

Effects of Tobacco Production on the Environment in Nkeyema District, Zambia: AI-Driven Environmental Monitoring, Sustainable Agriculture and Community Resilience

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Abstract —Tobacco production is one of Zambia's most economically significant agricultural export commodities, yet its environmental consequences encompassing deforestation, soil degradation, water contamination, and air pollution impose severe and often irreversible ecological costs on tobacco-growing communities. In Nkeyema District, Western Province, the concentration of commercial tobacco production around the JTI tobacco processing plant has generated significant local environmental challenges that threaten long-term agricultural land productivity, biodiversity, and community health. This article examines the environmental effects of tobacco production in Nkeyema District, situating local findings within global scholarship on agricultural sustainability, AI-driven environmental monitoring, precision agriculture, and green economy transition. Drawing on a descriptive survey of farmers, environmental officials, and community members, findings document extensive deforestation for curing fuel, soil chemical degradation, agrichemical water contamination, and farmer occupational health impacts. The article argues that AI-powered environmental monitoring systems, precision agriculture technologies, and community-based agroforestry programmes offer pathways for mitigating tobacco production's environmental impacts while supporting sustainable livelihood transition. Policy recommendations are presented.

Keywords — Tobacco Production; Environmental Effects; Nkeyema District, Zambia; AI Environmental Monitoring; Sustainable Agriculture; Deforestation, Soil Degradation.

1. Introduction

Commercial tobacco cultivation has been a significant component of Zambia's agricultural export economy for decades, generating foreign exchange earnings and rural employment while imposing well-documented environmental costs on tobacco-growing regions (Vettriselvan & Anto, 2018; Shanthi et al., 2025). The environmental footprint of tobacco production is substantial and multidimensional, encompassing deforestation for both land clearing and fuel wood used in tobacco curing barns, soil chemical degradation from intensive pesticide and fertiliser application, water source contamination from agrichemical runoff, and occupational health impacts on farmers and processing workers (Ashifa, 2020a; Vettriselvan et al., 2025b). In Nkeyema District, Western Province, the presence of a major tobacco processing facility and associated contracted farmer network has concentrated these environmental impacts in a geographically bounded area, creating local ecological stress that threatens the long-term agricultural viability of affected communities (Vettriselvan et al., 2025a; Kariveliparambil et al., 2026b).

Global advances in AI-powered environmental monitoring, satellite-based deforestation detection, precision agriculture technology, and community-based environmental management offer new possibilities for

mitigating tobacco production's environmental impacts while supporting economically viable livelihood transitions (Shanthi et al., 2025; Venice et al., 2025a). This article examines these impacts in Nkeyema District and identifies evidence-based technological and governance pathways for environmental protection.

2. Literature Review

2.1 Deforestation and Land Degradation

Deforestation is the most extensively documented environmental impact of tobacco production globally, with tobacco-growing regions in Zambia, Zimbabwe, Malawi, and Mozambique among the most severely affected (Shanthi et al., 2025; Vettriselvan & Anto, 2018). Tobacco curing the process of drying harvested tobacco leaves to develop commercial quality requires large quantities of firewood, generating an estimated 18 kg of firewood demand per kg of cured tobacco. In Nkeyema District, where the majority of smallholder tobacco farmers use traditional flue-curing barns, annual firewood consumption per household can exceed 10 tonnes a volume that far exceeds sustainable forest regeneration rates at current farming densities (Vettriselvan et al., 2025a; Kariveliparambil et al., 2026b). Deforestation for land clearing to expand tobacco cultivation areas and for curing fuel generation has converted significant areas of Nkeyema's miombo woodland a biodiversity-rich

ecosystem providing ecosystem services including watershed protection, carbon sequestration, and non-timber forest product provisioning into degraded agricultural and waste land (Ashifa, 2021a; Shanthi et al., 2025). AI-powered satellite imagery analysis systems that detect early-stage deforestation events can alert environmental authorities to illegal clearing activities within days of occurrence enabling timely enforcement intervention that conventional ground-based monitoring cannot achieve (Venice et al., 2025a; Akila et al., 2025).

2.2 Soil and Water Contamination

Intensive tobacco cultivation requires high inputs of synthetic fertilisers and pesticides, with documented soil chemical accumulation effects that alter soil microbial communities, reduce soil organic matter, and ultimately impair long-term productivity (Ashifa, 2020a; Vettriselvan et al., 2025b). Agrichemical runoff from tobacco fields during rainfall events contaminates adjacent water sources including streams, boreholes, and shallow wells used by communities for drinking, cooking, and domestic use with organochlorine pesticides, heavy metals, and nitrate compounds associated with significant health risks at chronic exposure levels (Ashifa, 2020b; Ranganathan et al., 2024).

AI-powered precision agriculture systems that optimise agrichemical application timing, placement, and dosage using sensor data on soil nutrient status, crop growth stage, and local weather conditions can substantially reduce the total agrichemical inputs required for commercial tobacco cultivation while maintaining yields, thereby reducing both production costs and environmental contamination impacts (Venice et al., 2025b; Devi et al., 2025). Blockchain-enabled agrichemical supply chain tracking that records the type, quantity, and application location of all agricultural chemicals used on contracted farmer plots provides environmental compliance data that supports regulatory oversight and farmer accountability (Rajeswari et al., 2026; Venice et al., 2025c).

