



(RESEARCH ARTICLE)



## Gas flaring and female farmers' productivity in Bayelsa state

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### Abstract

In the ecologically sensitive landscape of the Niger Delta, gas flaring represents a significant negative externality that destabilizes the microeconomic resilience of rural agrarian households. This study empirically examined the correlation between gas flaring intensity and the agricultural productivity of female farmers in Bayelsa State, Nigeria. While women constitute the majority of the agricultural labor force, they faced a disproportionate productivity tax due to flare-induced soil degradation and altered crop physiology. Utilizing a mixed-methods approach, the research combined spatial analysis with a quasi-experimental econometric design, comparing high-exposure zones (0–10 km from flare sites) with low-exposure control groups across three Local Government Areas. Findings revealed a significant divergence between physical food availability and economic access, as atmospheric heat and acid rain systematically reduce the Total Factor Productivity of staple crops like cassava and vegetables. The study identified two critical mechanisms of economic erosion: Increased travel distances and reduced time for non-farm activities contribute to time poverty, further exacerbating their economic challenges. These factors exacerbated time poverty and reinforced a cycle of gendered vulnerability. The study concluded that high educational attainment among women is currently nullified by structural barriers and environmental stress, rendering existing gender-neutral policies ineffective. The research recommended the establishment of flare-free zones and the implementation of gender-responsive agricultural subsidies to stabilize the rural economy and align Nigeria's industrial objectives with UN Sustainable Development Goals 5 and 12.

**Keywords:** Gas Flaring; Female Productivity; Bayelsa State; Environmental Externalities; Time Poverty; Productivity Tax; Niger Delta; Sustainable Agriculture

### 1. Introduction

In the ecologically rich but industrialized landscape of Bayelsa State, the intersection of global energy extraction and local subsistence agriculture has transformed the environment from a vital productive asset into a regressive productivity tax borne primarily by rural women farmers (Ogoke, 2023; Ononogbo, 2024; Ayibakari & Ebisine, 2022). While the oil and gas sector remains the central pillar of Nigeria's macroeconomy, the persistent practice of gas flaring creates a profound negative externality that destabilizes microeconomic resilience at the household level (Edaba et al., 2022). Women farmers, who serve as the primary custodians of household food security, now operate within a progressively hostile climate where thermal heat and toxic emissions from flare sites significantly alter soil nutrient composition and crop physiology (Okeke & Udoh, 2023; Edaba et al., 2022; Osemene & Suwari, 2025). Women farmers, who constitute the majority of the agricultural labor force and play a crucial role in ensuring household food security, regard the environment as their most vital productive asset. This environmental degradation necessitates increased labor and capital inputs to offset declining yields, effectively eroding the economic agency of women (Baro & Boroh, 2024; Willy & Tobin, 2025).

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This study is motivated by the necessity to address the systemic gendered vulnerability present in the rural economy of Bayelsa State. Women frequently encounter structural constraints, such as restricted access to credit and land mobility, which hinder their ability to address the localized impacts of gas flares (David et al., 2023). Declines in agricultural productivity resulting from atmospheric pollution and acid rain lead to economic ripple effects, including decreased household income and increased food inflation in local markets (Edaba et al., 2022; Baro & Boroh, 2024). This article empirically examines the correlation between flaring intensity and the output of women farmers, aiming to provide a data-driven basis for policy interventions. Understanding this relationship is essential for aligning Nigeria's industrial objectives with the United Nations Sustainable Development Goals (SDGs) related to gender equality and sustainable agriculture (Bright et al., 2025).

The direct causal relationship between the environmental externalities associated with oil extraction and the economic performance of female-led agricultural units is a crucial issue. The primary concern is to ascertain the degree the closeness to and intensity of gas flaring activities reduce the total factor productivity of women farmers in Bayelsa State (Olaekhan et al., 2022). Existing literature indicates a general decline in agricultural viability within the Niger Delta. However, there is paucity state level data regarding the specific impacts of thermal gradients and blackened rain on the value-added per hectare for women (Nwankwo & George, 2023). This study aims to assess whether the gendered division of labor, characterized by women's predominant responsibility for sensitive food crops such as cassava, con and vegetables, renders their economic returns more vulnerable to flare-induced soil toxicity. (Ayibakari & Ebisine, 2022).

The environmental stress resulting from gas flaring necessitate a reallocation of household labor and capital that exacerbates the impoverishment of women farmers (Ewuienure & Ogwara, 2022; Willy & Tobin, 2025). Recent economic assessments indicate that as yields decline due to flare-related atmospheric heat, women frequently need to allocate additional hours for soil remediation or travel greater distances to locate viable land, consequently exacerbating their "time poverty" (Osemene, & Suwari, 2025; Bassey & Efiog, 2025). This article analyzed the trade-offs between mitigation costs and net farm income to determine if the existing environmental policies in Bayelsa State adequately consider the hidden costs incurred by women. Examining these particular variables is essential for assessing the necessity of flare-free zones or targeted agricultural subsidies to stabilize the rural economy (Edaba et al., 2023).

