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Review

Integrated Watershed Management Framework and Groundwater Resources in Africa—A Review of West Africa Sub-Region

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Abstract: Human activities mostly impact the trend and direction of rainwater, groundwater, and other river basin resources in the watershed in Africa. These activities alter river flows and the quality of usable water supplies at both highlands and lowlands. A watershed is indeed a conserved area of land that collects rain, sleet and snow, and empties or penetrates groundwater sources. The act of managing the activities around the watershed is integrated watershed management, which considers the social, economic, and environmental issues in tandem with the human, institutional, natural, and sustainability systems, which are the key drivers as identified in this study, as well as community interests and participation, to manage groundwater resources sustainably. These watersheds, river basins, and groundwater resources provide important services for communities and biodiversity. This paper reveals that the best way to protect groundwater resources is on a watershed basis using sustainable management measures. This technique enables us to handle a variety of concerns and objectives while also allowing us to plan in a complicated and uncertain environment. Sustaining a regional and sub-regional watershed involves cooperation and participation from a wide range of community interests and water users, including municipalities, companies, people, agencies, and landowners, for stakeholders' input to be successful. All of the strategies and plans are produced with regard to one another, as well as the overall conditions of the watershed, local land uses, and specific regional transboundary issues.

Keywords: Africa; biodiversity; groundwater resources; integrated watershed management; river basins

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1. Introduction

A watershed is a biophysically defined region delimited by the direction of the water network and drained by a tide or series of streams to a single outlet point or catchment area [1,2]. A "land area that drains into a stream" is referred to as a watershed [2]. "The use, management, and investment in multiple interrelated resources within watersheds" is what watershed management entails. It refers to the sustainable management and protection of all the ecological resources in a watershed, the natural forests and other land uses, as well as groundwater, which is not left out. Watersheds are distinct locations that are generally defined by a diversity of ecological, political and socioeconomic characteristics [1]. The interests of stakeholders, who might differ across upstream and downstream consumers as well as between sectors of the economy, are, nevertheless, extremely complicated. "Watersheds are usually large, and several people, communities, companies and groups are willing to participate in how they are managed" [3]. Water, soil, nutrients, and pollutants move across various areas of a watershed, forming physical links and landscape network connectivity between individuals who are geographically apart [3]. Watersheds are brimming with production and consumption externalities in economic terms. It has long been understood that water resources are inextricably linked to the ecosystem and people who live in it [3]. The increased focus on watershed management can also be seen in the large amount of money invested in watershed projects in recent years all around the world, but especially in Africa and Asia [3,4]. Even though the focus of this review paper is on integrated watershed management and other natural groundwater resources in the watershed, river basins and catchment areas are taken into account. The goal of this review is therefore on the evaluation of the homogeneous watershed management, river basin framework, and groundwater resources integration in Africa; while also considering the river basin organizations (RBOs) and agencies in Africa with an emphasis on the West Africa sub-region.

2. Watershed Management in Africa

A drainage basin is a land area where water flows and drains into a widespread water body, including a stream, lagoon, lake, or coast [4]. A watershed is a natural system that includes water, plants, animals, marshes, moraines, and forests that interact [5]. When water flows out of the watershed, the watershed boundary will approximately track the steepest slope around the stream channels, finally meeting at the bottom or lower part of the land, the canal mouth. The majority of the water comes from rain and stormwater runoff. Within a watershed, all changes to the land, such as extraction, farmland, roads, urban development, and human anthropogenic factors, affect the quality and quantity of stormwater [4,5]. Watersheds are separated from one another by naturally elevated areas [5].

Why Are Watershed and Groundwater Resources Important?

Surface water features and stormwater runoff within a watershed eventually flow to other bodies of water, making watersheds significant. When executing water quality protection, sustenance, and restoration initiatives, it is critical to consider these downstream effects [5]. Everything that happens upstream eventually ends up downstream. We must keep in mind that we all live downstream and that our daily actions might have an impact on downstream rivers. Environmental management has traditionally been focused on individual concerns, such as air, land, and water [6]. The majority of these efforts have resulted in lower pollutant emissions to the air and water; improved landfills, waste sites, and contaminated groundwater remediation; protection of rare and endangered species; development of best management practices to control water and contaminant runoff; and much more. Nonpoint source pollution and habitat loss continue to be a challenge for our river basins and seas. These are the issues that are causing the majority of the water quality issues across the board. They are often difficult to manage encumbered by complicated challenges. Nonpoint pollution and habitat degradation are often considered to be cross-program regional issues [7].

The primary goal of the erosion and watershed management initiatives is to reduce soil erosion susceptibility in designated sub-watersheds across Africa, particularly in West Africa. The capital investments in erosion and watershed management component will support on-the-ground interventions to help reduce vulnerability to land degradation; erosion and watershed management institutions and information services will strengthen the enabling environment for effective erosion and watershed management implementation. These approaches will improve the capacities, modernization, and coordination of relevant federal, state, and local institutions involved in investment preparation, governance, evaluation, regulation, and surveillance of watershed and erosion-related activities, as well as flood risk management; the adaptation and mitigation elements will include climate actions that help strengthen Africa's theoretical foundation for dealing with climate change and all its environmental and ecological impacts [8].

Watershed management's ultimate goal is to maintain balanced social, economic, and ecological watershed functions, therefore contributing to long-term development and the decrease in negative external consequences in an area of action [8]. This assumes that at the regional level, proper policies, regulations, and institutions are in place and respected. The goal establishes a framework for achieving the following major watershed management objectives: ensuring that beneficial uses of water resources and other related resources are maintained, achieving specified and agreed-upon management targets for water and related resources, avoiding negative off-site impacts (externalities) on water and related resources, and recognizing and avoiding negative human impacts on watershed functions. It also helps to promote social and economic growth, to protect, reduce, or repair natural resources and the environment, reduce local susceptibility to climate extremes, and maintain a balanced biodiversity action [9].

The aforementioned watershed management goals are dependent on country-specific circumstances, as well as the priorities of higher-ranking development programs and plans. These vary significantly between nations and sub-regions at large, however as one country-specific example action [10]. To attain these goals, a variety of activities and methods are possible, including but not limited to drafting and passing relevant policies and legislation, as well as establishing supporting institutions. Reducing riverbank erosion, minimizing sediment transit and buildup, and increasing water quality, biodiversity preservation, aquatic habitat control and climate change mitigation/adaptation are all benefits of managing the river flow regime as illustrated in Figure 1 [11]. This helps to maintain good water quality and supply standards that comply with government regulations and community expectations. Flooding, erosion, weathering, droughts, and landslides are all-natural calamities that may be avoided [6].

