments for hydrological ecosystem services which can be used as a political instrument to promote sustainable natural resource use and rural development. A case study from Nicaragua by Hack (2010) has demonstrated the potential of this instrument to reduce poverty and improve natural resource management. The application of payments for hydrological ecosystem services has had positive effects on natural resource use and development.

Overall, High-water provision can be a good opportunity if the water quality is improved. Good habitat quality in poor areas can help with water quality. However, the water provision in the area is not within forests where it can contribute to cleaning the water. Instead, water provision in the mangrove region can benefit from the mangrove's water-purification capabilities as mangrove wetlands provide water purification (Xu, 2004). There is also an interlinkage between multiple ecosystem services in impoverished areas; high habitat quality in poor areas can support recreation, carbon sequestration, and aesthetic quality.

In low-poverty areas, it is recommended that conservation be prioritized to prevent urban expansion from depleting current ecosystem services provision in the area.

C. High Poverty and High Ecosystem Services Case Study

Looking at Figure 13, the findings of this research showed Ilaje and Ese Odo Local Government Areas to be places rich in ecosystem services yet highly vulnerable to poverty. Most of the residents of these two LGAs rely on fisheries for their daily livelihoods. They belong to the ecosystem biome of coastal which comprises estuaries, seagrass/algae beds, coral reefs, and the continental shelf in different proportions (Olajide et al., 2020).

