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RESEARCH ARTICLE

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Wetland Service Demand and Household Welfare: Evidence from the River Nyando Wetland Ecosystem, Kenya

Michael Oluoch Wayumba[1*]; Joel Sumukwo[2]; Ng'eno Elijah Kiplangat[3]

[1]*School of Environmental Sciences and Natural Resource Management, University of Eldoret, Eldoret, Kenya.*
[2]*Department of Environmental Planning, Sustainability and Geoinformatics, University of Eldoret, Kenya.*
[3]*Department of Economics, University of Eldoret, Eldoret, Kenya.*

Abstract

Despite their foundational importance to rural economies and sustainability, wetland ecosystems are increasingly compromised by institutional failures and land-use shifts. This study evaluated the empirical relationship between Wetland Service Demand and household economic welfare in Kenya's River Nyando ecosystem, filling a vital knowledge gap on resource dependence under weak regulatory environments. Framed around Indirect Utility Function (IUF) Theory, the study adopted an explanatory design and captured primary data from 377 riparian household heads using mixed methods, including questionnaires, interviews, and Focus Group Discussions (FGDs). The sampling techniques used included multistage sampling, purposive sampling, stratified sampling, and systematic random sampling. The semi-log (log-linear) framework model was used to evaluate the demand-side determinants of wetland ecosystem service utilization and their subsequent impact on household welfare. Semi-logarithmic regression analysis results show that household credit access significantly boosts economic well-being ($\beta = 0.143, p < 0.01$), expanding household welfare by 15.4% by mitigating liquidity constraints. Social capital and local governance frameworks also play vital roles; institutional trust ($\beta = 0.121, p < 0.01$) and social trust ($\beta = 0.118, p < 0.01$) enhance welfare metrics by 12.9% and 12.5%, respectively, by fostering sustainable co-management rules and informal community safety nets. Furthermore, market access heavily influences economic outcomes ($\beta = 0.164, p < 0.01$), generating a 17.8% increase in welfare due to minimized transactional costs and reduced resource use. Conversely, access to extension services shows an inverse relationship ($\beta = -0.087, p < 0.05$), resulting in an 8.3% decline in household welfare indicators. The study concludes that the River Nyando Wetland serves as a crucial economic safety net for resource-poor households. The strong negative coefficients attached to education, off-farm work, and private land sizes confirm that intensive wetland extraction is fundamentally driven by poverty and structural resource deprivation. The study recommends that a profound institutional transformation is required within the regional environmental governance apparatus to replace counterproductive administrative structures.

Keywords: Household Welfare; Overutilization; Semi-Log Framework Model; Wetland Ecosystem; Wetland Service Demand.

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INTRODUCTION

For many rural households, especially in low-income settings, wetlands function as safety nets by supplying food, income, and other services during lean seasons or in the face of shocks (Baffoe et al., 2021). This is because there is a recognized strong association between wetland ecosystem services and the livelihoods of communities (Baffoe et al., 2021). The Ramsar Convention on Wetlands of 1971, the Rio-de-Janeiro Conference, the Kyoto Protocol of 1995, and the Copenhagen Climate Meeting of 2009 were outcomes of the acceptance that global and regional climate changes are a threat to the land resources on which human survival thrives. They universalized the importance and scope to embrace all aspects of wetland conservation and "wise use" of the more than 1800 wetlands designated as internationally important. Yet in recent decades, land use and cover change, poorly managed drainage projects, increasing population pressure, intensification of agriculture, increased settlement density, infrastructural development, invasive species, pollution, and climate variability have continued to alter hydrological regimes and reduce wetland extent and functionality. The alteration has continued without conservation being considered, yet the benefits of wetland conservation are often greater than the benefits associated with their alteration (Miller, 2018). These threats to wetland ecosystem services have resulted in the loss of direct livelihood goods, reduced water quantity and quality, increased exposure to hazards, a decline in adaptive capacity, market and institutional impacts, and gendered and intergenerational effects.

However, studies by Adunde et al. (2023), Barasa et al. (2021), and Muendoh and Sakwa (2024) link wetland conversion to reduced flood regulation and water quality issues, with ripple effects on agriculture and public health in East African countries. Despite this growing body of evidence, there remains a significant gap in understanding how household-level demand for wetland ecosystem services specifically translates into economic welfare outcomes, particularly in contexts characterized by weak institutional frameworks and ambiguous property rights regimes. The River Nyando Wetland ecosystem presents a unique empirical setting to investigate this relationship because it exemplifies the complex interplay between ecosystem service provision, human use, and socioeconomic outcomes amid ongoing environmental degradation and institutional failures.

River Nyando wetlands, located in Kisumu County and the larger Nyando River basin in western Kenya, are an illustrative case of the complex interplay between ecosystem service provision, human use, and socioeconomic outcomes, including land use and cover changes. The wetlands along the River Nyando historically supported diverse livelihoods, smallholder agriculture, artisanal fishing, harvesting of papyrus and reeds, and livestock grazing while providing flood attenuation, water purification, and habitat for biodiversity (Maithya et al., 2020; Odaro et al., 2023). Despite the ecological, environmental, and socio-economic importance of these wetlands, they face threats from overexploitation, degradation, agricultural encroachment, and climate variability, which undermine both the ecosystem and the livelihoods that depend on them (Barbier, 2011). This puts wetlands under intense pressure from different causes, including rising population and high population densities around wetland zones, urban expansion, food security and nutrition status, high rate of rural unemployment, low household income and expenditure savings, high environmental and economic shocks, consumption patterns and poverty traps, urbanisation, drainage, pollution, invasive species, and climate change (Barbier, 2011). The resulting degradation threatens not only biodiversity but the proper functional capacity of wetlands, making them unable to deliver highly demanded services to different households or the larger community (Mohammed et al., 2022).