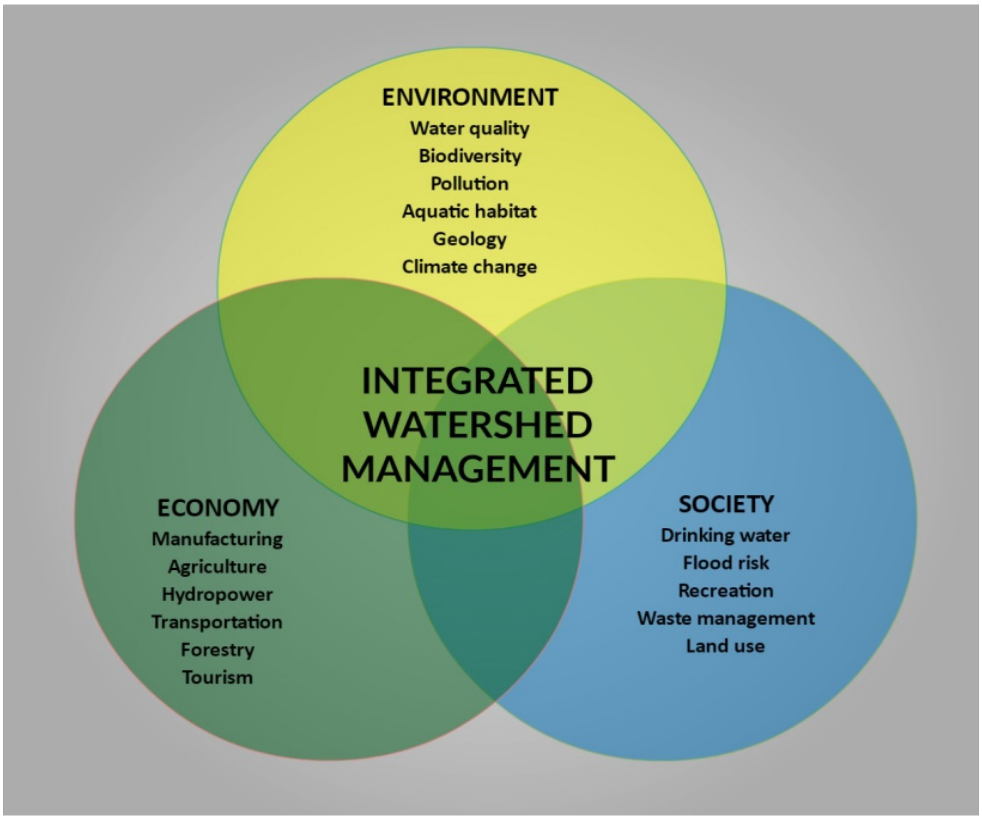
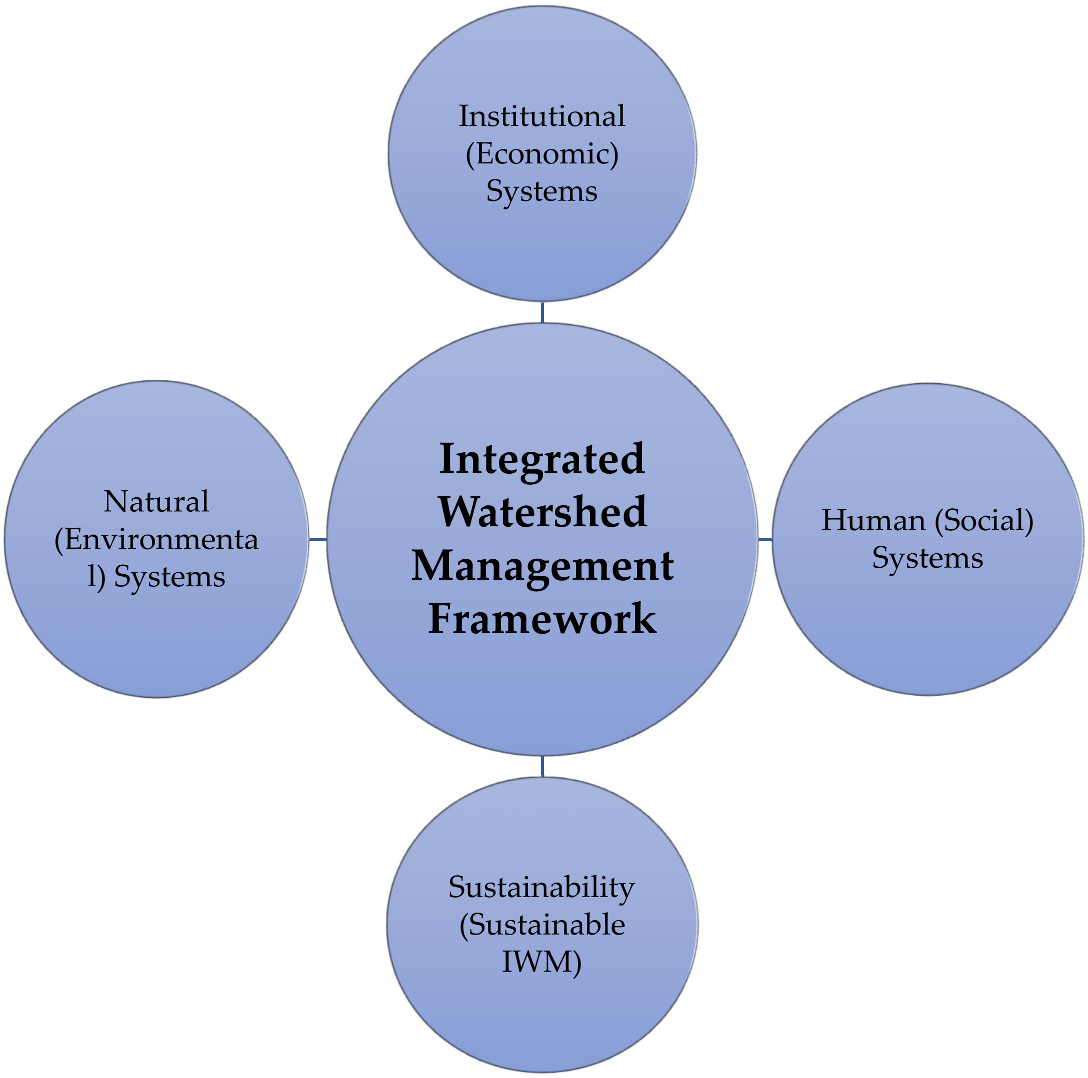


