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Consumption-Based Water Footprint Analysis of Food and Non-Food Sectors for Sustainable Management of the Jambo Aye Watershed

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Abstract: Water is a vital resource that supports the sustainability of life and the economic activities of communities. This study analyzes the water footprint (WF) of food and non-food consumption as a basis for water resource management in the Jambo Aye Watershed, Aceh Province, Indonesia. A quantitative descriptive approach was applied using secondary data on household food and non-food consumption from the National Socio-Economic Survey (SUSENAS) of Statistics Indonesia (BPS) and population data for 2023 and 2024. The WF was calculated by multiplying the per capita consumption of each commodity by its virtual water coefficient, adopting the standardized global coefficients of the Water Footprint Network (Mekonnen & Hoekstra), and aggregating the results at the watershed scale; the analysis employed total (aggregate) virtual water values without disaggregating the green, blue, and grey components. The results show that the WF of food consumption reached 688.90 million m³ in 2023 and increased by 8.27% to 745.84 million m³ in 2024, accounting for more than 99% of the total WF, with rice as the main contributor. The WF of non-food consumption was considerably smaller, rising by 9.11% from 3.00 million m³ in 2023 to 3.28 million m³ in 2024, driven mainly by housing and household facilities. These findings indicate that water resource management in the Jambo Aye Watershed should prioritize improving water-use efficiency in the food sector, particularly rice-based agriculture, to support the long-term sustainability of water resources.

Keywords: Food consumption; Jambo Aye watershed; non-food consumption; Water footprint; Water resources

Introduction

Water is a vital natural resource underpinning human well-being, economic development, and ecological stability (Alam, 2024; Gleick & Cooley, 2021; Kanaoujiya et al., 2024). Beyond its role in meeting direct domestic needs, water functions as a critical input in almost all production systems, making its availability a determining factor for regional social, economic, and environmental sustainability (Ahmed et al., 2025; Bocanegra, 2021; Kumarapandiyan et al., 2024; Malik et al., 2025). Rapid population growth and changing consumption patterns have intensified pressure on water resources, not only through direct use but also through indirect water embedded in the production of goods and services consumed by society (Ahmad et al., 2025; Debaere & Konar, 2022; Dijkstra & de Roda Husman, 2023; Gule et al., 2024).

Among consumption sectors, the food sector particularly agriculture remains the largest user of freshwater worldwide, due to substantial water requirements for crop cultivation, livestock production, and agro-industrial processing (Bonetti et al., 2022; Cheikhaoui et al., 2024; Hussain et al., 2025; Iftikhar et al., 2025; Villholth, 2024). In parallel, non-food consumption such as housing, clothing, energy use, and services also contributes to water demand through indirect production processes, although these contributions are often overlooked in conventional water management discussions.

To capture the full complexity of water use, the water footprint (WF) concept has emerged as a

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comprehensive analytical instrument capable of measuring both direct and indirect water consumption across the entire production–consumption chain (Chaturvedi et al., 2025; Ma et al., 2024; Muthu, 2024). Introduced as a consumption-oriented indicator, the water footprint framework incorporates the concept of virtual water, referring to the hidden water embedded in commodities that is transferred across regions through trade and consumption (Ansorge & Stejskalová, 2022; Pierrat et al., 2023). This perspective enables a more accurate assessment of human pressure on water resources, particularly in regions where consumption patterns drive water demand beyond local abstraction.

At the spatial level, watersheds constitute a critical unit for water resource management, as they function as integrated hydrological systems that collect, store, and distribute water from upstream to downstream areas (Addisie & Molla, 2021; Chand & Mistri, 2024; Zerga, 2025). Consequently, understanding water use dynamics at the watershed scale is essential for designing effective and sustainable management strategies, especially in regions with strong dependence on land-based livelihoods.

The Jambo Aye Watershed, one of the major watersheds in Aceh Province, plays a strategic role in supporting agriculture, fisheries, and domestic water supply. Its upstream areas are partially located within the Leuser Ecosystem Area, an important water catchment zone, while increasing human activities in the middle and downstream sections pose potential risks to hydrological balance and water availability (Azizah et al., 2021). Given the high dependence of local communities on water resources, data-driven and integrative management approaches are urgently required to mitigate the risks of water scarcity and environmental degradation.

