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Original Article

Valuing Water as an Economic Good in the Kilombero River Catchment, Tanzania: Where Does It Return the Most?

Onesmo Zakaria Sigalla[1,2], Joshua Mwakalikamo[3], Reuben Mpuya Joseph Kadigi[4], Jane Joseph[2]

[1]Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania
[2]Rain Drop Initiative (RADI), Dar es Salaam, Tanzania.
[3]MASSA Institute of Social Sciences Research, Sam Nujoma Road, Dar es Salaam, Tanzania
[4]Sokoine University of Agriculture, Morogoro, Tanzania

Corresponding Author: onesigalla@gmail.com

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Abstract

Across the world, the importance of water in production sectors is unparalleled. About 70% of freshwater withdrawals are used in agriculture, roughly 20% and 10% for industrial and domestic uses respectively. These multiple strategic water users in a catchment such as Kilombero, present managers with a daunting task of allocating the available water efficiently among sectors. This paper contributes to the knowledge of efficient water allocation mechanisms by evaluating water productivity (WP) and its marginal productivity (MP). The study employed summary statistics, water productivity metrics, and correlation and regression methods for data analysis. The results revealed that WP for paddy and sugarcane are respectively 0.44Kg/m³ or 0.01US$/m³ and 6.18Kg/m³ or 0.10US$/m³, while hydropower generation yielded 2.05 kWh/m³ or 0.19US$/m³. In addition, sugarcane showed the highest MP, albeit elastic values over the years whereas, hydropower and paddy had lowest but more stable MP values. Notably, paddy exhibits diminishing returns observed post-2018. Despite the lowest WP of paddy compared to sugarcane, we advocate for prioritizing the former in water allocation due to its substantial contributions to the regional and local food and employment security. To enhance paddy production without additional water demand, implementation of an improved rainfed rice intensification system is recommended.

Keywords · Marginal Productivity of Water, Water Productivity, Water Allocation, Sugarcane; Kilombero River

1. Introduction

1.1 Background

Water is a critical resource for agriculture, energy production, and other economic activities (Ngene et al., 2021). The available statistics indicate that water consumption for agricultural production is considerably high (Mekonnen & Gerbens-Leenes, 2020). As of 2017, over 70% of the global freshwater was used for agricultural production (WB, 2017).

Moreover, the literature indicates that industry accounts for approximately 20% of total freshwater consumption, with energy production accounting for three-quarters and manufacturing for one-quarter (Misstear et al., 2022). Hence, striking a balance between water consumption and economic expansion in developing economies is a critical issue (Wang et al., 2024). This becomes increasingly significant as the world's population grows, reaching 8 billion in 2023, with projections indicating it will reach 10 billion by 2058 (Roser et al., 2013). Tanzania's population, for example, has grown to 61.7 million in 2024, up from 44.9 million in 2023, marking an increase of 16.8 percentage points (URT, 2022). Yet, approximately one-third (36%) of the household population lacks access to basic drinking water services (Ministry of Health, 2022).

In Tanzania, renewable water resources are decreasing due to increased pollution, and many rivers showed reduced flow in the 2022/23 hydrological year compared to the three preceding years(MoW, 2021). This calls for further studies on the allocation of water among different sectors of the economy (Meena et al., 2024). However, in many developing regions, allocating water efficiently across competing uses is a pressing challenge. Tanzania, like many countries in sub-Saharan Africa, faces growing water demands from agriculture and hydropower amidst concerns of water scarcity (Mekonnen & Gerbens-Leenes, 2020; Misstear et al., 2022; Sigalla et al., 2024). Freshwater resources are finite and unevenly distributed, requiring careful management to maximize socioeconomic benefits (Roser et al., 2013; Wang et al., 2024). The Kilombero River Catchment (KRC) in southern Tanzania offers a distinctive case study for evaluating water-allocation trade-offs, as it supports extensive irrigation and a major hydropower facility within the Rufiji Basin, which occupies about a third of Tanzania’s landmass and serves as a leading food basket in the country. For instance, the area under cultivation grew from about 739 ha in 1991 to over 207,000 ha in 2021 (Sigalla et al., 2024), largely driven by irrigation development for crops such as rice and sugarcane. This agricultural growth, while beneficial for food production and livelihoods, has greatly increased water withdrawals from rivers and aquifers. At the same time, the catchment is home to the Kihansi hydropower plant and other downstream users that depend on adequate water flows. These trends heighten the importance of understanding the economic returns of water in different uses to inform allocation decisions (Sigalla & Kadigi, 2025)

1.2 Summary of Key Concepts Used

1.2.1 Water and Economy

Public policies and decisions regarding water allocation always have significant economic consequences for households, communities, businesses, and the ecosystem. It is not uncommon that, across the world, water is allocated to less valued uses, without any reaping of benefits (Young & Loomis, 2014). Long term observation shows that, global water withdrawals are directly proportional to population growth (FAO, 2022). According to the 2020 UN World Water Development Report, Global water uptake has shot up by a factor of six over the past 100 years and sustains steadily at a rate of around 1% per annum owing to simultaneous growth in population, economic development and shifting consumption patterns (UNESCO, 2021; WMO, 2012). Population increase and resultant effects contribute to a fall in available water resources in Tanzania from 2700 m^3 per person per year in 2001 (URT, 2018) to 1608 m^3 per person per year as of 2015 (World Bank, 2017), and a projection of 1400 m^3 by the year 2025 raise a valid alarm (URT, 2018). This is because water is an important input to all sectors of the economy, and hence its deterioration will inevitably be reflected in the economy.

A hydro-economic analysis by the year 2030 Water Resources Group (WRG) indicates that Tanzania's national water demand already exceeds accessible water by 50% during dry seasons when environmental flow requirements are considered (2030 WRG, 2014). Under a business-as-usual scenario, demand is projected to increase by 216% by 2035 (2030 WRG, 2014). Government analysis showed that drought-related impacts on water and hydropower reduced overall GDP growth in 2011 from 7% to 6.4% (2030 WRG, 2014). This 0.6% GDP reduction corresponded

to $142 million in 2011 prices, equivalent to the GDP contribution of over 250,000 people (2030 WRG, 2014).

Based on the global GDP, population projections, and agricultural production projections by the International Food Policy Research Institute (IFPRI), it was indicated that, there will be no water productivity gains between 2005 and 2030 (Playán & Mateos, 2006). This calls for action to study water productivity options and to implement appropriate measures.

1.2.2 Productivity Value of Water

water, process-depleted water, or available water, essentially output per unit of water consumed..

On the other hand, the marginal productivity of water refers to the monetary value of the additional output generated by one more unit of water (Buttinelli et al., 2024). It is calculated as the marginal physical productivity of water multiplied by the output price (Buttinelli et al., 2024; Gleick et al., 2011). This metric reflects water's contribution to production value and is crucial for efficient water allocation and pricing, ensuring water is used until its marginal value productivity equals its marginal supply cost.