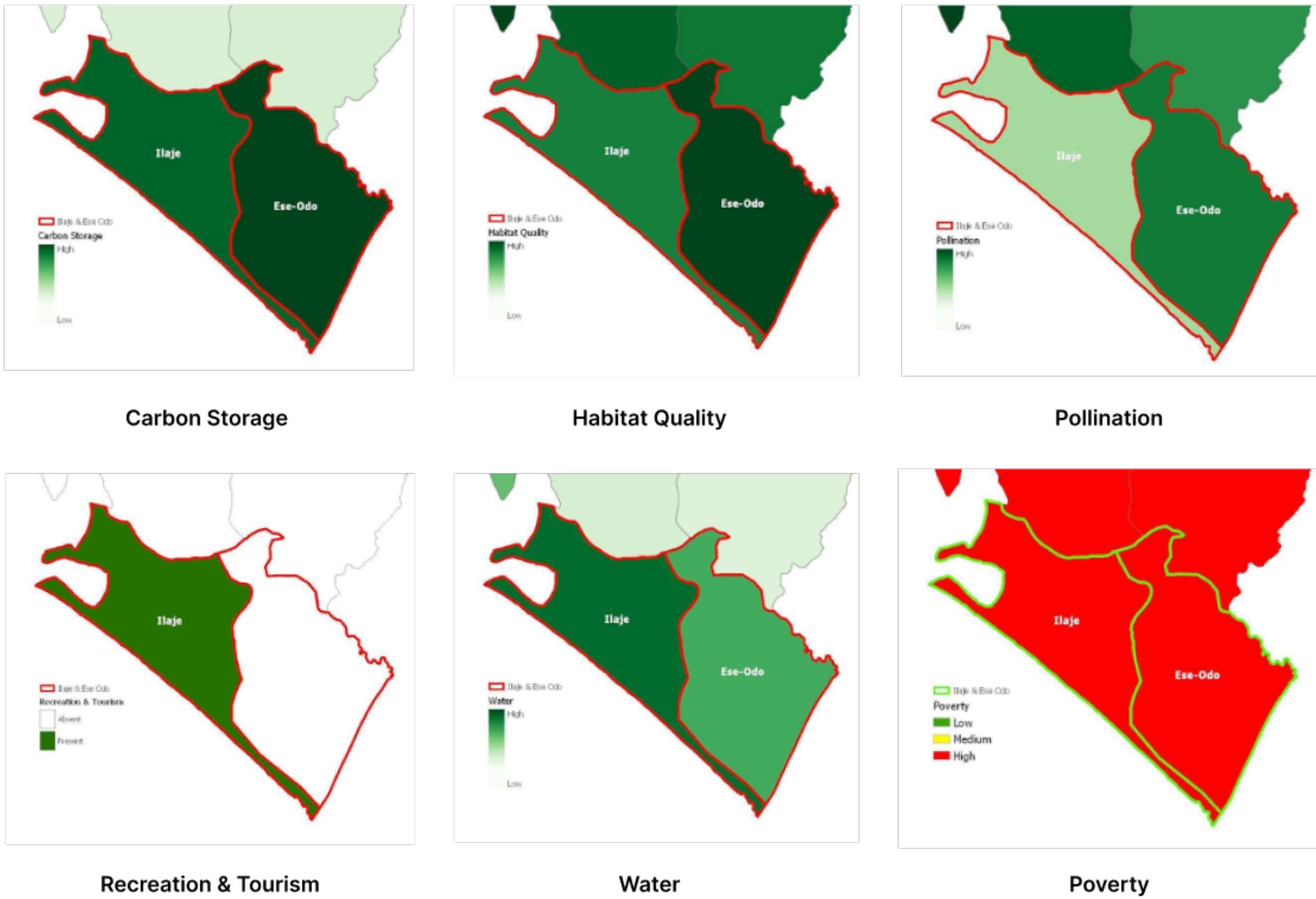

Figure 11. Maps of Ilaje and Ese Odo LGAs showing the ecosystem services provision (Carbon Storage, Water Provision, Habitat Quality, Crop Pollination, Recreation and Tourism)

These findings suggest that there are several opportunities for poverty vulnerability reduction in these areas which were found to have high scores in the following ecosystem services: Carbon Storage, Water Provision, Habitat Quality, Crop Pollination, and Recreation and Tourism.

Leveraging an ecosystem service like Carbon Storage, Ese Odo and Ilaje can generate significant revenue from carbon offset programs. These programs enable companies to offset their carbon emissions by purchasing carbon credits generated by conservation or restoration projects that sequester carbon. According to the news by carbon credits on October 31, 2022, the federal government of Nigeria is pioneering a billion-dollar worth of voluntary carbon market on the African continent. It is an innovative climate change solution which will create, over the period of energy transition, millions of new jobs in Nigeria alone, according to estimates of the international experts. The establishment of the voluntary carbon market (VCM) is one of the efforts of Nigeria to help achieve the global net zero emissions target. For Africa at large, the The Africa Carbon Markets Initiative (ACMI) was launched during the last COP27 (International Climate Change Conference of the Parties) in Egypt in November to lead the way in making carbon credits an effective tool to reduce emissions while financing green initiatives across Africa. This is the kind of potential opportunity that could reduce the poverty vulnerability in places like Ese Odo and Ilaje that are high carbon storage and poverty vulnerable area. Carbon trading has been found to work in rural areas of China through the work of Zhang and Zhange (2020) showing that the estimated effects correspond to an increase of approximately 752.6 yuan in annual rural residential income and 2.35% in the ratio of rural employed population to the total employed population, accounting for 9.5% of the rural residents' income and 7.11% of the rural employment, specifically. Through the results, the authors implied that the implementation of carbon trading schemes is beneficial to income growth and job creation for rural areas of China. This mean the scheme may be conducive to poverty vulnerability reduction in the local areas of Ondo State such as Ese Odo and Ilaje if the strategy of China is adapted.

The high habitat quality in this area also provides another opportunity for poverty reduction. Forest and trees have been found to contribute beyond income-based measures to the achievement of SDG 1: No Poverty, which calls for an end to poverty in all its manifestations by 2030. Forests and tree-based systems provide both tangible and intangible inputs to household well-being, including the material aspects of people's lives such as energy, health, housing, income and nutrition and non-material aspects such as community relations and trust and those relating to culture and spirituality (Razafindratsima et al., 2021). In this regard, development agencies in Ondo state can promote Forest-Associated pathways out of poverty in these areas. According to Reed et al. (2017), Razafindratsima et al. (2021) and Miller and Hajjar. (2020), Forest-Associated pathways out of poverty may emerge directly through the sustainable sale of forest and tree products and indirectly through the enhancement of soil fertility, water regulation and the provision of other ecosystem services supporting food production and other livelihoods needs. Actions like this will also create employment that can generate income for residents and improve the overall livelihood of people in the local government areas. Issues that may arise with Forest-Associated pathways out of poverty are the question of who owns the land? This may not be a critical issue in Ondo state as there is a communal land tenure system where community heads power over lands.