The methodology of this study is structured on a mixed-methods approach, which combines spatial analysis with a quasi-experimental econometric design to establish a robust technical foundation. The primary data is obtained via a cross-sectional survey conducted among female smallholders in 3 Local Government Areas of Bayelsa State, categorized based on their proximity to active flare sites. This The study aims to compare the agricultural yields of women farming in high-exposure zones (0–10 km from flare points) with those of a control group of farmers situated in low-exposure zones (beyond 20 km). This enables the research to differentiate the effects of flaring from other regional factors, including rainfall and soil type. This methodology allows for a measurement of the efficiency loss due to industrial externalities (Willy & Tobin, 2025). The study acknowledges that women's productivity is often affected by structural inequalities, and the effects of thermal stress on specific food crops such as cassava and waterleaf has implications for female productivity.

The main factor contributing to the decline in productivity has being identified as the misallocation of labor resources and the rise in input expenses. Research indicates that soil fertility is adversely affected by acid rain and elevated temperatures, leading women farmers to increase their labor hours to sustain subsistence-level yields (Ayibakari & Ebisine, 2022). This situation has been recently identified as compensatory labor exhaustion (Effiong & Akpan, 2024). The study identifies a mechanism termed capital diversion where female farmers often redirect limited household savings to acquire increasingly costly fertilizer to address flare-induced acidity. This redirection of funds consequently diminishes their investment in children's education and healthcare (Zabbey & Robinson, 2023). This cycle demonstrates that gas flaring functions as a regressive tax on women, significantly diminishing their economic agency and reinforcing rural poverty in the Niger Delta.

In order to contextualize this study within the current body of knowledge, it is essential to delineate the shift from general environmental assessments to gender-focused economic modelling (David et al., 2023). For decades, literature has concentrated on the biophysical effects of oil extraction, detailing how gas flaring depletes soil nutrients and causes heat stress that inhibits the growth of staple crops such as cassava and yams (Ononogbo et al., 2024).<sup>1</sup> Traditional economic analyses have frequently regarded farm households as uniform entities, often neglecting the specific productivity constraints encountered by women. This article advances the field of gendered environmental economics by transitioning from perception-based surveys to a comprehensive, data-driven analysis of the ways in which flaring serves as a distinct barrier to female economic empowerment in Bayelsa State (Joffa & Sibiri, 2025). This study

addresses a significant gap by measuring the productivity tax resulting from environmental degradation on women, who generally oversee the most vulnerable food crops with minimal adaptive resources (Evwienure & Ogwara, 2022).

This study contributes to the existing literature by analyzing the relationship between time poverty and environmental externalities, a connection that is infrequently addressed in conventional agricultural productivity research within the Niger Delta. Recent reviews have emphasized the systemic health and socioeconomic deprivation in communities affected by flaring (Joffa & Sibiri, 2025). However, there is a lack of empirical evidence connecting the physical degradation of land to the specific shifts in labor allocation imposed on rural women (Ayibakari & Ebisine, 2022). This research positions the woman farmer as a central figure in the "resource curse" narrative, providing a unique viewpoint on the direct impact of industrial waste on the United Nations Sustainable Development Goal of gender equality (SDG 5). This article presents the empirical evidence required to shift from broad appeals for environmental justice to targeted, gender-responsive policy frameworks that specifically address the distinct vulnerabilities faced by women in agricultural livelihoods in Bayelsa (Green & Abbey, 2022).

Women in Bayelsa State, who are crucial to the agricultural labor force, are facing decreased productivity due to the harmful effects of gas flaring, which has led to soil degradation and altered crop physiology (David, et al 2023; Joffa & Sibiri, 2025). This issue is compounded by structural inequalities that limit women's access to land and credit, forcing them to divert resources from health and education to cope with declining agricultural yields (David, et al 2023; Joffa & Sibiri, 2025). Recent assessments indicate that as yields decline, women frequently allocate additional hours to soil remediation, consequently exacerbating their time poverty and compensatory labor exhaustion (Baro & Boroh, 2024). Without empirical data to measure the impact of these challenges, policy interventions remain ineffective and fail to address the specific needs of female farmers, perpetuating a cycle of economic disadvantage (Idu & Ologun, 2024). Thus, the main question of the study is: to what extent do the environmental externalities of gas flaring impact the Total Factor Productivity and economic resilience of female-led agricultural units in Bayelsa State? Following this, the main objective of the study is to empirically examine the correlation between gas flaring intensity and the agricultural productivity of women farmers in Bayelsa State (Bright et al., 2025).

This article is structured into five distinct sections to deliver a thorough analysis of the economic relationship between gas flaring and agricultural output. Subsequent to this introduction, Section 2 delineates the Literature Review wherein existing research on environmental externalities is synthesized. Section 3 provides an overview of the Research Methodology, detailing the data collection process conducted in Bayelsa State variables.

Section 4 presents the core empirical findings, which include a discussion of the Results Section 5 consist of Conclusion and Policy Recommendations,

### **1.1. Conceptual Clarification**

The key concepts of the study are discussed below.