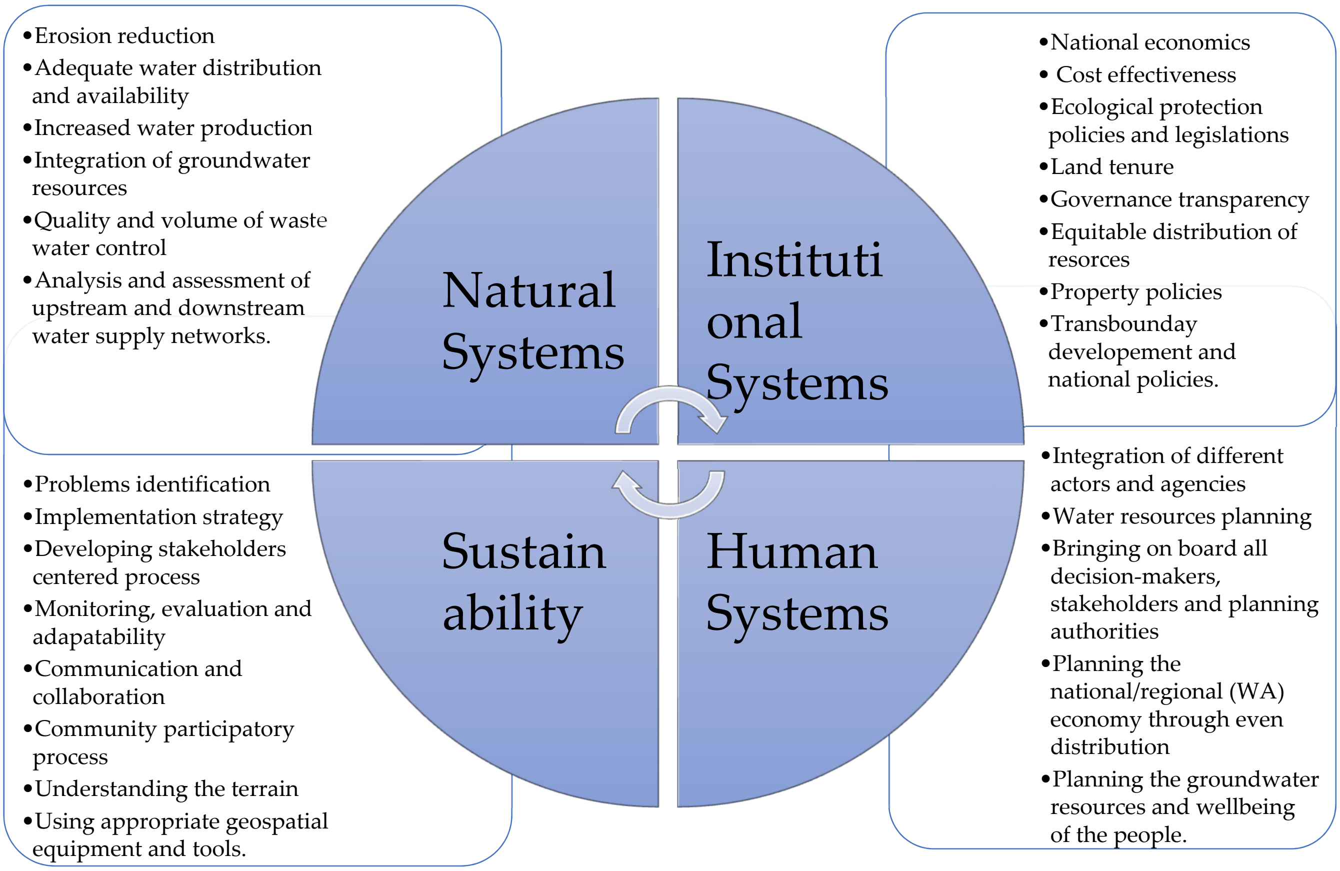
Figure 1. Policy priorities of Integrated Watershed Management. Source: https://conservationontario.ca/Conservation Ontario (2012) (accessed on 1 December 2021) [11].

Integrated watershed management effectively uses natural resources to reduce negative impacts and consequences, avoid environmental degradation, boost water output, and increase biomass production. Promoting suitable agriculture and forestry land-use practices, as well as accompanying soil and water conservation measures that allow for adequate production levels, while minimizing long-term negative consequences on the watershed's natural resources. This promotes economic and human exploration and production through job and income-generating activities. Encourage the use of the development of indigenous technical knowledge and materials through simple, accessible, and economical technology solutions and institutional structures. The economic and social circumstances of the poor and those with limited resources are drastically improved while also helping in increasing the distribution of the benefits of land and water resources development across all the environmental stakeholders. Most of these actions and measures have been planned and implemented in the past under the umbrella of watershed management in some form or another [6–9]. This might explain why there are so many different perspectives and definitions of watershed management [6]. The proposed IWM conceptual framework in this study (Figure 2a,b), according to various literature, gives a detailed illustration of the key drivers of IWM and the strategic continental, sub-regional and national management measures.



(**a**)

Figure 2. *Cont.*



(**b**)

Figure 2. (**a**) Integrated Watershed Management key drivers, (**b**) IWM conceptual framework illustrating the natural, institutional, human, and sustainability strategies as part of watershed management measures.

Watershed management has acquired prominence and relevance in both environmental preservation and the wellbeing of the people living in watershed regions during the previous past decades (see Figure 2b). The Bhutan government, a country of south-central Asia, located on the eastern ridges of the Himalayas as well as the Nigerian government in West Africa, for example, identified IWM as the "major and critical approach to preserve the resource base to support the national economy" in its policy statements [11].

The idea behind watershed management initiatives is that some groundwater resources are better-controlled on a river basin scale. Multiple scales and a combination of physical and social variables are prevalent, necessitating an interdisciplinary approach [11]. Due to a variety of physical and social properties, rivers and streams are seen to be useful ecological components and action units for every natural habitat [12]. Table 1 clearly explain the biophysical and environmental (socio-cultural) factors that characterized the management, sustainable usability and functions of watersheds in Africa.

According to the World Bank report [13], over 65% of Africa's population lives in rural areas, with many of them on modest subsistence farms. Rockström and Falkenmark [14] also shared the same opinion about the population of Africa. Rain-fed agriculture accounts for 95% of cropland in sub-Saharan Africa, leaving most people highly reliant on the annual rainfall pattern. Rainfall that is timely and enough is critical for small agricultural communities' livelihoods and food security [15]. The impact of adequate groundwater supply is important in certain countries, such as the West Africa sub-region, where agriculture employs more than 80% of the people [15,16].

Table 1. Showing the physical and environmental characteristics of watersheds/catchments and river basins in Africa.

