Advances in Bioscience and Bioengineering
2025, Vol. 13, No. 1, pp. 6-16
https://doi.org/10.11648/j.abb.20251301.12

Review Article

Comparative Analysis of Wheat Yield and Water Productivity Under Irrigation and Rain-fed Conditions Across Various Regions of Ethiopia: A Review

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Abstract

This review presents a comparative analysis of wheat yield and water productivity under irrigation and rain-fed conditions in Ethiopia. The review shows significant yield improvements across various regions due to irrigation, highlighting its transformative impact on agricultural productivity. In Oromia region, East Shoa (Koka) zone, irrigation increased yield by 156%, from 3.1 to 8.2 t ha^{-1}. Secondly Jimma zone recorded the next higher yield, irrigation increased by 119%, from 3.2 to 7.0 t ha^{-1} reflecting the optimization potential of irrigation practices. In Amhara region (Adet district) experienced a 75% yield boost, indicating irrigation's critical role. In the Afar Region, the rainfed yield is 3.1 t ha^{-1}, and the irrigated yield increases to 4.5 t ha^{-1}, indicating a 45.2% increase. The analysis of water productivity (WPc) revealed significant enhancements. In the Oromia Region, the WPc in Horo Guduru and Jimma zones showed an increase of 144%, rising from 0.7 to 2.1 kg kg m^{-3}, and a 100% rise from 0.7 to 1.75 kg m^{-3}, respectively, demonstrating improved efficiency, which is crucial for optimizing water usage in irrigated wheat agriculture. In the Amhara Region (Koga), irrigation raised WPc by 75%, with figures fluctuating between 0.63 and 1.1. Interestingly, in the Afar Region (Warar), irrigation improved WPc by 92%, with values between 0.66 and 1.27 kg m^{-3}, highlighting the significant impact of water management practices on agricultural productivity. These findings underscore the critical role of irrigation in improving both yield and water productivity, suggesting that Ethiopia can significantly enhance agricultural outputs, contributing to food security and economic growth by adopting efficient irrigation practices. The study aligns with global trends focused on sustainable resource use, addressing challenges such as climate change and water scarcity. Emphasizing efficient water management and advanced irrigation technologies will be vital for securing a resilient agricultural future for Ethiopia.

Keywords

Irrigated Wheat, Rain-fed, Yield and Water Productivity

1. Introduction

In Ethiopia, agriculture, particularly wheat cultivation, plays a vital role in the economy, with rainfed methods dominating the landscape. In 2023, rainfed wheat covered 2 million hectares, while irrigated wheat accounted for 0.67

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Received: 14 December 2024; **Accepted:** 26 December 2024; **Published:** 14 January 2025

million hectares, totaling 2.6 million hectares of wheat cultivation. The Ethiopian government has prioritized irrigated agriculture to enhance food security and reduce reliance on imports, yet challenges such as inadequate infrastructure and investment persist [2, 10]. Despite the significant area under rainfed agriculture, studies indicate that many regions suitable for irrigation remain underutilized. Climate change further complicates agricultural productivity, necessitating adaptive strategies to mitigate its impacts [35]. The success of the irrigated wheat initiative, which aims to emulate Asia's Green Revolution, hinges on effective water management and stakeholder engagement. Thus, while rainfed agriculture remains prevalent, the potential for increased irrigated cultivation is critical for achieving sustainable food security in Ethiopia. The benefits of irrigation are evident in the yield data. Irrigated wheat areas in Ethiopia demonstrated an average yield of 4.6 tons per hectare, significantly outperforming rainfed areas where the average yield stood at 2.9 tons per hectare. Moreover, irrigated wheat fields have the potential to achieve even higher yields when combined with appropriate fertilization, with estimates reaching up to 8.9 tons per hectare under optimal conditions [13]. These figures underscore the importance of irrigation in increasing productivity and ensuring food security in the country.

The transition towards irrigation in Ethiopia is crucial not only for enhancing agricultural yields but also for building resilience against climate change impacts, such as erratic rainfall and prolonged droughts. The Ethiopian government has prioritized irrigated wheat production to achieve food self-sufficiency, yet challenges remain in policy implementation, infrastructure, and resource management. Research indicates that while irrigation can significantly improve crop yields, it also complicates water resource management, necessitating efficient practices to prevent scarcity [1]. The potential yield of wheat in Ethiopia is substantial, with some farmers achieving yields close to theoretical maxima under optimal conditions, highlighting the importance of irrigation and modern agricultural practices. However, climate change continues to threaten agricultural productivity, necessitating integrated adaptation strategies, including improved irrigation systems and water management practices. Thus, strategic investments in irrigation infrastructure are essential for optimizing water use and enhancing food security in the face of climate variability [42].

