HUMAN URINE AS A LIQUID FERTILIZER FOR SMALLHOLDER CROP PRODUCTION: AGRONOMIC POTENTIAL, ADOPTION BARRIERS, AND FOOD SECURITY IN NIGERIA

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Abstract.
Human urine has been recognized as a valuable resource for agriculture, a sustainable solution compared to the use of chemical fertilizers to enhance soil fertility for crop production, particularly for smallholder farmers. Rich in nitrogen, phosphorus, and potassium, human urine is an underutilized resource that can serve as an effective organic fertilizer, especially for crop production. Undiluted or diluting urine with water at a ratio of 1:3 to 1:10 and allowing the mixture to sit in a tank or can with a lid for 1-6 months will significantly help in eliminating odor and create a nutrient-rich fertilizer that addresses soil fertility issues sustainably. This paper reviews the adoption of human urine as a liquid fertilizer for crop production in smallholder farmers to ameliorate food insecurity. Studies revealed that these approaches not only recycle waste materials but also offer several benefits, including cost-effectiveness, convenience/feasibility, an increase in crop yield, and safe/nutritious food. However, it presents challenges such as unpleasant odor and cultural perception regarding its use. Proper handling, storage, and application methods are crucial to maximizing its benefits while minimizing the risks. Adoption of this fertilizer can contribute to more sustainable agricultural practices for food security. Awareness and training programs to educate farmers on the application are essential for the safe usage of this fertilizer. In conclusion, this innovation presents a promising opportunity for smallholder farmers to enhance soil fertility and crop yield in a sustainable and cost-effective manner for a sustainable food system.

Keywords: *Adoption, human urine, liquid fertilizer, sustainable*

Introduction

Food insecurity is a pressing global issue, particularly in the face of surging population, climate instability, and urbanization. A growing global population, compounded by low incomes, has led to an increasing demand for food production (Elferink & Schierhorn, 2016).

In the Sub-Saharan Africa region, agriculture is dominated by smallholder farmers who continuously struggle to maintain the productivity of their land. With decreasing availability of arable land, the challenge will be to increase production on existing agricultural lands, in part by adoption of new and innovative methods that improve soil fertility and water management (Elferink & Schierhorn, 2016; FAO, 2014). Nearly 90% of the 525 million farms worldwide are small-scale (defined as < 2 hectares) (IAASTD, 2009) and often run by families. These family farms produce more than half of the world's total food (Graeub *et al.,* 2016). Leveraging food production in smallholder farmers through improved production practices is therefore increasingly seen as a solution to global food insecurity and rural poverty (Graeub *et al*., 2016). These farmers make up to 80% of farmers in Nigeria and produce a substantial percentage of the food consumed by Nigerians (Mgbenka & Mbah, 2016). Low yield is the most critical factor affecting the profitability and competitiveness of smallholder farmers. The traditional use of inorganic fertilizers to enrich their farms, though expensive, has adverse environmental, soil, and human health implications.

Who are the smallholder farmers? They are producers who cultivate, rear livestock, or raise fish on a limited scale, typically on a family-owned enterprise operating on less than 10 hectares of land. Smallholder farmers in most of sub-Saharan Africa still produce in an agricultural system that is characterized by low input and low outputs (Mgbenka & Mbah, 2016).

Plant nutrition is a key factor that determines plant growth and development; therefore, fertilizer application has become a common practice in agriculture. The macronutrients, such as nitrogen, phosphorus, and potassium, are more frequently required for plant nutrition in large proportions than micronutrients (Ranasinghe *et al.,* 2018). Though each macronutrient is important for all plants, the nitrogen requirement is greater than the total use of other macronutrients and micronutrients together. However, plant nutrients are depleting in the soil at an alarming rate due to unplanned continuous farming practices. Therefore, most of the farmers have adapted to apply chemical fertilizers in order to increase the available nutrients and hence the land productivity.

While inorganic or chemical fertilizer is applied to the soil to boost its fertility, research has shown that it is damaging many properties of the soil that, in the long-term, will reduce its fertility and make it more challenging to grow healthy, high-quality crops (Moore, 2022). Also, when fertilizers are applied to land, there are several potential routes to human exposure. A key pathway is via food products, as crops can accumulate harmful contaminants. Certain contaminants and secondary fertilizer compounds have adverse effects on human health, including neurotoxicity, infectious diseases, carcinogenicity, and endocrine-disrupting effects (EEA, 2025). For instance, the overuse and misuse of chemical fertilizers is attributed to critical environmental and health problems, such as chronic kidney disease (CKD) in Sri Lanka.

