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Forage grass management using treated cassava wastewater in Kalasin, Thailand

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Abstract. *Chinnabutr K, Poungchompu S. 2025. Forage grass management using treated cassava wastewater in Kalasin, Thailand. Asian J Agric 9: 645-652.* At present, both small and large-scale farmers have been widely using forage grass production for animal feed, which can effectively reduce the cost of animal production and improve feed availability throughout the year. This study evaluates the economic benefits of using treated cassava wastewater for forage grass production in Kalasin Province, Thailand. Surveys were conducted during the 2021-2022 crop season with 90 farmers, including 50 users with treated wastewater and 40 farmers dependent on other water sources. Data was analyzed using descriptive statistics and an independent t-test. The results showed that farmers using treated wastewater obtained higher yields (36,253.882 kg/ha) and lower production costs (578.352 US\$/ha) compared with non-users (25,035.751 kg/ha; 731.244 US\$/ha). Net returns were also significantly higher among users (1,089.327 US\$/ha or 0.030 US\$/kg) than non-users (470.472 US\$/ha or 0.019 US\$/kg). Statistical analysis showed that yield ($t = 3.19$, $p<0.05$), cost ($t = 1.79$, $p<0.01$), and profit ($t = 4.29$, $p<0.01$) had significant differences. In addition, treatment was found to reduce fertilizer costs for farmers using wastewater by 150.50 US\$/ha and enable them to sustain pastures into the dry season. This result clearly indicates that wastewater reuse is both cost-effective and environmentally friendly. This not only minimizes input costs and increases profitability, but also serves as a nature-based solution in support of year-round forage production in sustainable cassava-based farming systems.

Keywords: Forage grass, production costs, returns, treated water from cassava factories, wastewater

INTRODUCTION

In Thailand, the cultivation of forage grass is necessary to help the country's livestock sector, particularly in the northeast. This region with arid soils and difficult climatic conditions can generate little economic wealth through traditional crops. Therefore, promoting the cultivation of fast-growing forage has become an essential strategy for supporting livestock farmers. These include napier grass (*Pennisetum purpureum*), Guinea grass (*Megathyrsus maximus*), and ruzi grass (*Brachiaria ruziziensis*), which are most commonly cultivated to feed cattle, dairy cows, buffaloes, goats, etc., that belong to the zoological order Artiodactyla. These grasses not only decreased the dependency on expensive concentrate feeds, but they also offer economic benefits as well, which include the multiple harvests a year-usually around 45 to 60 days, which meant continuous cash flow and the most optimum use of land. Napier grass averaged 8,000 tons/ha/year with a net profit of 684.93 US\$/ha, which was considerably higher than Jasmine rice (2,016.25 kg/ha; 193.96 US\$/ha) (Capstaff and Miller 2018; Bureau of Animal Nutrition Development 2021). This comparative advantage underscores the potential of forage farming as a low-cost and productive alternative land-use system in highland and dry-tropical areas in Thailand. Moreover, the government of Thailand has recognized the importance of sustainable livestock development and has encouraged farmers to integrate forage production with other agricultural activities. This approach not only improves household income but also strengthens national food security and reduces reliance on imported animal feed. In addition, the expansion of forage grass plantations contributes to better the country's long-term agricultural sustainability goals.

The rapid growth of Thailand's cassava industry has raised serious environmental alarms. A total volume of about 21 million cubic meters of wastewater is generated per year and with high levels of biological oxygen demand (BOD), chemical oxygen demand (COD), nitrogen, ammonia, and suspended solids (Olukanni and Olatunji 2018). To reduce these risks, treatment processes have been applied in factories to treat pollutants to an allowable level (BOD<60 mg/L; pH 5.5-9.0) and to recover nutrients, specifically nitrogen, phosphorus, and potassium (Pollution Control Department 2022; Aguilar-Torrejón et al. 2023; Achi et al. 2024). Treated water, especially wastewater, is therefore an important source of irrigation and can help to diminish the use of chemical fertilizers and contribute to sustainable agriculture (dos Santos et al. 2022; Parra-Orobio et al. 2023). The untreated cassava wastewater has long been known to be a source of environmental pollution, while properly treated cassava wastewater can be used as an important agricultural input to enhance crop productivity and diminish dependency on chemical fertilizers (Velasco-Muñoz et al. 2022). In sum, using treated cassava effluent as an irrigation source represents an ecofriendly and cost-effective innovation for agricultural areas suffering from limited water resources.