Physical & Environmental Factors	Characteristics
Biophysical System	Natural biophysical units such as watersheds/catchments and river basins are useful for monitoring natural processes.
Multiple Scales	Watersheds/catchments and river basins establish distinct nested landscape hierarchies that emphasize biophysical interdependence at large numbers.
Process Investigations	Large scale, input-output, and irrigation analyses, as well as cause-and-effect interactions, may all be analyzed using watersheds and river basins.
Integrated Framework	Watersheds take into account all land-use consequences and emphasize the connections between land use and other natural systems.
Assist in Addressing Complexity	Its cumulative impacts can be studied, and interactions between the atmosphere, soil, and water can be determined.
Socio-cultural Factors	
Tool for Making Scientific Decisions	Watersheds make scientific judgements easier since they are geological divisions. These serve as a stable platform for complex and adaptable governance.
Links Across Borders	Watersheds are defined by watercourses, which comprise interconnected natural resources. This unites countries and regions by inland flow and continuing occurrence across stream borders.
Social Organization	As a result of their social construction, watersheds may serve as a communal gathering spot for dialogue, settlement, management, and observation.

The importance of timely rainfall to the whole economy cannot be overstated. However, rainfall in Africa varies dramatically on an annual, decadal, and longer time scale [17]. Senegal, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Ethiopia, Somalia, Kenya, Tanzania, Zambia, Malawi, Mozambique, Zimbabwe, and South Africa account for the majority of Africa's 100 million people living in water-stressed rain-fed agriculture [18–20].

3. Methods

This study did an exploratory literature review of selected case studies of watershed management in Africa and also explored a comparative analysis of the watershed/catchment and river basins in Africa. With the emphasis on groundwater resources distribution of the sixteen countries in Western Africa (Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo).

It captures data within the worldview of the other regions, such as Northern Africa (Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Sudan, Tunisia), Eastern Africa (Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Uganda), Central Africa (Cameroon, Central African Republic, Chad, Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Sao Tomé and Principe), Southern Africa (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, United Republic of Tanzania, Cairo, Zambia, Zimbabwe), and The Western Indian Ocean Islands (Comoros, Madagascar, Mauritius, Seychelles). This study emphasized the IWM and the characteristics of groundwater resources in African shared watersheds and river basins in line with the following sub-themes; the multitude of shared watercourses, most countries share at least one watercourse with neighbours sharing up to 15 shared watercourses in Guinea alone, about 80 watersheds in Africa, major basins. Approximately 20 major river/lake basins. Covering 60% (18,000,000 km) of landmass), about 400 million people (45% of the population) live within the catchment of the basins [19].

Study Area: Africa (West Africa)

To replicate Africa's surface water systems, hydrologists employed data sets on precipitation, temperature, evapotranspiration, topography, soils, and man-made diversions and impoundments. Satellite data were recently used in research to more accurately define land-surface processes across the African continent, allowing for more accurate estimates of vegetation water use. When paired with climate data, this yields a map of "evapotranspiration", which is an estimate of total surface evaporation and plant transpiration. This data layer was used to more precisely construct a water balance map, as seen in Figure 3 (Africa's river basin boundaries). This map showing the major river basins in Africa is used to mimic the behaviour of water sources, as well as streamflow and the potential of reservoirs and other water storage technologies and facilities. The continent's geology and climate, which includes recurrent dryness and widely varying precipitation, contributes to the continent's incessant water scarcity. The problem is exacerbated by an expanding population, urbanization, increased farming activities, increased water demand, rising water costs, and restricted water supplies.

Water supply is limited by a trend toward urbanization and higher living standards, inadequate or no infrastructure planning, a scarcity of resources, and competition for water bodies across sectors including industrial, water from the public, and farming, including between countries that share watercourses. Water stress or scarcity has emerged in the region, with the volume and quality of water potentially insufficient to supply safe drinking water, food, and hygiene, stifling economic development and severely limiting environmental resources. Individuals lack access to safe drinking water and adequate sanitary facilities as a result of these issues [20,21]. Africa's landmass and geographical location also include dams and some of the biggest natural and man-made waterways globally.

As represented in Figure 3, the total capacity of Africa's river basins, freshwater bodies, riparian areas, wetlands and groundwater reservoirs is approximately twice that of North America [21–24]. With a total land area of roughly 68,800 km^2, Lake Victoria, Africa's widest lake, the second-largest globally freshwater lake, ranked after Lake Superior, is vast in size (with a water volume of approximately 2500 km^3 even though it is a little shallow. The lake's lowest area is near Kenya to the east, and the lake is normally lower on the western side along the Ugandan beachfront and the south all along the borders of Tanzanian and Ugandan beachfront and national shorelines [22].

The continent's waterways sustain large-scale aquaculture that employs large numbers of people and contributes meaningfully to food production. Africa is second only to Asia in the worldwide capture of inland fish, with Uganda, Kenya, the Republic of Tanzania, Egypt, and the Democratic Republic of the Congo among its significant inland fishing nations [25]. As illustrated in Figure 3, Africa has approximately seventy numbers of shared basins that encompass over 65% of the continent, and the West Africa sub-region has the most idyllic, preserved and greenest of it [24,26].

Most of the identified river basins have unique characteristics as Table 2 explains that the mostly semi-arid Limpopo River watershed receives the majority of its precipitation during a brief, strong rainy season in the austral summer (December–February). Rainfall varies greatly throughout the year and across seasons, rendering the basin vulnerable to severe drought and flooding while the Volta Basin spans sections of approximately six West African countries. Burkina Faso and Ghana account for around 45% of the basin's total area. Togo accounts for 8% of the total, while Benin, Côte d'Ivoire, and Mali account for the remaining 12% (see Table 2) [26,27]. The average watershed profiling of the sixteen selected countries (see Figure 4) the green zone/area shows the total landmass of the countries while the yellow area on the map shows the immediate surrounding regions (neighbouring countries bordering the Atlantic Ocean, the North and Central Africa regions) of the West Africa sub-region.

Due to the lack of roads and other means of transportation in many sections of the Congo Basin, transportation along the river's navigable channels is critical for commercial activity, as seen in the table above in the order of arrangement (see Table 2) [26]. Shabelle's discharge usually ends up in marshes just before it meets the Juba in most years. Lake Turkana is the world's biggest desert lake, while Lake Chad is one of the Sahel's greatest freshwater reservoirs. Irrigation is unreliable due to Limpopo's unpredictable streamflow [28]. In the arid Sahel, the Niger River provides a lush oasis of life, beautiful landscapes and greenery. The Nile with its inherent ecological services and rich landscapes is vital to about 78 million Egyptians who depend on it for food and many livelihood benefits [29,30].