Consequently, from the perspective of a demand-side analytical framework, ecosystem service use is determined by household socio-economic characteristics, for example, different categories of income, education, household size, land ownership, wetland attributes, and institutional factors, such as benefit, attitude, knowledge, distance to wetland, and awareness of environmental benefits (Freeman et al., 2014; Millennium Ecosystem Assessment, 2005). These determinants shape household demand functions, willingness to pay (WTP) for conservation, and willingness to accept (WTA) compensation for loss of services (Hanley & Barbier, 2009). Therefore, understanding wetland ecosystem service demand requires integrating economic valuation and behavioral analysis, recognizing that households make rational choices based on perceived utility and opportunity costs (Kahneman & Tversky, 2000).

In the context of the River Nyando Basin, wetland ecosystem service demand forms a fundamental and significant livelihood strategic reference for local households and the larger communities of Kisumu County (Oduor et al., 2020; Osumba et al., 2010). The degree of dependence on these services affects income generation, food security, and resilience to environmental shocks (Rongoei et al., 2023; Swallow et al., 2009).

This study contributes to advancing existing knowledge by empirically examining the pathways through which household demand for wetland ecosystem services influences economic welfare. Unlike previous studies that have primarily focused on aggregate ecosystem service valuation or conservation outcomes, this research provides micro-level econometric evidence on the demand-side determinants of ecosystem utilization and their welfare effects. Furthermore, by situating the analysis within the River Nyando ecosystem—a site characterized by acute resource pressure, institutional fragmentation, and high poverty rates, the study offers critical insights into the poverty-environment that can inform more effective and equitable wetland governance in similar contexts across sub-Saharan Africa.

THEORETICAL FRAMEWORK

The Indirect Utility Function Model

The Indirect Utility Function (IUF) model is a foundational mathematical tool in neoclassical welfare economics. It bridges the gap between abstract human satisfaction and observable market data. This is the most common model used in the Nyando study. Following standard environmental valuation theory, the model assumes that an individual's maximum achievable satisfaction (utility) is indirectly constrained by market prices (P), household income or budget (Y), and the prevailing quality of the surrounding environment (Q), as shown in Equation 1:

$$V = v(P, Q, Y) \qquad (1)$$

Originally, the IUF was designed strictly for market goods, omitting Q. It was adapted for environmental and resource economics through the pioneering work of economists like Bergson (1938) and Karl-Göran Mäler (1974) and was later popularized in environmental cost-benefit analysis by Freeman, Herriges, and Kling. The adoption happened because environmental assets like the Nyando wetland are non-market goods; they do not have a

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direct price tag (P_q)). To value them, economists had to treat Q as a "public good" or an exogenous parameter that is fixed outside the consumer's control. Because the consumer cannot buy more or less of Q in a store, the level of Q shifts their entire welfare plane. This adaptation allowed economists to mathematically link changes in nature directly to changes in human wealth. A person enjoys a level of welfare (V_0) given current prices, current income, and a healthy wetland (Q_0), as shown in Equation 2.

$$V_0 = v(P, Q_0, Y) \quad (2)$$

If the Nyando wetland becomes polluted, the environmental quality drops from Q_0 to Q_1. Because Q directly affects well-being, utility drops to V_1as shown in Equation 3.

$$V_0 = v(P, Q_1, Y), \text{ where } V_1 < V_0 \quad (3)$$

Because utility (V) cannot be measured in dollars, the IUF model introduces Compensating Variation (CV) to turn changes in welfare into a monetary figure. CV is the amount of money that must be given to (or taken from) a person to precisely offset a change in their environment, leaving them exactly as well-off as they were before the change. To calculate how much the Nyando wetland degradation costs an individual, we look for the exact amount of additional income (CV) needed to bring utility back up to the original level (V_0), despite the lower environmental quality (Q_1), as shown in Equation 4.

$$v(P, Q_0, Y) = v(P, Q_1, Y + CV) \quad (4)$$

In this context, CV represents the individual's minimum Willingness to Accept (WTA) compensation for the destruction of the wetland. If the study evaluates an improvement in the wetland, CV would represent their maximum Willingness to Pay (WTP) to secure that improvement. By analyzing how respondents trade off income (Y) for changes in the wetland's health (Q), the study maps out the empirical parameters of Equation 4. This allows stating exactly how many Kenyan Shillings were required to compensate the local community for a specific drop in ecosystem services.

The IUF framework informed the empirical design of this study in several ways. The selection of variables was guided by the theoretical parameters specified in the utility function, prices (P), household income (Y), and environmental quality (Q). Household welfare (the dependent variable) was operationalized as a composite measure capturing income, expenditure, and asset accumulation. Environmental quality (Q) was measured by the quality and accessibility of ecosystem services. The questionnaire was developed to capture detailed information on household socio-economic characteristics, resource use patterns, institutional interactions, and environmental quality. The econometric model specification (Equation 6) was derived from the Marshallian demand function, with the dependent variable (wetland service demand) serving as the empirical counterpart to the theoretical demand for environmental quality. The welfare implications of changes in ecosystem service demand were interpreted through the use of compensating variation, where the regression coefficients represent welfare effects of changes in explanatory variables.

RESEARCH METHODOLOGY

Research Design

The present study adopted an explanatory research design, specifically utilizing a cross-sectional descriptive survey to examine the influence of Wetland Service Demand (Demand-Side Determinants) on Household Welfare (or Economic Well-being) in the River Nyando Wetland ecosystem. An explanatory design was appropriate for this type of study because it successfully combines quantitative data collection with qualitative insights, allowing the researcher to generate both robust statistical findings and deep contextual explanations (Creswell & Creswell, 2018). For the empirical analysis, the quantitative component applies econometric estimations and demand-side valuation models to examine how the demand for specific wetland ecosystem services impacts key household welfare outcomes.