Rainfed agriculture remains crucial in Ethiopia despite the growing focus on irrigated farming. It faces challenges like low crop yields due to erratic rainfall and inadequate techniques [46]. To improve productivity, initiatives are underway to implement innovative practices, including supplemental irrigation, which can stabilize yields. Recently, Ethiopia has significantly expanded its irrigated agriculture, with 20% of its wheat-growing area now irrigated, enhancing food security and reducing reliance on wheat imports. However, there is still room for improvement in irrigation methods to maximize benefits [13]. Research and development efforts continue to focus on optimizing production systems in both irrigated and rainfed agriculture. Bridging the yield gap between irrigated and rainfed areas remains a key priority to ensure food security and sustainable agricultural practices. By addressing water management inefficiencies and promoting the adoption of best practices, Ethiopia aims to maximize wheat production potential and build a resilient agricultural sector capable of withstanding future challenges [26, 30].

In general, the expansion of irrigated agriculture in Ethiopia, particularly in wheat cultivation, has been instrumental in enhancing food security and increasing agricultural productivity. Strategic investments in irrigation infrastructure and water management are essential to sustain these gains and ensure the long-term viability of agriculture in the country [34]. By balancing the benefits of irrigation with sustainable practices in rainfed farming, Ethiopia is working towards a more secure and prosperous agricultural sector that can meet the growing food demands of its population. This review aims to compare wheat yield and water productivity under irrigation and rain-fed conditions in Ethiopia, assessing current practices, identifying challenges, and proposing strategies for enhancing production and water productivity.

2. Study Methodology and Data Sources

The review used information from three sources: Scopus, ScienceDirect, and Google Scholar. Furthermore, insights from the Ethiopian Institute of Agricultural Research (EIAR) and regional research centers across diverse agro-ecological zones were collected and examined. The documents retrieved from Google Scholar (164 documents) and Scopus (263 documents) were evaluated using VOSviewer bibliometric software [40]. Following the analysis, crucial documents closely related to the terms “Irrigated wheat,” “Rainfed wheat,” and “Ethiopia” were identified and utilized in the review process. Following the meta-analysis, 49 documents were utilized and referenced throughout the manuscript. Field observations made during monitoring and evaluation were reviewed and integrated into the analysis. Government publications and various released magazines were also evaluated. Moreover, FAO and EES wheat productivity statistics were employed for comparing rainfed and irrigated systems. Additionally, visual presentations from field visits, depicting water management methods, were incorporated. For instance, various images were showcased for irrigated wheat in the Jimma Zone, highlighting soil erosion, waterlogging, over-irrigation, under-irrigation, and inadequate distribution uniformity.