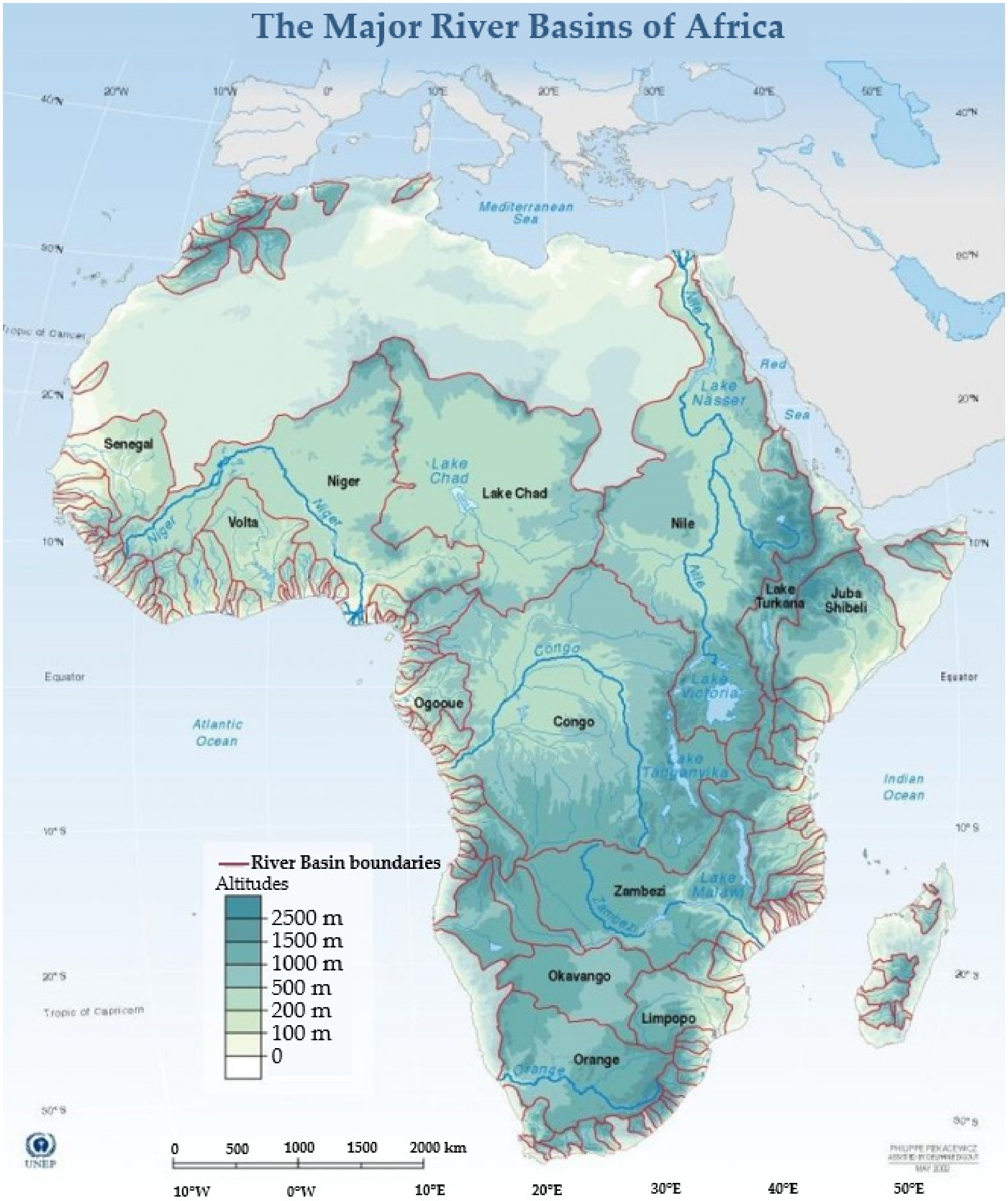


Figure 3. Map showing the Major River Basins and Watersheds in Africa. Source: World Resources Institute (WRI), Washington DC, 2001, Cartographers: Philippe Rekacewicz and Delphine Digout, https://www.grida.no/resources/5774 (accessed on 1 December 2021).

Table 2. Table showing the thirteen (13) selected key locations of watershed/catchment and river basins in Africa.

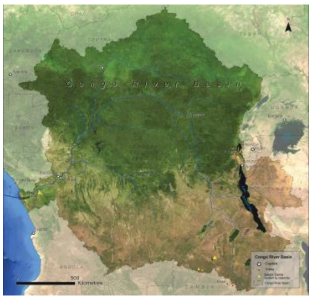
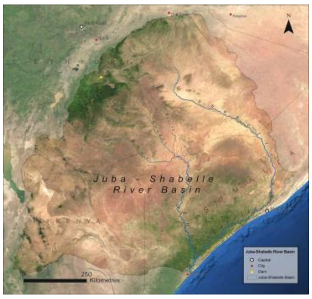
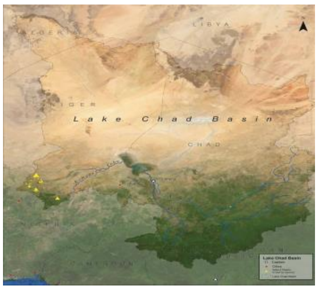
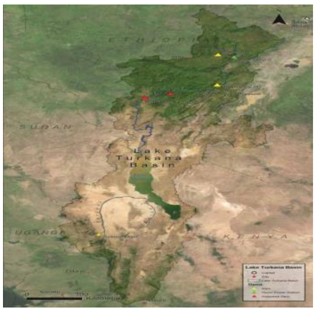
Key Locations	Images of the Major River Basins in Africa	Position within Africa's Worldview	Remarks
Congo River Basin			The Congo Basin is a massive 3,900,000 km depression that stretches almost 2200 km north-east and south-west. It stretches across the globe and accumulates a lot of rain, which falls on the tropical rainforests that cover a large portion of its area.
Juba Shabelle Basin			Both the Juba and the Shabelle hail from the southern Ethiopian Highlands, which are about 3000 mm above sea level. Despite its small drainage basin, the Juba receives more rain and has significantly greater runoff around in its sources.
Lake Chad Basin			The Chad Basin watershed region is shared by eight countries: Algeria, Cameroon, Central African Republic, Chad, Libya, Niger, Nigeria, and Sudan. It encompasses a little over 8% of Africa's land area.
Lake Turkana Basin			Even though the Lake Turkana Basin spans four nations, just two of them account for approximately 95% of its total area. Ethiopia, which receives about three-quarters of the basin's rainfall, accounts for more than half (50–54%).
Limpopo River Basin			The mostly semi-arid Limpopo River watershed receives the majority of its precipitation during a brief, strong rainy season in the austral summer (December–February). Rainfall varies greatly throughout the year and across seasons, rendering the basin vulnerable to severe drought and flooding.