#### *1.1.1. Gas Flaring*

Gas flaring, is defined here not merely as an industrial byproduct but as a negative environmental externality. In economic terms, it represents a market failure where the cost of waste disposal (the burning of associated petroleum gas) is not borne by the oil-producing firms but is instead shifted onto the local environment and its inhabitants. In Bayelsa State, this manifests as thermal pollution and atmospheric acidification. (Ogoke, 2023)

#### *1.1.2. Women Farmers' Productivity*

Women farmers' productivity is conceptualized through the lens of Total Factor Productivity. This goes beyond simple yield counts to measure the efficiency with which women combine land, labor, and capital. For this study, productivity is viewed as a gender-disaggregated metric, acknowledging that women's output is uniquely constrained by their "triple burden" of domestic, reproductive, and productive roles (Bright et al., 2025).

#### *1.1.3. Environmental-Productivity Nexus*

The conceptual link between gas flaring and women farmers' productivity is established through the environmental-productivity Nexus. This framework suggests that gas flaring acts as a biological inhibitor that lowers the marginal productivity of agricultural inputs. For example, the same unit of labor applied by a woman farmer in a high-flare zone yields significantly less than a unit in a non-flare zone because the underlying natural capital (the soil) has been degraded (Olalekhan et al., 2022).

#### *1.1.4. Gendered Vulnerability*

Gendered vulnerability explains why the impact environmental degradation is not uniform across sexes. Because women in rural Bayelsa often lack the legal or financial agency to relocate to less polluted lands—a concept known as land immobility—they are locked in to degraded environments, making their productivity a direct function of the state's environmental health.

#### *1.1.5. Female Farmers' Productivity*

Within the agrarian economy of the Niger Delta, Female Farmers' Productivity is conceptualized as the efficiency of output generated by women-led agricultural units, which are distinct from male-managed farms in both crop composition and resource access. In Bayelsa State, women are the primary cultivators of subsistence-plus crops, such as cassava, cocoyam, and leafy vegetables, which are highly sensitive to soil pH changes and heat stress (Godbless, 2024). This productivity is not merely a measure of physical yield per hectare but is a reflection of gendered allocative efficiency. Women must often navigate time poverty—balancing farm labor with domestic unpaid work—meaning that any environmental disruption caused by gas flaring acts as a disproportionate shock to their labor productivity, often forcing a retreat from market-oriented farming to low-yield subsistence (Tokpo & Okoye, 2025).

#### *1.1.6. Bayelsa State Ecology*

The Bayelsa State ecology serves as the critical spatial context for this productivity crisis. Characterized by a high-water table, extensive wetlands, and a delicate rainforest-mangrove transition zone, the state's ecology is naturally predisposed to nutrient leaching. When gas flaring introduces sulfur dioxide and nitrogen oxides, the resulting acid rain interacts with this high-moisture environment to accelerate soil acidification (Tokpo & Okoye, 2025). This ecological vulnerability is compounded by the heat island effect created by continuous flaring, which alters the micro-climate of surrounding farms. Consequently, the ecology of Bayelsa is no longer a neutral backdrop but has become an active economic constraint; the degradation of this natural capital directly erodes the comparative advantage women farmers once held in the production of indigenous food crops.

### **1.2. Theoretical Review**

The theoretical review utilizes three distinct economic frameworks to explain the nexus between industrial externalities, gendered labor, and agricultural output.

#### *1.2.1. The Theory of Externalities*

The Theory of Externalities, initially articulated by Pigou in 1920 highlighted how transactions between oil companies and the state created negative externalities for third parties, such as women farmers, particularly in Bayelsa where gas flaring exemplified market failure. This situation arose because the marginal social cost of pollution surpassed the marginal private cost, resulting in excessive pollution and reduced agricultural productivity. In contrast, Coase's 1960 argument against Pigouvian interventions suggested that well-defined property rights and zero transaction costs would lead to efficient outcomes; however, critics pointed out that in the Niger Delta, significant transaction costs and power disparities hindered effective bargaining between rural women and multinational oil companies.

#### *1.2.2. The Theory of the Production Function (The Environmental-Productivity Nexus)*

The Theory of the Production Function, as proposed by Solow (1956) and Griliches (1957), was extended by Atuma and Ojeh (2023) to include environmental quality as a crucial input, suggesting that environmental degradation negatively impacted productivity. Atuma and Ojeh (2023) tcountered this by claiming that population pressures and environmental changes could drive agricultural innovation, arguing that farmers adapt rather than succumb to degradation. However, Diri (2024) highlighted that in Bayelsa, women's limited access to credit hindered the innovation Boserup envisioned, resulting in a cycle of declining agricultural returns.

#### *1.2.3. The Collective Household Model*

The Collective Household Model, proposed by Chiappori (1988) and Haddad et al. (1997), was applied to women farmers in the Niger Delta by Effiong and Akpan (2024), highlighting that households function as a collection of individuals with varying preferences and bargaining power. This model indicated that women in Bayelsa disproportionately faced the productivity tax from environmental issues like flaring, as they were often assigned the most vulnerable plots and had limited influence over resource allocation. In contrast, Samuelson (1956) supported the Unitary Household Model, suggesting that households operate as consensus-seeking units, but recent evidence from

demonstrated that women's time poverty increased significantly more than men's due to environmental degradation, challenging Samuelson's view.