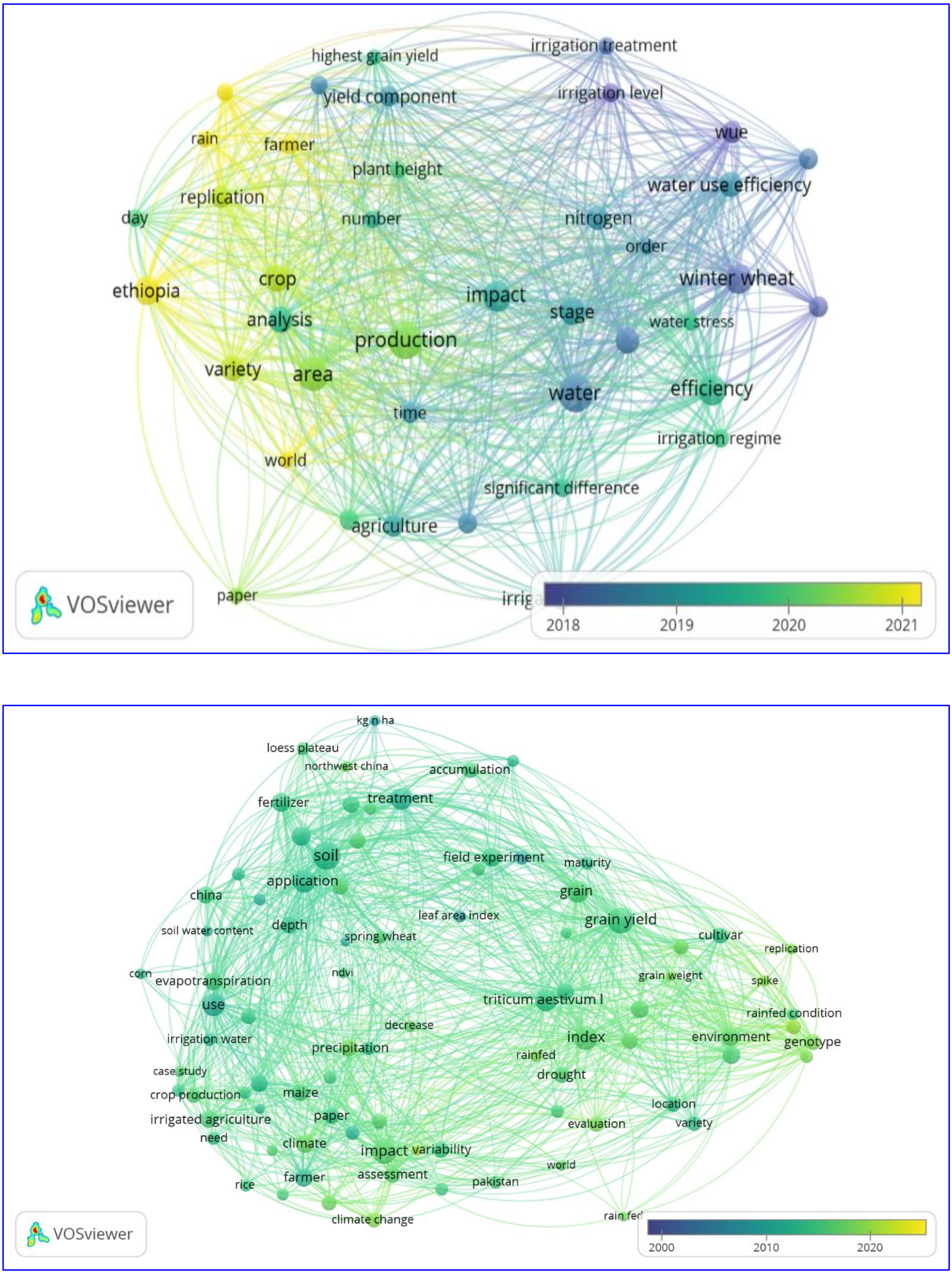

Figure 1. *The journals downloaded from google scholar (upper) and Scopus data bases (lower).*

3. Review

3.1. Evolution of Irrigated Wheat in Ethiopia

Ethiopia has significant potential for irrigated wheat production, with 5.3 million hectares of land suitable for this purpose, though less than 2% has been utilized. Historically reliant on rain-fed agriculture, the country began implementing medium and large-scale irrigation schemes in the 1950s, particularly in the Awash River basin and later in other regions for various crops. Research on irrigated wheat began in the 1980s at the Worer Agricultural Research Center, but despite existing irrigation schemes for cotton, there has been no irrigated wheat production, and cotton farmers have not considered double cropping with wheat or legumes [25].

The initiative for irrigated wheat production in Ethiopia began in 2009, focusing on off-season accelerated seed multiplication of wheat varieties at Worer ARC, supported by external project. Subsequent years saw the testing and release of heat tolerant wheat varieties, with demonstrations in Afar and Oromia regions under different zones such as Jimma zone, Bunno Bedelle and East Shoa zones. Due to rising wheat demand and the need for import substitution, the Ethiopian government prioritized irrigated wheat production for food security, planning to cultivate 500,000 hectares of irrigable land by 2024. Wheat cultivation increasing at alarming rate 21,000 in 2020 to 600,000 hectares in 2023 [11], with yields ranging from 4 to 8.9 t ha^{-1}. Encouraged by these results, the government aims to expand irrigated wheat production to 3 million hectares in the next five years [47].

In irrigated regions, wheat is frequently rotated with crops such as maize, particularly in mid-latitude and high-altitude areas like Jimma and Bedelle, which are usually sown in winter. Within the wheat-maize rotation, the harvesting of maize is postponed until late October, which consequently delays wheat sowing until late December, with land preparation taking around 20 days. This postponement makes wheat vulnerable to unexpected rainfall during the April harvest, adversely affecting the harvesting process, yield, and grain quality. It is crucial to develop for high-yield, early-maturing varieties of both crops to enable successful double cropping. It is vital to adhere closely to the crop calendar to address these challenges effectively.

3.2. Impact of Irrigation on Wheat Yield

Table 1 and Figure 2 present findings concerning wheat yield across different regions in Ethiopia under both rainfed and irrigated scenarios. A lot of studies was conducted nationwide in various locations, from semi-arid zones to highland areas, to assess the effect of irrigation on wheat yield and water productivity. The results from these studies indicate significant variations in yield across different regions and between rainfed and irrigated wheat production. Besides irrigation, the influence of fertilizer application on yield and water productivity was analyzed during the dry season (from November to April) in irrigated wheat fields. From this, we gained valuable insights, revealing that it is possible to increase wheat yield to exceed 8.9 t ha^{-1}, indicating that evaluations of irrigation and fertilizer under various irrigation levels in different agro-ecological zones are necessary. Limited studies have been carried out to investigate the impact of fertilizer in both rainfed scenarios and fully irrigated situations independently, making it challenging to evaluate their interactions thoroughly. This lack of research hinders our understanding of how various water management techniques can affect fertilizer performance and agricultural output. Furthermore, understanding these interactions is crucial for developing sustainable agricultural practices that optimize resource use and enhance crop yields. Consequently, assessing fertilizer rates under varying irrigation levels is essential to optimize both water and fertilizer usage, thereby improving wheat yield and water productivity.