2.3 Farmer Health and Occupational Safety

Tobacco farmers and processing workers face significant occupational health risks associated with green tobacco sickness a nicotine poisoning condition caused by dermal absorption of nicotine from wet tobacco leaves during harvesting and handling as well as chronic pesticide exposure risks from inadequately protected agrichemical application (Ashifa, 2020a; Ashifa, 2021a). The health impacts of occupational tobacco exposure disproportionately affect women and child labourers who participate in tobacco harvesting and leaf handling activities without adequate protective equipment (Vettriselvan & Anto, 2018; Ashifa et al., 2019). Mobile

health monitoring platforms that enable farmers to report occupational symptoms, access health information, and connect with healthcare providers represent an important complement to environmental protection in tobacco-growing communities (Shanthi et al., 2025; Venice et al., 2025a).

2.4 Sustainable Agriculture and Livelihood Transition

The environmental and health costs of tobacco production make livelihood diversification and transition to more sustainable agricultural systems a priority for long-term community well-being in tobacco-growing districts (Vettriselvan et al., 2025a; Kariveliparambil et al., 2026a). AI-powered agricultural advisory platforms that provide personalised recommendations for alternative crop selection, agroforestry system design, and sustainable soil management can support farmer transition to less environmentally damaging livelihood systems while maintaining household income (Venice et al., 2025b; Vasantha et al., 2025). Community-based agroforestry programmes that integrate tree planting with tobacco cultivation replacing firewood demand for curing with solar or biomass briquette curing technologies offer a practical pathway for reducing deforestation while maintaining tobacco production economic viability during the transition period (Shanthi et al., 2025; Swadhi et al., 2025a).

3. Methodology

A descriptive survey design was used to examine the environmental effects of tobacco production in Nkeyema District. Mixed methods combined structured farmer questionnaires, environmental officer interviews, community focus group discussions, and environmental transect observations (Kombo & Tromp, 2014; Orodho & Kombo, 2012). The sample comprised 50 tobacco farmer respondents, 8 environmental and agricultural officer key informants, and 3 community focus groups. Environmental transect observations documented deforestation extent, soil erosion indicators, and water source proximity to tobacco farming areas. Quantitative data were analysed descriptively; qualitative data through thematic analysis.

4. Findings and Analysis

4.1 Deforestation Extent

Farmer respondents reported clearing an average of 2.3 hectares of natural woodland per household per year for tobacco cultivation expansion and curing fuel, with 78% of respondents reporting significant decline in local forest cover over the preceding decade. Environmental officers estimated that 35–45% of Nkeyema District's miombo woodland cover has been lost since large-scale commercial tobacco contracting began a rate of deforestation

significantly exceeding national projections (Shanthi et al., 2025; Vettriselvan et al., 2025a).

4.2 Soil and Water Quality

Soil quality assessments conducted by environmental officers indicated elevated heavy metal concentrations (particularly cadmium from phosphate fertiliser application) in 60% of tested tobacco farm plots. Water source contamination with agricultural chemicals was confirmed in 40% of borehole samples taken within 500 metres of active tobacco fields (Ashifa, 2020a; Ranganathan et al., 2024). Community members reported increased incidence of skin rashes, gastrointestinal illness, and respiratory symptoms associated with proximity to tobacco farming and curing areas.

4.3 Farmer Health Impacts

Green tobacco sickness symptoms were reported by 72% of farmer respondents, with women farmers reporting significantly higher symptom rates than men owing to their greater involvement in leaf handling activities without protective equipment. Pesticide exposure-related symptoms including headaches, dizziness, nausea, and eye irritation were reported by 65% of respondents (Ashifa, 2020b; Ashifa et al., 2019; Vettriselvan & Anto, 2018).

4.4 Environmental Awareness and Transition Interest

Environmental awareness among farmer respondents was moderate, with 65% able to identify tobacco production as a primary cause of local deforestation but fewer than 40% aware of soil or water contamination risks. Interest in alternative livelihood options was expressed by 58% of respondents, with the primary barrier to transition identified as lack of information about profitable alternative crops and access to alternative crop markets (Venice et al., 2025b; Vasantha et al., 2025).

5. Discussion

The environmental impacts of tobacco production in Nkeyema District are severe and compound: deforestation, soil degradation, water contamination, and occupational health impacts collectively constitute a trajectory of environmental deterioration that threatens the long-term agricultural and ecological viability of the district. Technology-mediated solutions AI satellite monitoring, precision agriculture, blockchain agrichemical tracking, and mobile health platforms can reduce the severity of specific impact dimensions, but sustainable environmental protection requires structural change in the tobacco value chain governance and farmer livelihood diversification

support systems (Shanthi et al., 2025; Venice et al., 2025a; Akila et al., 2025).

6. Conclusion and Recommendations

This article has examined the effects of tobacco production on the environment in Nkeyema District, connecting local evidence with global scholarship on AI environmental monitoring and sustainable agriculture. Recommendations: (1) deploy AI satellite deforestation monitoring in Nkeyema District with mandatory reforestation compliance for tobacco contractors (Venice et al., 2025a; Shanthi et al., 2025); (2) implement precision agriculture platforms reducing agrichemical application intensity and runoff (Venice et al., 2025b; Devi et al., 2025); (3) establish blockchain agrichemical supply chain tracking for regulatory compliance (Rajeswari et al., 2026; Venice et al., 2025c); (4) provide mobile health monitoring and occupational safety training for tobacco farmers (Ashifa, 2020a; Venice et al., 2025a); and (5) develop AI-powered alternative livelihood advisory platforms supporting crop diversification transition (Vasantha et al., 2025; Swadhi et al., 2025a).

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