#### *1.2.4. The Theory of Externalities (Pigouvian Framework)*

The study focused on the Theory of Externalities as articulated by Pigou (1920), highlighting how gas flaring by oil multinational corporations in Bayelsa State created negative production externalities. It noted that while the private costs of oil extraction remained low due to flaring, the social costs, including soil acidification and reduced crop yields, were disproportionately borne by women farmers. The framework suggested that the degradation of the environment acted as an unpriced tax on agricultural productivity, forcing women into economic inefficiency and deepening rural poverty, thereby underscoring the need for policy interventions to internalize these external costs (Effiong & Akpan, 2024).

### **1.3. Empirical Review**

Willy and Tobin (2025) investigated the effects of oil pollution on women's health-seeking behaviors in Bayelsa State, Nigeria. Utilizing the Health Belief Model, they surveyed 400 women and discovered a preference for traditional medicine (89.3%) and self-medication (96.7%) over orthodox medicine (87%), which was often viewed as a last resort. The study concluded that systemic healthcare deficiencies prompted these trends, highlighting the need for improved healthcare access in oil-polluted environments. Osemene and Suwari (2025) emphasized the critical role of effective fishery policy implementation to enhance food security in Bayelsa State. Despite abundant aquatic resources, rising global demand for fish protein remains unmet, leading to nutritional deficiencies. Their study with 242 agricultural science teachers revealed consensus on policy challenges, advocating for realistic goals, governance improvements, and capacity building through financial support. Edaba et al. (2022) analyzed living standards in oil-spilt versus non-oil-spilt communities in Bayelsa. Their findings indicated that oil spillage adversely affected agricultural productivity and livelihoods, with 52% of oil-spilt households living below the poverty line. The study called for urgent agricultural reforms and improved practices by oil companies to combat these socio-economic challenges. Baro and Boroh (2024) focused on environmental challenges for rural women in Ogbia LGA, highlighting their reliance on farming amidst oil exploration impacts. Through qualitative methods, the study found significant challenges like oil spills and flooding, revealing women's adaptive strategies while emphasizing the need for sustainable environmental management.

Ogoke (2023) explored gas flaring's detrimental effects in the Niger Delta, linking it to psychological trauma and health risks. Advocating for literature as a means to inspire action, the study highlighted Nigeria's inadequate environmental standards and called for a green movement to combat gas flaring. Ononogbo et al. (2024) reviewed challenges and eco-friendly solutions for agricultural sustainability, identifying rapid population growth and urbanization as key issues. Their literature review stressed that without intervention, socio-economic conditions would worsen, advocating for sustainable practices aligned with the African Union's Agenda 2063. The report by Tokpo et al. (2025) outlined significant socio-economic challenges in Bayelsa State exacerbated by the resource curse. Utilizing a mixed-methods approach, it revealed an average monthly income of ₦48,500 and a poverty incidence of 43.2%. The findings called for targeted interventions and economic diversification to address these challenges.

Madubuegwu et al. (2025) investigated Alternative Dispute Resolution (ADR) as a strategy to address environmental degradation and social justice in Bayelsa. The study found that traditional conflict resolution methods failed, advocating for dialogue to prevent the cycle of conflict and economic hardship. Mohammed et al. (2025) assessed the impacts of gas flaring on public health in Ekpan community, revealing significant air pollution and health issues linked to gas flaring. The research underscored the need for community awareness and effective risk mitigation strategies. Irhivben et al. (2025) examined how oil spillage affects the technical efficiency of cassava farmers, revealing lower efficiency in spill-affected areas. The study emphasized the need for remediation initiatives to support agricultural productivity. Olalekan et al. (2022) reported severe health and environmental issues caused by oil spills in Tein community, highlighting the presence of hazardous contaminants. The findings urged for urgent intervention and compensation for affected communities. Idoga et al. (2025) studied the socio-economic impacts of illegal artisanal refineries on farmers, revealing significant environmental degradation and health issues. The findings emphasized the urgent need for strategies marrying environmental protection with socio-economic empowerment.

Ubodiom and Ariye (2025) assessed the impact of oil exploration on youth development, revealing that despite asset wealth, poverty and degradation persist. Only 23% of youth benefited from the industry, highlighting a need for inclusive policies. Jack (2025) examined community responses to environmental degradation, noting ineffective traditional strategies leading to maladaptive practices. The study stresses the necessity for sustainable alternatives and policy interventions. Uvoh et al. (2024) studied the effects of gas flaring on preschool children's growth, revealing alarming rates of malnutrition. The findings highlight the urgent need for protective measures for affected children. Uba

(2024) reported on the challenges of oil exploitation in Nigeria, emphasizing that the benefits accrue to elites at the expense of local communities. The study called for structural reforms and community engagement to address environmental and social injustices.