Recent research has shown that the effluent offers an option for an alternative water supply that can potentially benefit the economy and environmentally sound irrigation. In Northeast Thailand, cassava factories where smallholder farmers sell their crop can facilitate access to treated waste for free, allowing for additional water for dry land cropping. Most of the forage production in provinces such as Kalasin utilizes this method to stabilize supply, decrease input cost, and secure farm income against climate change (Putra et al. 2025; Ungureanu et al. 2025). However, information from experiments on forage grass grown under treated cassava wastewater irrigation in terms of economic and ecological performances is limited, particularly for smallholders in the northeast of Thailand. This knowledge gap limits evidence-based guidelines for the expansion of wastewater reuse in animal feed production. Based on this gap, the study assumes that utilization of treated cassava effluent can result in higher break-even yields with lower costs and higher net returns compared to the water use practice. The purpose is to evaluate the economic viability of forage grass grown using treated cassava effluent in Kalasin Province, Thailand.

MATERIALS AND METHODS

Study area

The survey was carried out in Mueang Kalasin District, Huai Phueng District, and Rong Kham District, Kalasin Province, located in the central area of Northeastern Thailand (approximately between 16º26′-16º48′ N latitude and 103º25′-103º45′ E longitude). The climate of Kalasin Province has a typical tropical savanna climate, and the average annual temperature is about 27-30°C, with 1,000-1,300 mm annual rainfall, which is suitable for forage grass growth. It is approximately 519 km from Bangkok and covers a total area of 6,946.75 square kilometers (Figure 1). This area represents about 4.1% of the Northeastern region. Agricultural land makes up 2,672,715 rai (427,634 ha), or 61.55% of the province's area. The total area includes 1,542,609 rai (246,817 ha) for rice cultivation, 656,810 rai (105,090 ha) for field crops, 225,153 rai (36,025 ha) for fruit and perennial trees, 3,343 rai (535 ha) for vegetable gardens and ornamental plants, and 244,800 rai (39,168 ha) for other agricultural uses (Kalasin Provincial Agricultural Office 2022).

Data collection

This research, which examined the management of forage grass production by farmers in Kalasin Province, focused on the use of treated water from cassava factories. The study's sample consisted of farmers producing forage grass for sale in the Mueang District and the Huai Phueng District, as recommended by the leader of the District Agricultural Extension Office, during the production year of 2021-2022. The study population consisted of all farmers, comprising 90 members, 50 of whom used treated wastewater and 40 used untreated wastewater.