Study Area

The study was conducted within the River Nyando wetland ecosystem, which is a deltaic complex situated across the Nyando and Nyakach sub-counties within Kisumu County, Kenya, as shown in Figure 1. Geographically, this wetland lies between latitudes 0°11' S and 0°19' S, and longitudes 34°47' E and 34°57' E. The ecosystem forms a substantial floodplain that encompasses the expansive Nyakach and Kano swamps, maintaining an average elevation of 1,134 meters above sea level (Government of Kenya, 2010; Raburu et al., 2012). It stands as one of the most prominent wetland networks within the Lake Victoria basin, and it is officially recognized as the second-largest wetland in Kenya after the Tana River Delta (Njuguna & Howard, 1992; Okotto-Okotto et al., 2016). Administratively, the overarching Nyando River basin spans 3,517 square kilometers, the Nyando sub-county encompasses 1,168 square kilometers, and the specific focus area of the Lower River Nyando Basin covers approximately 500 square kilometers (Bloemertz, 2014). The spatial scope of this research covers six specific locations and their corresponding sub-locations, which include Border II, Ayucha, Border I, and Wang'aya within the Awasi location. It also includes the sub-locations of Kakola/Ombaka, Kakola Ahero, and Tura within the Kakola location, alongside Magina, Ayweyo, and Nyakongo sub-locations within the Wawidhi location. The remaining study areas consist of West Kabodho sub-location within the Kabodho West location, North Kabodho sub-location within the Central Nyakach location, and both Jimo East and Awach/Achego sub-locations within the North East Nyakach location (County Government of Kisumu, 2018; KNBS, 2015). Topographically, these study sites represent two distinct bands where five of the locations lie entirely within the low-lying, flood-prone plains of the Lower Nyando Basin, while the Nyakach/Jimo East zone is situated on a higher terrain that is hydrologically shielded from seasonal flooding regimes (Bloemertz, 2014; County Government of Kisumu, 2018).

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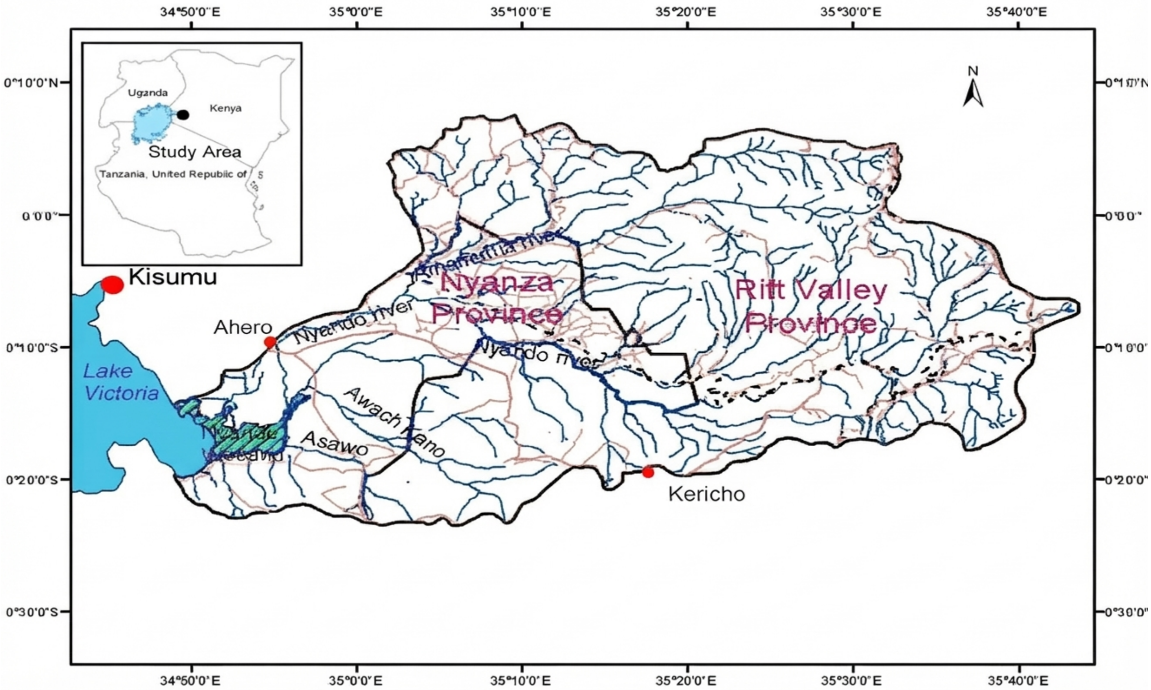

Figure 1: Location Map of Nyando River Basin
Source: Adapted from Community-Based Approach to the Management of Nyando Wetland, Lake Victoria Basin, Kenya (Raburu et al., 2012).

Catchment Hydrology and Ecological Significance

The primary hydrological driver of this wetland is the River Nyando, which originates from the Mau Escarpment (Opere & Okello, 2011). The river has an expansive catchment area of 3,600 square kilometers and discharges into the Winam Gulf of Lake Victoria at an average rate of 15 cubic meters per second, functioning as the leading contributor of sediment loads and phosphorus influxes into the lake (Opere & Okello, 2011). The wetland landscape transitions smoothly from upland agriculture and riverine forests into lowland plains, permanent marshes, papyrus swamps, and seasonally inundated grasslands (Bloemertz, 2014; Raburu et al., 2012). These eco-zones are governed by bimodal rainfall patterns, upstream land-use pressures, and catchment-level hydrology (Raburu et al., 2012). Crucial ecological services include regulating microclimates and filtering pollution, while the habitat sustains high native biodiversity, including the endangered Sitatunga antelope (*Tragelaphus spekii*), the African civet (*Civettictis civetta*), and foundational flora such as the papyrus reed (*Cyperus papyrus*) (Gichuki, 2001; Obiero et al., 2021). However, historical fluctuations in Lake Victoria's water levels, combined with anthropogenic climate shocks, have severely disrupted local water availability, depressed net fish catches, exacerbated water-borne diseases, and sparked intense resource-access conflicts (UNEP, 2006).