The Oromia Region shows a significant improvement in wheat production when full irrigation is utilized along with the recommended fertilizer application. On average, the yield increased from 3.16 t ha^{-1} to 5.64 t ha^{-1}, indicating a 77.8% increase, with the maximum yield attaining 8.9 t ha^{-1}. The study carried out in Horo Guduru within the Jimma Geneti district reveals a significant improvement in wheat productivity when grown under irrigation. The yield increases from 2.96 t ha^{-1} to 8.20 t ha^{-1}, representing a 177.7% increase [13]. A study conducted by JARC in the Jimma zone, specifically in the Nedi-gibe district, reveals notable improvements in wheat productivity aimed at examining various fertilizer application rates (P and N) on wheat yield under optimal irrigation during the dry season (December to April). The yield increases from 3.26 t ha^{-1} to 7.01 t ha^{-1}, representing a 115.3% increase. This result was obtained through the proper utilization of nitrogen and phosphorus applications under optimum irrigation [16]. In addition, experiment conducted in East Shoa (Koka) indicated, the yield increased dramatically by 81.3%, from 3.1 to 5.6 t ha^{-1} [4, 28, 29]. This remarkable increase is likely attributed to optimal application of irrigation water and fertilizer during critical plant growth stages [38].

Likewise, in the Amhara Region, some studies were carried out to evaluate the impact of irrigation on improving wheat productivity. Among these, the trial carried out in Koga district and Adet (west Gojjam) shows a significant increment in wheat yield under irrigated conditions. In Koga district, the yield increases from 3.09 t ha^{-1} to 5.60 t ha^{-1}, which corresponds to an 80.6% increase [5, 9]. Meanwhile, in Adet, the yield increased from 2.00 t ha^{-1} to 3.50 t ha^{-1}, indicating a 75% increment [7]. In a manner similar to other areas, research carried out in the semi-arid Afar region at Amibara District by EIAR indicates a notable improvement in wheat yield under irrigation. The yield increased from 3.03 t ha^{-1} to 5.32 t ha^{-1}, signifying 75.6% increments. The increase in wheat yield is linked to a consistent irrigation water application, along with recommended fertilizer application that is essential during sensitive growth phases [20, 12].

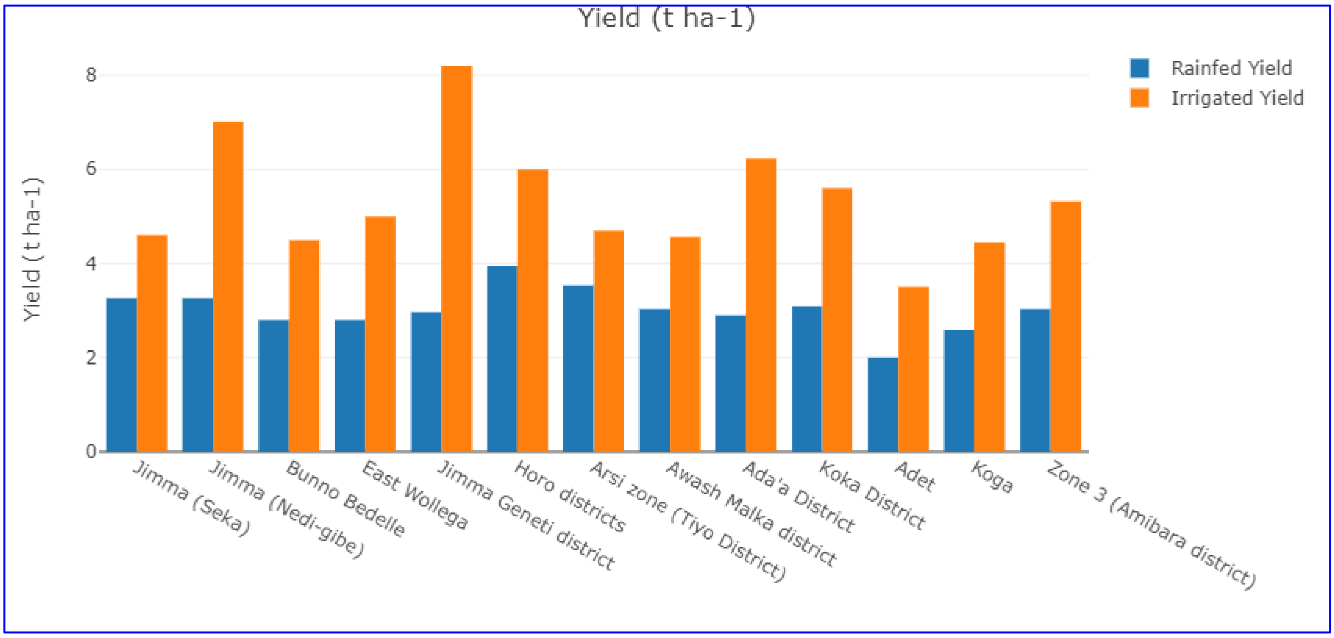

Figure 2. *Wheat yield productivity in various regions, whether irrigated or relying on rainfall, in Ethiopia.*

