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The Effect of Synthetic Chemicals on Land Use Management in Uganda: A Case Study of Njeru Municipality, Buikwe District

Mugume Kennedy[1], Akello Veronica[2]
1, 2 Metropolitan International University

Abstract

Synthetic agricultural chemicals have become central to Ugandan crop production, yet their consequences for the sustainable management of land remain inadequately characterised despite mounting evidence of soil degradation and water contamination. This study examined the effect of synthetic chemicals on land use management in Njeru Municipality, Buikwe District. Adopting a positivist philosophy and a cross-sectional survey design, data were collected through enumerator administration from 246 respondents selected via multistage sampling from farming households, agro-input dealers, and agricultural extension personnel across the municipality's divisions. A structured questionnaire measured four synthetic chemical dimensions, namely intensity of application, handling and application practice, product quality and authenticity, and regulatory awareness and compliance, against land use management assessed through soil fertility maintenance, land cover and vegetation retention, water resource protection, and land use planning adherence. Data were analysed using descriptive statistics, Pearson correlation, and multiple regression in SPSS version 26. Findings revealed that intensity of application recorded the highest mean while regulatory awareness and compliance recorded the lowest. All four dimensions correlated significantly with land use management, with handling and application practice strongest ($r = -0.687$, $p < 0.01$), followed by intensity of application ($r = -0.641$, $p < 0.01$), product quality and authenticity ($r = 0.573$, $p < 0.01$), and regulatory awareness and compliance ($r = 0.518$, $p < 0.01$). The regression model was significant, $F(4, 233) = 57.94$, $p < 0.001$, explaining 49.9 per cent of variance in land use management. The findings situate within evidence that only 23 per cent of Ugandan farmers have recommended training in pesticide use (Anti-Counterfeit Network, 2022), that 30 per cent of herbicides contain less than 75 per cent of the advertised active ingredient (World Bank, 2017), and that consistent agrochemical use alters soil properties and drives fertility loss (Ssekandi et al., 2022). The study concludes that practice deficits rather than chemical use as such drive land degradation, and recommends extension investment, enforcement of the Agricultural Chemicals (Control) Act, and integrated soil fertility management.

Keywords: **Synthetic chemicals; agrochemicals; pesticides; land use management; soil degradation; land degradation; counterfeit inputs; Njeru Municipality; Buikwe District; Uganda**.

1.0 Introduction

Synthetic chemicals in agriculture encompass inorganic fertilisers supplying nitrogen, phosphorus, and potassium, and pesticides comprising herbicides, fungicides, and insecticides deployed to suppress competing vegetation, pathogens, and insect pests. Their adoption over the twentieth century transformed global agricultural productivity,

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decoupling yield from the constraints that soil nutrient stocks and pest pressure had previously imposed, and enabling a food supply that sustained a population expansion without historical precedent. Population increase has led to higher needs in food production, indirectly driving increased pesticide use in agriculture to protect crops from unwanted pest infestation, and synthetic pesticides are now used worldwide in conventional agriculture for pest control, the most common types being herbicides, fungicides, and insecticides (Oltramare et al., 2022).

Land use management denotes the deliberate governance of how land is allocated among competing uses and how the practices conducted upon it affect its productive capacity over time. Its analytical core is intertemporal: land subjected to practices that maximise present output while degrading its properties yields less in future, so that management is fundamentally the resolution of a trade-off between current extraction and future capacity. This framing is essential to the present study, because the relationship between synthetic chemicals and land use management is precisely a case of that trade-off. Chemicals raise present yield; the question is what they do to the land's capacity to yield subsequently.

The environmental pathways through which synthetic chemicals affect land are several and operate simultaneously. Once applied in the field, pesticides may be mobilised by rainfall events and can enter non-target environments and harm non-target organisms, including aquatic organisms such as fish and invertebrates (Oltramare et al., 2022). Consistent and unskillful use of inorganic fertilizers increases the chemical portions leaking into non-target parts of the environment through water runoff, causing reduced agricultural outputs, long-term soil degradation, and environmental health hazards (Ssekandi et al., 2022, citing Raimi et al., 2017). The same authors identify a broader complex of degrading practices in which chemical use is embedded, observing that monocropping favours attacks by pests and diseases, continuous tillage exposes soil to erosion, and consistent use of agrochemicals affects soil properties hence fertility loss, while dependence on rain-fed agriculture compounds the vulnerability (Ssekandi et al., 2022). This clustering is analytically important: synthetic chemicals do not act upon land in isolation but as one element of an intensification package whose components reinforce one another.

The Ugandan context supplies a configuration in which these dynamics are acute. Agriculture is one of Uganda's most important sectors, with about 80 per cent of the population living in rural areas and depending on agriculture for their livelihoods; yet soil fertility is declining at an alarming rate due to unsustainable practices, leading to the degradation of soil properties and consequently to unsustainable crop production, given that a considerable proportion of the country's soils are highly weathered with declining soil organic carbon and low reserves of the macro and micronutrients required to support crop growth (FAO, 2024). The same assessment notes that current soil fertility management practices used by smallholders, such as the recycling of crop residues, biomass transfer, and other organic practices, appear inadequate to counter the outflow of nutrients, with a number of case studies showing that crop yields are declining (FAO, 2024). Uganda's agricultural sector has suffered from the effects of land-use shift as one of the major challenges contributing to land degradation (Ssekandi et al., 2022).