Human urine is a valuable, yet underestimated and under-utilized , resource for plant fertilization that has been used in agriculture since ancient times, not least in intensive farming systems in various parts of Asia (Gwara *et al*., 2021). Nevertheless, in much of sub-Saharan Africa, such as Ethiopia, Uganda, Nigeria, etc., its use in agricultural production is not a common practice (Winblad & Simpson-Hébert, 2004 as cited in Windberg & Otterpohl, 2016).

What is in human urine? When we eat food, our kidneys filter out excess nutrients that our body is unable to use, and these nutrients are then expelled from the body as urine. Our urine contains approximately 9-15 g/liter of nitrogen, 1-2 g/liter, and 2-5 g/liter of potassium, depending on diet, hydration, and individual metabolism (Heinonen-Tanski & Wijk-Sijbesma, 2005). It shows that an adult's urine contains enough nutrients to fertilize 50-100% of the crops needed to feed one adult. Urine is the major product of ecological sanitation toilets such as urine diversion dry toilets (UDDT), and its utilization as an agricultural input is a current challenge in developing countries. Urine contains plant nutrients that may supplement or replace commercial fertilizers for crop production (Jonsson *et al.,* 2004). In many regions, especially African and Asian countries, pilot studies have demonstrated their effectiveness in improving crop yields, reducing fertilizer costs, and promoting circular nutrient economy practices.

Despite these benefits, the adoption of urine fertilizer remains limited due to cultural, health, logistical, and regulatory challenges. This paper aims to review the use of human urine as a liquid fertilizer in crop production in smallholder farmers to ameliorate food insecurity with specific objectives on (i) its effectiveness as a liquid fertilizer, ii) to identify barriers to adoption (iii) to evaluate its potential contribution to food security in low-income and resource-limited settings. (iv) research gap and further studies (v) summary and conclusion

Methodology

This review adopted a narrative approach, combining peer-reviewed literature, institutional reports, and case studies on the use of human urine as fertilizer. Literature was sourced primarily from database studies, including Google Scholar, Scopus, ScienceDirect, and PubMed, using keywords such as 'human urine, smallholder farmers, liquid fertilizer, innovation, and food security.

Studies published between 2000 and 2026 were prioritized, focusing on those with empirical evidence from Africa and Asia. Grey literature such as publications by the Stockholm Environment Institute, World Health Organization (WHO), and EcoSanRes were also reviewed for their relevance to practical applications, health guidance, and policy. Publications were also selected based on relevance, scientific rigor, and their application to smallholder agriculture and food security contexts.

Thematic review based on specific objectives

The effectiveness of human urine as a liquid fertilizer

Nutrient composition and agronomic value of human urine: Ranasinghe *et al.* (2018) revealed that most of the nutrients present in the urine are readily available for the plants. Urine is considered to be a well-balanced nitrogen-rich fertilizer, and 75 – 90 % of the nitrogen present in the urine is in the available forms (either urea or ammonium), which becomes ammonium ions in an aqueous solution at neutral pH. Phosphorus and potassium present in the urine are in an inorganic form and are directly plant-available. An average of human urine contains approximately 9-15 g/liter of nitrogen, 1-2 g/liter, and 2-5 g/liter of potassium, depending on diet, hydration, and individual metabolism (Heinonen-Tanski & Wijk-Sijbesma, 2005). Additionally, urine contains micronutrients like sulphur, magnesium, and calcium in smaller but beneficial quantities (Pradhan *et al.,* 2007)

Compared to traditional compost, urine offers a more concentrated and fast-acting nutrient source. Research in sub-Saharan Africa has shown that applying stored urine to maize, sorghum, and vegetable crops significantly improves yields often comparable to results from chemical fertilizers (Adeoluwa & Cofie, 2014). However, researchers did discover that urine fertilization increased the relative amounts of nitrifying and denitrifying groups compared to synthetic fertilizer - implying that more nitrogen oxides could be emitted when fertilizing with urine