Table 2. *Cont.*

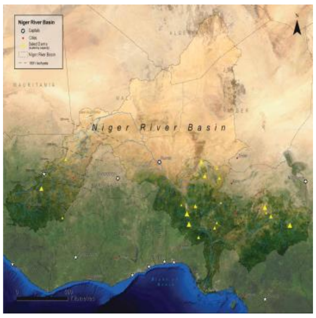
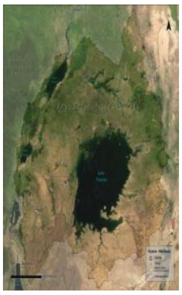
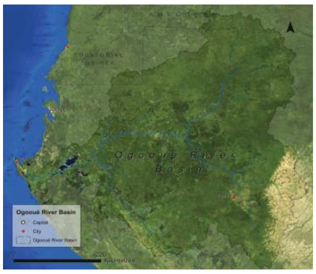
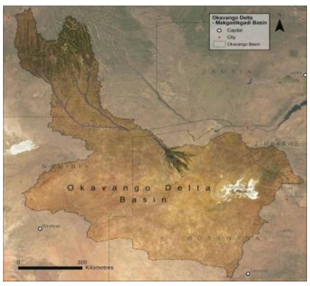
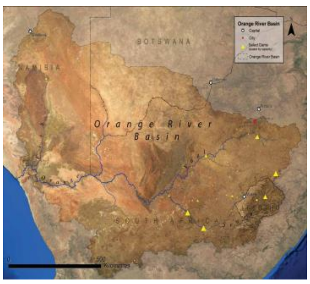
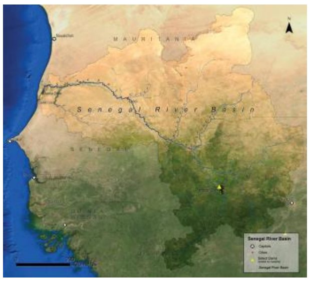
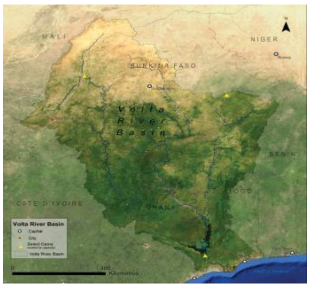
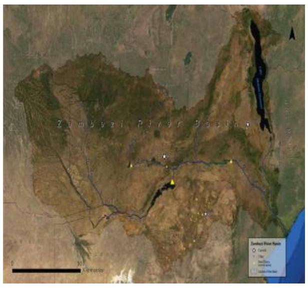
Key Locations	Images of the Major River Basins in Africa	Position within Africa's Worldview	Remarks
Niger River Basin			The Niger River originates in eastern Guinea's Fouta Djallon mountains and Côte d'Ivoire's extreme northwestern corner. The mean annual precipitation is the heaviest in the basin, with 1635 mm/year in Guinea and 1466 mm/year in Côte d'Ivoire [27].
Nile River Basin	 		In northern Burundi, the Nile begins its 6800 km trek to the sea at 1600 m above sea level. The Mara, Nzoia, Katonga, Kagera, Yala, Isanga, Sondu, Ruizi, Kibos, Simiyu, and Sio are among the many rivers that pour into Lake Victoria; however, only the Victoria Nile flows out.
Ogooué River Basin			The Ogooué River rises near Gabon's border at a relatively low height. Approximately 85% of the basin is located in Gabon, with the remaining 12% in Congo and Cameroon, and Equatorial Guinea. A thick network of perennial streams feeds the river.
Okavango Delta Makgadikgadi Basin			The Okavango Delta Basin is a sub-catchment of the larger Makgadikgadi Salt Pans drainage basin. However, the pans are only flooded periodically, and the Okavango system contains the majority of the basin's water supplies.
Orange River Basin			The Orange River begins high in the Drakensberg Mountains in Lesotho, where its tributary, the Senqu, begins. Despite accounting for only 3% of the basin, Lesotho's mountains get some of the greatest mean annual rainfall in the basin, and Lesotho supplies almost 17% of the Orange River's water budget.

Table 2. *Cont.*

Key Locations	Images of the Major River Basins in Africa	Position within Africa's Worldview	Remarks
Senegal River Basin			The Bafing and Bakoye Rivers, both of which originate in the Guinea Highlands, are the Senegal River's two main tributaries. The Bafi River, which starts at 800 m in the Fouta Djallon, is the source of the majority of Senegal's flow. The Bakoye originates around 250 km to the east, on the Manding Plateau.
Volta River Basin			The Volta Basin spans sections of six West African countries. Burkina Faso and Ghana account for around 40% of the basin's total area. Togo accounts for 8% of the total, while Benin, Côte d'Ivoire, and Mali account for the remaining 12%.
Zambezi River Basin			The Zambezi River flows at roughly 1500 m above sea level in the Kalene Hills, where the boundaries of eastern Angola, northern Zambia, and southern DRC meet. As it passes through Angola and northern Zambia, the topography is dominated by miombo woodlands with channels of grassland swamps across drainage channels and river system woodlands along larger creeks.

Source: Partly adapted and modified from UNEP (2010). "Africa Water Atlas". An article by the Division of Early Warning and Assessment (DEWA) and the United Nations Environment Program (UNEP), Nairobi, Kenya [26,27].

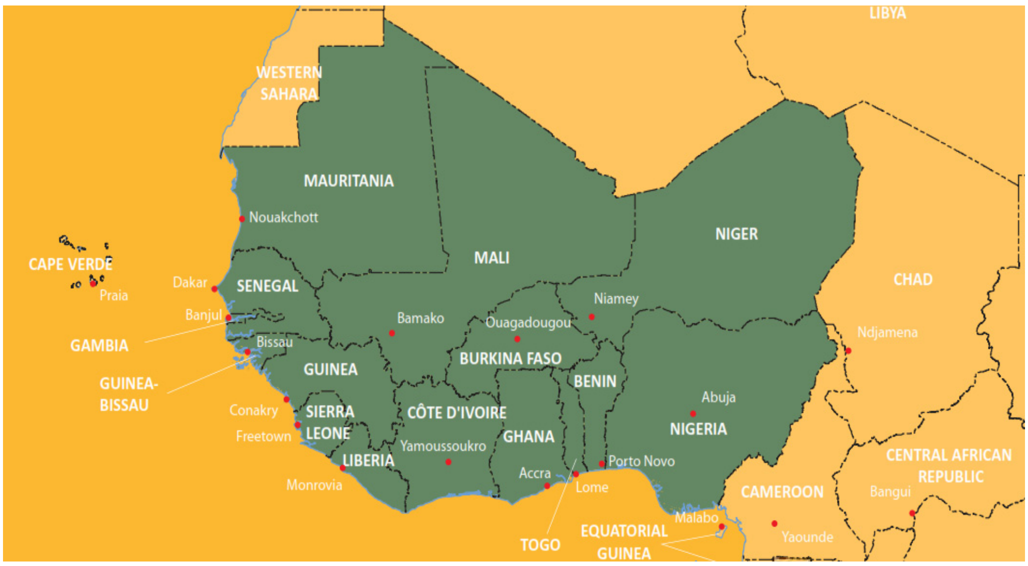


Figure 4. Map showing the sixteen countries of the West Africa sub-region (green zone/area only).