The difference between PVW and MPW is that the

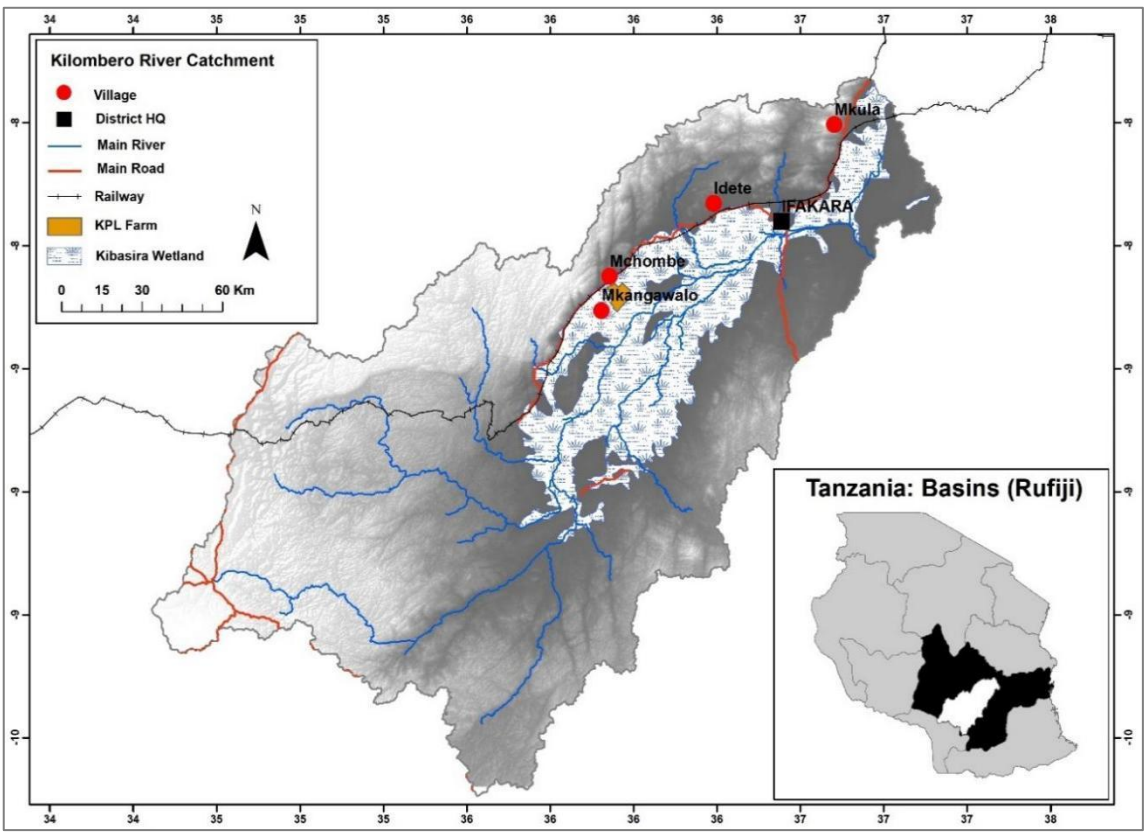


Figure 1: Map of Kilombero River Catchment showing the surveyed villages/wards

Water productivity (WP) and marginal productivity of water (MPW) are increasingly becoming important for sustainable river basin management (Mdemu et al., 2013). WP, however, lacks a universally accepted definition, varying with study scale and purpose. For example, Molden (1997) and Molden et al. (2003) who defined WP as the ratio of physical mass or economic value of a product to gross inflow, net inflow, depleted

former is the ratio of total output to water consumed, while the latter indicates the incremental change in output per unit of water. These concepts are explained in more detail in Section 0.

1.2.3 Hydro-economic Models

Hydroeconomic models, which describe the relationship between water input and production

output, have evolved since the 1960s. Early approaches, such as those by Bear et al. (1968) and Rogers and Smith (1970), used economic water demand curves to optimize water resource systems. Noel et al. (1980) further developed a framework for regional-scale IWRM models, allocating water to maximize net economic benefits. Since then, this approach has been termed hydrologic economic (Gisser & Mercado, 1972), hydroeconomic (Noel & Howitt, 1982), economic–hydrologic–agronomic (Lefkoff & Gorelick, 1990) and integrated hydrologic–economic-institutional (Booker, 1995), among others, reflecting applications and extensions in integrated river basin optimization (Ward & Lynch, 1996), and efficient allocation (Diaz et al., 1992). Other variations include integrated economic–hydrologic (Rosegrant et al., 2000), economic-engineering (Lund et al., 2006), integrated hydrologic–agronomic– economic (Cai et al., 2003), demand and supply (Griffin, n.d.), integrated hydrologic–economic (Pulido-Velázquez et al., 2006), holistic water resources–economic (Cai, 2008), integrated hydrodynamic– economic (Jonkman et al., 2008), and integrated ecological–economic (Volk et al., 2008) models.

The overall objective of this study is to assess the economic productivity of water (EPW) across sectors to inform water allocation strategies and policies, using empirical evidence on water productivity in the study area.

The specific objectives of the study were to:

i. Examine water productivity among the main economic activities in the study area; namely paddy farming, sugarcane farming, and hydropower generation.

ii. Analyse the trade-offs in water allocation among these economic sectors within the study area.

With limited water available during dry periods, it is unclear which water use—irrigated agriculture or hydropower generation—yields the greatest economic value in KRC. Policymakers need evidence on the productivity of water in competing sectors to guide allocation and investment. Valuing water as an economic good in this context can reveal opportunities to improve welfare by reallocating water or by increasing water-use efficiency in certain sectors.

To achieve the study objectives, we first calculate physical and economic productivity of water indicators for the selected sectors based on field data and existing records. We then use a water productivity metric to simulate how changes in water allocation could affect outputs and value-added in each sector. By integrating micro-level productivity analysis with an economy-wide model, we provide a comprehensive assessment of the value of water. The findings will help identify water allocation strategies that maximise economic returns while considering food and energy security. Although the analysis is specific to the Kilombero catchment, the approach demonstrates how combining farm-level and economy-level tools can inform water management in similar basins.

2. Materials and Methods

2.1 Study Area

The Kilombero River Catchment (KRC) (Figure 1), the focus of this assessment, is a significant sub-basin of Tanzania's largest hydrologic basin, the Rufiji River Basin (RRB), which covers approximately 20% of Tanzania (177,420 km^2) (WREM & RBWB, 2013). The KRC, in particular, span between Longitudes 34º00'E - 37º20'E and Latitudes 07º40'S - 10º00'S encompasses roughly 40,000 km^2 (WREM & RBWB, 2013). Despite being the second largest RRB sub-basin, KRC is the most important in terms of flow contribution (Table 1). Its graben structure features the Udzungwa mountain range and Mbarika escarpments as northern and southern crests, respectively, with a central floodplain trough of approximately 1967 km^2 (Figure 2) (Kato, 2007; Mombo et al., 2011). This central area includes the Kibasira wetland, one of East Africa's largest, situated around 300 m above mean sea level (Kangalawe & Liwenga, 2005), and recognized internationally as a Ramsar site (Wilson et al., 2017). In RRB, the study area is the most important catchment in respect of agriculture development potential, energy production, natural resources, and flow to RRB (Wilson et al., 2017). The KRC is the RRB's most crucial catchment regarding agricultural potential,

Table 1: Attributes of the Kilombero river catchment

No	Sub Basins	Catchment Area	% of Drainage Area	% of Annual Runoff
1	Great Ruaha	85,554	47	15
2	Kilombero	40,430	23	62
3	Luwegu	26,300	15	18
4	Rufiji	27,160	15	5
5	**Total**	**183,791**	**100**	**100**

*Source WREM & RBWB, (2013)