Socio-Economic Profile and Livelihood Strategies

The riparian communities around the Nyando wetland employ diversified livelihood strategies that integrate small-scale subsistence agriculture, pastoralism, artisanal fishing, and open-access resource harvesting (Oduor et al., 2016). Recessional crop farming utilizes fertile alluvial soils left during dry-season water recessions to grow staple food commodities. Livestock keeping is dominated by indigenous Zebu cattle, goats, and sheep, which rely on the wetland for dry-season grazing and water (Ministry of Planning, 2005). Artisanal fishing

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serves as a critical seasonal economic buffer, with 33% to 65% of households engaging in the sector during heavy rain cycles to stabilize food and income lines (Ministry of Planning, 2005; Raburu et al., 2012). Furthermore, direct extraction of non-timber forest products includes harvesting papyrus and reeds for commercial mat-making and basketry, alongside commercial sand harvesting and brick-making from wetland clays (Oduor et al., 2016).

Study Target Population

The target population for this inquiry comprised all the riparian households that were residing within the immediate and contiguous zones of the Nyando and Lower Nyakach wetlands. These households are defined as units whose micro-economies are directly or indirectly reliant on the provisioning, regulating, and cultural services of the ecosystem. Key livelihood actions, such as small-scale irrigation, artisanal fishing, papyrus or reed processing, and domestic energy collection, are structurally organized at the household level (KNBS, 2019). Consequently, the primary unit of inquiry and statistical analysis was the household head. The accessible sample framework spanned eight locations, including North Kabotho, West Kabotho, Nyakach/Jimo East, Awach/Achego, Kakola-Ombaka, Wawidhi, and Awasi, comprising a total accessible population of 80,540 individuals distributed across 19,386 distinct households (KNBS, 2002).

Sample Selection

To ensure statistical representation and adequate power for subsequent econometric modeling, the optimal household sample size was mathematically derived from the total accessible household population of 19,386 households (KNBS, 2019) using the formula proposed by Krejcie and Morgan (1970). The estimation assumed a 95% confidence level, a margin of error of 0.05, and a population proportion set at 0.5 to maximize the required sample variance. The model is specified as:

$$n = \frac{X^2NP(1\text{-}P)}{d^2(N\text{-}1)+X^2P(1\text{-}P)} \quad \text{..} \quad (5)$$

Within this mathematical specification, n represents the required sample size for the study, and X^2 represents the chi-square table value for one degree of freedom at the 95% confidence level, which is equivalent to 3.841. The parameter N represents the total target household population of 19,386 households, while P is the estimated population proportion assumed to possess the characteristic under study, which is set at 0.5. Finally, the parameter *d* represents the acceptable margin of error or degree of precision expressed as a decimal value of 0.05. To find the sample size, the variable values are then fitted into Equation 5 as shown below.

$$n = \frac{3.841\text{x } 19{,}386 \text{ x } 0.5\ (1\text{-}0.5)}{0.05^2(19{,}386\ \text{-}1)+3.841 \text{ x } 0.5(1\text{-}0.5)} = \frac{18{,}615.4065}{49.42275} = 377$$

Therefore, the sample size for this study was 377 respondents.

Sampling Procedures and Techniques

The study employed a multistage sampling technique to systematically select representative riparian households and qualitative informants within the River Nyando Wetland Ecosystem. This approach was executed in three sequential stages to ensure geographic and statistical representation.

In the initial stage, purposive sampling was used to select Nyando and Nyakach sub-counties, specifically focusing on the Nyando and Lower Nyakach divisions. These administrative areas were targeted due to their ecological proximity to the wetland and the high levels of community livelihood dependence on the wetland ecosystem.

In the second stage, a stratified sampling technique was employed to categorize the study area into seven locations and fifteen sub-locations surrounding the wetland ecosystem. This stratification ensured that diverse micro-ecological and socio-economic zones were represented. The first stratum comprised the Awasi location, encompassing the sub-locations of Border II, Ayucha, Border I, and Wang'aya. The subsequent strata included Kakola location (encompassing Kakola/Ombaka, Kakola Ahero, and Tura sub-locations), Wawidhi location (encompassing Magina, Ayweyo, and Nyakongo sub-locations), and Ahero location (encompassing Ahero sub-location). The remaining strata consisted of the Kabodho West location (encompassing West Kabodho sub-location), Central Nyakach location (encompassing North Kabodho sub-location), and North East Nyakach location (encompassing Jimo East and Awach/Achego sub-locations).

In the final stage, a systematic random sampling approach was used to identify the 377 riparian households for the survey. To ensure an unbiased selection process, every fifth household was sampled from the serially numbered lists provided by local area chiefs who maintain the most current administrative records. These lists were randomized to give every eligible household head an equal chance of inclusion. The proportional allocation of households across strata was based on the population distribution within each location, ensuring that locations with larger populations contributed proportionally more households to the sample.

To complement the household survey, purposive sampling was used to select key informants for semi-structured interviews and participants for focus group discussions. This nonprobability, targeted approach intentionally selects individuals with specialized institutional memory, regulatory oversight, or knowledge of the wetland (Creswell & Creswell, 2018; Patton, 2015). This method is highly effective when researchers must target individuals based on their professional or specialized expertise (Oso & Onen, 2009). For this study, key informants were defined as actors with deep, reliable knowledge relevant to wetland governance and economic use. They included local community elders, administrative officers such as chiefs and assistant chiefs, and institutional heads of various non-governmental organizations and government departments operating at both the county and national governments.

Focus Group Discussions (FGDs) were organized with participants selected through community leader nominations, to ensure representation across gender, age cohorts, and livelihood activities. Each FGD comprised between 8-12 participants, and discussions continued until thematic saturation was reached, which was achieved after the sixth FGDs.