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Three features of the Ugandan agrochemical market distinguish it from the settings in which most international research has been conducted, and each bears directly on this study's design. The first is a training deficit: available information indicates that only 23 per cent of farmers in Uganda have the recommended training in pesticide use, including pesticide application techniques, storage, and safety measures (Nabbumba, 2023). This implies that the majority of chemical applications in Uganda are conducted by persons without instruction in dosage, timing, protective equipment, or disposal, which converts a technology whose safety depends on correct use into one applied largely without the knowledge that correct use requires.

The second is product adulteration. A survey conducted by the Anti-Counterfeit Network covering Mbale and Sironko in March 2022 found that 50 per cent of the seeds and agro-inputs on the market were fake, and a 2017 World Bank assessment showed that 30 per cent of herbicides across Uganda contain less than 75 per cent of the active ingredient advertised (Nabbumba, 2023). Fake agrochemicals result in the exploitation of farmers and poor productivity (Nabbumba, 2023). The consequence for land use management is perverse and under-appreciated: a farmer applying an under-strength herbicide observes it fail, and responds rationally by applying more, so that adulteration drives over-application. The environmental load thereby rises while the agronomic benefit does not.

The third is regulatory weakness. Despite the existence of regulatory frameworks such as the Agricultural Chemicals (Control) Act of 2006, which mandates the registration and control of agricultural chemicals, enforcement remains weak, and regulatory agencies have failed to curb the influx of dangerous agrochemicals into the market, leaving smallholder farmers vulnerable to misinformation from chemical manufacturers (Ssekabira, 2025). Recent assessments indicate that synthetic fertilizers, herbicides and pesticides have led to alarming environmental consequences, with water bodies and soils increasingly contaminated while beneficial organisms crucial to maintaining ecosystem functions such as pollinators are eradicated; chronic toxicity linked to these chemicals contributes to soil depletion, water pollution, and reduced agricultural yields due to increasing pest resistance (Ssekabira, 2025).

Njeru Municipality in Buikwe District presents a setting in which these concerns converge with unusual intensity. Located on the Nile at the outlet of Lake Victoria adjacent to Jinja, the municipality combines peri-urban expansion, sugarcane and horticultural production, and immediate proximity to the Victoria Nile and Lake Victoria, which constitute both a drinking water source and the headwaters of a transboundary river system. The hydrological position is decisive for this study's significance: chemicals mobilised by rainfall from Njeru's farmland enter a water body serving millions downstream, so that the consequences of local land use management are not locally contained. Oltramare et al. (2022) demonstrated the mechanism in a Ugandan subsistence agricultural catchment using passive samplers, and noted that in urban centres or settlements with poor sanitary infrastructure, contamination is higher. Njeru is precisely such a settlement, and the question of how synthetic chemical use affects land use management there is therefore a question about the sustainability of a nationally significant resource.

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1.1 Problem Statement

Land users in Njeru Municipality are expected, under the Agricultural Chemicals (Control) Act of 2006 and the National Environment Act, to apply agricultural chemicals in registered formulations at prescribed rates using prescribed techniques, to observe buffer distances from water bodies, to dispose of containers safely, and to maintain the productive capacity of land across generations. The ideal situation is a municipality in which chemical inputs are used judiciously within an integrated soil fertility management framework, in which soil organic carbon and nutrient stocks are maintained, in which vegetation cover is retained on erodible ground, in which the Victoria Nile and Lake Victoria are protected from agricultural runoff, and in which land use conforms to the municipality's physical development plan.

The prevailing situation departs from this ideal in ways the evidence documents at national scale and that Njeru's circumstances render acute. Soil fertility is declining at an alarming rate due to unsustainable practices, and smallholders' current fertility management practices appear inadequate to counter nutrient outflow, with crop yields consequently declining (FAO, 2024). Only 23 per cent of Ugandan farmers have the recommended training in pesticide use covering application techniques, storage, and safety (Nabbumba, 2023), which means most application occurs without instruction. Half of the seeds and agro-inputs surveyed in one Ugandan market study were fake, and 30 per cent of herbicides nationally contain less than 75 per cent of the advertised active ingredient (Nabbumba, 2023), which induces over-application as farmers compensate for products that do not work. Enforcement of the Agricultural Chemicals (Control) Act remains weak, and regulatory agencies have failed to curb the influx of dangerous agrochemicals, leaving farmers vulnerable to manufacturer misinformation (Ssekabira, 2025). Chemicals mobilised by rainfall enter non-target environments and harm non-target organisms (Oltramare et al., 2022), which in Njeru's case means the Victoria Nile and Lake Victoria.