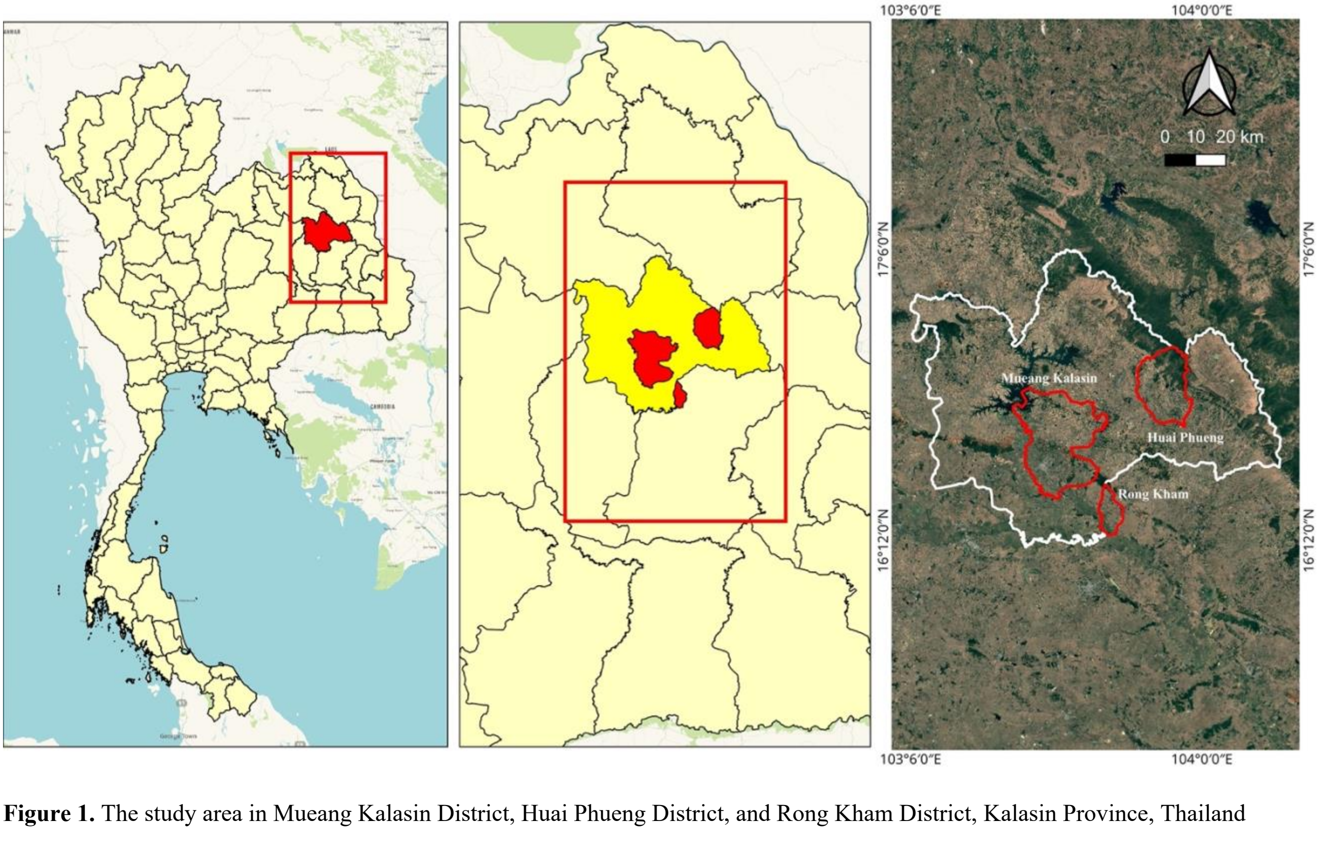

Figure 1. The study area in Mueang Kalasin District, Huai Phueng District, and Rong Kham District, Kalasin Province, Thailand

Sampling technique

A representative sample was established using Taro Yamane's formula, and the purposive sampling technique was employed. Purposive sampling was employed because only a few farmers residing in the study area had access to and were using treated cassava wastewater, which made random sampling virtually impossible. The data was collected using questionnaires containing both closed-ended and open-ended questions.

The research explored the practices of forage grass production management among farmers in Kalasin Province, Thailand, and the use of treated wastewater from cassava starch processing plants. The study was conducted in order to evaluate and compare the production practices of farmers using treated wastewater with those of farmers who were not using treated wastewater. The target respondents for this study were forage grass growers living in the Mueang and Huai Phueng Districts. The district Agricultural Extension Officers reported these two districts as the two main forage-producing and working districts during the growing year of 2021-2022.

The total population was 90 farmers, 50 of whom were using treated wastewater and 40 of whom were not. The sample size was calculated through the application of Taro Yamane's formula for a finite population at a 95% confidence level and with a 5% margin of error to ensure the representative nature of the findings. The respondents were purposively selected, having the experiences and insights that met the requirements of the study. The data was collected through semi-structured interviews with some closed and open questions.

Treated effluent

Treated effluent (BOD<60mg L^{-1}; pH BOD 5.5-9.0) was collected from a small local cassava factory with anaerobic and aerobic wastewater treatment systems, based on Thai standard effluent discharge criteria (Pollution Control Department 2022; Aguilar-Torrejón et al. 2023; Achi et al. 2024). Farmers during the dry season used 25-30 m^3/ha of treated wastewater per irrigation. These results are in line with a study by Bezerra et al. 2017 maximum forage yield response to 120m^3/ha/cut in *Brachiaria brizantha* under cassava mill effluent treatment. Thai standards that the Ministry of Industry released include pH 5.5-9.0, COD≤400 mg/L^{-1}, BOD≤60 mg/L^{-1}, TKN≤200 mg/L, SS≤150 mg/L, and TDS ≤5000 mg/L (Costa et al. 2020). These standards are to ensure sufficient effluent treatment before discharge, among which the anaerobic UASB system is being adopted in cassava factories for simultaneous treatment and biogas recovery.