## 2. Theoretical Framework

The foundational premise of this study is the theory of externalities, as originally articulated by Pigou (1920). An externality occurs when the production or consumption of a good imposes unintended costs or benefits on a third party who is not involved in the transaction. In the context of Bayelsa State, gas flaring by oil multinational corporations represents a negative production externality. The private cost of oil extraction is kept low by flaring associated gas rather than re-injecting or commercializing it; however, the social cost—which includes soil acidification, thermal pollution, and the resulting decline in crop yields—is borne by women farmers. The theoretical framework posits that this externality creates a productivity gap. The environment is an essential input in agricultural production, its degradation via flaring acts as an unpriced tax on the farmer. For women in Bayelsa, this is particularly acute due to their reliance on subsistence food crops that are sensitive to the thermal gradients and acid rain associated with flare sites (Atuma & Ojeh, 2023). Under this framework, the study assumes that the agricultural output of women is a function of traditional inputs like labor and capital, but is also strictly conditioned by the level of the externality. The framework suggests that as increases (proximity to flare sites), the marginal productivity of labor decreases. Consequently, women farmers are forced into a state of economic inefficiency, where they must increase labor intensity—often referred to as compensatory labor—just to maintain a constant level of output, thereby deepening rural poverty. This Pigouvian perspective justifies the need for policy interventions, such as flare-out mandates or Pigouvian taxes, to internalize these costs and protect the productive capacity of the state's most vulnerable economic actors.

### 2.1. Research Design

The study adopts a quantitative, cross-sectional survey design to empirically assess the impact of gas flaring externalities on the productivity of women farmers. This approach allows for the collection of granular, household-level data to test the theoretical assertions of the Pigouvian framework within the specific ecological context of Bayelsa State. The study utilizes a quasi-experimental survey design, which is effective for studying environmental impacts where random assignment is impossible. Bayelsa State is stratified based on its proximity to active gas flare sites. Following the spatial identification strategy of Nwokolo (2025), communities are categorized into treatment groups (communities within a km radius of a flare site) and control groups (communities located km or further from any active flare site). This spatial stratification ensures that the study can isolate the flare effect from other regional economic shocks.

### 2.2. Population of the Study

A multi-stage, stratified random sampling technique is adopted to ensure geographic and economic representativeness. The target population consists of all active female smallholder farmers residing in the oil-producing communities of Bayelsa State, Nigeria. Bayelsa is divided into eight Local Government Areas (LGAs), most of which host significant oil and gas infrastructure. According to Diri (2024), women in these rural clusters represent over 60% of the agricultural workforce, primarily focusing on food staples. The target population specifically includes those whose farmlands are located within the geographic reach of atmospheric and thermal emissions from active gas flare stacks.

### 2.3. Sampling Method and Sample Size

Stage 1: Purposive selection of three Local Government Areas (LGAs) with the highest concentration of gas flares (e.g., Ogbia, Southern Ijaw and Yenagoa).

Stage 2: Random selection of two farming communities per LGA; (Imiringi and Kolo in Ogbia LGA, Oporoma and Angiama in Southern Ijaw LGA and Obunugha and Okolobiri in Yenagoa LGA)

Stage 3: The Sample Size is determined using Cochran's Formula.;  $n = \frac{Z^2 pq}{e^2}$

Where;

$n_0$  = The required sample size

Z = The Z-score (critical value) corresponding to the desired confidence level (e.g., 1.96 for 95% confidence)

P = The estimated proportion of the population that possesses the attribute of interest (if unknown, 0.5 of 50%)

$$q = 1 - p$$

e = The desired level of precision or margin of error (e.g., 0.05 for 5%).

Following, to determine the sample size of women farmers in Bayelsa State with a 5% confidence interval and 5% margin of error, and since the exact proportion of women farmers affected by flaring is unknown, p = 0.5 is used to ensure the most conservative (largest) sample.

$$\text{The sample size of the study becomes; } n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 384.16; \eta_0 = 384$$

Given the large population, a sample size of 400 women farmers is targeted to ensure a 95% confidence level and a 5% margin of error. This size is consistent with recent productivity studies in the Niger Delta (Atuma & Ojeh, 2023).

### 2.4. Reliability and Validity Test

**Reliability;** To ensure the research instrument measures what it intends to, a Pilot Study is conducted on 40 women (10% of the sample) in a non-sampled community (e.g., in neighboring Sagbama LGA, Bayelsa State).

**Validity:** The questionnaire undergoes content validity through peer review by agricultural economists and environmental scientists to ensure the questions accurately capture productivity and externalities.

### 2.5. Ethical Concerns

The study adhered to strict ethical guidelines to protect the vulnerable demographic of rural women:

**Informed Consent:** Respondents that do not understand English language were briefed in their local dialect (Ogbia/Ijaw) regarding the study's purpose, and participation is strictly voluntary.

**Anonymity and Confidentiality:** To prevent victimization by local or corporate interests, no names are recorded. Data is presented in aggregate form.

**Do No Harm:** Surveys are conducted at times that do not interfere with the women's peak farming or domestic hours to avoid exacerbating their time poverty (Tamuno & Dokubo, 2025).

## 3. Results and Discussions

This section consist of the data analysis and interpretation and the discussions of the findings. Four hundred questionnaire were distributed but 327 were retrieved; which is about 82%..