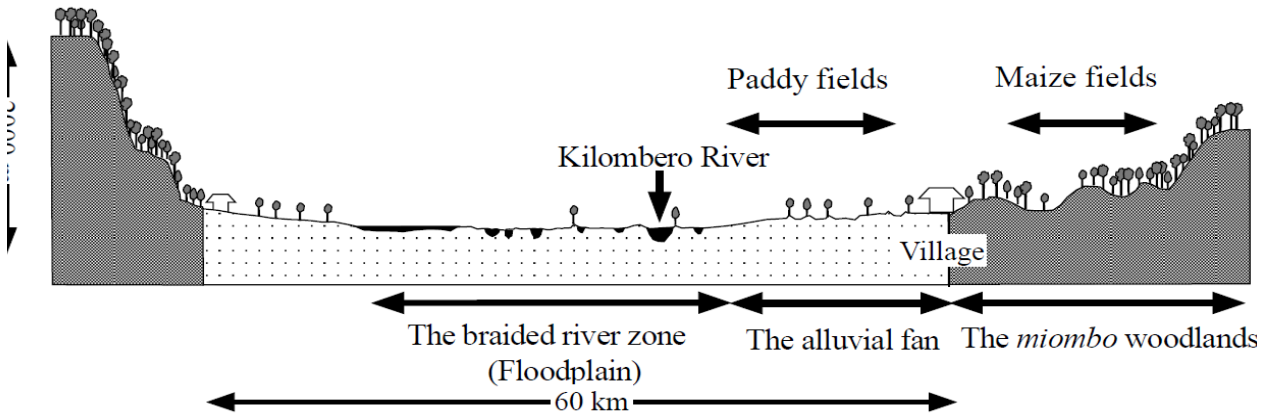


Figure 2: Cross-section of the Kilombero River Catchment adopted from Kato, (2007).

energy production, natural resources, and overall flow contribution (Wilson et al., 2017). Key tributaries of the Kilombero River include the Lumemo, Luipa, Mngeta, Kihansi, Mpanga, Mnyela, Ruhuji, and Furua. Most of the KRC area lies within the Morogoro administrative region, and its most developed centre, Ifakara is located approximately 230Km from Morogoro town and about 432 km from Dar es Salaam.

2.2 Data Used and Sources

Data source and data collection protocol

Data were collected from five villages (Mkangawalo, Itongoa, Kidete, Njage and Mkula) distributed across the Kilombero River Catchment (Figure 1 and Table 2). Socioeconomic profiles of the Ulanga, Ifakara, Malinyi, and Mlimba administrative councils were also examined. The sampling procedures and methodology were adopted from the authors' parallel research (Sigalla & Kadigi, 2025).

Table 2: Demographic data on the sampled village and details of sample size

N	Village Name	Ward	Selected Village Demography				Sampled population		
			M	F	Total	HH	M	F	Total
1	Mkangawalo	Mngeta	1,655	1,796	3,451	633	63	28	91
2	Itongowa	Mngeta	1,219	1,475	2,694	321	35	11	46
3	Kidete	Mngeta	820	744	1,564	253	26	10	36
4	Njage	Mchombe	624	723	1,347	298	31	11	42
5	Mkula	Mkula	683	785	1,468	230	19	16	35
Total			**5,001**	**5,523**	**10,524**	**1,735**	**174**	**76**	**250**

* Only heads of households were interviewed meaning that we considered 14% of all households

Table 3: Key informant respondents and type of data collected

S/N	KII Respondent	Respondents	Department/Section	Data collected
1	District Councils (Ulanga, Ifakara, Malinyi, and Mlimba)	4	Agriculture & Irrigation	Harvests, Prices, types of farming practices
2	Rufiji Basin Water Board (Ifakara Sub Office)	1	Head of Office	Water uses, water permits
3	Kilombero Agricultural Training and Research Institute	1	Crop Science	Soil, Moisture levels and farming practices
4	Kilombero Plantations Limited (KPL) plantations Ltd	2	Production and Irrigation	Water use, inputs and yield,
5	Water Users Association	2	Leaders	Water allocation, water fee
6	Kilombero Sugar Company Ltd (CSCL)	2	Irrigation & Production	
7	Out growers Irrigation Schemes	8	Leaders	Water allocation, types of farming practices
8	Tanzania Electricity Supply Company (TANESCO)	2	Generation	Water inflow, outflow, Power generated, price of electricity
9	Village Government	5	VEO	Water allocation, Demography
10	Ward Government	2	WEO	Demography, types of farming
11	**Total**	**29**		

2.2.2 Hydro-economic Data

Hydropower generation data from the Kihansi hydro-electric power station, including a decade of long-term power generation figures in appendix (Appendix

Table 13 to Table 16), were obtained from TANESCO, and used to calculate water productivity values. The cost to generate a kWh was TZS 27 or USD 0.01, based on TANESCO records. Annual evaporation from the Udzungwa escarpment (location of the Kihansi dam) was obtained from Sigalla et al., (2023) and factored in as consumptive water use. Sugarcane production data for both small-holder and large-scale plantations were collected from KSCL and surrounding communities (Table 17 and Table 18 in appendix). Finally, paddy production and water productivity data were compiled and calculated from data provided by the agriculture departments of riparian administrative district councils (Table 19) in the appendix.

2.3 Data Analysis Methods

2.3.1 Water Productivity

The Physical Water Productivity (PWP) for key sectors were assessed using Equation. (1 below, whereas the Economic Water Productivity (EWP) employed the residual imputation approach (RIA) presented in Equation 1 to 5 below.

$$PWP = \frac{Quantity\ of\ yield\ (Y)}{Applied\ or\ Abstracted\ Water\ (m^3)} \quad (1)$$

The RIA that was used to calculate EPW entails the isolation of the unknown incremental value of input following consideration of all other inputs of production. It follows, therefore that, the 'residual' value of water in this approach is guided by two Euler's principal postulates (Chiang, 1984, 2005) discussed also in (Kadigi et al., 2004; Mdemu et al., 2013; Musamba et al., 2011; Young, 1996):

i. Competitive Equilibrium - that requires the alignment of resource prices with their marginal returns. It is presumed that producers, aiming to maximize profits, will keep adding inputs until the Value Marginal Products (VMPs) are equivalent to the inputs' opportunity costs or 'Value', and

ii. The Total Value of Product (TVP) - which posits that the TVP can be distributed into portions, ensuring each resource is compensated by its Value Marginal Product (VMP), thus fully allocating the TVP.

In this case, the production process, in which output (Y) is produced by the following factors of production: capital (C), labor (L), and other natural resources for instance land (R) and water (W). The production function can be written as Equation. (2 below. In this regards therefore, the value of water is not lumped because all the other inputs of production are considered as opposed to other approaches such as the Change in Net Income (Hussain et al., 2001). This approach assumes the average value of water as a ratio of the product by subtracting the net value of the product that is produced while incorporating the consumed water and that without water use to the amount of water used. Here, there is no consideration of other inputs of production that contribute to the net value of the product in question.

$$Y = f(C, L, R, W) \tag{2}$$

By the second postulate, it then follows that:

$$\begin{aligned} TVP_Y = VMP_c * Q_c + VMP_L * Q_L \\ + VMP_R * Q_R \\ + VMP_W * Q_W \end{aligned} \tag{3}$$

Where: TVP is the total value product Y, $VMP_{C,L,R,W}$ and $Q_{C,L,R,W}$ are the value marginal product and respective quantities of resources C, L, R and W.