Ese Odo and Ilaje can also benefit from recreation & tourism such as nature-based tourism for poverty reduction. Nature-based tourism in protected areas of low-income can contribute to the economy, reduce poverty, and help to develop rural areas. A study by Job and Paesler (2013) analyzed the situation on Wasini Island, a peripheral island neighboring the Kisite Marine National Park on the southern coast of Kenya. An economic impact analysis was undertaken, and the results show an increased income from tourism, which has led to population growth and improved standards of living. However, as good as tourism may be, it can also have a negative impact on livelihood. In the same study by Job and Paesler, they found that on one of the islands studied, tourism has made other livelihoods, such as small-scale fishery and subsistence agriculture, redundant. Nevertheless, the benefits to livelihood that come through tourism are beyond the negative contributions.

Some of the ideas for nature-based tourism that could be implemented in these areas are Beach tourism, which can be achieved by developing eco-friendly resorts and activities for tourists that emphasize the natural beauty of the beach environment. This could include surfing lessons, beach cleanups, and beachside yoga and meditation classes. Another one is Adventure tourism which offers outdoor adventure activities that allow visitors to experience the natural environment, such as hiking, camping, rock climbing, kayaking, and zip-lining. Birdwatching tours are also another wonderful nature-based tourism idea. Many bird species migrate to specific locations at certain times of the year. Tours can be organized to these locations where bird enthusiasts can observe and photograph rare species in their natural habitats. Ecotourism is the last one which would encourage sustainable travel and environmental conservation by offering guided tours that focus on the natural environment and educate visitors on conservation practices. These ideas will generate income for the community while creating employment opportunities for the educated and uneducated members of the local government area.

High water provision is another ecosystem service opportunity in the two selected areas. Water Provision Ecosystem service is paramount to the achievement of Sustainable Development Goals 6 “Clean Water and Sanitation”. According to UN (2015), SDG 6 aims to ensure availability and sustainable management of water and sanitation for all. This goal comprises six targets, with SDG 6.1 and 6.2 focusing on achieving access to safe and affordable drinking water and adequate sanitation and hygiene for all - the most crucial uses of water. However, these overarching targets heavily depend on the achievement of the other SDG 6 targets, which include protecting water quality from pollution (SDG 6.3), increasing water-use efficiency (SDG 6.4), implementing integrated water resources management (SDG 6.5), and protecting water-related ecosystems (SDG 6.6). All SDG 6 targets are interdependent and intrinsically linked to each other and must be considered as such to enable effective integrated water resources management. High water provision in these areas presents a good opportunity for poverty vulnerability reduction. This has been proven through the work of Smith (2004) that examined agricultural intensification through the practice of irrigation as a strategy for poverty reduction. The author found four inter-related mechanisms through which irrigated agriculture can reduce poverty. They are (1) improvements in the levels and security of productivity, (2) employment and incomes for irrigating farm households and farm labor; (3) the linkage and multiplier effects of agricultural intensification for the wider economy; (4) provision of opportunities for diversification of rural livelihoods and multiple uses of irrigation supply.

The two selected areas are also rich in crop pollination; however, they are low in crop production. This means that harnessing crop pollination for increasing crop yield in the area will be a good step to reducing poverty vulnerability in the area especially in the health related/food security dimension. Crop pollination is very important as Eilers et al. (2011) found that crop plants that depend fully or partially on animal pollinators contain more than 90% of vitamin C, the whole quantity of Lycopene and almost the full quantity of the antioxidants β-cryptoxanthin and β-tocopherol, the majority of the lipid, vitamin A and related carotenoids, calcium and fluoride, and a large portion of folic acid. The ongoing pollinator decline may thus exacerbate current difficulties of providing a nutritionally adequate diet for the global human population. By harnessing crop pollination ecosystem services, there will be pesticide use regulation which will contribute to the ecosystem's overall health. This means that the people in this area will have the opportunity to consume food that is nutritious and healthy thereby reducing poverty vulnerability from the health/food security dimension.

To maximally utilize the ecosystem services in these areas for reducing poverty vulnerability, there will be the need to embrace the payment for ecosystem services (PES) tool. PES is a policy innovation to alleviate poverty by harnessing market forces to obtain more efficient environmental outcomes (Bulte et al., 2008). It is an incentive-based mechanism by which ecosystem services can be conserved sustainably through direct or indirect payment to the environmental service provider (rural landowners) for engaging in practices that produce external benefits to individuals or the entire society (Pagiola and Platais, 2007; Engel et al., 2008).