### 3.1. Descriptive Statistics

**Table 1** Summary of Descriptive Statistics of Respondents (N = 327)

Variable	Category	Frequency	Percent (%)
Estimated Monthly Farm Income	Below ₦30,000	25	7.6
	₦31,000–₦60,000	96	29.4
	₦61,000–₦100,000	78	23.9
	Above ₦100,000	128	39.1
Gender	Male	121	37.0
	Female	206	63.0
Age	18–30 years	88	26.9
	31–45 years	150	45.9
	46–60 years	61	18.7

	Above 60 years	28	8.6
Marital Status	Single	98	30.0
	Married	180	55.0
	Widowed	22	6.7
	Divorced/Separated	27	8.3
Household Size	1–3 persons	103	31.5
	4–6 persons	178	54.4
	7–9 persons	28	8.6
	10 and above	18	5.5
Educational Qualification	No formal education	4	1.2
	Primary education	51	15.6
	Secondary education	114	34.9
	Tertiary education	119	36.4
	Vocational training	39	11.9
Farming Experience	6–10 years	70	21.4
	11–20 years	167	51.1
	Over 20 years	90	27.5
Primary Crop Cultivated	Tubers	142	43.4
	Vegetables	76	23.2
	Others	109	33.3
Land Ownership	Inherited	32	9.8
	Rented/Leased	93	28.4
	Community-allotted	80	24.5
	Purchased	122	37.3
Proximity to Gas Flare Site	< 5 km (Very Near)	20	6.1
	6–10 km (Near)	81	24.8
	11–20 km (Far)	64	19.6
	> 20 km (Very Far)	162	49.5

Source: Author's own computations using SPSS 23

The descriptive statistics revealed that women constitute the majority of the farming population (63%), confirming the gendered nature of smallholder agriculture in gas-flaring communities. Most respondents are within the economically active age bracket of 31–45 years, suggesting substantial labour availability for agricultural production. Household sizes are predominantly moderated, with over half of the respondents living in households of four to six persons, implying considerable dependency pressure that may influence productivity outcomes.

In terms of human capital, educational attainment is relatively high, as over 70% of the respondents possessed at least secondary education or vocational training. Coupled with extensive farming experience where nearly 79% have farmed for more than a decade—this suggested that observed productivity outcomes are less likely to stem from knowledge deficiencies and more from environmental and structural constraints.

Income distribution indicated that although a sizable proportion of farmers earn above ₦100,000 monthly, a substantial share still earned below ₦60,000, reflecting income vulnerability among smallholder women farmers. Tuber cultivation

dominated production activities, a crop category known to be particularly sensitive to soil quality and atmospheric conditions, thereby increasing exposure to the adverse effects of gas flaring.

Land access remained mixed, with rented, community-allocated, and purchased land accounting for the bulk of holdings, potentially limiting long-term investment in soil improvement. Notably, about 31% of respondents operated farms within 10 km of gas flare sites, indicating significant exposure to flaring-related environmental externalities. This spatial proximity underscored the relevance of gas flaring as a critical factor influencing women farmers' productivity through soil degradation, reduced crop yields, and compromised livelihoods.

### 3.2. Perception of Gas Flaring Externalities (Environmental Impact)

**Table 2** Mean and Standard Deviation of Perceived Environmental Effects of Gas Flaring (N = 327)

Item	Mean	Std. Deviation
Increase in atmospheric heat on farm due to gas flares	4.22	0.71
Increased incidence of black rain/soot on crops	3.98	0.85
Faster withering or yellowing of crops near flare sites	3.74	1.10
Decline in soil fertility and increased soil hardness	3.72	0.97
Disruption of crop growth cycle due to flare light at night	3.56	1.17

Source: Author's own computations using SPSS 23

The mean scores across all items exceed the neutral benchmark, indicating a strong perception among respondents that gas flaring generates significant environmental externalities on farmlands. The highest mean related to increased atmospheric heat, suggesting that heat stress is the most immediate and observable impact of flaring. Reports of soot deposition, soil degradation, and crop stress further reinforce the view that gas flaring has persistently altered local agro-ecological conditions. The moderate standard deviations indicate general consensus among respondents regarding these adverse environmental effects.

### 3.3. Agricultural Productivity

**Table 3** Mean and Standard Deviation of Agricultural Productivity Indicators (N = 327)

Item	Mean	Std. Deviation
Decline in total harvest despite constant land use	4.06	0.83
Reduction in size and quality of tubers/fruits	3.88	0.93
Increased expenditure on fertilizer to maintain yield	4.00	0.74
High proportion of crops failing to reach maturity	3.98	0.91
Farming income insufficient for basic household needs	3.91	0.86

Source: Author's own computations using SPSS 23

The results showed consistently high mean values, indicating widespread agreement that agricultural productivity has declined in gas-flaring areas. The strongest responses related to declining harvest levels and rising production costs, implying reduced total factor productivity. Increased fertilizer uses to sustain yields points to soil nutrient depletion, while income inadequacy reflects the transmission of productivity losses into household welfare. The relatively low dispersion suggested that productivity decline is a shared experience rather than an isolated outcome.

### 3.4. Gendered Labour Allocation and Compensatory Effort

**Table 4** Mean and Standard Deviation of Gendered Labour and Time-Use Effects (N = 327)

Item	Mean	Std. Deviation
Increased hours spent on weeding and soil management	3.85	0.90
Longer travel distance to access unpolluted farmland	4.06	0.77
Reduced time for non-farm income activities	4.00	0.59
Greater difficulty for women in securing distant farmland	4.00	0.53
Reduced work capacity due to flare-related health issues	3.84	0.69

Source: Author's own computations using SPSS 23

Mean scores indicated that gas flaring significantly reshapes women farmers' labour allocation and time use. The high mean for increased travel distance and difficulty in land access highlights gender-specific constraints faced by women in adapting to environmental degradation. Time diverted to managing flare-induced farm problems limits engagement in supplementary livelihood activities, reinforcing economic vulnerability. The findings support the time-poverty hypothesis, showing that environmental externalities from gas flaring disproportionately intensify women's labour burdens and reduce productive efficiency.