In this context, the Water Footprint Network (WFN) framework, which integrates green, blue, and grey water footprints, offers a robust theoretical basis for assessing consumptive water use and pollution-related pressures at the watershed scale (Boulay & Lenoir, 2020; D'Ambrosio et al., 2020). Recent studies demonstrate that consumption-based WF analysis is particularly effective in identifying sustainability thresholds and sectoral dominance, with household food consumption consistently emerging as the primary driver of freshwater appropriation in developing regions (R. Liu et al., 2025; Shen & Yao, 2023). However, despite growing applications, empirical evidence on the comparative water footprints of food and non-food consumption at the watershed level remains limited, especially in developing contexts where high-resolution data and integrated socioeconomic analysis are often lacking (Boulay & Lenoir, 2020; Liang et al., 2024).

Addressing this gap, the present study analyzes the water footprint of food and non-food consumption in the Jambo Aye Watershed to provide an integrated picture of sectoral water use and consumption-driven pressure on water resources. The novelty of this study lies in three aspects. First, unlike most previous WF studies that focus exclusively on the agricultural or production sector, this study applies a consumption-based approach that simultaneously quantifies and compares food and non-food water footprints within a single analytical framework. Second, whereas existing consumption-based WF assessments have generally been conducted at national or provincial scales, this study operationalizes the framework at the watershed scale—a hydrologically meaningful management unit—in a data-constrained developing region. Third, by providing the first WF estimates for the Jambo Aye Watershed, this research contributes empirical evidence for improving water-use efficiency, supporting sustainable watershed management, and informing policy decisions in Aceh and comparable regions.

Method

Research Design and Analytical Approach

A quantitative descriptive research design was employed, utilizing a consumption-based Water Footprint (WF) assessment to quantify and compare water use embedded in both food and non-food consumption within the Jambo Aye Watershed. The adoption of a descriptive water footprint framework is grounded in the Water Footprint Network (WFN) perspective, which positions water footprint accounting as a diagnostic tool for revealing sectoral water-use pressures and sustainability implications, rather than establishing causal relationships. At the watershed scale, consumption-based WF analysis is frequently applied to support water resource planning by identifying primary consumption drivers and prioritizing management interventions, especially in data-constrained developing regions.

Accordingly, the study emphasizes accounting-based measurement and comparative analysis of water use across sectors and over time (2023–2024), rather than inferential modeling or causal estimation. Although this approach does not address behavioral or economic determinants of water consumption, it offers a robust empirical foundation for identifying structural water-use patterns and informing evidence-based watershed management. The exclusion of causal inference represents a deliberate analytical boundary and highlights opportunities for future research utilizing econometric or system-dynamics methodologies.

Study Area and Research Period

The study was conducted in the Jambo Aye Watershed, located in Aceh Province, Indonesia, encompassing North Aceh, East Aceh, Central Aceh, Bener Meriah, and Gayo Lues Regencies. This watershed was chosen for its strategic importance in agricultural production, domestic water supply, and regional livelihoods. The research period of 2023–2024 allows for interannual comparison of consumption-driven water footprint dynamics.

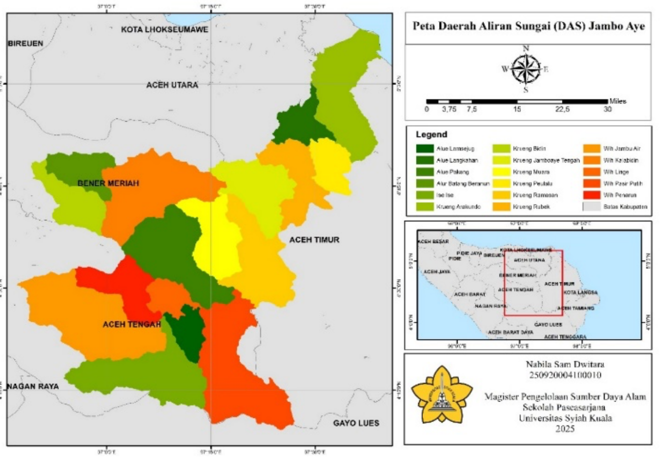

Figure 1. Study Location Map

Data Types and Sources

This study relies on secondary data obtained from official and reliable sources relevant to the research objectives. Four main datasets were used. The first is population data for the regencies located within the Jambo Aye Watershed (North Aceh, East Aceh, Central Aceh, Bener Meriah, and Gayo Lues) in 2023 and 2024, obtained from Statistics Indonesia (BPS). The second is household food and non-food consumption data derived from the National Socio-Economic Survey (SUSENAS) conducted by BPS in 2023 and 2024. The third is the virtual water coefficient (VWC) of each food and non-food commodity, which served as the basis for calculating the water footprint. These coefficients were adopted from the standardized global database of the Water Footprint Network, specifically the assessments of Mekonnen and Hoekstra (2011) for crops and derived crop products and Mekonnen and Hoekstra (2012) for farm animal products, and were matched to the commodity classification used in SUSENAS. The fourth is a map of the Jambo Aye Watershed used to support spatial analysis and to delineate the boundaries of the study area.