Data Sources and Survey Instrument

The study was based on both primary and secondary data to ensure a comprehensive assessment of the empirical relationship between Wetland Service Demand and household economic welfare in Kenya's River Nyando ecosystem.

Primary data for this study were collected through field surveys, personal interviews, and direct observations from household heads using a pre-tested structured questionnaire, and

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from key informants using key informant interview guides and focus group discussion schedules. The primary household survey instrument explicitly captured the utilization patterns of diverse ecosystem services representing the environmental parameters being valued. These included provisioning services (such as fish abundance, clean water supply, and harvesting levels of papyrus reeds, sand, clay, and grass for crafts or construction), regulating services (comprising flood control, water purification, and biodiversity habitat maintenance), as well as supporting and cultural services. The questionnaire was administered face-to-face to 377 sampled household heads across the study area. To optimize the data collection process, two research assistants were recruited and trained thoroughly on instrument administration, behavioral protocols, and data recording techniques to maximize the internal reliability of the field information. The field survey was executed over eight weeks, conducted entirely in the local language by the research team, and subsequently translated into English for data entry and econometric analysis.

To complement the household datasets with institutional and expert insights, qualitative field tracking was carried out through Key Informant Interviews. Key Informant Interviews were held with 22 purposively selected local leaders, including wetland managers, environmental officers, and administrative authorities. These informants were chosen based on their institutional oversight, daily interactions with wetland usage, and direct exposure to the regional socioeconomic shocks of environmental degradation and ecosystem loss. The interviews targeted cross-cutting policy frameworks, landscape changes, and regulatory management dynamics using a semi-structured interview schedule. Concurrently, Focus Group Discussions were organized to capture community-level qualitative consensus regarding resource use conflicts and ecological challenges. These focus groups ranged in size from 8 to 12 participants and were moderated by the primary researcher alongside a team of enumerators. To anchor the qualitative narratives in actual production dynamics, each group was systematically structured to include at least one active member of a local cooperative directly involved in the commercial extraction of River Nyando wetland resources.

Secondary data were compiled from published and unpublished sources to complement the primary information. This study integrated secondary data from a variety of institutional and geographical repositories to contextualize the relationship between resource demand and household welfare. Socio-economic baselines and rural welfare thresholds were extracted from the Kenya National Bureau of Statistics (KNBS) publications, including the Kenya Integrated Household Budget Surveys (KIHBS), as well as the County Integrated Development Plans (CIDPs) for Kisumu County. To calibrate the microeconomic price parameters within the resource demand framework, official market records and commodity pricing indicators for agricultural and harvested wetland products (such as rice, fish, and papyrus mats) were sourced from local sub-county offices and the Ministry of Agriculture, Livestock, and Fisheries. Furthermore, hydrological and flooding frequency metrics were obtained from records maintained by the Water Resources Authority (WRA) of Kenya. Finally, policy-level context concerning weak institutional governance was evaluated using regulatory assessments, environmental guidelines, and resource management reports published by the National Environment Management Authority (NEMA) and the Lake Victoria Basin Commission (LVBC).

Ethical Considerations

Ethical approval for this study was obtained from the University of Eldoret, where two senior faculty experts from the University evaluated the questionnaire structure, relevance, and

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clarity, and from the Kisumu County Government administrative offices. Informed consent was obtained from all participants prior to data collection. The study objectives, procedures, potential risks, and benefits were explained to participants in the local language, and written consent was obtained using a consent form approved by the university. Confidentiality was maintained by using unique codes instead of respondent's names, storing data in password-protected files, and restricting access to the research team. All data were made to be anonymous during analysis and reporting to ensure that participants could not be identified. Furthermore, community leaders and local authorities were briefed on the study objectives prior to fieldwork to ensure community acceptance, cooperation and ownership.

Data Processing, Analysis, and Econometric Model Specification

Upon collection of the field instruments, raw primary and secondary data underwent an intensive preliminary screening process. The completed questionnaires, key informant interview guides, and focus group schedules were systematically sorted, coded, classified, tabulated, and cleaned to transform the qualitative and quantitative field responses into a machine-readable data file (Kothari, 2004). During this processing phase, incomplete data sources or compromised questionnaires were discarded to protect data integrity. The cleaned and coded dataset was subsequently keyed into statistical packages for computing. Data analysis was conducted using both descriptive statistics (frequencies, percentages, means, and standard deviations) and inferential econometric statistics, using SPSS Version 25 and Microsoft Excel.

To examine the influence of Wetland Service Demand (Demand-Side Determinants) on Household Welfare (or Economic Well-being) in the River Nyando Wetland ecosystem, a structural demand model was specified to identify the drivers of household wetland service demand. This approach reveals both the implicit demand and the marginal utility derived from wetland exploitation (Freeman et al., 2014). Grounded in standard microeconomic consumer theory, Equation 6 specifies a Marshallian demand function modeled via a semi-log empirical framework to examine a household's utilization or contingent valuation of wetland ecosystem services (Varian, 2010; Wooldridge, 2010).

$$Q_{di} = \beta_0 + \beta_1 P_{wi} + \beta_2 P_{sub} + \beta_3 I_i + \beta_4 Z_i + \beta_5 E_i + \ + \ \beta_6 IN_i + \varepsilon_i \ldots\ldots \quad (6)$$

Where:

Q_{di} = The quantity or intensity of demand for a specific wetland service by household i and is log-transformed, P_{wi} = the implicit price or extraction cost (e.g., travel distance or collection time) of the wetland service, I_i = household income or physical asset endowment, Z_i = a vector of socio-economic shifting factors (household size, gender, education level, proximity to the wetland), E_i = A vector of environmental factors influencing the household (e.g., proximity to the wetland, soil type, and topography), IN_i = a vector of institutional factors influencing household decisions (e.g., access to extension services, land tenure security, or group membership), E_i = ecosystem service use characteristics (intensity of use, diversified dependence, and single dependence), and ε_i = the stochastic error term capturing unobserved preference shocks. The normally distributed stochastic error term, assumed to be $\varepsilon_i \sim N(0, \sigma^2)$. Under this framework, a rational household maximizes its utility subject to a budget constraint. This means that its demand for environmental services is driven by price signals, budget constraints, and structural shifts in taste or awareness.