The first postulate, which asserts that value P of product i is represented by P_i = MPV_i, permits substitution of P_i into Equation 3 and rearrangement of the same gives (Equation 4):

$$TVP_Y - \sum_{i=j}^{N} P_i\, Q_i = P_w Q_w \tag{4}$$

When all the variables in Equation 4 are known, then the unknown P_w can be solved to impute the value of residual claimant (water), P_w (Equation 5).

$$\frac{TVP_Y - \sum_{i=j}^{N} P_i\, Q_i}{Q_w} = P_w \tag{5}$$

2.3.2 Hydro-economic Trade-offs

In this study, the selection of trade-offs was based on the calculation of the marginal productivity of water. The Marginal productivity metric and regression were used to calculate the MP while checking the accuracy of the results with R^2 and p-values (Leeper, 2017; Paidipati et al., 2022). The present study examined the correlation between water usage and income generation to gauge water's economic impact in this sector. Additionally, we utilized the Marginal Productivity of Water (MP_W) to determine where extra water usage could yield the highest economic benefits. The analysis involved a detailed examination of the correlation between production fluctuations, measured in US dollars, and corresponding changes in water consumption, as recorded in the socioeconomic profiles of the riparian district councils and the water use permits issued by the Rufiji Basin Water Board. As such, the MP_W was calculated as the ratio of the change in profit to the change in the volume of water used, measured between two consecutive years over the decade from 2011 to 2021 (Equation 6).

$$MPW = \frac{\Delta\text{Change in profit/revenue}}{\Delta\text{Change in Water use}} \tag{6}$$

3. Results and Discussion

3.1 Water Productivity in Farming

The water productivity results for sugarcane indicate that the average Physical Water Productivity (PWP) and Economic Water Productivity (EWP) were 12.8 kg/m³ and $0.19/m³ for KSCL, respectively, and 8.08 kg/m³ and $0.10/US$/m³ for smallholder farmers (Table 4 and Table 5). For paddy farming, results from ten years of documentation by the KRC riparian district councils (Ulanga, Ifakara, Malinyi, and Mlimba) showed that the water productivity of smallholder farmers was 0.44 kg/m^3 or 0.01 US$/m^3. A comparison with other scholars for similar crops showed that, the PWP (sugarcane) in the study area is slightly higher than FAO database, which estimated a range of 4 – 8Kg/m^3 (FAO, 2023) and matches well with other scholars such as Leal et al., (2017) who estimated as high as 11 – 18Kg/m^3 in similar tropical environments of India. Values for paddy over ten consecutive years are presented in Table 6. Furthermore, a paddy-specific study by Sigalla et al., (2022) in this area adds to the productivity value of paddy for large-scale production (Kilombero Plantations Ltd - KPL), which ranges between 0.33– 0.68 kg/m^3 and 0.05– 0.11 US$/m^3 in rainfed and irrigated systems, respectively. These paddy water productivity values compare well with results by other scholars as presented in Table 6.

The results for large-scale farming, i.e., KSCL and KPL, yield higher EPW due to efficient water-use systems and significantly lower production costs per hectare. This indicates that, as in paddy production reported by Sigalla et al., (2022),there is a substantial opportunity to increase water productivity in smallholder operations by improving irrigation systems, which constitute the denominator. Furthermore, the collective organization of farmers with strong leadership and protracted capacity building would increase the bargaining power and lead to better prices and reduced operational costs compared to

Table 4: Summary of results for PWP and EWP for Sugarcane Production at KSCL

Year	Area (Ha)	Water Use (m^3)	Cane (Tons)	Ton/ha	Profit (USD)	PWP (Kg/m^3)	EWP (USD/m^3)
2015	5,672.06	29,606,397	457,019	80.57	6,817,747	15.437	0.23
2016	6,047.01	61,337,569	495,356	81.92	7,477,016	8.076	0.12
2017	5,984.51	29,548,743	520,897	87.04	8,186,735	17.628	0.28
2018	5,522.95	36,236,260	452,519	81.93	6,831,400	12.488	0.19
2019	5,304.33	28,933,123	422,388	79.63	6,247,360	14.599	0.22
2020	5,695.46	37,401,014	505,059	88.68	8,030,577	13.504	0.21
2021	5,452.37	53,794,524	427,493	78.40	6,250,142	7.947	0.12
Mean	**5,668.39**	**39,551,090**	**468,676**	**82.60**	**7,120,140**	**12.811**	**0.19**

Table 5: Summary of results for PWP and EWP for Sugarcane small-holder farms

Year	Area (Ha)	Water Use (m^3)	Cane (Tons)	Ton/ha	Profit (USD)	PWP (Kg/m^3)	EWP (USD/m^3)
2015	11,535.86	60,361,405	472,970	41	4,967,137	7.836	0.08
2016	11,702.45	61,233,085	468,098	40	4,367,901	7.645	0.07
2017	11,860.55	62,060,304	486,282	41	4,913,700	7.836	0.08
2018	15,695.43	82,126,311	627,817	40	9,130,353	7.645	0.11
2019	12,990.99	67,975,355	545,622	42	7,297,017	8.027	0.11
2020	13,287.37	69,526,177	677,656	51	10,191,465	9.747	0.15
2021	16,244.19	84,997,724	666,012	41	10,200,003	7.836	0.12
Mean	**13,330.98**	**69,754,337**	**563,494**	**42**	**7,295,368**	**8.081**	**0.10**

individual effort, which is limited in scale. This would then increase water productivity both in terms of PWP and EPW. In addition, some smallholder farmers had access to highly fertile wetlands, resulting in higher yields than those of larger-scale farms. However, in many cases, these wetlands are legally protected, thereby making their endeavours illegal and unsustainable. An additional comparison of sugarcane yield data from large-scale and small-scale farms was nearly identical. This means that water uptake, or the amount of water consumed, was the key factor determining the variance in water productivity between the two agricultural systems.

3.2 Water Productivity in Hydropower Generation

Daily records spanning 12 years, from 2010 to 2021, were obtained from the state-owned energy utility, the Tanzania Electrical Supply Company (TANESCO). The data included water inlet and outlet levels, dam levels, turbine discharge, power generation, and production costs. Table 7 and Table 8 present the calculated water productivity in the hydroelectric power (HEP) sector. Three scenarios were analysed: the nonconsumptive scenario, which considered turbine discharge under the assumption that HEP does not consume any physical water; the consumptive component, which included evaporation from the collected water at the dam; and the combined scenario, which aggregated the first two scenarios. The analysis results indicated PWP values of 2.06, 591.13, and 2.05kWh/m^3, and EWP values of 0.19, 54.03, and 0.19 US$/$m^3$ for the respective scenarios, as shown in Table 7 and Table 9. The notably higher value for the consumptive use scenario is attributed to the Udzungwa Escarpment, where Kihansi is located, having the lowest evaporation rate in the catchment. This evaporation value was adopted from a parallel study by the corresponding author (Sigalla et al., 2023), who at the time intended to investigate trends in hydroclimatic parameters in the same study area. The results were consistent with those of other scholars such as Näschen et al. (2018) who conducted similar work in part of the study area.

3.3 Decadal Consideration of Water Productivity Across Sectors

Table 8 and Figure 3 summarize a decade of water productivity (WP) data across economic sectors, extracted from the more comprehensive data presented in Section 2.2.2. Long-term WP averages are 0.44 kg/m^3 (0.01 US$/$m^3$) for paddy, 6.19 kg/$m^3$ (0.10US$/$m^3$) for sugarcane, and 2.05 kWh/m^3 (0.19 US$/$m^3$) for HEP. In hydropower sub-sector, the assessment here used the combine scenario i.e.,

Table 6: Comparison of water productivity values for paddy in Tanzania

N	Water Productivity	Area (region/catchment)	Research Source	Received Rainfall (mm)
1	0.44Kg/m^3 & 0.001US$/m^3	Study area in Kilombero catchment	Current compilation	1200 – 1400
2	0.30 – 0.68Kg/m^3 0.002 – 0.11US$/m^3		(Sigalla et al., 2022)	
3	0.85Kg/m^3 or 0.23US$/ m^3		(Musamba et al., 2011)	
4	0.15 – 0.51Kg/m^3	Arusha in Kikuletwa Catchment	(Kavishe et al., 2021)	590 – 1460
5	0.17 – 0.22Kg/m^3 0.02 – 0.8US$/m^3	Usangu in Great Ruaha catchment	(Mdemu et al., 2013)	669
6	0.126 – 0.265Kg/m^3 0.01 – 0.04US$/m^3		(Kadigi et al., 2004)	669
7	0.14 – 0.47Kg/m^3	Morogoro in Wami Catchment	(Kahimba et al., 2013)	669