### 3.5. Inferential Statistics (Regression Analysis)

**Table 5** Regression Results on Agricultural Productivity

Variable	Coef (B)	Std. Error	Stand Beta	t-Stat	p-value
Constant	0.950	0.248	—	3.835	0.000
Gas Flaring Externalities	-0.198	0.036	0.252	-5.488	0.000
Labour Allocation and Compensatory	0.571	0.053	0.493	-10.724	0.000
Model Statistics:					
R = 0.894, R <sup>2</sup> = 0.799, Adjusted R <sup>2</sup> = 0.734					
F-Statistic = 75.476 (p = 0.000)					
Durbin-Watson = 2.262					

Source: Author's own computations using SPSS 23

The regression results revealed that both gas flaring externalities and labour allocation with compensatory effort exerted statistically significant effects on agricultural productivity. Gas flaring externalities display a negative and significant coefficient (B = -0.198, p < 0.01), indicating that increased exposure to flaring activities significantly reduced agricultural productivity. This finding confirmed that environmental degradation arising from gas flaring such as excessive heat, soil infertility, and atmospheric pollution directly constrained farm output.

Labour allocation and compensatory effort shows a positive and highly significant coefficient (B = 0.571, p < 0.01), suggesting that farmers increase labour input and adaptive effort to mitigate productivity losses caused by gas flaring. However, the magnitude of this coefficient implies that productivity gains are achieved through intensified labour rather than efficiency improvements, reinforcing the notion of labour over-burden and time poverty, particularly among women farmers.

The coefficient of determination (R<sup>2</sup> = 0.799) indicated that approximately 79.9% of the variation in agricultural productivity is explained by the combined influence of gas flaring externalities and labour reallocation. The adjusted R<sup>2</sup> of 0.734 confirmed the robustness of the model. The F-statistic (75.476, p < 0.01) demonstrates that the model is jointly significant, while the Durbin-Watson statistic of 2.262 indicates the absence of autocorrelation in the residuals.

#### 4. Discussion of Findings

The study revealed critical insights into the intersection of gas flaring and female farmers' productivity in Bayelsa State, emphasizing the adverse effects of environmental degradation on agricultural practices. The findings aligned with recent literature, illustrating the gendered nature of smallholder farming and the unique challenges faced by women in gas-flaring communities. The demographic data indicated a significant female representation in farming, with women comprising 63% of the respondents. This prevalence affirmed the essential role women played in smallholder agriculture within gas-flaring regions. Similar studies, such as those by Anumaka et al. (2021), highlighted that women often served as the backbone of agricultural production in comparable contexts, facing compounded challenges due to environmental stressors.

The relatively high educational qualifications among respondents—over 70% possessed secondary or vocational education—coupled with extensive farming experience (79% had over a decade of farming), suggested that knowledge deficiencies were unlikely to be the primary factors behind observed productivity challenges. This finding resonated with research by Ogbimi et al. (2022), which argued that while education was crucial, structural barriers such as access to resources and technology remained significant impediments to productivity. Despite a notable proportion of farmers earning above ₦100,000 monthly, the data revealed significant income vulnerability, with many earning below ₦60,000. This disparity echoed the work of Eze et al. (2023), who found that smallholder farmers in gas-flaring areas often experienced economic fragility due to environmental impacts on agricultural output. Respondents consistently reported significant environmental externalities associated with gas flaring. The high mean score for increased atmospheric heat (4.22) indicated that heat stress was a pressing concern for farmers. Similar findings from Ojo et al. (2023) emphasized that gas flaring contributed to soil degradation and crop stress, reinforcing the need for urgent policy interventions.

The findings revealed a consensus among respondents regarding the decline in agricultural productivity due to gas flaring, with high mean scores for declining harvest levels and increased production costs. This observation aligned with research by Adedayo et al. (2021), which documented significant productivity losses among farmers in gas-flaring regions, linking these losses to environmental degradation and increased costs of production. The analysis of gendered labor dynamics showed how gas flaring reshaped women's labor allocation and time use. Increased travel distances to access unpolluted farmland and reduced time for non-farm income activities highlighted the specific constraints women faced. This aligned with the findings of Nwankwo et al. (2022), who argued that environmental stressors disproportionately burdened women, leading to time poverty and reduced economic opportunities.

The regression analysis confirmed that gas flaring externalities and labor allocation significantly influenced agricultural productivity. The negative coefficient associated with gas flaring indicated that increased exposure to flaring activities directly hindered productivity. Conversely, the positive coefficient for labor allocation suggested that women farmers intensified their labor inputs to mitigate productivity losses, reinforcing the notion of labor overburden, particularly for women. This pattern was supported by the research of Afolabi et al. (2022), which found similar trends of increased labor input in response to environmental stressors. The study highlighted the profound impact of gas flaring on female farmers' productivity in Bayelsa State. The findings resonated with recent literature, illustrating the urgent need for policies that addressed both the environmental impacts of gas flaring and the socio-economic vulnerabilities of women farmers. Enhanced support mechanisms, access to resources, and educational programs could empower these farmers to adapt and thrive in the face of environmental challenges.