During the crop growth cycle, information on yield, frequency of irrigation, application of fertilizers, and marketing was collected through farm gate observations. Yield was reported in fresh biomass (kg/ha) and values related to dollars per hectare for the economic data. This methodology facilitated the collection of quantitative data that was amenable to statistical analysis, as well as qualitative data related to the participants' perceptions, practices, and challenges. Two interview guidelines were prepared: one focused on forage grass farmers and the other on forage grass collectors. The farmer protocol dealt with issues including cultivation practices, production management, water usage, input costs, returns to sales, and institutional support. The collector schedule included a business profile, procurement and distribution practices, volume (capacity) management, and insights into market issues and policy recommendations. To conduct proper, complete, and contextual data collection, all interviews occurred at the field site in the presence of the researchers, as well as the trained research assistants.

Data analysis

In this research, both descriptive and inferential statistics were used to enhance the depth of knowledge of forage grass production management, and the market practices of the lands utilized by the farmers in the study area of Kalasin Province. Based upon the respondents' characteristics and the detailed information shared about the different production management procedures, involving land preparation, planting practices, irrigation types, weed control, harvesting, and marketing, the summary statistics were compiled, which consisted of frequency distributions, percentages, means, and standard deviations. These analyses were used to draw inferences from the general patterns and trends of the commercial forage grass-growing farmers. Both descriptive and inferential statistics were used. The analyses were performed with IBM SPSS Statistics (version 17.0; IBM Corp 2017). Descriptive statistics were used to describe frequency distributions, percentages, means, and standard deviations, while inferential analysis used an independent t-test to compare the users and non-users of wastewater.

RESULTS AND DISCUSSION

Farmer characteristics

The study described a general profile of forage grass farmers in Kalasin Province. The majority of producers were male (72.3%) and had an average age of 54 years. Most of them were married and had finished primary school as shown in Table 1. They were primarily rice farmers with trade as a secondary occupation, and the majority of them had cultivated cassava and rice, with forage grass later introduced. The increasing demand for forage grass, due to good market prices offered, short growth cycle (monthly harvesting), and easy cultivation process, has placed it on the same level as other economic crops usually harvested only once a year. Increased cultivation of forage grass varieties provides farmers with potential income-generating opportunities, and adopters enjoy higher biomass yields and increased profitability due to multiple harvests each year. These farmers viewed forage grass as a new crop with low production costs and high profitability. Additionally, the crop has been promoted by the Kalasin Provincial Livestock Office. However, the supply of forage grasses fails to meet demand because it is increased with the soaring population of ruminants, up 48.44% over the national goal of developing livestock production and competitiveness in the international market. As a major roughage source, forage grass also cuts down feed costs and directly impacts livestock production and sustainability in tropical systems. Forages like Pangola grass are known for their flexibility, high digestibility, and the ability to enhance nutrient utilization efficiency and animal growth (Alfaro et al. 2022; Kearney et al. 2023; Basheer et al. 2024; Holzknecht et al. 2025).

Production management

The average area planted to forage grasses among those farmers using treated water was 1.47 ha, with the majority cultivating less than 4.48 ha per productive unit. Israeli stevia was identified as the most suitable species because of its high nutritive value and multi-feeding applications for small-scale livestock (e.g., ducks, chickens, crickets, grasshoppers) and aquaculture species (ducklings and fish) without prior chopping. Napier Pak Chong-1, Dwarf Napier, Emperor Napier, Taykhuan Super Leaf Napier, Sweet grass, and Pangola grass were used as forage grasses. Cuttings were mostly used for planting because they are easier to cultivate, sprout faster, and save considerable amounts of money and time compared to seed sowing. The average cutting rates per rai were as follows: 2,888.89 pieces for Napier Pak Chong-1, 3,397.92 pieces for Dwarf Napier, 3,117.11 pieces for Emperor Napier, and 3,390.71 pieces for Israeli stevia. The average spacing between the rows and plants was 66.67 x 67.22 cm, 70.50 x 62 cm, 67.89 x 62.92 cm, and 64.40 x 62.80 cm, respectively as shown in Table 2. For Pangola grass, the spacing was 155.36 cm. Pipes pumped water from treatment ponds into the furrows dug within the plots for watering. Depending on the species, fresh grass can be harvested every 45 days, with most harvesting done manually. However, larger farms employed both manual labor and machinery to harvest as fresh grass and cuttings for sale.