RESULTS AND DISCUSSIONS

The estimation results of the semi-log (log-linear) framework model (Table 1) suggest that the collective explanatory variables, the demand-side determinants (institutional factors, socioeconomic/demographic factors, ecosystem service use characteristics, and environmental/governance factors), exercise a profound systemic influence on household welfare in the River Nyando Wetland ecosystem.

Results under institutional factors reveal that household credit access ($\beta = 0.143$, $p < 0.01$) has a positive and statistically significant relationship with household welfare. Econometrically, this implies that households with access to credit experience an approximate 15.4% (0.143, i.e., $e^{0.143} - 1$) increase in welfare compared to those without because the logarithmic scale is non-linear and therefore, the exact change is actually slightly higher than 14.3%. This shows that providing credit access to a household shifts their welfare metric upward by approximately 15.4%, holding all other institutional and socio-demographic, ecosystem service use, and environmental/governance factors constant. Financial inclusion allows extractors to purchase more efficient harvesting tools, process raw materials, or cushion against environmental shocks. This finding aligns with wider literature across Sub-Saharan Africa, notably by Moyo et al. (2022), who argued that relaxing liquidity constraints transforms wetland use from a desperate coping strategy into an optimized economic venture.

On the other hand, social trust ($\beta = 0.118$, $p < 0.01$) displays a statistically significant positive effect, raising household welfare by roughly 12.5%. Social capital creates informal safety nets, enables labor-sharing arrangements during harvesting seasons, and lowers transaction costs within community-based marketing groups. This result supports the social capital frameworks detailed by Swallow et al. (2007) in the Nyando Basin, which demonstrated that strong community-level cohesion prevents cutthroat competition over open-access resources, preserving economic returns for riparian dwellers.

Institutional trust ($\beta = 0.121$, $p < 0.01$) similarly exerts a positive and significant influence on economic well-being. Households that exhibit high trust in local resource management committees are roughly 12.9% better off. Trust in institutions encourages community members to buy into sustainable harvesting schedules and co-management rules, mitigating local resource degradation. This finding closely mirrors the institutional dynamics observed by Wu et al. (2024) in Poyang Lake, where administrative trust lowered conflict rates and preserved consistent economic yields for local fishers.

However, access to extension services ($\beta = -0.087$, $p < 0.05$) reveals an unexpected, statistically significant negative relationship with welfare. Riparian households interacting heavily with environmental extension agents see an 8.3% drop in welfare indicators. This indicates a deep-seated disconnect where extension officers enforce "command-and-control" restrictions rather than offering livelihood support. This finding is corroborated by Oduor et al. (2015) in the Lake Victoria Basin, who observed that regional extension advice heavily penalizes resource extraction without transferring viable, off-farm economic alternatives to affected populations.

Table 1: Log-Linear Results for Wetland Ecosystem Service Demand on Household Welfare

Exploratory Variable	**Unstandardized Coefficients (β)**	**% ΔWelfare = e^{β}- 1)*100)**	**Std. Error**	**Standardized Beta**	***t***	**Sig. (*p*)**
Constant	*0.912*	148.9%	*0.284*	—	*3.21*	*0.001**
Institutional Factors						
Household Credit Access	0.143	15.4%	0.041	0.158	3.49	0.001*
Social Trust	0.118	12.5%	0.039	0.132	3.03	0.003*
Institutional Trust	0.121	12.9%	0.044	0.116	2.75	0.006*
Access to Extension Services	−0.087	−8.3%	0.038	−0.098	−2.29	0.022**
Socioeconomic/Demographic Factors						
Household Head Age	0.052	5.3%	0.021	0.087	2.48	0.014**
Market Access	0.164	17.8%	0.047	0.172	3.49	0.001*
Household Income	0.219	24.5%	0.058	0.201	3.78	0.000*
Household Size	0.187	20.6%	0.045	0.193	4.16	0.000*
Education Level	−0.146	−13.6%	0.051	−0.138	−2.86	0.004*
Marital Status	0.061	6.3%	0.028	0.073	2.18	0.030**
Land Size/Ownership	−0.128	−12.0%	0.049	−0.121	−2.61	0.009*
Off-farm Activity Participation	−0.172	−15.8%	0.054	−0.159	−3.19	0.002*
Household Assets Owned	0.134	14.3%	0.046	0.129	2.91	0.004*
Distance to Wetlands	−0.263	−23.1%	0.059	−0.248	−4.46	0.000*
Ecosystem Service Use Characteristics						
Intensity of Use	0.312	36.6%	0.071	0.291	4.39	0.000*
Diversified Dependence	0.284	32.8%	0.065	0.267	4.37	0.000*
Single Dependence	−0.197	−17.9%	0.058	−0.183	−3.40	0.001*
Environmental/Governance Factors						
Reinforcement	−0.133	−12.5%	0.047	−0.129	−2.83	0.005***

of Restrictions						
Conservation Awareness	−0.119	−11.2%	0.043	−0.118	−2.77	0.006*
Knowledge of Wetlands	0.101	10.6%	0.040	0.107	2.53	0.012**
Perception of Wetlands as Wastelands	−0.147	−13.7%	0.046	−0.135	−3.20	0.001*
Model Diagnostics: $R = 0.781$ $R^2 = 0.610$ Adjusted $R^2 = 0.596$ F-statistic = 41.87 Notes: *p < 0.000, **p< 0.05 and ***p< 0.10 [a.] Dependent Variable: Household Welfare (or Economic Well-being)						

Source: Author's Computation from Survey Data (2019)

Results for socioeconomic/demographic factors show that the household head's age ($\beta = 0.052$, $p < 0.05$) is positively correlated with welfare, showing that a one-year increase in the age of the household head increases economic well-being by approximately 5.3%. Older household heads accumulate substantial experiential capital over time, allowing them to better predict seasonal flood patterns and locate premier harvesting zones. This trajectory mirrors the research of Onuonga (2011) in the Sondu-Miriu system, where ancestral ecological knowledge was isolated as a core determinant of financial success among traditional wetland resource extractors.