Research Variables

The main variables in this study are water footprint of food consumption and water footprint of non-food consumption. The food consumption variable includes plant and animal food commodities that are predominantly consumed by the public, while the non-food consumption variable includes housing commodities, clothing, goods and services, and other domestic needs. Supporting variables include population and level.

Data Collection Techniques

Data collection is carried out through the documentation study method, namely by collecting and reviewing official documents in the form of BPS statistical publications, research report results, and scientific literature related to the concept of water footprint and virtual water. All data collected are adjusted to the needs of the analysis and the scope of the research.

Data Analysis Techniques

Data analysis was carried out using the Water Footprint Assessment framework through four sequential stages. First, the per capita consumption of each food and non-food commodity was calculated from SUSENAS data. Second, the per capita consumption of each commodity was multiplied by its virtual water coefficient to obtain the per capita water footprint, as expressed in Equation (1):

$$WF_{cap,i} = C_i \times VWC_i \quad (1)$$

where $WF_{cap,i}$ is the per capita water footprint of commodity i (m^3/capita/year), C_i is the per capita consumption of commodity i (kg or unit/capita/year), and VWC_i is the virtual water coefficient of commodity i (m^3/kg or m^3/unit). Third, the per capita water footprint was multiplied by the total population of the watershed (*P*) to obtain the total water footprint of each commodity, as shown in Equation (2):

$$WF_{total,i} = WF_{cap,i} \times P \quad (2)$$

The total water footprint of each consumption sector (food or non-food) was then obtained by summing the total water footprints of all n commodities within the sector, as formulated in Equation (3):

$$WF_{sector} = \Sigma\, WF_{total,i}, \text{ for } i = 1, \ldots, n \quad (3)$$

Fourth, the total water footprints of food and non-food consumption in 2023 and 2024 were compared to identify changes and trends in water use over the study period.

It should be noted that, although the Water Footprint Network framework conceptually distinguishes green, blue, and grey water footprints, this study employed aggregate (total) virtual water coefficients without component disaggregation, owing to the absence of locally validated component-specific coefficients for the commodities consumed in the study area. Consequently, the reported WF values represent the total volume of water embedded in consumption, and component-specific disaggregation is identified as an important avenue for future research.

Comparative Water Footprint Analysis

Comparative analysis was carried out to determine the proportion of water use between food and non-food consumption. The results of the calculations are presented in the form of a table and analyzed descriptively to identify the sectors and commodities that exert the greatest pressure on water resources in the Jambo Aye watershed.

Presentation of Data

The results of the water footprint analysis are presented in the form of tables, graphs, and descriptive narratives. This presentation aims to facilitate the interpretation of the results and provide a clear picture of the amount of water use in each consumption sector.

Results and Discussion

Water Footprint of Food Consumption in the Jambo Aye Watershed

The analysis demonstrates that food consumption represents the largest component of water resource use in the Jambo Aye Watershed. The water footprint (WF) of food consumption was calculated by multiplying the per capita consumption of each food commodity by its corresponding virtual water coefficient and subsequently scaling the results by the population residing within the watershed in 2023 and 2024. This consumption-based approach captures indirect water use embedded throughout the production, processing, and distribution stages of food commodities.

Based on the results, the total WF of food consumption in the Jambo Aye Watershed reached 688,896,692.14 m^3 in 2023 and increased to 745,841,195.03 m^3 in 2024, indicating a substantial rise in consumption-driven water demand over the study period. This increase reflects growing pressure on water resources associated with demographic change and evolving consumption patterns. The distribution of water footprint values across major food commodities in the Jambo Aye Watershed for 2023 and 2024 is presented in Table 1.