This table shows that the current study's results are comparable to those of other scholars.

consumptive and non-consumptive to represent the more realistic picture in real life. Water productivity values in Table 8 are consistent with previous studies, indicating a similar pattern in economic returns per unit of water consumed. While hydroelectric power (HEP) exhibits the lowest water use and highest economic water productivity (EWP), its impact is primarily at national macroeconomic level. Despite agriculture's lower economic water productivity (EWP) compared to HEP, particularly in paddy fields and general farming as a sub-sector, it remains crucial for food and employment security. In Africa, agriculture provides 59-78% of rural incomes (Blein et al., 2017; Davis et al., 2010) . In Tanzania, it contributes approximately 28.9% to the national GDP and employs about 65% of

Table 7: Calculated water productivity across the years for HEP at Kihansi plant

Generation Item	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Total Generation (kWh) x 10^6	867.32	774.22	592.88	795.65	861.99	836.77	793.83	815.02	772.25	956.58	806.35	770.63	803.62
Total Water Use (m^3) x 10^6	412.78	373.45	279.88	394.38	416.14	403.72	383.06	435.73	373.05	462.08	389.16	372.45	391.32
PWP (kWh/m3)	2.10	2.07	2.12	2.02	2.07	2.07	2.07	1.87	2.07	2.07	2.07	2.07	2.06
Average Tarrif (USD/kWh)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Annual Turnover (USD) x 10^6	89.47	79.87	61.16	82.08	88.92	86.32	81.89	84.08	79.67	98.68	83.18	79.50	82.90
Generation Costs (USD/kWh)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Annual Gen Costs (USD) x 10^6	10.19	9.10	6.97	9.35	10.13	9.83	9.33	9.58	9.08	11.24	9.48	9.06	9.44
Annual Net Profit (USD) x 10^6	79.28	70.77	54.19	72.73	78.79	76.49	72.56	74.50	70.59	87.44	73.71	70.44	73.46
Net - EWP (USD/m^3)	0.19	0.19	0.19	0.18	0.19	0.19	0.19	0.17	0.19	0.19	0.19	0.19	0.19
Raw - EWP (USD/m^3)	0.22	0.21	0.22	0.21	0.21	0.21	0.21	0.19	0.21	0.21	0.21	0.21	0.21
Consumptive (Evaporation) component													
Reservoir area (m^2) x 10^4	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00	260.00
Evaporation (m)	5.27	5.19	5.24	5.31	5.18	5.26	5.20	5.24	5.19	5.17	5.13	5.40	5.23
Vol evaporated (m^3) x10^6	1.37	1.35	1.36	1.38	1.35	1.37	1.35	1.36	1.35	1.34	1.33	1.40	1.36
PWP (kWh/m^3)	633.39	573.56	435.04	576.49	640.65	612.05	587.16	598.03	572.10	712.09	604.16	548.86	591.13
Raw - EWP (US$/$m^3$)	65.34	59.17	44.88	59.47	66.09	63.14	60.57	61.69	59.02	73.46	62.33	56.62	60.98
Net - EWP (USD/m^3)	57.90	52.43	39.77	52.70	58.56	55.95	53.67	54.67	52.30	65.09	55.22	50.17	54.03
Evaporation and turbine discharge component													
Vol of water (m^3) x 10^6	414.15	374.80	281.24	395.76	417.48	405.09	384.41	437.10	374.40	463.42	390.50	373.85	392.68
PWP (kWh/m^3)	2.09	2.07	2.11	2.01	2.06	2.07	2.07	1.86	2.06	2.06	2.06	2.06	2.05
Raw - EWP (US$/$m^3$)	0.22	0.21	0.22	0.21	0.21	0.21	0.21	0.19	0.21	0.21	0.21	0.21	0.21
Net - EPW (US$/$m^3$)	0.19	0.19	0.19	0.18	0.19	0.19	0.19	0.17	0.19	0.19	0.19	0.19	0.19

Table 9: Summarized water productivity under different scenarios at Kihansi HEP

Item Description	Scenarios		
	Non-Consumptive	Consumptive	Combined
Generation Component			
Annual Generation (kWh) x 10^6		803.62	
Average Tarrif (US$/kWh		0.10	
Average Generation Costs (US$/kWh)		0.01	
Annual Generation Costs (US$) x 1M		9.44	
Annual Turnover (US$) x 10^6		82.90	
Turnover Less Costs (US$) x 10^6		73.46	
Water Use Component			
Annual Turbine Discharge (MCM)	391.32		
Evaporated Volume (m^3) x 10^4		136.01	
Combine Water Use (MCM)			392.68
Water Value/Productivity			
Physical Water Productivity (kWh/m^3)	2.06	591.13	2.05
Lumped EWP (US$/$m^3$)	0.21	60.98	0.21
Residual EWP (US$/$m^3$)	0.19	54.03	0.19

the population (NBS, 2020; Rudari et al., 2019). Furthermore, in KRC, agriculture supports 71% of livelihoods, with paddy cultivation representing 82% of these activities (Sigalla & Kadigi, 2025). Efficient technologies like the System of Rice Intensification (SRI) can improve paddy cultivation's water productivity, and farmer groups can enhance bargaining power and the economic value of water as pointed out in Sigalla & Kadigi, (2025).

3.4 Hydro-Economic Trade-offs

As pointed out above, to analyze the trade-offs between productivity and economic values of water across key economic sectors, the Marginal Productivity of Water (MPW) approach was employed. Sugarcane was found to have the highest MPW but was also the most unstable (elastic), whereas paddy and HEP displayed nearly identical patterns and were the most

Table 8: Decadal productivity value of water for KRC riparian districts

N	Years	PWP			EWP (US$/$m^3$)		
		Paddy (Kg/m^3)	Cane (Kg/m^3)	HEP (kWh/m^3)	Paddy	Cane	HEP
1	2010	0.32	5.44	2.09	0.001	0.076	0.19
2	2011	0.32	5.56	2.07	0.001	0.068	0.19
3	2012	0.31	6.41	2.11	0.002	0.038	0.19
4	2013	0.34	5.38	2.01	0.002	0.068	0.18
5	2014	0.46	6.19	2.06	0.002	0.083	0.19
6	2015	0.46	6.19	2.07	0.009	0.090	0.19
7	2016	0.46	6.86	2.07	0.010	0.170	0.19
8	2017	0.55	6.18	1.86	0.027	0.152	0.17
9	2018	0.58	6.13	2.06	0.034	0.151	0.19
10	2019	0.46	6.97	2.06	0.010	0.116	0.19
11	2020	0.56	6.87	2.06	0.027	0.114	0.19
12	2021	0.46	5.97	2.06	0.011	0.096	0.19
Average		**0.44**	**6.18**	**2.05**	**0.01**	**0.10**	**0.19**