3.3. Water Productivity (WPc) Analysis

Table 1 and Figure 3 show significant variations in WPc across different regions and between rainfed and irrigated wheat production. The experiment carried out on irrigated wheat and rainfed wheat at diverse location from semi-arid to highland showed that there are greater improvement in water productivity due to improved yield under irrigated condition. The Oromia region also exhibits a significant improvement in water productivity under irrigated conditions. The WPc increases from 0.71 kg m^{-3} to 1.37 kg m^{-3}, showing a 94.4% improvement. This indicates that irrigation not only increases yield but also enhances the efficiency of water use, which is vital in regions facing water scarcity and climate variability. The higher WPc suggests that irrigation allows for better utilization of water resources, resulting in more grain produced per unit of water consumed. This finding is consistent with global studies that emphasize the critical role of irrigation in enhancing water use efficiency, particularly in water-scarce regions. The use of optimized fertilizers, such as P and N, further optimizes plant growth and water use, contributing to the higher WPc. By ensuring that plants have the necessary nutrients, fertilizer application helps in more efficient water use and better yield, thereby improving water productivity. Similarly, in the Amhara region, the rainfed WPc is 0.54 kg/m^3, and the irrigated WPc increases to 0.85 kg/m^3, showing a 57.4% increase. In the Afar Region, the rainfed WPc is 0.36 kg/m^3, and the irrigated WPc increases to 1.01 kg/m^3, indicating a 180.6% increase. On average, the rainfed WPc is 0.65 kg/m^3, while the average irrigated WPc is 1.22 kg/m^3, showing an average increase of 67.3%. These findings demonstrate the significant impact of irrigation on water productivity, highlighting the potential for improving WPc through the adoption of more efficient irrigation methods and better agronomic practices. The results align with global studies that emphasize the critical role of irrigation in enhancing water productivity [15, 17, 20, 24, 27, 39].

The study conducted in Horo Guduru at Jimma Geneti district also exhibits a significant improvement in water productivity under irrigated conditions. The WPc increases from 0.74 kg m^{-3} to 2.18 kg m^{-3}, showing a 194.6% improvement. This indicates that irrigation not only increases yield but also enhances the efficiency of water use, which is vital in regions facing water scarcity and climate variability. The higher WPc suggests that irrigation allows for better utilization of water resources, resulting in more grain produced per unit of water consumed. The Jimma (Nedi-gibe district) zone also shows a significant improvement in water productivity under irrigated conditions. The WPc increases from 0.73 kg m^{-3} (rainfed) to 1.75 kg m^{-3} (irrigated), showing a 139.7% improvement. This indicates that irrigation not only boosts yield but also optimizes water use, which is essential for sustainable agriculture in water-scarce regions. The higher WPc suggests that irrigation allows for better utilization of water resources, resulting in more grain produced per unit of water consumed. This finding is consistent with global studies that emphasize the critical role of irrigation in enhancing water use efficiency. The results highlight the potential for irrigation to play a key role in improving food security and agricultural sustainability in Ethiopia (Table 1).

Water productivity enhancements are equally notable. East Shoa at Koka's modest 6.7% increase, from 0.75 kg/m^3 to 0.80 kg/m^3, reflects improved efficiency, crucial in arid regions striving to maximize water use [4, 28]. At Adet the WPc increased 33.3% indicating irrigation's role in water efficiency, similar to practices in the Sahel [7]. In Kulumsa, 89.7% gain mirrors advanced management strategies like those in Australia, where precision irrigation leads to substantial gains [11, 49]. The Bedelle and East Wellega's improvements align with global efforts to enhance water productivity, especially in water-scarce regions, reflecting the importance of adopting efficient irrigation technologies [8, 11]. Warar's dramatic 180.6% increase and Adama's 159.3% rise underscore the potential of water-saving technologies, similar to those employed in Israel and the Middle East, emphasizing innovation in water management [11, 12, 20, 23].

Overall, these findings stress the critical role of irrigation in enhancing both yield and water productivity. By adopting efficient irrigation practices and fertilization methods, Ethiopia can significantly improve agricultural outputs, contributing to food security and economic growth. These efforts align with global trends focused on optimizing resource use sustainably, addressing challenges like climate change and water scarcity. Emphasizing efficient water management and advanced irrigation technologies will be vital in achieving these goals and securing a resilient agricultural future.