Fresh urine is composed of 95 % water with the remaining 5% made up of amino compounds, such as urea or creatinine, organic anions, and inorganic salts, making it a source of bioavailable nutrients and micronutrients for plant growth. After 12 months of storage, urine had a depleted microbiome but contained few common strains of urine. Thus, storing urine for several months, with the resulting increase in its pH value (about 9 rather than 6.5 for fresh urine) and its free ammonia concentration, is considered sufficient to inactivate most human pathogenic bacteria and break down extracellular DNA. Soil bacterial communities were resistant to urine fertilization, with only 3% of groups of organisms impacted. The urine's high salt concentration had little discernible effect on the bacterial community (Adeoluwa & Cofie, 2014).

However, nutrient variability across individuals and populations requires some standardization or blending before large-scale application. Despite this, the urine’s high nutrient density makes it a practical and accessible input for farmers

Effects of urine fertilizer on crop yield

Several field and greenhouse studies have shown that human urine significantly boosts crop yield, often matching or exceeding those obtained in conventional synthetic fertilizer across various agro-ecological zones. Its high nitrogen content enhances vegetative growth, while phosphorus and potassium contribute to root development and fruiting. In a comparative trial, Pradhan *et al.,* (2007) reported that cabbage fertilized with stored urine performed equally well as artificial fertilizer with no negative effect on taste or appearance.

Research in Zimbabwe, Guzha *et al.* (2005), observed that urine application increased maize yield by 30-50% compared to non-fertilized control plots. Similarly, in Ghana and Nigeria, urine applications in vegetable farming (e.g amaranth, tomatoes, and cabbage) produced yields compared to urea-treated plots while reducing input cost (Adeoluwa & Cofie, 2012).

However, excessive or continuous application without dilution can lead to ammonia toxicity, an increase in salinity, or nitrate leaching (Richert *et al.,* 2010). To avoid this, urine is often diluted at a 1:3 to 1:10 ratio with water before use.

Urine handling, storage, and application technique

The safe and effective use of human urine in agriculture depends heavily on proper collection, storage, treatment, and application. Fresh urine is generally sterile but once excreted, it can be contaminated if not properly handled. The safe storage and application practices are crucial to minimize health risks and nutrient loss.

i. Collection and storage:

Urine is typically collected using urine-diverting toilets, jerry cans, or tanks fitted with closed lids to minimize odor and contamination. To improve safety, the World Health Organization (WHO) recommends storing urine at least 1-6 months, depending on ambient temperature, to inactivate pathogens (WHO, 2006). Storage also leads to urine hydrolysis, converting urea to ammonia, thereby increasing its fertilizing effect (Jonsson *et al.,* 2004)

ii. Dilution and Application:

Urine can be applied:

Neat (undiluted) for high-demand crops, especially during active growth stages. According to Hoglund *et al.* (2002), urine is considered sterile and can be used as a liquid plant fertilizer directly without further treatment. To overcome this problem, a urine diversion (UD) or no mix toilet has been designed by Larsen *et al.,* (2001) to separate human urine at source. Urine can be diluted (1:3 to 1:10 with water) to reduce the risk of plant burn and odor, especially in seedlings or light feeders (Richert *et al.,* 2010)

Application is usually done by furrow placement or around the root zone, avoiding contact with leaves. This method improves nutrient uptake and reduces ammonia volatilization.

iii. Integration with Organic Materials

To enhance nutrient retention and reduce leaching or odor, urine is sometimes combined with biochar, ash, compost, or even sawdust (Pradhan *et al.,* 2010). These mixtures can also serve as slow-release fertilizers and improve soil structure.