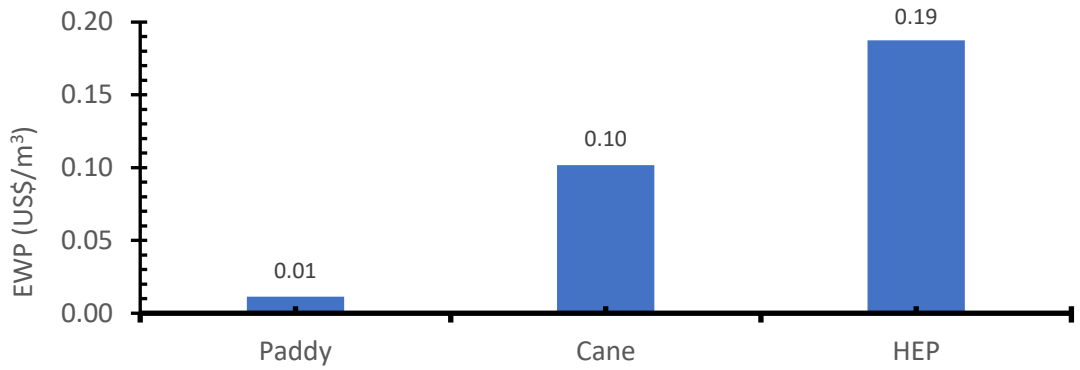


Figure 3: Decadal average EWP for main sectors of economy showing favorable results for HEP

stable. This could be attributable to the unstable sugar markets associated with a market monopoly in the country, in which sugarcane producers are the same

47.7% and decreased overall investment in the sugar supply chain (ibid). Furthermore, Kilima (2006), who investigated the effects of global markets on sugar,

Table 10: Comparison of Water Productivity for the same sectors but different scholars showing a similar range of WP in other areas.

N	Sector	Water Productivity		Source for Others
		Current Study	Others	
1	Paddy	0.44Kg/m^3 or 0.01US$/m^3	Ref. Table 8	(Sigalla et al., 2022)
2	Sugarcane	6.19Kg/ m^3 or 0.01US$/m^3	4 – 8 kg/m^3 to 11 – 18 Kg/m^3	(FAO, 2023; Leal et al., 2017)
3	HEP	2.05kWh/ m^3 or 0.19 US$/ m^3	0.06 – 0.21 US$/11 – 18 Kg/m^3	(Kadigi et al., 2005, 2008)

ones with permits to import the product (Kangile et al., 2022). Among other policy arguments, it was

rice, wheat, and cotton, demonstrated the limited negotiating power of developing countries. He

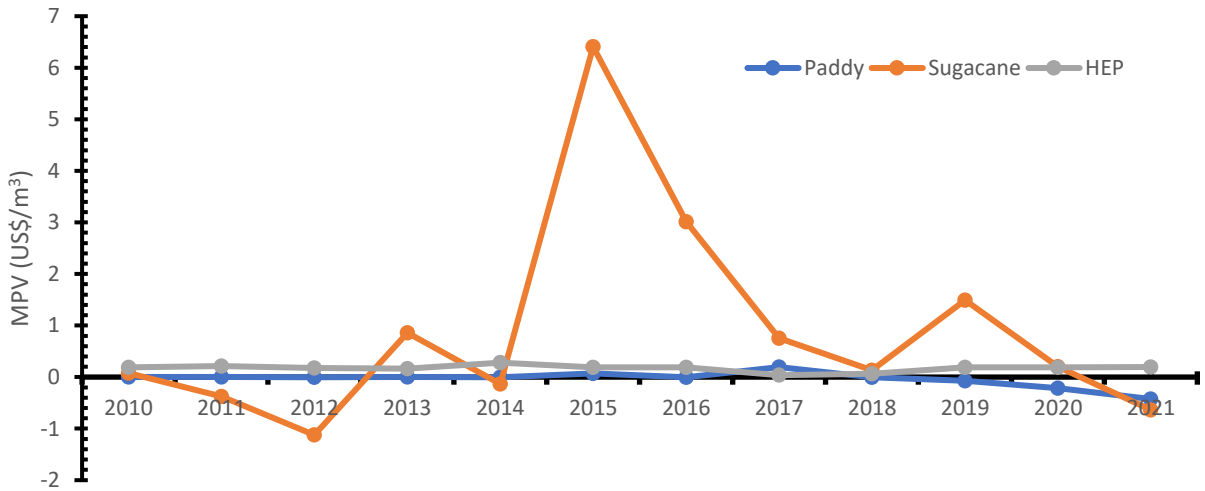


Figure 4: Marginal productivity of water for different sectors of the economy indicates sugarcane farming fetches a higher value for an additional unit of water

highlighted that abrupt trade policy changes significantly ($p < 0.05$) reduced commodity trade by

recommends that regional policymakers collaborate to

reduce the impact of monopolies in these markets and enhance the efficiency of price transmission.

The results for this study are illustrated in Figure 4 and summarized in Table 11. The results indicate that the Marginal Productivity of Water (MPW) in paddy farming has remained relatively stable, with a slight upward trend in returns, peaking in 2017. However, this trend began to decline consistently shortly after 2018, leading to diminishing returns for the sector from around 2019 onward. This is because, following this year, there was a negative change in profit between two consecutive years (indicating a loss), or a decrease (negative change) in water usage compared to the previous year. The HEP sector, though modest in scale, has experienced annual increases in returns, primarily attributable to consistent performance across revenue, profit, and water consumption. The stable water usage can be credited to the strategic location of the Kihansi Dam, which is situated upstream of any water utilization and lies within the protected Udzungwa mountain ranges, where evaporation losses are minimal (Sigalla et al., 2023). These MPW estimates for paddy, sugarcane, and HEP were accurate and significant at $p < 0.01$, $p < 0.06$, and $p < 0.1$, respectively (Table 12).

Table 11: Summary of MPV of water for paddy farming, sugarcane farming and HEP productions

Years	Change Profit (US$)			Change Water Use (m^3)			MPV of Water (US$/$m^3$)		
	Paddy	Cane	HEP	Paddy	Cane	HEP	Paddy	Cane	HEP
2010	1,083,424	11,004,882	79,279,676	737,678,261	145,425,692	414,148,494	0.001	0.08	0.19
2011	-79,825	-914,272	-8,510,127	-25,873,913	2,422,462	-39,349,832	0.003	-0.38	0.22
2012	160,966	-4,353,658	-16,575,334	-35,278,261	3,878,308	-93,557,735	-0.005	-1.12	0.18
2013	520,041	4,965,779	18,534,501	192,715,217	5,790,923	114,516,621	0.003	0.86	0.16
2014	-179,067	1,414,413	6,064,305	91,060,870	-10,767,538	21,724,880	-0.002	-0.13	0.28
2015	8,325,087	1,104,499	-2,305,421	118,728,261	172,409	-12,393,593	0.070	6.41	0.19
2016	275,364	12,400,051	-3,924,756	-103,305,217	4,112,705	-20,677,537	-0.003	3.02	0.19
2017	18,905,499	-3,253,636	1,936,703	97,779,130	-4,328,860	52,684,080	0.193	0.75	0.04
2018	604,026	1,796,922	-3,910,006	-204,018,261	13,319,774	-62,699,610	-0.003	0.13	0.06
2019	-18,607,523	- 6,010,290	16,849,365	258,976,957	-4,025,071	89,029,219	-0.072	1.49	0.19
2020	17,494,607	-710,214	-13,732,330	-80,703,478	-3,484,248	-72,928,349	-0.217	0.20	0.19
2021	-16,939,020	-2,479,324	-3,264,679	39,746,957	3,906,877	-16,643,262	-0.426	-0.63	0.20

Table 12: Accuracy assessment for the calculation of marginal productivity water

Variables	Paddy	Sugarcane	HEP
Profit	1.06e-09***	6.59e-09***	2.29e-09***
	(0)	(-6.21e-11)	(0)
Water use	-0**	-7.06e-10***	-4.39e-10***
	(0)	(7.73e-11)	(0)
Constant	0.00643**	0.107***	(0)
	(0.00265)	(0.0115)	(0.000091)
Observation	12	12	12
R-squared	0.989	0.999	0.997