Market Access ($\beta = 0.164$, $p < 0.01$) shows a significant positive influence on economic well-being, translating to a 17.8% expansion in welfare metrics. Proximity or reliable transportation links to local trading centers minimize perishability losses and lower transport costs for heavy raw materials like papyrus or harvested sand. This strongly confirms spatial economic assertions made by Ikiara et al. (2010) in the Yala Wetland, which highlighted that market integration is crucial for converting harvested wetland biomass into tangible financial capital.

Household Income ($\beta = 0.219$, $p < 0.01$) maintains a highly significant positive coefficient. A unit increase in baseline income improves household welfare by 24.5%. Wealthier households possess the working capital to hire external labor or add value to wetland goods (e.g., processing raw papyrus into high-grade mats) rather than being forced to sell crude resources immediately at depressed prices. This finding aligns with the baseline economic assessments published in the AquaDocs repository (Government of Kenya, 2006), which highlighted that a lack of initial capital traps the poorest riparian segments in low-value primary extraction.

Household Size ($\beta = 0.187$, $p < 0.01$) shows a positive and highly significant relationship with welfare. Each additional household member expands economic well-being by roughly 20.6%. Because primary wetland harvesting, such as clay excavation, sand scooping, and reed cutting, is highly labor-intensive, larger households command an abundance of domestic

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labor. This allows them to exploit multiple provisional services simultaneously, supporting the findings of Okotto-Okotto et al. (2018) that demographic volume often acts as a critical factor in determining total wetland income.

Education Level ($\beta = -0.146$, $p < 0.01$) displays a significant negative coefficient, indicating that an advancement in formal education decreases wetland-derived household welfare by 13.6%. This does not suggest that education degrades overall intelligence; rather, it highlights a structural exit strategy. Highly educated individuals leverage their qualifications to secure formal, off-farm employment, voluntarily pulling away from manual wetland extraction. This directly matches trends noted by Zhang and Pang (2024), where rising literacy levels in rural ecologies consistently lowered dependence on primary ecosystem extraction.

Marital Status ($\beta = 0.061$, $p < 0.05$) is positively linked to household welfare. Married household heads experience a 6.3% increase in economic well-being over single or divorced peers. Marriage typically increases the domestic labor pool and enables spousal diversification strategies, where one partner harvests raw wetland materials while the other focuses on retail distribution or off-farm trades. This pattern was similarly identified by Obwoyere et al. (2018) across Western Kenyan river basins as a primary factor in stabilizing agrarian household income.

Land Size/Ownership ($\beta = -0.128$, $p < 0.01$) yields a statistically significant negative relationship. Expanding a household's private landholding size is associated with a 12.0% decline in wetland welfare metrics. When a household owns ample terrestrial acreage, its labor and capital resources shift toward land-based cash cropping or livestock husbandry, bypassing the fragile wetland banks. This outcome validates land substitution theories explored by Swallow et al. (2007), who noted that wetland exploitation in Nyando is frequently born out of terrestrial landlessness or acute farm fragmentation.

Off-farm Activity Participation ($\beta = -0.172$, $p < 0.01$) is negatively associated with household welfare metrics. Engaging in formal or informal off-farm activities cuts the wetland welfare indicator by 15.8%. Off-farm employment presents a high opportunity cost for manual labor, effectively absorbing the household's working time. This mirrors the "livelihood diversification" dynamics documented by Wu et al. (2024), where expanding off-farm labor markets dramatically lowered ecosystem degradation by redirecting human effort away from sensitive riparian buffer lines.

Household Assets Owned ($\beta = 0.134$, $p < 0.01$) positively influences the dependent variable, signifying a 14.3% boost in welfare for each asset unit increase. Households with strong asset structures (machinery, transport vehicles, or secure storage facilities) avoid the common pitfall of panic-selling during seasonal flooding events. This directly corresponds to asset-vulnerability theories formulated by Onyango et al. (2005), which showed that physical asset wealth insulates River Nyando communities from climate-induced economic shocks.

Distance to Wetlands ($\beta = -0.263$, $p < 0.01$) exhibits a sharp, highly significant negative coefficient. For every unit increase in distance away from the wetland periphery, household welfare drops by approximately 23.1%. This confirms a classic economic distance decay effect; physical distance introduces severe transport frictions that erode profit margins for distant extractors. This result strongly validates spatial rent frameworks applied to East African wetlands by Ikiara et al. (2010), proving that economic demand for ecosystem services is intensely localized around the immediate geography of the water body.

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Results on ecosystem service use characteristics revealed that intensity of use ($\beta = 0.312$, $p < 0.01$) is the single strongest positive predictor within the econometric model results, indicating that an increase in extraction intensity expands household welfare by 36.6%. Extracting massive volumes of fish, papyrus, or domestic water generates substantial immediate financial liquidity. However, this finding presents a sustainability warning; while intensive harvesting elevates welfare in the short term, it risks precipitating an ecological collapse, a tension extensively highlighted by Okotto-Okotto et al. (2018) across the wider Lake Victoria gulf.

Diversified Dependence ($\beta = 0.284$, $p < 0.01$) reflects a statistically significant positive correlation with welfare, driving a 32.8% optimization in economic well-being. Spreading extractive activities across multiple resource channels, such as interleaving seasonal sand harvesting with papyrus weaving and recession agriculture, shields the household from single-stream shocks. This confirms livelihood resilience arguments advanced by Moyo et al. (2022), who discovered that diversified wetland users maintain far higher economic security than specialized counterparts.