Environmental benefits and use of treated waste

The release of wastewater from cassava factories in Kalasin Province has led to significant pollution in local water sources. To solve this issue, factories and governmental agencies have been working together to reduce environmental harm and create value for the community. One of the solutions has been to supply treated wastewater to farmers for agricultural purposes. Cassava starch wastewater (CSW) contains high levels of nutrients, such as nitrogen and phosphorus, which, if left untreated, can damage ecosystems by encouraging excessive weed growth. However, when responsibly managed, these nutrients can be beneficial for agricultural activities, such as irrigation. Regarding the farmers, they typically use between 6.4 and 8.0 cubic meters of water per rai per day, which is drawn from factory treatment ponds during operating hours. Around 10 cubic meters of water per rai per day are generally released by the factories, which total 5,000 to 6,000 cubic meters per month, except during the rainy season from June to October. The PVC tube supplies water to the forage grass plot, which distributes it through soil furrows connected with 32 mm PVC joints. Grass can be harvested approximately 45 days after planting (Figure 2). While the utilization of recycled water is advantageous, it also involves expenses. Farmers need permission to use water, with farmers farther from the factories paying top dollar for PVC-pipe expansion. Extra expenses are for fuel (54.98 US$/ha) and PVCs installation (4.30 US$/ha). However, this is counterbalanced by long-term savings costs of (up to 121.91 US$/ha) particularly from the reduced use of fertilizer compared with other conventional water sources such as irrigation and ground water. Therefore, cassava factory effluent becomes a recycled industrial by-product for sustainable runoff conservation and to increase forage grass production.

The results clearly show that the use of treated wastewater for irrigation is environmentally and agronomically successful, avoiding discharge of untreated effluents to water bodies. This is in agreement with the findings of Okunade and Adekalu (2017), who found that biological treatment is effective at reducing toxic cyanide in cassava effluent for reuse. Where wastewater is concerned, which is rich in essential nutrients, if treated can substitute for chemical fertilizer and sustain crop growth luxuriously as per Bezerra et al. (2017). In the same vein, Bureau of Animal Nutrition Development (2021) reported higher nutrient content in forages irrigated with treated wastewater, which is essential for better productivity. Velasco-Muñoz et al. (2022) also highlighted that wastewater reuse is core to the circular economy, converting industrial waste into essential agricultural inputs, producing renewable biogas and recycling nutrients back into farming systems for sustainable agriculture.

Table 1. Socio-demographic characteristics of forage grass farmers

Characteristic	Category	Percentage (%)
Gender	Male	72.3
	Female	27.7
Marital status	Single	11.11
	Married	87.78
	Divorced	1.11
Education level	Primary school	40
	Lower secondary	21.11
	Upper secondary	22.22
	Diploma	3.34
	Bachelor’s degree	13.33

Table 2. Average cuttings and planting spacing of forage grasses grown by treated-wastewater users

Forage grass	Average cuttings per rai (pieces)	Average spacing (cm)
Napier Pak Chong-1	2,888.89	66.67 × 67.22
Dwarf Napier	3,397.92	70.50 × 62.00
Emperor Napier	3,117.11	67.89 × 62.92
Israeli Stevia	3,390.71	64.40 × 62.80