Standard errors in parentheses
***p<0.01, **p<0.05, p<0.1

4 Conclusion and Recommendations

4.1 Conclusion

Our research assessed water productivity and its marginal value across three subsectors: paddy farming, sugarcane farming, and hydroelectric production. These metrics are vital for guiding water allocation decisions, especially when water is considered an economic commodity or production input in different sectors. The study used socio-economic and hydrological data spanning twelve years, from 2010 to 2021, and included findings from other relevant research. It showed that large-scale mechanised paddy farmers achieve higher economic water productivity but lower physical water productivity compared to other methods. Conversely, mechanised sugarcane farming demonstrated superior results, likely due to its monopoly in the value chain, unlike the competitive paddy market. This is attributable to the fact that, sugarcane production operates under a vertically integrated structure dominated by a single large milling and processing company, which effectively creates a monopsonistic market arrangement for out-growers. This “monopoly in the value chain” confers several advantages. First, it provides guaranteed market access for farmers through structured off-take agreements, thereby reducing price uncertainty and transaction costs. Second, the integrated model facilitates coordinated irrigation scheduling, input provision (seed cane, fertiliser, technical advice), and logistical support, which can enhance production efficiency and stabilise water productivity outcomes. Third, economies of scale in processing and marketing allow the sector to capture higher aggregate economic returns per unit of water compared to fragmented smallholder systems. However, this concentration of market power also presents notable disadvantages. The monopsonistic structure may suppress farm-gate prices, limiting the share of value accruing to out-growers despite relatively high water productivity. It can reduce bargaining power for smallholders and constrain competitive incentives for innovation. Moreover, water allocation decisions may become skewed toward maintaining industrial throughput rather than optimising basin-wide social welfare. From a resource-efficiency perspective, guaranteed market access may dampen incentives to improve marginal water efficiency when production volumes are contractually secured. Additionally, preferential allocation to a dominant industrial actor could crowd out alternative high-value or socially critical water uses, such as diversified food crops.

Additionally, the research indicated that the marginal water productivity in sugarcane is elastic, while the figures for paddy farming and hydroelectric production were more stable and the lowest observed. Due to its profitability, paddy farming provides the most employment in the area and ensures a steady supply of staple food locally and beyond the study are. Furthermore, the spatial distribution of the studied sectors shows that Hydroelectric Power (HEP) is located further upstream within the protected Udzungwa National Park. As a primarily non-consumptive user, it has minimal negative impacts on water availability for downstream users. However, caution needs to be exercised as HEP are known to have some adverse impacts as well. Dam operations can alter natural flow regimes, affect seasonal flooding patterns, and influence sediment transport dynamics. These changes may disrupt aquatic ecosystems, fish migration, Kihansi spray tods ecosystem and downstream wetland functions. Additionally, modified environmental flows could affect water availability for downstream users and ecological integrity. Therefore, while HEP demonstrates high economic water productivity, future allocation decisions should incorporate environmental flow assessments and ecosystem monitoring to ensure long-term basin sustainability. In addition, the eluded elasticity in in sugarcane indicates that additional water can generate relatively high but highly variable economic returns, depending on market conditions, input efficiency, and operational performance. This makes sugarcane attractive under efficiency-oriented allocation strategies, yet also exposes the basin to economic and

climatic risks. In contrast, paddy and hydropower exhibit more stable marginal returns, offering predictability and resilience despite lower economic value per unit of water. Practically, water allocation should therefore balance the high but volatile gains from sugarcane with the stability, food security, and energy reliability provided by paddy and hydropower.

4.2 Recommendations

Recognizing the role of water as an economic good, we underline the need to consider the economic values of water in its different uses as one of the principles of fair and rational water allocation. In particular, we recommend that:

i. Water allocation favourable to paddy production should be implemented through productivity-informed water permitting by the Rufiji Basin Water Board, incorporating food security and livelihood indicators alongside economic water productivity. A tiered allocation system could guarantee minimum dry season supplies for staple crops before distributing surplus water based on marginal returns. Environmental flow thresholds must be secured prior to sectoral allocation. Further, water allocations in this catchment should be mindful of the role this catchment plays for the entire RRB and its downstream users such as the flagship Nyerere HEP, fisheries, farming and mangrove community at Rufiji delta. Therefore, allocation reforms should consider basin-wide externalities to avoid unintended ecological or economic consequences

ii. Improving water productivity in smallholder systems requires addressing financial, infrastructural, and training barriers. Limited access to credit, inadequate mechanisation, and weak extension services constrain efficiency gains. Targeted credit schemes, strengthened cooperatives, shared mechanisation services, and improved irrigation practices (e.g., SRI) are essential. Institutional alignment between agricultural policy and water governance, along with transparent permit monitoring, will reduce risks of inequity and regulatory capture..

iii. Future research should prioritise environmental flow maintenance, wetland protection, biodiversity conservation, and sediment dynamics. Valuation approaches may include environmental flow modelling, ecosystem service valuation, and hydro-ecological simulation. Recognising environmental water as an economic asset strengthens sustainable allocation frameworks.

iv. An updated Decision Support System (DSS) should integrate hydrological monitoring, sectoral water-use data, production and price information, and environmental indicators. Combining marginal productivity analysis, and hydrological simulations would allow scenario testing under drought and reallocation conditions. Such a system would support adaptive, transparent, and evidence-based water allocation decisions.

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Author Contribution

Conceptualization, methodology and writing of original draft O.Z.S; formal investigation, analysis and data curation O.Z.S, J.M and J.J.M; writing-review and editing R.M.J.K and O.Z.S. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declared no conflict of interest.

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Appendix

Table 13: Average monthly water inflow to the Kihansi reservoir (m^3/s)

Mon/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	9.54	10.34	10.34	11.27	13.17	13.56	15.25	8.11	14.90	13.79	16.23	14.50
February	15.50	11.17	10.66	10.21	11.31	14.81	16.70	10.51	12.78	16.27	23.45	12.99
March	16.66	13.46	12.36	22.96	15.08	20.05	15.53	14.84	14.13	13.64	21.86	12.21
April	24.87	32.98	15.70	27.84	39.01	27.62	33.42	34.43	22.57	22.79	25.64	30.19
May	28.99	26.85	16.53	25.13	38.22	26.71	22.21	34.73	21.11	47.13	23.99	26.00
June	19.60	16.52	12.26	16.24	24.61	17.69	16.14	20.49	15.54	26.07	16.66	17.16
July	16.27	13.32	10.21	13.66	18.26	14.47	13.83	15.74	13.11	19.04	15.98	13.99
August	13.65	11.51	9.10	11.88	15.29	12.49	12.29	13.70	11.22	15.34	13.70	12.37
September	11.78	10.60	7.48	9.95	-	10.93	10.69	11.94	11.44	13.32	11.91	10.80
October	10.21	10.38	6.44	9.71	12.57	9.36	9.20	10.14	9.42	14.31	10.54	9.30
November	9.92	8.88	6.83	7.64	12.15	10.41	8.12	9.57	8.13	11.20	9.42	7.91
December	9.43	12.07	6.66	9.99	11.51	9.65	7.48	13.98	11.90	14.42	9.88	7.93

Table 14: Average monthly turbine discharge for the Kihansi reservoir (m^3/s)