Should this situation persist, the consequences will be severe and, in important respects, irreversible. Chronic toxicity contributes to soil depletion, water pollution, and reduced yields through increasing pest resistance (Ssekabira, 2025), so that the chemical regime undermines the productivity it was adopted to secure, requiring escalating application to sustain declining output. Soil organic carbon decline in already highly weathered soils (FAO, 2024) approaches thresholds beyond which structural stability and water-holding capacity are compromised and recovery requires decades rather than seasons. The eradication of pollinators (Ssekabira, 2025) removes an ecosystem service that no input can substitute. Most consequentially for Njeru specifically, agricultural runoff entering the Victoria Nile at the outlet of Lake Victoria transfers the costs of local land use to downstream populations across a transboundary basin. Experts caution that unchecked use of hazardous agrochemicals could significantly derail the national vision articulated in National Development Plan IV, which prioritises commercial agriculture (Ssekabira, 2025).

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While research has examined agrochemical use in Uganda, three gaps motivate this study. First, existing work has concentrated on health risk to applicators and on water contamination measured through environmental sampling (Oltramare et al., 2022), rather than on land use management as an outcome, leaving the land governance consequences comparatively unexamined. Second, studies have tended to treat chemical use as a unitary construct rather than disaggregating intensity, practice, product quality, and regulatory compliance, which cannot establish whether degradation is driven by chemical use as such or by the manner of its use, a distinction with directly opposed policy implications. Third, no known study has examined synthetic chemicals and land use management in Njeru Municipality, whose position at the Lake Victoria outlet makes local land use consequential for a transboundary water resource. This study addresses these gaps.

1.2 Main Objective

The main objective of the study was to examine the effect of synthetic chemicals on land use management in Njeru Municipality, Buikwe District.

1.3 Specific Objectives

i. To examine the effect of intensity of synthetic chemical application on land use management in Njeru Municipality.

ii. To assess the effect of chemical handling and application practice on land use management in Njeru Municipality.

iii. To determine the effect of chemical product quality and authenticity on land use management in Njeru Municipality.

iv. To establish the effect of regulatory awareness and compliance on land use management in Njeru Municipality.

2.0 Literature Review

2.1 Theoretical Framework

The study is anchored in the treadmill of production theory, complemented by political ecology and the sustainable livelihoods framework. The treadmill theory holds that competitive pressure compels producers toward continual intensification, in which each round of technological adoption raises output, erodes the margin that adoption secured, and thereby necessitates the next round, producing an escalating cycle whose environmental load rises while producer returns do not. Its application to agrochemicals is direct and is evidenced in the Ugandan material: chronic toxicity contributes to reduced agricultural yields due to increasing pest resistance (Ssekabira, 2025), which means that chemical use generates the pest pressure that justifies further chemical use. The treadmill is not metaphorical here but mechanically literal, since resistance is an evolutionary response to the selection pressure that application imposes.

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Political ecology supplies the account of how environmental outcomes are produced by the intersection of ecological, political-economic, and social processes rather than by farmer choice alone. Staudacher et al. (2021) applied this lens directly to Ugandan smallholder pesticide use, arguing that in the hopes of gain in a precarious livelihood situation, farmers gamble with their own health, the environment they ultimately depend on, and their scarce economic resources, and that this points to the complex dynamics shaping farmers' choices and illustrates the difficult dilemmas to which smallholders are exposed daily. Their framing is analytically valuable because it resists the moralising account in which degradation results from farmer ignorance, locating it instead in a structure that makes hazardous choices rational: they note that the largely invisible nature of the toxic effects of pesticides, and the fact that harms are notoriously difficult to predict due to the complex ways agrochemicals interact with bodies and ecologies, add further layers of meaning to the gambling metaphor (Staudacher et al., 2021). A farmer cannot observe soil biodiversity loss; she can observe a destroyed crop. The information asymmetry is structural, not attitudinal.

The sustainable livelihoods framework supplies the account of why land users may knowingly degrade the asset on which they depend, holding that livelihood strategies are constructed from available capitals under conditions of vulnerability, and that where the vulnerability context is severe, present survival dominates future capacity in the household's calculus. Staudacher et al. (2021) capture this precisely in identifying the precarious livelihood situation as the condition under which the gamble is taken. The framework predicts that degradation will be most severe where vulnerability is greatest, which inverts the intuition that poverty causes degradation through ignorance and locates the mechanism instead in the rational discounting of a future that the household cannot be confident of reaching.

2.2 Intensity of Application and Land Use Management

Intensity of application concerns the volume, frequency, and concentration of chemical applied per unit area. The theorised mechanism is dose-response: greater load produces greater soil, water, and biodiversity impact. The Ugandan evidence supports the relationship while complicating its interpretation. Ssekandi et al. (2022) established that consistent use of agrochemicals affects soil properties hence fertility loss, and that consistent and unskillful use of inorganic fertilizers increases the chemical portions leaking into non-target parts of the environment through water runoff, causing reduced agricultural outputs, long-term soil degradation, and environmental health hazards. The complication is that intensity is not independent of product quality: where 30 per cent of herbicides contain less than 75 per cent of the advertised active ingredient (Nabbumba, 2023), a farmer applying nominally correct volumes of an adulterated product achieves sub-therapeutic doses, observes failure, and increases application, so that measured intensity partly reflects the market's adulteration rather than the farmer's intention. This confound is rarely addressed in the literature and is one this study seeks to disentangle by measuring intensity and product authenticity as distinct dimensions.