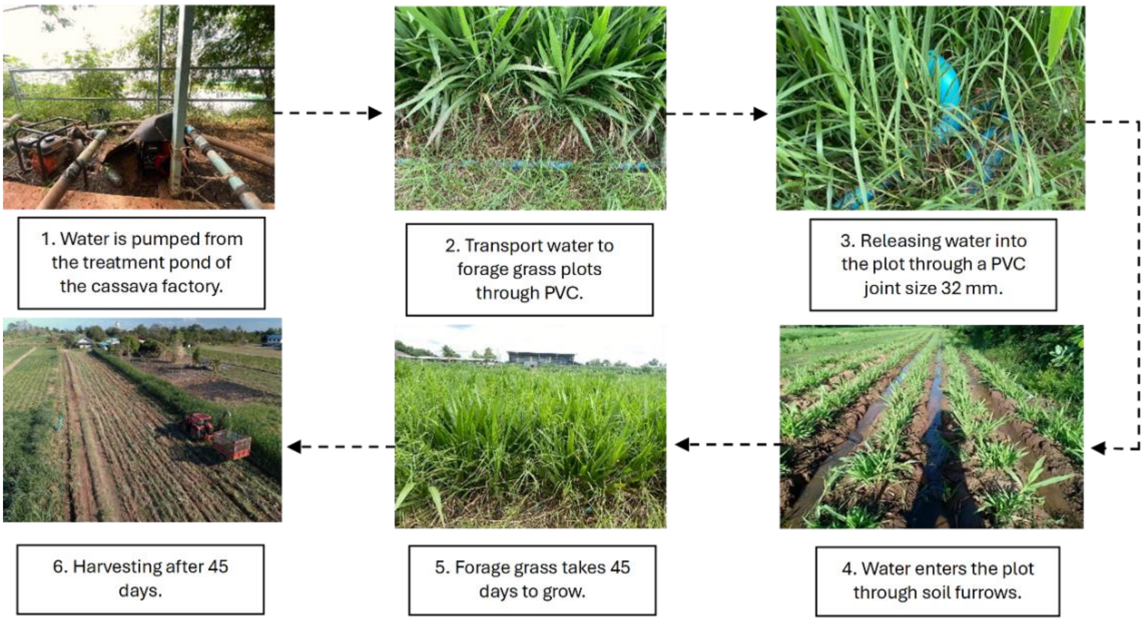

Figure 2. The process of forage crops using wastewater from the cassava starch industry

From an economic perspective, the reuse of reclaimed water represents a long-term investment in savings, especially with regard to fertilizer costs (Costa et al. 2020; Putra et al. 2025), which stresses its double benefit for reducing farm costs and improving environmental sustainability. Temporary costs are due to construction, e.g., pipe and fuel, but these are mitigated by ongoing forage supply and reductions in input expenses. In Kalasin, cassava wastewater reusing is thus a sustainable solution which combined productivity of soil crop and environmental conservation. It is also economic feasible to turn pervasive pollution source into valuable resources in rural area, promote the development of livestock field, and decrease chemical fertilizer dependence. Both sets of results reflect both applications in the field and an increasing body of scholarly work that establish water reuse as a sustainable avenue for agricultural growth.

Costs and return analysis

Farmers from both groups had large labor costs for plowing, planting, fertilizing, watering, and harvesting. In contrast, farmers had lower average total costs for production (578.352 US$/ha) using treated water (29.07% for labor cost). These were small-scale farmers, most of whom relied on their families for labor. However, during periods of planting and harvesting, some laborers were hired. For farmers that used treated water, they earned more than those farmers, who did not use treated water by around 618.855 US$/ha because the farmers using treated water were able to grow forage grass throughout the year. Meanwhile, the farmers, who did not use treated water, were limited by season. After accounting for all the expenses, the net income per hectare for treated water users (1,089.327 US$/ha) was greater than that for non-treated water users (470.472 US$/ha). Additionally, treated water users had a higher net income/kg of grass (0.011 US$) and were able to produce more (11,218.131 kg/ha). This result shows the economic feasibility of using treated water for the forage grass production (Table 1). The studies discussed Napier grass and other forage crops. Therefore, they support the idea that treated wastewater can lower production costs by an average of 152.892 US$/ha, a savings that can be attributed to the nutrients contained in the water, particularly nitrogen, which promote the growth of plants. For farmers lacking treated water, however, fertilizer prices pose a significant financial burden, as they can make up to 39.94% of their variable costs (Manouchehrinejad et al. 2020; Fuglie et al. 2021). These results highlight both the cost savings and yield advantages that are offered to forage production through the economic and sustainable use of treated water. Thus, these results highlight the benefits and sustainability of treated water in forage production in terms of cost-effectiveness and productivity.