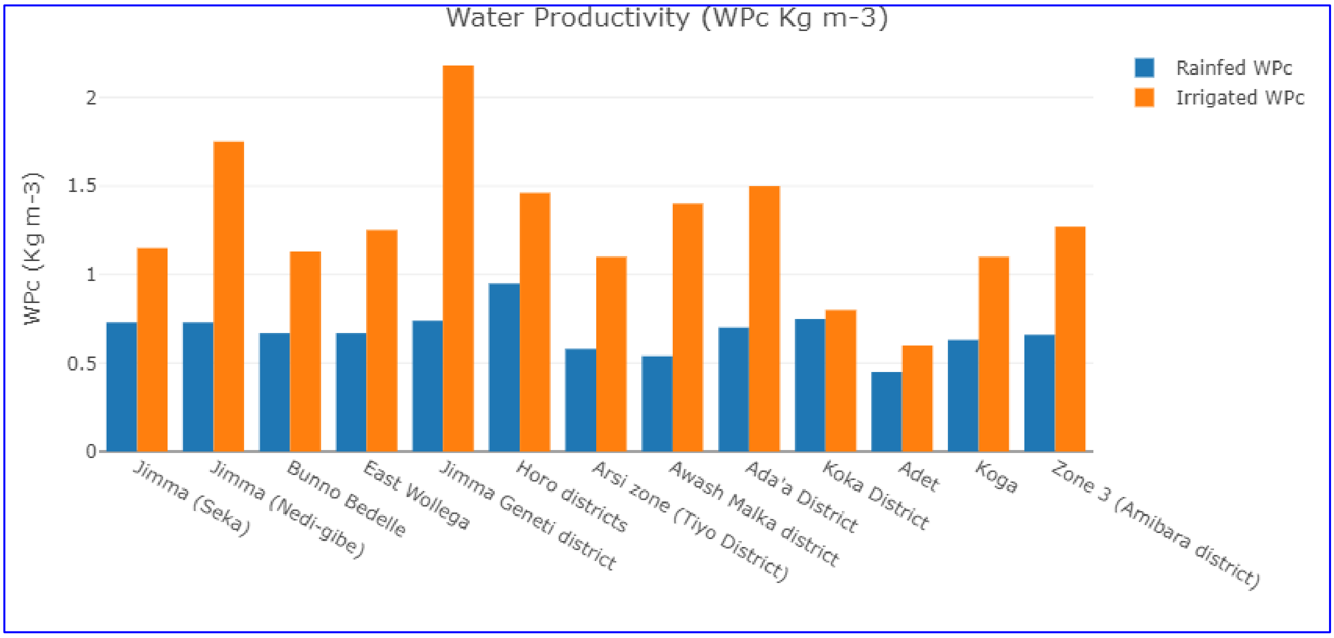

Figure 3. *Wheat WPc in various regions, whether irrigated or relying on rainfall, in Ethiopia.*

Table 1. *Comparative examination of the effects of irrigation and rainfed systems on the yield and water efficiency of wheat in Ethiopia.*

Region	Location	Rainfed		Irrigated		Reference
		Yield t ha^{-1}	WPc Kg m^{-3}	Yield t ha^{-1}	WPc Kg m^{-3}	
Oromia	Jimma (Seka)	3.26	0.73	4.6	1.15	[8, 36]
	Jimma (Nedi-gibe)	3.26	0.73	7.01	1.75	[16]
	Bunno Bedelle	2.8	0.67	4.50	1.13	[8, 11]
	East Wollega	2.8	0.67	5.00	1.25	[8, 11]
	Jimma Geneti district	2.96	0.74	8.20	2.18	[11, 13] (P rate+irr)
	Horo districts	3.95	0.95	6.00	1.46	[11, 13] (P rate +irr)
	Arsi zone (Tiyo District)	3.53	0.58	4.70	1.12	[11, 49]
	Awash Malka district	3.03	0.54	4.56	1.41	[12, 23]

Region	Location	Rainfed Yield t ha^{-1}	Rainfed WPc Kg m^{-3}	Irrigated Yield t ha^{-1}	Irrigated WPc Kg m^{-3}	Reference
	Ada'a District	2.9	0.7	6.23	1.50	[14]
	Koka District	3.09	0.75	5.6	0.80	[4, 28]
Amhara	Adet	2.00	0.45	3.5	0.60	[7]
	Koga	2.59	0.63	4.45	1.10	[5]
Afar	Zone 3 (Amibara district)	3.03	0.66	5.32	1.27	[11, 18, 20]
	Average	3.00	0.65	5.15	1.22	

3.4. Global Wheat Productivity Variability Across Different Countries: Comparing Irrigated with Rainfed Systems

The FAO's report indicates the significant difference in wheat yields between countries utilizing advanced irrigated systems and those relying on rainfed agriculture. Countries like Ireland (10.43 t ha^{-1}), the Netherlands (9.4 t ha^{-1}), New Zealand (9.4 t ha^{-1}), and Egypt (6.8 t ha^{-1}), which have adopted efficient irrigation practices and advanced technologies, achieved remarkable yields, with Ireland leading at 10.43 kg/ha. In contrast, Somalia (0.4 t ha^{-1}), dependent on rainfed systems, reported much lower yields of 0.40 kg/ha, primarily due to erratic rainfall and climate variability [48]. Even Egypt has improved wheat productivity, which may reach 6.8 t ha^{-1} with the use of irrigation and improved nutrient management. Other studies indicated that in Egypt, the maximum wheat yield of 8.5 t ha^{-1} was obtained when irrigated with subsurface drip irrigation, with a water productivity of 1.78 kg/m^3 [24]. The use of drip irrigation improved yield and water productivity, demonstrating that choosing the appropriate irrigation method can enhance yield and water productivity. In contrast, Somalia exhibited lower productivities, as the country totally relies on rainfed production, although it receives lower rainfall compared to Ethiopia.