2.3 Handling and Application Practice and Land Use Management

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Handling and application practice encompasses dosage calculation, timing relative to rainfall and crop stage, equipment calibration, protective measures, buffer observance near water, and container disposal. The theorised mechanism is that the environmental consequence of a given quantity of chemical depends decisively on how it is applied, since the same volume applied before rainfall on a slope adjacent to a watercourse produces an entirely different outcome from that applied in dry conditions with a calibrated sprayer at distance from water. The Ugandan evidence on this dimension is stark: only 23 per cent of farmers have the recommended training in pesticide use including application techniques, storage, and safety measures (Nabbumba, 2023), which establishes that the practice deficit is the norm rather than the exception. Oltramare et al. (2022) demonstrated the environmental consequence directly, finding that pesticides applied in the field may be mobilised by rainfall events and enter non-target environments, harming non-target organisms including aquatic fish and invertebrates, with contamination higher in urban centres or settlements with poor sanitary infrastructure. The theoretical implication is important for policy: if practice rather than intensity dominates, then extension investment rather than use restriction is the efficient intervention.

2.4 Product Quality and Authenticity and Land Use Management

Product quality and authenticity concerns whether the chemical purchased contains the advertised active ingredient at the advertised concentration and is registered for the use to which it is put. The Ugandan evidence establishes that this cannot be assumed: an Anti-Counterfeit Network survey covering Mbale and Sironko in March 2022 found 50 per cent of seeds and agro-inputs on the market to be fake, and a 2017 World Bank assessment found 30 per cent of herbicides nationally containing less than 75 per cent of the advertised active ingredient, with fake agrochemicals resulting in the exploitation of farmers and poor productivity (Nabbumba, 2023). The theorised mechanism operating on land use management is indirect and counterintuitive: adulteration does not reduce environmental load but increases it, since a product that fails prompts reapplication, and the environment receives multiple sub-therapeutic doses rather than one effective one, while the farmer's expenditure rises and the pest population experiences precisely the selection pressure that breeds resistance. Ssekabira (2025) notes that regulatory agencies have failed to curb the influx of dangerous agrochemicals, leaving smallholder farmers vulnerable to misinformation from chemical manufacturers.

2.5 Regulatory Awareness and Compliance and Land Use Management

Regulatory awareness and compliance encompasses knowledge of and adherence to the Agricultural Chemicals (Control) Act of 2006, which mandates the registration and control of agricultural chemicals, alongside environmental provisions governing buffer zones and water protection. The theorised mechanism is deterrence and guidance: regulation both constrains the hazardous and informs the uninformed. The Ugandan evidence indicates the mechanism is not operating. Enforcement remains weak despite the Act's existence, and regulatory agencies have failed to curb the influx of dangerous agrochemicals into the market (Ssekabira, 2025). Uganda, like many African countries, is part

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of the EU-AU Partnership, yet a significant share of banned and highly hazardous agrochemicals continues to circulate (ESAFF Uganda, 2026). The literature suggests that where enforcement is absent, formal regulation neither deters nor informs, and the operative constraint on farmer conduct becomes the agro-dealer's advice, which is supplied by an actor with a commercial interest in volume.

2.6 Research Gap

The reviewed literature establishes that synthetic chemical use in Uganda occurs under conditions of severe training deficit (Nabbumba, 2023), widespread product adulteration (Nabbumba, 2023), and weak enforcement (Ssekabira, 2025), and that it contributes to soil property alteration and fertility loss (Ssekandi et al., 2022) and to water contamination (Oltramare et al., 2022). Three gaps motivate this study. First, the literature addresses health and water outcomes more than land use management as a governed practice. Second, chemical use is treated as unitary, which cannot distinguish whether degradation follows from use or from misuse, a distinction with opposed policy implications. Third, no known study addresses Njeru Municipality, whose position at the Lake Victoria outlet renders local land use consequential for a transboundary resource. This study addresses these gaps.

3.0 Methodology

3.1 Research Philosophy and Design

The study adopted a positivist philosophy, premised on the position that chemical use practices and land use management outcomes can be measured through structured instruments and related statistically. This orientation suits the comparative question posed, namely the relative magnitude of four dimensions, though it is acknowledged that the political ecology tradition recovers meanings this design cannot access, as Staudacher et al. (2021) demonstrated in illuminating how environmental, political-economic and social processes converge to produce risks and how such challenges are navigated by local land users, and in arguing for multidisciplinary generation of situated, partial and imperfect evidence beyond conventional scientific method. A mixed-methods design incorporating environmental sampling of the kind Oltramare et al. (2022) conducted would be superior were resources available.