Table 1. Water Footprint Value of Food Consumption in the Jambo Aye Watershed

Food Commodities	WF 2023 (m^3)	WF 2024 (m^3)
Local rice/glutinous rice	395.273.760,30	428.351.042,32
Purebred/Village Chicken Meat	45.823.245,57	55.214.476,34
Tempeh	48.228.487,37	56.805.384,20
Tofu	34.177.616,78	40.272.679,49
Coconut	42.758.950,21	30.218.986,36
Total Food WF	688.896.692,14	745.841.195,03

As shown in Table 1, local rice and glutinous rice dominate the food-related water footprint, accounting for the largest share of total WF in both years, followed by chicken meat, tempeh, tofu, and coconut. The predominance of these commodities indicates a high virtual water content, particularly associated with agricultural and agro-industrial production systems. Rice emerges as the principal driver of water consumption due to its water-intensive cultivation requirements, while animal-based products contribute disproportionately large water footprints relative to their consumption volume.

The dominance of food consumption in the total WF aligns with water footprint assessment theory, which consistently identifies the agricultural sector as the largest global user of freshwater, especially in regions highly dependent on land-based food production. The exceptionally high WF associated with rice in the Jambo Aye Watershed reflects the concept of virtual water, whereby the volume of water used during cultivation, processing, and distribution far exceeds the water directly consumed by households. Similarly, the substantial contribution of chicken meat is consistent with evidence that animal-based foods generally have higher water footprints than plant-based foods due to combined water requirements for livestock rearing and feed production (Bayindir-Gümüş & Yardimci, 2025; Giusti et al., 2022; Góralska-Walczak et al., 2024; Zhang et al., 2022).

The observed increase in food-related WF from 2023 to 2024 further reflects the influence of population growth and changes in consumption patterns. Previous studies emphasize that water consumption at the watershed scale is strongly shaped by demographic dynamics and dietary structure, such that increases in population are typically accompanied by proportional increases in water demand (Balanay et al., 2025; L. Liu et al., 2023; S. Liu et al., 2022; Xu et al., 2021). This relationship underscores the importance of considering consumption-side drivers in water resource assessments.

Recent watershed- and consumption-based WF studies corroborate the patterns observed in the Jambo Aye Watershed, where food consumption accounts for more than 99% of total WF and is dominated by staple crops and animal-based products. Evidence from the Yellow River Basin shows that grains and meat are the primary drivers of WF growth, reflecting structural dependence on water-intensive agricultural commodities (Meng et al., 2024). Similar patterns have been reported in South Korea, where cereals and meat jointly account for more than three-quarters of the national food-related WF, highlighting the persistent dominance of staple crops and livestock products in shaping consumption-based water pressure (Adeyi et al., 2025). The particularly high contribution of rice in

Jambo Aye also aligns with findings from Manipur, India, where rice production exhibits a large virtual water footprint due to its reliance on combined green and blue water inputs under irrigation-dependent systems (Chanu & Oinam, 2023).

From a management perspective, these convergent findings indicate that the agricultural sector constitutes the primary source of pressure on water resources in the Jambo Aye Watershed. Consequently, sustainable water management strategies should prioritize improvements in agricultural water-use efficiency through irrigation modernization, optimized cropping patterns, and more efficient livestock systems, complemented by consumption-side interventions. Empirical studies demonstrate that targeted improvements in irrigation efficiency and agricultural input management can substantially reduce water footprints without compromising food security objectives (Chen et al., 2020; Zhou et al., 2023). In addition, the literature on virtual water trade highlights its potential to alleviate local water stress by redistributing water-intensive food production across regions with differing water endowments, offering an additional policy pathway for watersheds such as Jambo Aye where food-sector dominance poses long-term sustainability challenges.

Water Footprint of Non-Food Consumption in the Jambo Aye Watershed

In addition to food consumption, this study examines the water footprint (WF) of non-food consumption, which includes housing and household facilities, clothing, durable goods, various goods and services, and other domestic needs. Although the magnitude of non-food WF is considerably smaller than that of food-related WF, this sector still contributes to overall water pressure in the Jambo Aye Watershed through both direct water use and indirect virtual water embedded in non-food commodities.

The results show that the total WF of non-food consumption increased from 3,004,364.91 m³ in 2023 to 3,278,034.08 m³ in 2024, indicating a consistent upward trend in consumption-driven water demand. This increase is primarily associated with the housing and household facilities sector, reflecting growing domestic activities and expanding residential infrastructure in the watershed. The distribution of water footprint values across major non-food consumption categories in the Jambo Aye Watershed for 2023 and 2024 is presented in Table 2.

As shown in Table 2, housing and household facilities represent the largest contributor to non-food WF, followed by miscellaneous goods and services and clothing-related commodities. This pattern indicates that water use in the watershed is not limited to direct household consumption but is increasingly driven by virtual water embedded in construction materials, household appliances, energy use, and manufactured goods. The predominance of housing-related water footprint is consistent with previous studies that emphasize the substantial contribution of the domestic sector to water use, not only through direct household consumption but also via the indirect water embodied in energy provision, construction materials, and household infrastructure systems (Chini et al., 2017; Fan et al., 2019; Schiller & Pruckner, 2024).