Mon/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	11.09	8.34	8.34	9.63	11.31	11.79	13.30	7.00	13.47	11.79	14.44	12.68
February	12.98	9.23	8.84	8.81	9.51	12.70	15.04	8.91	10.81	14.28	17.35	11.28
March	14.82	11.56	10.74	21.40	13.09	16.33	13.45	12.54	12.49	11.65	15.84	10.43
April	19.93	20.68	13.62	21.85	20.30	22.09	21.01	21.47	18.80	18.33	15.45	21.16
May	20.51	20.30	14.85	21.23	22.75	21.48	18.78	36.64	19.16	22.96	15.09	20.47
June	17.65	14.94	10.54	14.60	21.51	15.65	13.95	17.79	13.56	21.96	10.55	15.05
July	14.10	11.52	8.22	11.25	16.14	12.60	11.50	13.06	11.24	16.61	13.53	11.78
August	11.66	9.47	7.72	9.86	13.19	10.45	9.97	11.02	9.27	13.26	11.53	10.30
September	10.03	10.60	6.40	8.20		7.21	8.66	9.34	9.41	11.19	9.72	8.19
October	8.37	8.37	5.62	8.02	10.41	7.16	7.47	7.99	7.56	12.19	8.63	7.56
November	8.47	6.90	5.36	6.53	10.11	8.42	6.31	7.70	6.79	9.22	7.52	6.40
December	7.57	10.14	5.98	8.36	9.66	7.81	6.15	11.90	9.35	12.41	8.15	6.49

Table 15: Average monthly power generation (kWh) for the Kihansi plant

Mon/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	66.90	47.10	58.66	52.87	62.99	65.34	73.76	37.51	74.62	66.21	79.85	70.28
February	65.86	47.19	45.38	44.01	47.49	63.57	77.72	44.62	54.10	71.26	89.95	56.46
March	83.30	65.25	59.89	97.46	72.62	90.49	74.77	69.51	69.25	64.55	87.79	57.66
April	107.37	111.73	73.90	117.42	109.20	118.51	113.37	115.14	100.85	98.35	82.87	113.51
May	113.91	112.21	82.57	116.16	126.33	119.03	104.08	116.39	106.18	127.25	83.67	113.52
June	95.25	80.86	57.35	78.32	115.41	83.93	74.83	95.41	72.72	117.75	56.61	80.73
July	80.03	64.52	46.51	64.56	89.44	69.85	63.72	72.41	62.29	92.09	75.00	65.27
August	64.96	54.03	41.84	54.58	73.07	57.60	55.29	62.21	51.43	73.50	63.92	57.07
September	54.16	48.85	33.77	43.71	-	38.79	46.49	50.28	50.59	60.03	52.13	43.95
October	46.40	46.82	31.63	44.88	57.71	41.21	41.43	44.27	41.90	67.53	47.82	41.88
November	46.54	38.75	28.48	35.33	54.20	45.17	34.28	41.30	36.44	49.48	41.55	34.32

Mon/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
December	42.64	56.90	32.91	46.34	53.53	43.29	34.10	65.96	51.89	68.57	45.20	35.98

Table 16: Average monthly evaporation (mm) in Udzungwa Escarpment

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	147.98	132.55	147.17	131.52	118.92	109.65	118.98	141.03	168.40	200.92	193.72	175.87
2011	156.20	131.20	142.60	120.93	119.18	113.05	127.93	146.15	163.35	196.25	187.03	159.87
2012	144.68	140.92	139.37	124.28	119.00	112.58	127.10	150.30	173.22	199.63	176.57	166.20
2013	146.70	138.82	146.13	126.78	122.20	117.12	127.65	148.88	177.42	195.43	194.07	174.43
2014	140.88	127.75	138.07	120.30	116.45	107.77	120.02	144.28	162.60	183.12	180.08	169.67
2015	139.90	133.80	141.47	125.75	121.37	117.87	128.45	149.43	172.72	191.58	172.82	159.88
2016	135.90	134.90	145.23	117.17	115.83	107.70	117.68	141.22	166.60	195.25	191.70	176.15
2017	154.27	133.07	134.15	119.48	113.43	106.58	119.05	132.30	160.13	189.90	174.90	163.43
2018	133.40	138.12	134.20	121.47	115.65	104.52	108.07	141.87	163.42	178.92	177.45	161.30
2019	150.83	131.35	145.65	122.28	112.58	112.57	126.12	148.20	164.67	178.80	175.10	150.22
2020	138.77	134.13	132.55	118.17	116.22	103.83	104.78	133.47	157.37	180.28	173.32	159.37

Table 17: Average annual production data for Sugarcane in Ilovo Plantations.

Year	Water Use (m^3)	Area (Ha)	Production (Tons)	Value of Cane (USD)	Production Cost (USD)
2015	29,606,397	5,672.06	457,019	11,730,890	4,913,143
2016	61,337,569	6,047.01	495,356	12,714,935	5,237,919
2017	29,548,743	5,984.51	520,897	13,370,517	5,183,782
2018	36,236,260	5,522.95	452,519	11,615,384	4,783,984
2019	28,933,123	5,304.33	422,388	10,841,976	4,594,616
2020	37,401,014	5,695.46	505,059	12,963,991	4,933,414
2021	53,794,524	5,452.37	427,493	10,972,991	4,722,849
Average	**39,551,090**	**5,668.39**	**468,676**	**12,030,098**	**4,909,958**

Table 18: Average production data for sugarcane for small-holder farmers

Year	Water Use (m^3)	Area (Ha)	Production (Tons)	Value of Cane (USD)	Production Cost (USD)
2015	57,808,915	11,535.86	452,970	11,626,951	7,173,189
2016	61,233,085	11,702.45	468,098	12,015,263	7,647,362
2017	62,060,304	11,860.55	486,282	12,482,021	7,568,321
2018	55,963,811	15,695.43	427,817	10,981,317	6,984,616
2019	50,533,741	12,990.99	405,622	10,411,610	6,708,139
2020	49,006,569	13,287.37	477,656	12,260,598	7,202,784
2021	51,816,044	16,244.19	406,012	10,421,621	6,895,359
Average	**55,488,924**	**13,330.98**	**446,351**	**11,457,055**	**7,168,539**

Notes: Volume of water used is a summation of water use permit from RBWB

Table 19: Average production data for paddy for small-holder farmers

Years	Production (Tons)	Prices (US$/Ton)	Revenue (US$)	Expenditure (US$)	Profit (US$)	Water Use (m^3)
2010	239,332.00	267.80	64,093,109.60	63,009,686.00	1,083,423.60	737,678,260.87
2011	227,430.00	271.10	61,656,273.00	60,652,674.00	1,003,599.00	711,804,347.83
2012	211,202.00	269.14	56,842,906.28	55,678,341.00	1,164,565.28	676,526,086.96
2013	299,851.00	274.00	82,159,174.00	80,474,568.00	1,684,606.00	869,241,304.35

Years	Production (Tons)	Prices (US$/Ton)	Revenue (US$)	Expenditure (US$)	Profit (US$)	Water Use (m^3)
2014	442,739.00	274.41	121,492,008.99	119,986,470.00	1,505,538.99	960,302,173.91
2015	499,354.00	273.75	136,698,157.50	126,867,532.00	9,830,625.50	1,079,030,434.78
2016	452,833.60	273.70	123,940,556.32	113,834,567.00	10,105,989.32	975,725,217.39
2017	593,812.00	280.00	166,267,360.00	137,255,872.00	29,011,488.00	1,073,504,347.83
2018	504,363.60	274.00	138,195,626.40	108,580,112.00	29,615,514.40	869,486,086.96
2019	519,093.00	274.80	142,646,756.40	131,638,765.00	11,007,991.40	1,128,463,043.48
2020	581,969.40	275.00	160,041,585.00	131,538,987.00	28,502,598.00	1,047,759,565.22
2021	502,253.00	275.10	138,169,800.30	126,606,222.00	11,563,578.30	1,087,506,521.74
Average	**422,852.72**	**273.57**	**116,016,942.82**	**104,676,983.00**	**11,339,959.82**	**934,752,282.61**