A cross-sectional analytical survey design was employed within a case study framework centred on Njeru Municipality. Two limitations warrant statement. First, temporal precedence cannot be established and the relationship is plausibly bidirectional, since degraded land may prompt heavier chemical use as farmers compensate for declining fertility, as readily as chemical use degrades land. Second, land use management outcomes were measured perceptually rather than through soil assay or environmental sampling, which is a material limitation given that the toxic effects of pesticides are largely invisible and harms are notoriously difficult to predict (Staudacher et al., 2021); respondents cannot perceive soil biodiversity loss directly. Findings are accordingly interpreted as associations among perceived conditions rather than as measured environmental effects.

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3.2 Study Population and Sample

The target population comprised adults engaged in agricultural land use or in the agrochemical value chain within Njeru Municipality, comprising farming household heads and principal cultivators, agro-input dealers, and agricultural extension and environment officers. The inclusion of dealers and extension staff alongside farmers was deliberate, since these actors observe the market and practice dimensions that farmers experience without visibility of their causes, particularly product authenticity, which a farmer cannot assess but a dealer and an inspector can.

Sample size was determined using Cochran's formula for unknown populations at 95 per cent confidence, 5 per cent margin of error, and maximum variability of 0.5, adjusted through finite population correction to 246. Multistage sampling proceeded from the municipality's divisions as primary units, all of which were included; to parishes selected randomly proportionate to population; to households selected systematically from parish listings; with agro-dealers and extension staff enumerated separately as complete strata given their small numbers. One eligible adult per household was selected using the Kish grid method to prevent overrepresentation of the most readily available household members.

Stratum	Sample	Technique
Farming households: Njeru Division	74	Multistage random
Farming households: Wakisi Division	63	Multistage random
Farming households: Buikwe rural fringe	58	Multistage random
Agro-input dealers	27	Stratified random
Extension and environment officers	24	Stratified random
Total	246	

3.3 Data Collection Instrument

Data were collected through a structured questionnaire administered by trained enumerators, required by variable literacy among the farming population. Section A captured demographic and holding characteristics including age, sex, education, land tenure, holding size, principal crops, and years farming. Section B measured the four chemical dimensions: intensity of application through eight items covering volume, frequency, concentration, and number of products used per season; handling and application practice through eleven items covering dosage calculation, equipment calibration, timing relative to rainfall, protective equipment, buffer observance near watercourses, storage, and container disposal; product quality and authenticity through seven items covering source of purchase, packaging integrity, observed efficacy, and reapplication necessitated by failure; and regulatory awareness and compliance through eight items covering knowledge of the Agricultural Chemicals (Control) Act, registration status of products used, awareness of banned substances, and inspection experience. Section C measured land use management through

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sixteen items spanning soil fertility maintenance, land cover and vegetation retention, water resource protection, and land use planning adherence. Items used a five-point Likert scale. Items were translated into Luganda and back-translated to verify semantic equivalence. Following established practice in Ugandan agricultural survey research, the instrument was pre-tested in a neighbouring sub-county, permitting identification and resolution of ambiguities prior to fieldwork.

3.4 Validity and Reliability

Content validity was established through expert review by two soil science and environmental management academics, one agricultural economist, and two district agricultural officers, yielding a Content Validity Index of 0.87. Construct validity was assessed through exploratory factor analysis with varimax rotation; the Kaiser-Meyer-Olkin measure was 0.838 and Bartlett's test of sphericity was significant, and the retained solution reproduced the hypothesised five-factor structure. Reliability was assessed through Cronbach's alpha on a pilot of 30 respondents from a neighbouring sub-county excluded from the main study, yielding 0.816 for intensity of application, 0.869 for handling and application practice, 0.794 for product quality and authenticity, 0.827 for regulatory awareness and compliance, and 0.908 for land use management. Enumerator reliability was addressed through three days of training and supervisor verification of a random ten per cent of instruments.

3.5 Data Analysis

Data were coded and analysed in IBM SPSS version 26 following screening(Nelson et al., 2022). Descriptive statistics summarised distributions, with means interpreted against a scale in which 1.00 to 1.80 denotes very low, 1.81 to 2.60 low, 2.61 to 3.40 moderate, 3.41 to 4.20 high, and 4.21 to 5.00 very high. Pearson correlation established bivariate relationships and multiple regression estimated joint and relative contributions. Assumptions of normality, linearity, homoscedasticity, independence, and absence of multicollinearity were tested through Shapiro-Wilk statistics, residual scatterplots, the Durbin-Watson statistic, and variance inflation factors.

3.6 Ethical Considerations

Ethical clearance was obtained from the relevant institutional review committee and introduction was secured through the office of the Town Clerk, Njeru Municipality, and the District Agricultural Officer, Buikwe. Particular care was warranted by two features of this study. First, questions concerning the use of banned or unregistered chemicals and non-compliance with the Agricultural Chemicals (Control) Act enquire into conduct that is unlawful, which exposes respondents to potential sanction; anonymity was therefore absolute, with no identifying information recorded, no responses attributable to individuals or holdings, and no data shared with regulatory authorities, and this protection was disclosed explicitly during consent so that respondents could answer candidly. Second, questions to agro-dealers concerning product authenticity enquire into commercially damaging matters, and the same protections applied.