The Ethiopian government recognized the role of irrigation in enhancing wheat productivity. Since 2018, through a campaign and supported with research, much of the irrigated area in the country has been covered with wheat, and the use of technology, varieties, and the distribution of water pumps to irrigated areas have been implemented. To boost public awareness, large-scale demonstrations were carried out in different parts of the country and became part of the government's agenda. For example, in the Jimma zone, much of the irrigated land became dedicated to wheat production, with the task followed by the Jimma Research Center as a mentor. Due to these factors, the productivity of irrigated land became greater than 4 t ha^{-1}, showing about a 33% yield advantage over the rainfed national average. Even the productivity of irrigated wheat may reach 8.9 t ha^{-1} when the appropriate variety and fertilizer are used, showing a 178% yield advantage compared to rainfed conditions [13].

Studies indicate that irrigated systems can enhance wheat yields by approximately 40% compared to rainfed systems, with specific studies showing increases of up to 55% in certain cultivars [14, 45]. This underscores the critical need for sustainable irrigation practices and technology adoption to bridge the productivity gap and ensure food security in the face of climate challenges [21, 43].

3.5. Challenges and Opportunities

In Ethiopia, particularly in southwest Ethiopia (Jimma and Buno Bedelle zones), irrigated wheat production faces several challenges, including over-irrigation, under-irrigation, waterlogging, soil erosion, and improper flow rates, all of which significantly impact yields. The field observations indicate that many farmers under irrigate, over irrigate, and some farmers experience waterlogging in their fields while others manage to irrigate their fields adequately (Figure 4). Additionally, some farmers face challenges with timely sowing or sow their wheat late, resulting in harvests coinciding with rainfall, which complicates the harvesting process. Late sowing negatively impacts the harvesting procedure, since rainfall occurs in early April and damages the crop output, challenging for the combine harvester. The best time to sow wheat in southwestern Ethiopia falls between early December and the end of December. Nevertheless, farmers are falling behind because of delayed delivery of seeds and fertilizers, as well as late preparation of the land. According to Jimma zone the agricultural office report there is approximately a 15% loss in yield attributed to the early onset of rainfall, which complicates the harvesting process and ultimately discourages farmers. This situation affects the sowing for the following year, with farmers showing less interest in cultivating wheat, opting instead for other crops that are believed to be more resilient to the erratic weather patterns. The reliance on motor pumps for irrigation, coupled with rising fuel costs, exacerbates water management issues, resulting in soil cracking and crop wilting due to stress [2, 33, 37]. Additionally, the use of higher flow rates during irrigation has been linked to increased soil erosion and water logging, ultimately reducing yields [14]. Despite the introduction of new irrigated wheat technologies, the lack of education and extension services, as well as inadequate infrastructure, hinder effective adoption and management practices [6]. Addressing these challenges through improved education, infrastructure, and irrigation strategies is crucial for enhancing wheat production efficiency in the region.

Furthermore, the lack of access to improved seed varieties and agricultural inputs intensifies the problem, resulting in a decrease in overall productivity and food security in the area. At present, fuel prices are rising rapidly, and farmers are facing difficulties in making local purchases while being restricted from buying at gas stations. Consequently, farmers are not effectively utilizing the large water pump. This situation raises the costs for farmers. Consequently, numerous farmers are now confronted with the grim reality of decreasing crop yields. As a result, farmers are forced to implement extended irrigation intervals, and skipping irrigation schedules and under-watering their fields [21].

In all irrigated regions of southwest Ethiopia, a significant number of farmers face challenges with land preparation, resulting in delays in starting work and causing the soil moisture to become depleted, rendering the soil unworkable or overly dry, which forms large clods when ploughed using oxen or a tractor. Additionally, they often fail to level the land, leading to an uneven surface that complicates furrow preparation. Moreover, the tractors used for preparing irrigated wheat fields lack both levelers and furrow makers. This results in the creation of large clods, forcing farmers to re-plough using oxen, which adds extra expenses for them. Furthermore, many farmers involved in irrigated wheat do not prepare the furrows with the correct length, width, or slopes; some even create furrows along the slope, which exacerbates soil erosion and leads to waterlogging at the lower end of the field. Longer furrows in sandy clay loam promote deeper percolation, which results in uneven irrigation across the field and negatively impacts the crops [3, 19]. Additionally, improper furrow management can lead to nutrient leaching, further diminishing soil fertility and crop yields over time [32]. Studies conducted in different countries indicates that inadequate furrow length and slope management can exacerbate issues like soil erosion and waterlogging, leading to uneven irrigation and negatively impacting crop yields [22, 31, 44]. The absence of leveling equipment on tractors further contributes to the problem, as it results in the formation of large soil clods that require additional ploughing, increasing costs for farmers [41].