Safety Measures

Farmers are advised to wear gloves and wash their hands after handling stored urine. Crops that are consumed raw, like lettuce, should not be fertilized with fresh urine unless there's a waiting period of 1-2 months before harvest (WHO, 2006)

Barriers to adoption

Perceptions, acceptance, and cultural barriers

Despite its agronomical significance and benefits, the adoption of human urine as fertilizer is strongly influenced by cultural beliefs, social norms, and the perception of hygiene. In many societies, urine is considered a taboo or 'waste', making its acceptance in agriculture a major challenge (Muriwah & Amoah, 2010)

Studies from sub-Saharan Africa and South Asia reveal mixed reactions, while some farmers are open to using urine due to its low cost and visible yield benefits. Others reject it due to concerns of smell, disease transmission, or religious beliefs (Dogerskag & Bonzi, 2010; Mehta *et al.,* 2013). For example, in Ghana, women farmers were more reluctant to handle urine due to social stigma, even when they were aware of its benefits (Muriwah & Drangert, 2011). However, study by Moussa *et al.* (2021) in Niger showed that women farmers successfully adopted sanitized human urine called Oga, a local innovation as a fertilizer in cultivating Pearl beans (Pennisetum glaucum). This resulted in 30% yield increased when it was compared to organic fertilizer.

Education and demonstration trials have been shown to increase acceptance, especially when farmers can observe improved crop performance and economic savings. Where community-led sanitation or ecosan projects have promoted urine reuse through training, perceptions tend to improve over time (Kvarnstrom *et al.,* 2011)
Religious views also play a role. In some Muslim communities, the use of urine in agriculture is seen as impure; however, scholars have debated whether stored, sanitized urine may be accepted for non-edible crops. Therefore, context-specific awareness campaigns and local leader involvement are crucial to addressing resistance.

Health, Sanitation, and Regulatory Considerations

The safe use of human urine in agriculture must align with public health and sanitation standards to minimize potential risks. Although fresh urine is typically sterile in healthy individuals, contamination can occur during collection, storage, or handling, especially in settings with poor hygiene practices (WHO, 2006). To ensure safety, the World Health Organization recommends storing urine for 1-6 months, depending on temperature, before use on food crops. This period allows for the inactivation of pathogens, particularly in urine that may be mixed with a small amount of faeces or collected in non-sanitary conditions (Schonning & Stenstram, 2004).

Human urine has minimum risk of infection, especially when complying to the duration of storage. However, as an additional safety measure, urine could be restricted to crops that are to be cooked or processed before consumption. Although hormones and pharmaceuticals are partly excreted with urine, there is a small possibility that this will be absorbed by plants and enter the human food chain. This risk is minimal compared to the risk in pharmaceuticals in animal manure, pesticide and herbicide (WHO, 2006).

In a study conducted in Australia by Engel *et al.* (2026) on modelling the health risk of urine-derived fertilizer application in Urban green areas using quantitative microbial risk assessment, the result showed that deactivating bacteria and virus can meet safety target through an extended period of time.

Environmental and Economic Implications

Using human urine as fertilizer offers significant environmental and economic advantages, especially in the context of sustainable agriculture and climate-smart practices.

i. Environmental Benefits

Urine diversion and its uses reduce the nutrient load in the wastewater, helping to prevent eutrophication of water bodies caused by nitrogen and phosphorus run-off (Winker *et al.* 2009). By recycling nutrients, locally urine-based fertilization contributes to closed-loop nutrient cycles, thereby reducing the demand for synthetic fertilizers, which are energy and cost-intensive to produce and often contribute to greenhouse gas emissions (Mourer *et al.,* 2006)

Urine application, particularly when paired with carbon-rich materials like biochar or compost, can improve soil fertility, reduce nutrient leaching, and enhance soil organic matter retention, hence contributing to long-term land productivity (Nartey & Zhoa, 2014)

ii. Economic Advantages

From an economic perspective, human urine is free and locally available, making it especially attractive to resource –poor small-holder farmers. Studies in sub-Saharan Africa have shown that farmers who replace synthetic fertilizers with stored urine can reduce costs by 50-80% while maintaining or improving yields (Adeoluwa & Cofie, 2012).

Additionally, adopting a urine system of fertilization can reduce household and municipal sanitation costs by lowering the volume of wastewater needing treatment. In an urban area setting, integrating urine into the eco-sanitation models could create economic opportunities through decentralized fertilizer production and sales. However, scaling up remains limited by the lack of formal market structures, investment in collection infrastructure, and public awareness. Government incentives and demonstration projects may help unlock these benefits at scale.