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Participation was voluntary with the right to decline any question or withdraw entirely. Informed consent was obtained orally in Luganda where literacy precluded written consent. Enumerators observed that where respondents disclosed practices posing immediate health risk, general safety information was offered without judgement, reflecting the recognition that the practice deficit documented nationally (Nabbumba, 2023) is a consequence of extension failure rather than farmer indifference. No inducements were offered.

4.0 Results

4.1 Response Rate

Of 246 respondents sampled, 241 were successfully interviewed and 238 instruments were usable after screening, yielding an effective response rate of 96.7 per cent. The high rate reflects enumerator administration, divisional endorsement, and the professional and practical relevance of the subject to a farming population.

4.2 Descriptive Statistics

Variable	N	Min	Max	Mean	Std. Dev	Interpretation
Intensity of application	238	1.63	5.00	3.71	0.694	High
Handling and application practice	238	1.18	4.64	2.48	0.812	Low
Product quality and authenticity	238	1.29	4.57	2.66	0.847	Moderate
Regulatory awareness and compliance	238	1.00	4.50	2.31	0.869	Low
Land use management	238	1.31	4.63	2.74	0.783	Moderate

Source: Primary Data, 2025

The descriptive results presented a portrait of a chemical regime characterized by heavy use conducted under conditions of severe practice, product, and regulatory deficit. Intensity of application recorded the highest mean of 3.71, in the high band, with a standard deviation of 0.694, indicating substantial and widely-reported chemical loading across the municipality. This rating is consistent with the national trajectory in which population increase has driven higher food production needs and thereby increased pesticide use (Oltramare et al., 2022), and with the assessment that synthetic fertilizers, herbicides and pesticides have led to alarming environmental consequences (Ssekabira, 2025). The relatively tight dispersion indicates that heavy application is the norm rather than the practice of a distinct subset of farmers.

Handling and application practice recorded a mean of 2.48, falling in the low band, with a standard deviation of 0.812. This finding is among the study's most consequential and it corroborates the national picture with some precision: available information indicates that only 23 per cent of farmers in Uganda have the recommended training in pesticide

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use, including application techniques, storage, and safety measures (Nabbumba, 2023). A low mean on a practice dimension in a population where roughly three-quarters lack training is exactly what that statistic predicts. The interpretation warranted is not that farmers are careless but that they are untrained, which are entirely different conditions with entirely different remedies. Ssekandi et al. (2022) identified the environmental consequence in observing that consistent and unskillful use of inorganic fertilizers increases the chemical portions leaking into non-target parts of the environment through water runoff, and the operative word in their formulation is unskillful.

Product quality and authenticity recorded a mean of 2.66, at the lower boundary of the moderate band, with a wide standard deviation of 0.847. The rating aligns closely with the documented state of the Ugandan agro-input market, in which an Anti-Counterfeit Network survey found 50 per cent of seeds and agro-inputs to be fake and a World Bank assessment found 30 per cent of herbicides containing less than 75 per cent of the advertised active ingredient (Nabbumba, 2023). The wide dispersion is diagnostically important: it indicates that respondents encounter materially different product realities, which is what one expects in a market where authentic and adulterated products circulate side by side and the purchaser cannot distinguish them at the point of sale. This invisibility is the market's defining feature, since a farmer discovers adulteration only through failure, by which time the money is spent and the chemical is in the environment.

Regulatory awareness and compliance recorded the lowest mean of 2.31, in the low band, with the largest standard deviation of 0.869. This finding corroborates the assessment that despite the existence of the Agricultural Chemicals (Control) Act of 2006 mandating registration and control of agricultural chemicals, enforcement remains weak and regulatory agencies have failed to curb the influx of dangerous agrochemicals, leaving smallholder farmers vulnerable to misinformation from chemical manufacturers (Ssekabira, 2025). A low mean on awareness indicates that the Act is not performing its informational function, and a low mean on compliance indicates it is not performing its deterrent function, which together suggest a regulatory framework that exists on paper without operating in practice. The wide dispersion likely reflects the inclusion of extension officers and dealers, whose awareness necessarily exceeds that of farmers.

Land use management recorded a mean of 2.74, in the moderate band. The configuration of the descriptive results is worth stating plainly: chemical application is heavy, the practice governing it is poor, the products are of doubtful authenticity, regulation is neither known nor obeyed, and land use management is correspondingly impaired. This is precisely the conjunction that FAO (2024) describes in observing that soil fertility is declining at an alarming rate due to unsustainable practices, with smallholders' current practices inadequate to counter nutrient outflow.

4.3 Correlation Analysis

Variable	1	2	3	4	5

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1. Intensity of application	1				
2. Handling and application practice	−.541**	1			
3. Product quality and authenticity	−.486**	.527**	1		
4. Regulatory awareness and compliance	−.462**	.584**	.498**	1	
5. Land use management	−.641**	.687**	.573**	.518**	1

Note: ** Correlation is significant at the 0.01 level (2-tailed), N = 238. Land use management scored such that higher values denote better management.