The introduction of cluster farming programs for irrigated wheat has sparked a variety of technological innovations in Ethiopia's irrigated areas. This includes land preparation with tractors, which have replaced the traditional oxen plowing method, as well as the use of combine harvesters that facilitate collective harvesting, minimize post-harvest losses, and encourage the adoption of modern technologies. Additionally, the government subsidized for seeds and fertilizers to encourage farmers to engage in wheat cluster farming and enhance wheat productivity. These initiatives not only improve productivity but also promote collaboration among farmers, allowing them to effectively exchange knowledge and resources and build stronger community ties. Additionally, the government provided water pumps in various sizes for collective or solo farmers facing challenges in diverting rivers or lacking access to irrigation systems, thus guaranteeing that irrigation remains both accessible and effective, allowing them to irrigate their fields without concern.

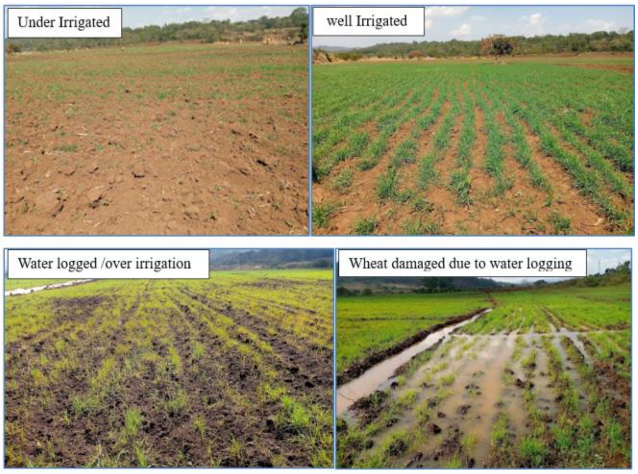

Figure 4. *The on-farm water management problems in irrigated wheat at seka-chokorsa district-Gibe scheme-2021.*

4. Conclusion

The comprehensive review clearly demonstrates the substantial impact of irrigation on wheat yield and water productivity (WPc) across various regions in Ethiopia. The studies reveal significant variations in yield and WPc between rainfed and irrigated conditions, underscoring the potential for improving wheat production through the adoption of more efficient irrigation methods and better agronomic practices. Yield increases range from 41.1% to an impressive 177.7%, with an average increase of 71.5%, bringing yields from 3.5 to 8.9 t ha^{-1}. Similarly, WPc improvements range from 33.3% to 200% (0.6 to 2.18 kg m^{-3}), with an average increase of 67.3%. These findings are consistent with global studies that highlight the critical role of irrigation in enhancing crop yields and water use efficiency, particularly in regions vulnerable to climate change and water scarcity.

5. Recommendations

Focus on on-farm water management by scheduling irrigation according to crop requirements and properly allocating water among upstream and downstream users.

Most irrigated wheat fields require land leveling, as well as the preparation of secondary and tertiary canals to distribute water from the main canals. However, almost all irrigation schemes in Oromia lack these secondary and tertiary canals. As a result, farmers have constructed them on their own, without proper design, highlighting the need for government support.

Implementing recommended fertilizer practices that enhance yield while considering fertilizer use efficiency is crucial. Aligning nutrient application with the amount of water supplied helps optimize input resources, such as water and fertilizer, to achieve improved wheat productivity.

Invest in irrigation infrastructure and provide farmers access to technologies and training to support sustainable wheat production.

Focus on adapting irrigation technologies to local conditions, ensuring they are cost-effective and energy-efficient.

By adopting these recommendations, Ethiopia can boost wheat production, enhance food security, and promote economic growth. Efficient water management and advanced irrigation technologies are crucial for a resilient agricultural future.

Abbreviations

FAO	Food and Agriculture Organization

Acknowledgments

The authors sincerely appreciate the staff of JARC, specifically the individuals from the soil and water management research process and the irrigation and water harvesting department, for their invaluable support and assistance in providing internet access and necessary data.

Authors Contributions

Minda Tadesse: Conceptualization, Data curation, Formal Analysis, Methodology, Software, Supervision, Visualization, Writing – original draft

Addisu Asefa: Data curation, Investigation, Methodology, Supervision, Writing – review & editing

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data Availability Statement

All data supporting the information in this review are available from the corresponding author upon reasonable request. The available datasets include climate data and information collected from journals and various papers.

Conflicts of Interest

The authors declare no conflicts of interest.

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