Moreover, the analysis further identified key differences between the two groups of farmers. As illustrated in Table 4, this hypothesis was also validated since those who were using treated water had a higher average income (1,667.679 US$) than those who did not use treated water (1,201.716 US$). In addition, there was a statistical significance at the 1% level ($p<0.05$). This evidence implies that the increased income was not merely a product of chance. Additionally, the farmers, who were using treated water had lower production costs with an average of 578.352 US$ versus 731.244 US$ for farmers, who did not use treated water. The difference in cost was also statistically significant ($p<0.01$), and it corresponded to a relevant reduction, which was probably associated with a lower demand for complementary fertilizers. The net profit figures clearly illustrated that those farmers, who had applied treated water, made a net profit of 1,089.327 US$, compared to 470.472 US$ for those farmers, who did not. Evidence of this difference is shown in Table 3. This difference ($p<0.01$)

between the mean profits showed the strong impact of water use from those farms that used water for crops that had been treated, since it allows for more efficient production all year round and less dependence on expensive inputs. These findings were consistent with earlier studies by Elahi et al. (2017) and Manouchehrinejad et al. (2020). From this study, it was discovered that treated water containing added nutrients, such as nitrogen, also results in plants with enhanced growth characteristics and a decrease in chemical inputs, both of which translate into increased profitability. We can conclude that forage grass production using treated water from cassava factories can result in higher returns or profits than forage grass production using other water sources. As illustrated in Table 4, the average annual household income of farmers using the treated water (9,908.14 US$) was significantly higher than that of non-users (7,061.81 US$; p<0.05). Their production cost was lower (3,322.17 US$/ha) compared with non-users (4,333.25 US$/ha; p<0.01), indicating reduced input expenses due to the nutrient enrichment of treated wastewater. Thus, the net profit of treated-water users (6,585.37 US$) was significantly higher than that of non-users (2,728.56 US$; p<0.01). The findings confirm that the use of treated cassava wastewater increases farm profitability and efficiency, contributing to a greater economic return and environmental sustainability in using reclaimed water for irrigating forage.

Marketing aspects

Fresh grass and cut plucking were the main marketing products of forage grass farmers using treated water and non-treated water, indicating that the marketing costs may differ between them. Farmers utilizing treated water sold fresh grass at the price of 0.046 US$/kg, and those not using treated water sold fresh grass at a slightly higher price of 0.048 US$/kg. Collection traders paid a price of 0.024 US$/kg, and the marketing costs averaged 0.013 US$/kg. Traders buy fresh grass and cuttings from farmers, and then they sell them as forage. The traders often buy from farmers in bulk and even hire workers to harvest the grass from the fields. In addition, the traders sell fresh-cut grass, allowing them to inspect the produce's condition prior to purchase. Payment is normally in cash and on sale. Fresh grass typically costs between 342.47 to 513.70 US$/ha during the rainy season and 1,712.33 US$/ha during the dry season associated with water scarcity, which drives up prices. Plantation owners set the prices themselves, while the collection traders sell the grass to livestock farmers. Other customers buy cuttings to grow grass themselves for feed for their animals. In summer and winter, small bundles (6-7 bundles) are sold for 2.92 US$ at the farm gate or in summertime, the average price is 0.083 US$/kg. The price for 8-10 kg bundles averaged at 0.058 US$/kg for bigger bundles (3-5 bundles). Then in the rainy season, when forage grass is abundant, the cost of green grass is also about 10-15 bundles for 2.92 US$. In that case, the local traders competed to drive the prices down. Consequently, farmers using treated water were more likely to sell forage grass at a lower price (0.0015 US$/kg) compared to those from the untreated category. On the other hand, treated-water users who marketed produce both on-farm and at pedestrian stalls were also more likely to market off-farm than non-users who sold only on-farm. These temporary stands, which were also positioned beside main roads, also provided points of sale for traders and gatherers.

Table 3. A comparison of the production costs for farmers growing forage in Kalasin Province during the crop years of 2021 and 2022

Items	Using wastewater from the cassava starch industry (1)	Not using wastewater from the cassava starch industry (2)	The difference between Using and Not using wastewater from the cassava starch industry (3) = (1) – (2)
Variable (US$/ha)	480.695	519.863	(39.168)
Fixed cost (US$/ha)	97.657	211.381	(113.724)
Total cost (US$/ha)	578.352	731.244	(152.892)
Yield (kg/ha)	36,253.882	25,035.751	11,218.131
Price per unit (US$/kg)	0.046	0.048	(0.002)
Total revenue (US$/ha)	1,667.679	1,201.716	465.963
Net profit (US$/ha)	1,089.327	470.472	618.855
Net profit (US$/kg)	0.030	0.019	0.011