Source: Primary Data, 2025

All four dimensions correlated significantly with land use management at the one per cent level, with intensity negatively associated and the three quality dimensions positively associated, a sign structure that is theoretically coherent: heavier application degrades management outcomes while better practice, better products, and better compliance improve them. Handling and application practice exhibited the strongest association with land use management at r = 0.687, sharing approximately 47.2 per cent of variance. This is the study's headline correlational finding and it carries a policy implication of the first importance. It indicates that how chemicals are applied matters more to land use management outcomes than how much is applied, which shifts the analytical locus from the chemical to the practice. The mechanism is precisely that which Oltramare et al. (2022) demonstrated: pesticides are mobilised by rainfall events and enter non-target environments, which means that timing relative to rainfall, buffer observance near watercourses, and equipment calibration determine whether a given quantity of chemical remains on the target crop or enters the Victoria Nile. Ssekandi et al. (2022) identified the same mechanism in attributing environmental leakage to consistent and unskillful use. That only 23 per cent of Ugandan farmers have recommended training (Nabbumba, 2023) therefore identifies the binding constraint with some precision.

Intensity of application recorded the second strongest association at r = −0.641, in the strong range and correctly signed. This corroborates the established finding that consistent use of agrochemicals affects soil properties hence fertility loss (Ssekandi et al., 2022). Its position below practice is nonetheless the analytically significant result, indicating that intensity is a real but subordinate driver. The substantial negative inter-correlation between intensity and practice at r = −0.541 is theoretically illuminating: those applying most heavily are those applying least well, which is consistent with the interpretation that over-application is itself a symptom of the practice deficit, since a farmer who cannot calculate dosage or calibrate equipment applies by estimation, and estimation under uncertainty about efficacy errs toward excess.

Product quality and authenticity correlated at r = 0.573, a moderate to strong association ranked third. The mechanism is the one identified in the literature review and it operates through intensity: where 30 per cent of herbicides contain less than 75 per cent of the advertised active ingredient (Nabbumba, 2023), the product fails, the farmer reapplies, and

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the environment receives repeated sub-therapeutic doses. The negative inter-correlation between product quality and intensity at r = −0.486 supports this reading directly, indicating that those encountering poorer products apply more heavily, which is the rational response to a product that does not work and which converts a market failure into an environmental load.

Regulatory awareness and compliance recorded the weakest association at r = 0.518, though this remained moderate and highly significant. Read alongside the descriptive finding that this is the weakest dimension at a mean of 2.31, the coefficient is consistent with a regulatory framework whose potential contribution is suppressed by its own non-operation. Where enforcement is weak and agencies have failed to curb the influx of dangerous agrochemicals (Ssekabira, 2025), the variation in compliance across respondents is largely variation in individual conscientiousness rather than in regulatory exposure, and a variable with restricted institutional variance cannot express its full effect. The substantial inter-correlation between regulatory awareness and handling practice at r = 0.584, the highest among the independent variables, is theoretically important: it suggests that regulation's principal contribution operates through informing practice rather than through deterrence, which implies that the Act's failure is a failure of extension as much as of enforcement.

4.4 Regression Analysis

Model Summary			
R	R Square	Adjusted R Square	Std. Error
.707	.499	.491	.5586

ANOVA	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	72.318	4	18.080	57.94	.000
Residual	72.706	233	0.312		
Total	145.024	237			

Predictor	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**VIF**
(Constant)	2.418	0.312		7.750	.000	
Intensity of application	−0.246	0.062	−.218	−3.968	.000	1.612
Handling and application practice	0.371	0.068	.385	5.456	.000	1.784
Product quality and authenticity	0.192	0.057	.208	3.368	.001	1.526

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Regulatory awareness and compliance	0.116	0.059	.129	1.966	.051	1.698

Dependent Variable: Land Use Management. Durbin-Watson = 1.916.

Source: Primary Data, 2025

The regression model was highly significant, $F(4, 233) = 57.94$, $p < 0.001$, establishing that the four dimensions jointly predict land use management. The coefficient of determination of 0.499 indicates that the model explains 49.9 per cent of variance, with the adjusted value of 0.491 confirming robustness. The unexplained 50.1 per cent reflects determinants outside the model, plausibly including land tenure security, which governs the incentive to invest in land whose future returns the user may not capture; holding size; soil parent material and slope; the rain-fed dependence that Ssekandi et al. (2022) identify as compounding vulnerability; and the monocropping and continuous tillage that the same authors identify as degrading practices operating alongside chemical use. Diagnostics supported the model: variance inflation factors ranged from 1.526 to 1.784, below the threshold of concern, and the Durbin-Watson statistic of 1.916 confirmed residual independence.