Table 2 reveals that the Congo Basin is a large 3,700,000 km^2 depression that runs over 2000 km north-south and east-west. It stretches across the equator and accumulates a lot of rain, which falls on the tropical rainforests that cover a large portion of its surface. While Algeria, Cameroon, Central African Republic, Chad, Libya, Niger, Nigeria, and Sudan are all part of the Lake Chad drainage basin, which encompasses approximately 10% of Africa's surface area [26,31].

Tables 3 and 4 juxtaposed the total surface area, average precipitation in-depth, the groundwater resources and some watershed management challenges. It also reveals that the population of the basins is largely centered around river systems in the region. There are no big dams or substantial water diversions on the Okavango's tributaries. Lesotho's highlands produce almost 17% of the basin's water budget, although accounting for only 3% of the basin's total area. Because of the river's transboundary character, managing the water resources of the Senegal River Basin is complicated. The Volta Basin spans sections of six West African countries. The Zambezi basin is home to more than 40 million people [4,26].

Table 3. Table showing the water profile in the sixteen countries in the West Africa sector (average water profiling from the year 2000–2021).

Country	Total Surface Area km^2 (ha)	Average Precipitation in-Depth (mm/year)	Water Resource and Watershed Management Challenges
The Federal Republic of Nigeria	923,768 km^2 91,077 ha	1150	Fadama regions, which are low-lying areas inundated during the rainy season, are found throughout most of the nation, including the Guinea Savannah, Sudan Savannah, and Sahel natural zones.
The Islamic Republic of Mauritania	1,025,520 km^2 (102,522 ha)	92	Since Mauritania is surrounded by deserts and experiences periodic droughts, water is inherently scarce. The building of two new dams on the Senegal River has aided the fast expansion of Mauritania's irrigated agriculture sector.
Republic of Benin	112,622 km^2 (11,063 ha)	1039	Water resources are unevenly allocated both geographically and through time, although enough water is available for present and future requirements.
Burkina Faso	274,000 km^2 (27,360 ha)	748	Burkina Faso is located in the Sahel, where droughts and floods are becoming increasingly frequent and severe. Rain-fed agriculture is being phased out, and people are flocking to peri-urban regions.
Republic of Cabo Verde	4033 km^2 (433 ha)	228	Cape Verde has limited rainfall and is subject to severe droughts on occasion, limiting water supplies. Aquifers along the shore have been overexploited, resulting in well seawater intrusion.
Republic of Côte d'Ivoire	322,463 km^2 (31,800 ha)	1348	Chemical waste from agricultural, industrial, and mining sources has resulted in considerable water contamination in Côte d'Ivoire.
Republic of Ghana	238,553 km^2 (22,754 ha)	1187	In Ghana, water reforms have made significant progress, increasing from about 54% in 1990 to 80% in 2008.
Republic of Guinea	245,857 km^2 (24,572 ha)	1651	Guinea is one of the wettest countries in West Africa, yet water treatment plants regularly fail, leaving the country without flowing water for weeks.
Republic of Guinea-Bissau	36,125 km^2 (3612 ha)	1577	The water and sanitation infrastructure of Guinea-Bissau is among the worst in the world. The bulk of the population relies on shallow wells, which are frequently polluted by sanitary facilities nearby.

Table 3. *Cont.*

Country	Total Surface Area km^2 (ha)	Average Precipitation in-Depth (mm/year)	Water Resource and Watershed Management Challenges
Republic of Liberia	111,369 km^2 (11,137 ha)	2391	The nearby wetlands are a valuable resource for the community. Residents of Liberia have complained of diarrhoea as a result of drinking the water.
Republic of Mali	1,240,192 km^2 (122,019 ha)	282	Droughts and desertification are becoming more of a danger to Mali's ecosystems and livelihoods. Mali is a landlocked country in western Africa.
Republic of Niger	1,267,000 km^2 (126,670 ha)	151	Only a small fraction of Niger's land is arable due to its dry environment and the fact that close to 65%of its area is within the Sahara desert.
Republic of Senegal	196,722 km^2 19,252 ha	686	Guinea, Mali, Mauritania, and Senegal are all riparian nations along the 1800 km Senegal River. Dam development, on the other hand, has put this crucial ecosystem in jeopardy, resulting in environmental deterioration and detrimental effects on residents' health.
Republic of Sierra Leone	71,740 km^2 (7162 ha)	2526	Notwithstanding the economic benefits, hydropower expansion frequently puts riparian populations' homes and livelihoods at risk.
Republic of The Gambia	11,295 km^2 (1290 ha)	836	Gambia's whole nation sits within the Gambia River's drainage basin, which has a highly seasonal flow. The salinity of the ocean has an impact on Gambia's lowlands, which has a significant impact on the country's flora and water consumption.
Togolese Republic	56,785 km^2 (5439 ha)	1168	Togo is vulnerable to sea-level rises due to its relatively flat geography and large coastline zone (1710 km).
Total	(6,138,044 km^2) 733,359 ha	17,060 mm/year	

Table 4. Table showing the groundwater resources usage in West Africa (average water withdrawal from 2000–2021).

Countries	Municipal	Industrial	Agricultural	Remarks
Federal Republic of Nigeria	21.1%	10.1%	68.8%	Generally adequate for agricultural purposes
Islamic Republic of Mauritania	8.9%	2.9%	88.2%	Generally adequate for agricultural purposes
Republic of Benin	31.5%	23.1%	45.4%	Generally inadequate for agricultural purposes
Burkina Faso	13%	0.8%	86.2%	Generally adequate for agricultural purposes
Republic of Cabo Verde	7.3%	1.8%	90.9%	Generally adequate for agricultural purposes
Republic of Côte d'Ivoire	23.7%	11.4%	64.5%	Fairly adequate for agricultural purposes
Republic of Ghana	23.9%	9.7%	66.4%	Fairly adequate for agricultural purposes
Republic of Guinea	7.9%	1.9%	90.1%	Generally adequate for agricultural purposes
Republic of Guinea-Bissau	13.1%	4.6%	82.3%	Generally adequate for agricultural purposes
Republic of Liberia	27.2%	18.2%	54.6%	Fairly adequate for agricultural purposes
Republic of Mali	9%	0.9%	90.1%	Generally adequate for agricultural purposes
Republic of Niger	4.1%	0.5%	95.4%	Generally adequate for agricultural purposes
Republic of Senegal	4.5%	2.6%	92.9%	Generally adequate for agricultural purposes
Republic of Sierra Leone	5.3%	2.6%	92.1%	Generally adequate for agricultural purposes
Republic of The Gambia	22.9%	11.8%	65.3%	Fairly adequate for agricultural purposes
Togolese Republic	52.7%	2.4%	44.9%	Generally inadequate for agricultural purposes.