Table 2. Water Footprint Value of Non-Food Consumption in the Jambo Aye Watershed

Non-Food Commodities	WF 2023 (m³)	WF 2024 (m³)
Housing & Household Facilities	1.551.950,47	1.741.592,18
Miscellaneous Goods and Services	761.426,34	825.317,42
Clothing, footwear, headgear	366.437,12	386.451,28
Durable Goods	204.878,58	214.671,63
Party & Ceremony Requirements	119.672,40	110.001,57
Total Non-Food WF	3.004.364,91	3.278.034,08

The contribution of clothing and various goods and services further reflects the water implications of modern consumption patterns, where industrial production processes—particularly in the textile and manufacturing sectors—carry substantial virtual water content. Kinanthi (2024) emphasizes that textile production is among the most water-intensive manufacturing activities due to water demands at the raw material cultivation and industrial processing stages. Although smaller in magnitude, these categories collectively contribute to the gradual intensification of non-food-related water pressure.

The observed increase in non-food WF between 2023 and 2024 also suggests socioeconomic dynamics within the Jambo Aye Watershed. Rising living standards and improved community welfare are commonly associated with increased demand for housing, durable goods, and lifestyle-related consumption, which in turn elevates both direct and indirect water use (Azzahra et al., 2025). Similar patterns have been reported in watershed- and sub-national-scale WF studies, where non-food water use emerges as a secondary but growing source of water stress alongside dominant food-related consumption (Ren et al., 2025; Zhang et al., 2019).

From a broader comparative perspective, recent studies consistently interpret rising non-food WF as an emerging consequence of lifestyle change, housing expansion, and socioeconomic development, even in regions where food consumption overwhelmingly dominates total WF. Economic growth tends to shift consumption toward more water-intensive non-food goods, particularly among higher-income households, thereby reinforcing inequalities in virtual water appropriation and increasing cumulative water stress (Frontuto et al., 2025; Mirabi et al., 2025). Consequently, although non-food WF remains quantitatively smaller than food-related WF in the Jambo Aye Watershed, its upward trajectory signals a structural transformation in water demand that warrants policy attention.

Overall, these findings indicate that water resource management in the Jambo Aye Watershed should not focus exclusively on the food sector, but must also anticipate and manage the growing contribution of non-food consumption. Integrated watershed management strategies should therefore incorporate water-efficiency policies for housing and domestic infrastructure, promote water-saving technologies, and enhance public awareness of sustainable consumption practices to mitigate long-term water scarcity risks associated with non-food consumption growth.

Comparison of Water Footprint of Food and Non-Food Consumption

The comparison between the water footprint (WF) of food and non-food consumption reveals a pronounced inequality in water use structure within the Jambo Aye Watershed. In both 2023 and 2024, food consumption overwhelmingly dominated total water use, indicating that water demand in the watershed is primarily driven by food-related activities, particularly agriculture. This dominance further intensified in 2024, reflecting a strengthening trend in consumption-driven water pressure.

In quantitative terms, food consumption accounted for approximately 99.56% of the total water footprint in 2024, while non-food consumption contributed only around 0.44%. This pattern confirms that the food sector is the principal user of water resources in the Jambo Aye Watershed and represents the most critical sector for water resource management interventions. Table 3 presents a detailed comparison of food and non-food water footprints for 2023 and 2024.

Table 3. Comparison of Water Footprint of Food and Non-Food Consumption in the Jambo Aye Watershed

Year	Food WF (m^3)	Non-Food WF (m^3)	Total WF (m^3)
2023	688.896.692,14	3.004.364,91	691.901.057,05
2024	745.841.195,03	3.278.034,08	749.119.229,11

As shown in Table 3, although the absolute value of non-food WF increased slightly between 2023 and 2024, its relative contribution remained marginal compared to food consumption. This finding indicates that agriculture-related consumption continues to exert the greatest pressure on water resources, reinforcing the central role of the food sector in shaping watershed-scale water demand.

From a watershed management perspective, this structure is consistent with conceptual frameworks that position agriculture as the dominant determinant of water sustainability, particularly in regions with strong dependence on land-based food production systems. Previous studies emphasize that effective watershed management should prioritize sectors exerting the greatest pressure on water resources in order to balance conservation objectives with water utilization needs (Bakari et al., 2025; Ebrahimi Gatgash & Sadeghi, 2023; Kamali et al., 2023; Sharma et al., 2024). In this context, the Water Footprint approach provides a relevant and practical decision-support tool for guiding water allocation, commodity planning, and river basin development strategies (Hatmoko et al., 2012).