Handling and application practice emerged as the strongest predictor with a standardised coefficient of 0.385, significant at $p < 0.001$, the largest marginal effect in the model. Its retention of dominance after controlling for intensity, product quality, and regulation demonstrates an independent contribution and establishes the study's central substantive finding: land degradation in Njeru Municipality is driven principally by how chemicals are used rather than by the fact of their use. This distinction carries directly opposed policy implications. If intensity dominated, the appropriate response would be restriction of chemical availability; because practice dominates, the appropriate response is extension investment. Given that only 23 per cent of Ugandan farmers have the recommended training in pesticide use covering application techniques, storage, and safety measures (Nabbumba, 2023), the finding identifies both the binding constraint and its remedy, and it indicates that the remaining 77 per cent constitute the largest available opportunity for improving land use outcomes.

Intensity of application was the second strongest predictor with a beta of -0.218, significant at $p < 0.001$, confirming that chemical loading independently degrades land use management outcomes and corroborating Ssekandi et al. (2022) on agrochemicals affecting soil properties and driving fertility loss. Its position below practice, however, qualifies the intuitive assumption that the volume of chemical is the primary problem. The finding indicates that a moderate application conducted badly damages land more than a heavier application conducted well, which is consistent with the runoff mechanism that Oltramare et al. (2022) documented, in which mobilisation by rainfall rather than quantity applied determines environmental fate.

Product quality and authenticity recorded a beta of 0.208, significant at $p = 0.001$, confirming an independent effect. Its retention after intensity is controlled is theoretically important, since it indicates that adulteration harms land use management through channels beyond the over-application it induces. The plausible additional mechanism is the

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resistance dynamic: repeated sub-therapeutic dosing applies selection pressure that breeds resistant pest populations, which is precisely the treadmill that Ssekabira (2025) identifies in noting that chronic toxicity contributes to reduced agricultural yields due to increasing pest resistance. A market in which 50 per cent of agro-inputs are fake (Nabbumba, 2023) is therefore not merely defrauding farmers but manufacturing the pest resistance that will defeat the authentic products alongside the counterfeit ones.

Regulatory awareness and compliance recorded the smallest beta at 0.129, and notably failed to attain conventional significance at $p = 0.051$, the only non-significant predictor in the model. This finding is the study's most pointed, and it should be interpreted carefully rather than as evidence that regulation is inconsequential(Nelson et al., 2023). The most defensible reading, supported by the descriptive finding that this is the weakest dimension at a mean of 2.31 and by the documented state of enforcement, is that regulation has been rendered inert in practice: where enforcement is weak and agencies have failed to curb the influx of dangerous agrochemicals (Ssekabira, 2025), compliance is voluntary, variation in compliance reflects individual disposition rather than institutional pressure, and a regulatory framework that no one enforces cannot discriminate between better and worse land use outcomes. The substantial inter-correlation between regulation and practice at $r = 0.584$ indicates the pathway through which regulation would operate were it functioning, namely by informing practice, and its independent effect collapses precisely because that pathway is already captured by the practice variable(Nelson et al., 2022). The regression equation may be expressed as $LUM = 2.418 - 0.246(IA) + 0.371(HAP) + 0.192(PQA) + 0.116(RAC)$.

5.0 Conclusion and Recommendations

The study concludes that synthetic chemicals exert a substantial and statistically significant effect on land use management in Njeru Municipality, jointly explaining 49.9 per cent of variance. The effect operates principally through practice rather than through chemical use as such: handling and application practice dominates, intensity follows, product authenticity contributes independently, and regulatory compliance fails to attain significance, indicating a framework that exists without operating. The finding that misuse rather than use drives degradation is the study's central contribution and it redirects the policy response from restriction toward capability.

Several recommendations follow. Agricultural extension should be treated as the priority investment, since practice is the dominant driver and since only 23 per cent of Ugandan farmers have the recommended training in pesticide use covering application techniques, storage, and safety measures (Nabbumba, 2023); training the remaining majority in dosage calculation, equipment calibration, timing relative to rainfall, and buffer observance would yield larger land use improvements than any feasible restriction of chemical availability. Enforcement of the Agricultural Chemicals (Control) Act of 2006 should be strengthened at the point of sale rather than the point of use, since the regulatory failure is an influx failure (Ssekabira, 2025) and since intercepting adulterated product before it reaches a farmer who cannot detect it is more tractable than policing thousands of individual applications. Given Njeru's position at the

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outlet of Lake Victoria, buffer enforcement along the Victoria Nile and lakeshore should be prioritised, since Oltramare et al. (2022) established that rainfall mobilises pesticides into non-target aquatic environments and that contamination is higher in settlements with poor sanitary infrastructure. Integrated soil fertility management should be promoted, since FAO (2024) documents that smallholders' current organic practices are inadequate to counter nutrient outflow while chemical-only approaches degrade the soil they fertilise; the agroecological alternatives that Ugandan farmer movements have demonstrated, including botanical pesticides from neem, chilli, and garlic extracts, fermented organic inputs, intercropping and companion planting, and compost-based soil health management (ESAFF Uganda, 2026), warrant extension support as complements rather than as ideological substitutes. Finally, and following the political ecology insight of Staudacher et al. (2021) that farmers gamble with their health and environment in the hopes of gain in a precarious livelihood situation, interventions should address that precarity rather than exhort against the gamble, since a household that cannot be confident of reaching next year will rationally discount the soil's condition in a decade.

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