Potential role in food security and sustainable agriculture

The adoption of human urine as a liquid fertilizer aligns strongly with the principle of sustainable agriculture and offers a viable pathway to improve food security, especially in low-income and resource-constrained settings.

a. Improving food accessibility and Affordability: Human urine provides a cost-free source of essential nutrients, making it highly accessible for smallholder and subsistence farmers who struggle to afford commercial fertilizer. In countries like Ghana and Burkina Faso, urine application has led to increased yields in maize, vegetables, and legumes, thus enhancing household food availability (Dogerskag & Bonzi, 2010; Guzha *et al.,* 2005).

By reducing dependency on costly external inputs, urine-based fertilization can stabilize food production during economic shocks, supply chain disruption, or inflation, all of which threaten food security.

b. Enhancing sustainability and resilience: The use of urine supports circular agriculture – integrating human-derived nutrients into the food system. This practice conserves resources, minimizes environmental pollution, and supports climate-smart agriculture by reducing fossil-fuel-based fertilizer use and enhancing soil health (Jonsson *et al.,* 2004; WHO, 2006).

In areas facing land degradation, drought, or nutrient depletion, urine can serve as a quick response solution for soil recovery when combined with organic matter, thereby promoting agroecological resilience.

c. Community and Institutional Integration: Programs that integrate the use of urine in school gardens, urban farming, or community-led sanitation can offer both food and education. By involving farmers, local leaders, and extension agents in participatory models, awareness and acceptance of the practice can increase, leading to broader uptake (Kvarnstrom *et al.,* 2011).

Ultimately, scaling urine fertilizer use, when supported by policy, education, and health safeguards, can contribute to local and national food security targets in line with SDG 2 (Zero Hunger) and SDG 6 (Clean water and Sanitation). The aim of SDG 2 is to end hunger by ensuring all year-round access to food for all, especially the poor and the vulnerable. improve nutrition, promote sustainable agriculture by doubling smallholder productivity and incomes of small-scale food producers, including women, indigenous people, family farmers, pastoralists, and fishers and achieve food security by 2030 (United Nations, 2015). In the same vein, SDG 6 is to ensure availability and sustainable management of clean water for all by 2030 targeting universal and equitable access to safe and affordable drinking water for all, substantially increase water use efficiency and ensure sustainable withdrawals to address water management, improve water quality by reducing pollution, eliminating dumping, minimizing hazardous chemical, reducing untreated water, increasing recycling and reuse of water (United Nations, 2015). These goals are deeply interconnected as sustainable farming in SDG 2 depends on water efficiency from SDG 6, unsafe water and poor sanitation causes diarrhea which prevent nutrient absorption and undermines SDG 2 even when there is availability of food. More so, safely managed human waste (excreta/urine) can be recycled as fertilizer supporting sustainable agriculture in SDG 2

Summary

The summary of key studies on human urine used in crop production is presented in Table 1.

Research gaps

Despite growing knowledge of the use of urine for crop fertilization, several knowledge gaps and implementation barriers remain that limit its widespread adoption and impact on the food system. Research is needed to explore sustainability over multiple impacts, growing seasons, and under different agro-ecological zones.

a. Variability in urine nutrient content makes it difficult to define standard application rates. Further research is needed on blending, dilution practices, and dose-response relationships across crop types to optimize use and reduce risks of over-fertilization or nutrient run-off.

b. Pathogen risk and Sanitation links: More data are needed on the pathogen survival rate in diverse climates and sanitation behaviors among farmers in Nigeria.

d. Clear regulatory guidelines and economic feasibility models for large-scale collection, treatment, and distribution are largely underdeveloped, especially in underdeveloped countries like Nigeria

e. Emerging technologies like biochar-urine blends, decentralized urine-treatment blends, decentralized-urine units, and mobile urine collection systems present promising innovation. Future research should assess their scalability, affordability, and impact on circular farming systems

Conclusion

The objective of the study is the use of human urine as liquid fertilizer for smallholder crop production. This review presents a practical, low-cost, and environmentally sustainable strategy to enhance crop production and to address food insecurity, particularly in low-income and agriculturally vulnerable regions. Its high nutrient content, especially nitrogen, phosphorus, and potassium, makes it a viable alternative to synthetic fertilizers, which are often unaffordable or inaccessible to smallholder farmers.

Evidence from various regions demonstrated that urine can improve crop yields, reduce input costs, and contribute to circular nutrient flows, especially when paired with complementary organic materials like biochar, ash, or compost. Additionally, the use of urine aligns with global goals for sustainable development, climate resilience, and resource recovery.