Single Dependence ($\beta = -0.197$, $p < 0.01$) exhibits a substantial, highly significant negative coefficient. Households relying exclusively on one single wetland service face a 17.9% contraction in welfare indicators. This extreme specialization exposes the family to seasonal market price crashes, depletion events, or regulatory crackdowns. This "specialization trap" aligns with findings from the Poyang Lake studies by Zhang and Pang (2024), which showed that single-source extraction dependency inevitably locks poor rural households into persistent cycles of economic stagnation.

Results for environmental and governance factors reveal that reinforcement of restrictions ($\beta = -0.133$, $p < 0.01$) displays a highly significant negative effect, indicating that stringent command-and-control regulatory crackdowns depress household welfare by 12.5%. When local enforcement agencies aggressively enforce seasonal bans or spatial exclusion zones, poor families are cut off from their primary safety valve. This dynamic represents a clear compliance burden, matching the contentions of Anyango (2021) that punitive, non-incentivized conservation measures in the Nyando Wetland often penalize vulnerable households.

Conservation awareness ($\beta = -0.119$, $p < 0.01$) similarly carries a significant negative coefficient, correlating with an 11.2% drop in economic welfare. This counterintuitive finding indicates a "knowledge-poverty paradox" where households that fully understand environmental regulations deliberately downscale their extractive activities to avoid legal sanctions or ecological destruction. This result mirrors findings by Moyo et al. (2022) in Southern African wetlands, where high environmental awareness without accompanying economic offsets resulted in direct livelihood sacrifices for local communities.

Knowledge of wetlands ($\beta = 0.101$, $p < 0.05$) operates in contrast to regulation awareness, revealing a positive and significant relationship that elevates welfare by 10.6%. This parameter captures eco-literacy regarding local ecological functions, such as understanding the reproductive cycles of local fish or optimal regeneration intervals for papyrus stalks. This matches the arguments of Obwoyere et al. (2018) that localized, sustainable harvesting knowledge allows households to maximize long-term yields without systematically depleting the baseline resource.

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Perception of Wetlands as Wastelands ($\beta = -0.147$, $p < 0.01$) exhibits a highly significant negative impact, eroding welfare indicators by roughly 13.7%. Households that view the surrounding wetland as an unproductive, diseased wasteland consistently fail to tap into its diverse provisioning streams. This cognitive barrier prevents families from exploiting viable livelihood options, confirming the cultural perception frameworks mapped out by Krhoda (2021) regarding the hidden economic values of Kenyan riparian zones.

The empirical findings generated by this semi-log model indicate that the River Nyando Wetland serves as a crucial economic safety net for resource-poor households. The strong negative coefficients attached to education, off-farm work, and private land sizes confirm that intensive wetland extraction is fundamentally driven by poverty and structural resource deprivation. Crucially, the persistent negative impact of conservation restrictions, extension friction, and conservation awareness reveals a sharp conflict between institutional environmental frameworks and human welfare. To resolve this imbalance, policymakers must move away from top-down, punitive conservation models. These empirical results support the arguments of Krhoda (2021) and Anyango (2021) that for environmental policies to succeed in Kenya, they must be restructured as "pro-poor" initiatives. By introducing financial incentives, credit programs, and alternative livelihood projects alongside conservation demands, management bodies can ensure that community compliance is rewarded rather than economically penalized.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The study examined the influence of Wetland Service Demand (Demand-Side Determinants) on Household Welfare (or Economic Well-being) in the River Nyando Wetland ecosystem. Diagnostic performance indicates that formal household credit access expands welfare by 15.4% ($\beta = 0.143$). Reliable market access minimizes transport friction by 17.8% ($\beta = 0.164$). Local governance structures provide critical community safety nets. High institutional trust lifts household welfare by 12.9% ($\beta = 0.121$). Informal social trust networks generate an additional 12.5% improvement ($\beta = 0.118$). Conversely, administrative extension services enforce restrictive command-and-control regulations ($\beta = -0.087$), causing an 8.3% drop in welfare. Demographic expansions reveal similar microeconomic resource dependency dualities. Rising household sizes supply essential physical extraction labor ($\beta = 0.187$). However, consumption demands ultimately trigger long-term resource dilution. Accumulating alternative asset portfolios facilitates structural exit strategies. Higher education levels cut wetland-derived welfare by 13.6% ($\beta = -0.146$). Expanding private land sizes lowers extractive reliance by 12.0% ($\beta = -0.128$). Active off-farm activity participation reduces ecosystem dependency by 15.8% ($\beta = -0.172$), trending smallholders away from fragile riparian zones.

The broader contribution of these findings lies in demonstrating that wetland-dependent welfare is not simply a function of resource availability but is critically mediated by institutional frameworks, market access, and household assets. The study advances understanding of wetland-dependent household welfare by providing empirical evidence that poverty, rather than preference, drives intensive wetland extraction. Furthermore, the findings underscore the importance of differentiating between different types of institutional interventions, showing that trust-building and participatory governance mechanisms yield positive welfare outcomes, while top-down regulatory approaches generate negative outcomes.

Policy Recommendations

A profound institutional transformation is required within the regional environmental governance apparatus to replace unproductive administrative structures. Regulatory bodies should remove punitive, command-and-control extension frameworks that penalize ecosystem reliance without offering survival alternatives, as these current enforcement measures systematically reduce household welfare. Instead, extension services should be restructured around community-led co-management rules that build formal institutional trust and capitalize on existing informal social networks. Devolving resource monitoring to local management committees should enhance statutory compliance, lower enforcement costs, and preserve consistent economic yields. By fostering a collaborative regulatory environment, local authorities can successfully transform the wetland from a desperate coping buffer into an ecologically managed economic asset.

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Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of AI use

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