Comparative evidence from watershed-scale water footprint studies further supports the patterns observed in the Jambo Aye Watershed. Research consistently interprets cases in which food consumption accounts for more than 99% of total water footprint as a structural outcome of agriculture's inherently high water intensity and the dominance of virtual water embedded in food supply chains. Agricultural production remains the largest contributor to freshwater appropriation due to the combined demands of green and blue water for crop cultivation and livestock production, with irrigation-dependent systems amplifying pressure on local hydrological capacity (Hoekstra, 2017; Meng et al., 2024; Muratoglu, 2019). Such patterns are widely interpreted as indicators of inefficiencies in agricultural water use, including suboptimal irrigation practices and water-intensive cropping and feeding structures (Sharafi et al., 2024).

To situate these findings within the actual hydrological context, the total consumption-based WF of approximately 749.12 million m^3 in 2024 must be interpreted against the water availability conditions of the Jambo Aye Watershed. As one of the largest watersheds in Aceh, Jambo Aye is characterized by pronounced seasonal flow variability, with abundant discharge and recurrent flooding during the wet season but markedly reduced flows during the dry season (Azizah et al., 2021). Under such conditions, consumption-driven water stress is not uniform throughout the year: although annual renewable supply may still exceed the aggregate consumption-based WF, dry-season availability—precisely when irrigation demand for rice cultivation peaks—constitutes the binding constraint. Following the sustainability assessment logic of the Water Footprint Network, in which the blue water footprint is benchmarked against blue water availability after subtracting environmental flow requirements (D'Ambrosio et al., 2020; Muratoglu, 2019), the concentration of more than 99% of the WF in water-intensive food commodities suggests that seasonal blue water stress in the middle and downstream reaches of the watershed is plausible and warrants formal quantification. The current absence of continuous discharge records for the Krueng Jambo Aye precludes the computation of a formal water scarcity index; establishing such hydrological monitoring, and subsequently benchmarking the consumption-based WF against monthly water availability, therefore constitutes a priority step toward operationalizing WF sustainability assessment in this watershed.

Although the contribution of non-food consumption to the total water footprint is currently limited, its upward trend suggests potential future water pressure associated with socioeconomic development, particularly from domestic and industrial sectors. This highlights the importance of adopting an integrated water resources management approach that prioritizes efficiency improvements in the food sector while proactively regulating the growth of non-food water demand. Accordingly, sustainable water management in the Jambo Aye Watershed should focus on improving agricultural water-use efficiency through irrigation modernization, optimized cropping patterns, and productivity-oriented management, while simultaneously ensuring that emerging non-food consumption pressures are anticipated and controlled to maintain long-term water resource sustainability .

Conclusions

This study demonstrates that food consumption is the dominant driver of water resource use in the Jambo Aye Watershed, accounting for more than 99% of the total water footprint in both 2023 (688.90 million m^3) and 2024 (745.84 million m^3), with rice as the principal contributor, followed by animal-based and processed food commodities. Non-food consumption contributed only a marginal share (3.00–3.28 million m^3) but exhibited a consistent upward trend, particularly in housing and household facilities. Theoretically, the study extends the consumption-based Water Footprint Network framework to the watershed scale in a developing-region context, confirming that agriculture-driven virtual water flows structurally dominate water use in land-based food systems. From a policy perspective, sustainable management of the Jambo Aye Watershed should prioritize agricultural water-use efficiency through irrigation modernization, optimized cropping patterns, and more efficient livestock systems, complemented by demand-side measures that encourage sustainable and diversified consumption patterns, while proactively anticipating the growing water demand of the non-food sector.

This study is subject to several limitations. It relies on secondary consumption data and literature-based virtual water coefficients that have not been locally calibrated; it does not disaggregate the green, blue, and grey components of the water footprint; and it employs a descriptive accounting approach that does not address the behavioral or economic determinants of water consumption. Future research should incorporate higher-resolution and locally validated data, component-specific water footprint estimation, formal benchmarking of the water footprint against monthly water availability and environmental flow requirements, and causal or scenario-based modeling to better capture the dynamics of consumption, production, and water stress in the Jambo Aye Watershed and comparable regions.

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Conflicts of Interest
No conflict of interest.

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