Table 4. A comparative analysis of incomes, costs, and profits related to forage grass production using treated water and non-treated water

	Production by using treated water (Mean)	Production without using treated water (Mean)	T-test
Income	9,908.140±3554.905	7,061.810±2688.490	3.193**
Grass production cost	3,322.770±1999.574	4,333.254±1362.902	1.789***
Net profit	6,585.370±3970.231	2,728.556±1823.299	4.294***

Note: **Significance level at p<0.05 ***Significance level at p<0.01

Discussions

The overall results reveal that the treated cassava wastewater is more profitable in making a reduction of production costs and increasing net return to forage grass production in Kalasin Province. The nutrients (e.g., N and P) contained in the effluent not only promote plant growth but also reduce the dependence of farmers on chemical fertilizers, which is economically and agronomically beneficial to smallholder farmers. The results were of the same order of magnitude as those found in a study by Pereira et al. (2016), which also emphasized the nutritional wealth of cassava fermentation effluents. Although the yield increases in our study were higher compared to controlled laboratory studies, as found by Costa et al. (2020), they highlighted the ecological advantages of agricultural wastewater for the environment. The current study was done among smallholder farmers with short production cycles, and there was no long-term assessment of soil and water quality. The lack of longitudinal data also means that long-term risks such as salinity accumulation or nutrient imbalances cannot be adequately assessed; therefore, findings are less generalizable.

Additionally, forage grass has a short growing period, but needs sufficient water to increase yield and income (Bezerra et al. 2017; Olukanni and Olatunji 2018). For example, farmers in Kalasin Province, especially those near Cassava factories, increasingly pay attention to animal feed grass instead of traditional cash crops, since their cultivation makes better use of the land. The oversupply of forage grass during the rainy season may reduce prices and increase competition. The use of treated wastewater lowers production costs for farmers living near cassava factories. It has also been reported by Ungureanu et al. (2025); Capstaff and Miller (2018) showed that treated municipal wastewater at 30-40 m^3/ha increased forage biomass up to 25% over the regular water sources. In this study, nutrient loadings such as nitrogen and phosphorus (N, P) absorption were also remarkably enhanced with no accompanied accumulation of heavy metals. Nevertheless, the biomass increases were of lower magnitude compared to those in previous literature, which could be due to the smallholder setting and shorter duration of production in Northeastern Thailand. Additionally, Putra et al. (2025) indicated that the use of effluents treated anaerobically to maintain soil fertility resulted in a 20% reduction in fertilizer cost and an increase in yield per ha. The results found a similar reduction in fertilizer cost but lower yield gain, reiterating once more regional constraints on the smallholder system relative to the wider Indonesian level. In line with Abou Jaoude et al. (2025), it was similarly found that bedding plants, ornamental nursery crops, and soil conditions, which affect the growth performance of crops, increased significantly with the reuse of treated wastewater with better soil health status. Previous studies have reported wider agronomic benefits, but this investigation indicates a lesser, though significant, productivity gain within forage grass systems, therefore maintaining the positive effects of wastewater reuse in other scenarios. As a result, policies must stimulate farmers to grow forage grass utilizing treated cassava wastewater as a sustainable means of generating income, and to agree on environmentally-friendly and community-oriented farming techniques. Hence, these findings indicated that efforts for implementing policies geared toward the use of treated wastewater in agriculture could provide a sustainable source of income for farmers, as well as encourage environmentally friendly practices.

In conclusion, in the present study, the use of treated cassava wastewater for the production of forage grass in the province of Kalasin was investigated, and effectiveness was shown with respect to farm productivity. Users of treated wastewater were found to produce greater yields from lower costs, with higher net profit (618.855 US$/ha; 0.011 US$/kg) in comparison with non-users. This indicates that a promotion of reused water can help in farm-level income generation, reduce dependency on chemical fertilizers, and enhance the sustainability of agriculture and therefore provide support to the policy makers and government departments in other drought-prone areas of the world. However, this study demonstrates that treated wastewater improves yield and profit, though future research could explore scalability and long-term monitoring. Additional research should test the scalability of these practices to other crops and regions.

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