However, adoption remains limited by cultural resistance, lack of policy support, safety concerns, and gaps in long-term agronomic data. Overcoming these challenges requires a multi-sectoral approach involving farmers, researchers, and policymakers. Community education, gender sensitive engagement, supportive regulation, and innovation in collection and treatment systems are all critical to scale up the use of urine safely and effectively.

Integrating urine-based fertilization into sustainable agriculture offers a promising solution to improve soil fertility, strengthen food systems, and close the nutrient loop. With targeted research, investment, and public engagement, human urine can be repositioned from waste to resource, supporting food security and environmental sustainability in the 21st century

Table 1: Summary of Key Studies on Human Urine Used in Crop Production

Authors	Crop studied	Method of Application	Location	Key Findings
Guzha *et al.* (2005)	Maize *(Zea mays)*	Direct application to root zone	Zimbabwe	30-50% yield increase over control. Similar to chemical fertilizer
Adeoluwa & Cofie (2012)	Amaranth (*Amaranthus caudatus)*	Urine + Water (1:3)	Ghana	Comparable yield to urea fertilizer
Pradhan *et al.* (2007)	Cabbage (*Brassica olerace*a)	Urine + Compost	Finland	Increased tuber weight and nutrient content
Mariwah & Drangert (2011)	Mixed vegetables	Stored Urine	Ghana	Increased yield
Richert *et al.* (2010)	Maize *(Zea mays*) Potatoes (*Solanum tuberrosum*) Cabbage (*Brassica oleracea*)	Stored and diluted	Niger	Increased yield
Nartey & Zhao (2014)	Soil studies	Urine + biochar	China	Enhanced soil Properties
Pandorf *et al.* (2019)	Beans (*Phaseolus vulgaris*	Urine only	USA	Matched synthetic fertilizer yield
Pradhan *et al*. (2010)	Beets (*Beta vulgaris)*	Urine combined with wood ash	Finland	Increased yield more than that of artificial fertilizer
ESAFF Uganda (2024)	Maize (*Zea mays) Banana* (*Musa spp*), leafy greens (*Amaranthus spp)*	Fermented urine	Uganda	Crop vigor and yield. Reduced harvest time and cost-effective farming practice
Heinonen-Tanski *et al.* (2007)	Cabbage (*Brassica oleracea*)	Human Urine only at 180kgN/ha	Finland	Increased yield, no significant hygienic threats or flavor.
Akpan-idiok *et al.* (2012)	Okra (*Abelmaschus esculentus*)	Human urine at the rate of 10,000. 15000 and 20,000L/ha	Cross River State	Increased in growth and yield compared to artificial fertilizer
Ekwere (2021)	Okra (*Abelmaschus esculentus*)	Treated human urine	Abak irrigation project. Akwa Ibom State	Significant in yield compared to inorganic fertilizer
Alamu *et al.* (2023)	Amaranth *(Amaranthus hybridus)*	Diluted human urine	Nigeria	Enhances soil microbial density and amaranth yield outperforming artificial fertilizer
Sheneni *et al.* (2015)	Maize (*Zea mays)*	Male and female urine	Kogi	Influences maize growth and phytochemical content
Adeoluwa *et al.* (2016)	Tomatoes (*Solanum lycopersicum*)	Human urine–compost mixture 2:1	University of Ibadan, Oyo State	Improved soil fertility, tomato yield and shelf life
Jonsson *et al.* (2004); Richert *et al*. (2010); Lundstrom & Linden (2001)	Barley (Hordeum vulgare) and Wheat (*Triticum durum)*	Human urine only. 40:80:120kgN/ha during growing season	Sweden	Increased yield. Urine nitrogen as effective as ammonium nitrate
Gensch & Miso (2008)	Maize	Human urine only. 60kgN/ha	Burkina faso	Increased yield
Sridevi (2011)	Banana *(Musa spp)*	Diluted human urine + water 1:5	India	Crops showed better yields, nutrient content, and cost benefit ratio
Moussa *et al.* (2021}	Pearl millet (*Pennisetum glaucum*}	Sanitized human urine (Oga)	Niger	30% increased yield compared to inorganic fertilizer

Source: Authors' compilation from reviewed literature (2000-2025)

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