PES is used for pollution control, conservation of natural resources and ecosystems, and to generate environmental amenities that are public goods (Bulte et al., 2008).

Numerous studies such as Landell-Mills and Porras (2002), Scherr et al. (2007), Peskett et al. (2008), Pagiola et al. (2008), and Milder et al. (2010) have shown that PES benefits the poor. As they participate in the scheme, they gain additional income, which prompts the evolution of more profitable and robust land use patterns, better land tenure systems, consolidates social capital, and helps institutions become more effective (Milder et al., 2010).

Indeed, as markets and compensation schemes for ecosystem services are established, rural landowners stand to benefit from the increased value placed on the services that these lands provide (Milder et al., 2010).

However, despite the possibilities presented by PES, a study by Popoola et al. (2018) found that the payment for ecosystem services scheme needed to conserve and manage the ecosystems sustainably was not in place in the two local government areas (Ilaje and Ese Odo). Therefore, it is paramount for development agencies in Ondo State to engage in the development of institutional frameworks for the scheme to improve well-being/livelihoods and alleviate poverty in the two local government areas and other related ones.

Given that Ilaje and Ese-Odo have ecosystem services that could contribute to reducing poverty vulnerability in the area, it is paramount to explore the existing barriers preventing the realization of this potential. The core barrier affecting the people of Ilaje and Ese-Odo is oil exploration. According to Ashton-Jones and Douglas (1998), more germane to the survival of the indigenous people is the danger of oil exploitation obliterating their source of livelihood since they rely solely on their immediate environment for their survival. Hence, anything that alters their environment threatens their very existence. Oil exploitation has created life-threatening ecological hazards and deterioration of health and social fabrics of the inhabitants of the oil communities. The implication is that the oil industry has exploited the ecosystems for resources beyond the level of sustainability.

Prior to the discovery of oil in the area, the rural economy of the oil producing areas was simple and met the needs of the people. The area was blessed with a long coastline, extensive brackish, and mangrove swamps supporting a wide range of fish species, such as Tilapia, Threadfins, Moon fish, Bony Tongue fish, Tiger fish, Catfish, Sea Catfish, Snappers, Cray fish, Sea Turtle, Lobsters, Sardines, West African Croakers, Mullets, Mackerels, Razor fish, and many others. A sizable proportion of these fishes are derived from artisanal fisheries involving peasant fishermen. Fish farming forms the most dominant economic activity in the study area.

The fish in the rivers and streams also received a lethal dose of oil, which effectively expels or destroys the fish population. Fish can no longer be caught in the shallow waters and the creeks have been invaded by salt water. Tidal waves also help to spread the oil quickly through the mangrove, destroying forests and soil in their wake. Gas flaring has also become another major pollutant of the local oil producing communities. Oil spills and gas flaring can destroy whole fishing communities, reducing vital fishery resources, destroying fishing implements, and terrestrial animals (Okonta & Douglas, 2001). A key informant revealed that their tradition demanded that visitors should be welcomed with a cup of water and a fish dish. This tradition is no longer applicable because of declining fishery output.

Other economic activities that are also income generating include forest products – timbers and non-timber forest products. The people harvest, process, transport, and market timber products to neighboring communities. Timber is used for canoe and paddle carving. Non-timber forest products, such as bamboo and raffia palm, are used for fishing gears, baskets, local gin, and wine. However, oil industry activities have led to the depletion in the population of aquatic animals and have thwarted the growth of timber and non-timber forest products. Fishing, the lifeline of most people, has been made impracticable and unprofitable because of incessant oil spillage, which pollutes streams and rivers. Oil spills became a perennial threat to the inhabitants of these areas' livelihoods. Due to oil spills, the water provided by the ecosystem could not be of beneficial use, though provided in high quantity. This has contributed to increasing poverty vulnerability in the areas as it has affected their capacity to sustain themselves.

Findings by Babatunde (2010) indicated that the negative impact of oil exploitation has radically altered the economic lifeline of this once self-reliant oil producing areas, for the worse.

In recent times, the Ondo State government has taken steps to address these concerns by partnering with the federal government and multinational oil companies to implement environmental and social programs aimed at mitigating the negative impact of oil exploration. The government has also established laws and regulations to govern oil exploration activities in the state. However, the situation gets worse.