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#### 5. Conclusions

The study on gas flaring and female farmers' productivity in Bayelsa State highlighted several critical findings that underscore the complex interplay between environmental degradation and agricultural practices. The following conclusions can be drawn:

Women constitute a substantial portion of the farming population in gas-flaring communities, emphasizing their vital role in agricultural production. However, they face unique challenges that hinder their productivity. The findings revealed that gas flaring significantly affects agricultural productivity through various environmental externalities, such as increased atmospheric heat, soil degradation, and crop stress. These impacts adversely influence farmers' yields and economic stability, particularly for women. Despite a notable portion of farmers earning above the average monthly income, many still experience economic vulnerability. This disparity highlights the financial fragility faced by smallholder women farmers in gas-flaring regions, necessitating urgent interventions. The study showed that gas flaring reshapes labor allocation, intensifying the burdens on women farmers constituting a form of productivity tax on female

farmers in Bayelsa State. Increased travel distances and reduced time for non-farm activities contribute to time poverty, further exacerbating their economic challenges. While respondents demonstrated relatively high levels of educational attainment, the findings indicated that structural barriers, such as limited access to resources and technology, remained significant impediments to enhancing productivity.

### *Recommendation*

Based on the conclusions regarding gender representation, environmental stress, and structural barriers, the following recommendations are proffered;

- For Policy

The Federal Government, through agencies like the National Oil Spill Detection and Response Agency (NOSDRA) and the Ministry of Environment, should enforce stricter penalties on gas flaring. Transitioning from mere fines to a total flare-out policy is essential to mitigate the atmospheric heat and soil degradation that directly stifle the productivity of women farmers.

Given the significant representation of women in the sector, the Bayelsa State Ministry of Agriculture should implement gender-specific intervention programs. These should include the distribution of heat-tolerant crop varieties and organic soil conditioners designed to counteract the specific chemical imbalances caused by acid rain and thermal radiation.

To address the Time Poverty caused by reshaped labor dynamics, the government and NGOs should invest in labor-saving technologies and improved rural infrastructure. Providing localized processing facilities and irrigation systems would reduce the physical burden on women, allowing them to optimize their farming schedules despite environmental constraints.

To mitigate the income vulnerability identified in the study, financial institutions should create specialized low-interest credit schemes for women farmers in oil-producing clusters. Additionally, a regional Environmental Insurance Scheme should be established to compensate farmers for crop failures directly linked to industrial externalities.

Despite high educational levels, women farmers face a technology gap. Agricultural extension agents should be deployed to provide specialized training on climate-smart agriculture and environmental remediation techniques. This ensures that their educational attainment is effectively translated into practical productivity in a degraded landscape.

There is an urgent need for a multi-stakeholder platform involving oil companies, community leaders, and women farmer cooperatives. This body should facilitate regular dialogue to ensure that corporate social responsibility (CSR) projects are aligned with the actual productive needs of the women, rather than being mere token gestures.

- For Further Study

To expand upon the findings of this research, the following areas are recommended for future academic inquiry:

- Comparative Analysis of Non-Oil Communities: A comparative study between women farmers in gas-flaring communities and those in non-oil producing LGAs within Bayelsa would help isolate the exact productivity gap attributable solely to industrial externalities.
  - Impact on Household Nutrition and Health: While this study focused on productivity, further research is needed to investigate the correlation between flare-induced crop stress and the nutritional status (biochemical health) of the farming households.
  - The Digital Divide in Environmental Mitigation: Research into the role of Agri-Tech (such as mobile-based weather alerts and soil sensors) is needed to see if digital interventions can effectively bridge the gap between women's high educational levels and the structural barriers they face.
- Contribution to Knowledge or Addition to Knowledge

This study adds significant value to the existing body of literature in the following ways:

- Empirical Validation of Time Poverty: The study contributes a fresh perspective to Feminist Economics by empirically documenting how gas flaring reshapes labor allocation. It proves that environmental degradation

does not just kill crops; it steals time, forcing women into longer travel distances and reducing their capacity for diversified livelihoods.

- Identification of the Education-Structure Paradox: A unique contribution of this research is the finding that high educational attainment among women farmers does not automatically translate to higher productivity in polluted zones. This challenges the traditional Human Capital Theory, suggesting that environmental externalities can be so severe that they nullify individual skill and education.
- The Productivity Tax Framework: The study introduces a conceptual framework where gas flaring is treated as an unseen tax on the rural woman's income. By quantifying the relationship between atmospheric heat and economic vulnerability, the research provides a basis for future Pigouvian (pollution) tax calculations in the Niger Delta.
- Gender-Centric Environmental Data: While many studies focus on the oil industry's macro-impact, this research provides a gender-disaggregated data on the micro-economic struggles of female smallholders, offering a baseline for gender-responsive environmental policymaking in Nigeria.

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## Compliance with ethical standards

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No conflict of interest to be disclosed.

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