CHAPTER V

CONCLUSION

A. Conclusion and Recommendation

The study explored how several ecosystem services could potentially contribute to poverty vulnerability in Ondo State, Nigeria, including provisioning services such as crop production and water; regulating services such as carbon storage and crop pollination; supporting services such as habitat quality; and cultural services such as aesthetic quality and recreation & tourism. The mapping of these services provides a useful tool for decision-makers in incorporating ecosystem services into poverty vulnerability reduction plans.

The study suggests ecosystem services can play a significant role in reducing poverty vulnerability in Ondo State. However, it is important to note that the success of this strategy relies on several other factors beyond the availability of ecosystem services. These factors include governance, economic opportunities, and infrastructure.

For instance, even though Ilaje and Ese Odo Local Government Areas are rich in ecosystem services that could potentially help reduce their poverty vulnerability, they have been unable to maximize this potential due to oil spillage problems. The oil spillage issues in these areas have become a significant hindrance to their ability to exploit their ecosystem services fully. The resolution of these issues is dependent on state-scale governance interventions.

Therefore, it is essential to recognize that ecosystem services alone cannot adequately address poverty reduction in Ondo State. Instead, there is a need for a comprehensive approach that considers multiple factors, including ecosystem services, governance, economic opportunities, and infrastructure. By addressing these issues, the potential benefits of ecosystem services can be harnessed to reduce poverty vulnerability effectively.

The findings of this study also imply that ecosystem services cannot always operate at local scale to reduce poverty vulnerability but needs to function at state scale in the case of Nigeria. Taking carbon storage for example, an area might be rich in its ability to store carbon, but the benefit such as carbon trading can only be realized through the involvement of the state government. If governance at the state does not build the right partnership to explore opportunity, the ecosystem service will continually be there without any benefit to the local.

The study also zeroed in on the ecosystem services for poverty reduction in highly poverty vulnerable areas of Ondo State that are rich in multiple ecosystem services. Ilaje and Ese Odo Local Government Areas fall into this category and were examined in the context of why they remain highly vulnerable to poverty despite their richness in ecosystem services that could potentially diminish their vulnerability. It was found that oil spillage has continually posed a challenge to the maximization of ecosystem services in the area.

Overall, the study provides a comprehensive understanding of the ecosystem services and their potential contributions to poverty vulnerability reduction in Ondo State, Nigeria. The findings of this study have implications for sustainable development planning in Ondo State and other regions with similar ecosystems. It reveals opportunities that might not have been explored by the development agencies of the state and underscores the need for integrated approaches to natural resource management, considering the value of ecosystem services for sustainable development.

B. Study Limitations

Even though this study mapped ecosystem services and their contributions to reducing poverty vulnerability in Ondo State, Nigeria, there are some limitations that must be acknowledged.

Firstly, the study relied on remote sensing data, which has inherent limitations, such as cloud cover and limited spatial resolution, which may have affected the accuracy of the results. Additionally, the accuracy of the maps may have been affected by using different modeling tools (InVEST and ARIES) for mapping, which may have produced slightly different results due to differences in the algorithms used. One of the limitations of InVEST is that it requires a significant amount of data input, which can be time-consuming and expensive. The accuracy of the output is related to the quality of the input data, which means that errors or biases in the data can lead to incorrect or misleading results. Additionally, the models used in InVEST are based on simplified assumptions, and the output may not reflect the complexity of the real-world systems being modeled. InVEST may also not be appropriate for all contexts or scales. The models are designed to work best in areas with sufficient data and where ecosystem services are easily quantifiable. InVEST may not be suitable for areas with limited data or where cultural or social factors play a significant role in decision-making.

Secondly, the study used secondary data sources for some of the ecosystem services, which may have introduced errors and inaccuracies in the results. The study was also limited by the availability and quality of data, particularly for cultural services, which are often difficult to quantify and map.

Thirdly, the study focused only on Ondo State and did not consider the wider regional and national context, which may have limited the generalizability of the findings. Moreover, the study did not consider the impact of climate change and other external factors on the ecosystem services and their contributions to sustainable development goals.

Finally, the study did not consider the economic implications of ecosystem services, such as the costs and benefits of their management and conservation. Future research could address these limitations by using more accurate and detailed data, incorporating economic considerations, and considering broader regional and national contexts.

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