Source: Partly adapted and modified from "Water Atlas of Africa" (2010). Early Warning and Assessment Division (DEWA). UN Environment Program (UNEP) [27].

Accordingly, Table 3 clearly shows average precipitation of 17,060 mm/year per annum over 6,138,044 km^2 (733,359 ha) of land with the Republic of Sierra Leone recording the highest, having a land cover of 71,740 km^2 (7162 ha) and 2526 mm/year per annum. The Islamic Republic of Mauritania despite having the third-largest land surface area of 1,025,520 km^2 (102,522 ha), had 92 mm/year per annum [26].

The Republic of Niger recorded the highest consumption of groundwater (95.4%) for agricultural use, the Republic of Benin recorded the highest for industrial use, while the Togolese Republic was top of the chart for the consumption within the city and suburb (see Table 4 above) [27].

4. Discussion

In Africa, river basins and groundwater are critical for municipal, industrial, and agricultural purposes, particularly around the arid sub-regions. Groundwater is widespread but restricted, accounting for approximately 15% of the continent's renewable water resources, yet providing drinking water to over three-quarters of the continent's population [26,31]. The IWM conceptual framework proposed in this study illustrates the Natural (Environmental), Institutional (Economic), Human (Social) and Sustainability systems and strategies as part of watershed management measures [31]. It embeds the following: erosion reduction; adequate water distribution and availability; increased water production; integration of groundwater resources; quality and volume of wastewater control; analysis and assessment of existing upstream and downstream water supply networks and the major indicators of the natural systems [32]. Part of the sustainability measure noted is the ability to identify IWM problems, implementation strategy, developing stakeholder-centered process, monitoring, evaluation and adaptability, communication and collaboration, community participatory process, understanding the numerous terrains, and the ability to use appropriate geospatial equipment and tools to carry out necessary topographical surveys.

Groundwater is used intensively for municipal water in Zambia, Namibia, Uganda, Ethiopia, and Cairo, Egypt, and it also serves to supply other municipalities, such as Lagos, Abidjan, Cape Town, and Pretoria [33]. Groundwater is a vital source of water for people and animals in rural areas of Africa, and it is quickly becoming the only realistic way to satisfy the demands of rural communities in the continent's dry and semiarid regions [34,35]. Many African countries rely on foreign contributions to their renewable water resources due to a large number of transboundary river basins. Egypt (97%), Mauritania (97%), Niger (90%), Botswana (80%), Sudan (77%), and Congo (77%) are also highly reliant countries (73%). Furthermore, it was revealed that the bulk of water basins is not shared by neighbouring nations. The Nile, Zambezi, Congo, Niger, Senegal, Lake Victoria, and Lake Chad are among the major river basin organizations (RBOs) that have been founded, and these organizations confront a variety of issues [36]. There are also some bilateral agreements between some of the countries that cannot be proven. The 1997 UN Convention on non-navigational uses of international watercourses is yet to be signed or implemented by any African country [36,37].

The findings of this study (see Tables 2–4) are based on the literature on watershed and groundwater resource management approaches that suggested integrating technologies within the natural boundaries of a drainage area for optimal land, water, and plant resource development to meet the basic needs of people and animals sustainably [38]. Integrated watershed management proposes land and water conservation practices, water harvesting in ponds, and groundwater recharging to increase water resources' potential and stress on crop diversification, improved seed varieties, integrated nutrient management, and integrated pest management practices to achieve its goal. Watershed and groundwater management necessitates diverse skills and competencies; the strategic community engagement model comprises main stakeholders, government and non-government organizations, and other institutions [39,40]. The observed outstanding results on the groundwater runoffs are mostly due to easy access and quick advice to the farmers within the local communities and regions [41,42].

What Are the Watershed and Groundwater Resources Management Issues?

In Africa, four major concerns impact the management of watersheds, river/catchment basins, and groundwater resources, as shown in Table 5. Finance, lack of data, human capacity, inadequate water access for various purposes, ecological habitat loss, and biodiversity loss.

Table 5. Table showing the major concerns and issues regarding IWM.

Key Issues	Impacts on the Management of the Watersheds
Finance	a. The majority of African nations are unable to establish viable institutional frameworks and invest enough in the water sector. b. Raising public knowledge of integrated watershed resource management (IWRM) and gaining political support for it. c. Several water-related initiatives, programs, and projects are being developed and/or supported by continental and regional organizations. d. Water policy changes are ongoing in most nations, with a focus on decentralization, stakeholder engagement, and transparency. e. Donors, multilateral organizations, and international development banks should increase their assistance and investment.
Lack of Data and Human Capacity	a. A scarcity of accurate and trustworthy facts (bathymetrical and topographical data). b. Advocacy for adequate data collection and administration must be robust, effective, and long-term. c. Africa has a scarcity of IWRM talents and enthusiasts. d. The Global Water Partnership's (GWP) efforts to raise knowledge and sensitize people about IWRM concepts. e. Strengthening IWRM capabilities through regional and national collaborations, as well as regional capacity-building networks. f. National, regional, and continental organizations and initiatives should join and support these relationships and networks.
Inadequate Access to Water for Various Purposes	a. To break the vicious cycle of poverty and insufficient water supply and sanitation, it is necessary to increase investments in water and sanitation services (a necessity for attaining most of the United Nations SDGs). b. Irrigation is used on less than 10% of agricultural land in most African nations. c. Food insecurity increased from 130 million in the early 1980s to 200 million in 2000 in sub-Saharan Africa, with an average daily per capita food supply of only 2200 kcal (global average of approximately 3000 kcal). d. To meet the SDGs' food security objective, irrigated lands must be increased by more than five times. Greater than 90% of Africa's population lacks access to power. e. With 950 kWh per capita, Botswana is the country with the highest per capita usage. This is significantly less than the global weighted average per capita of 2750 kWh.
Loss of Ecological Habitats and Loss of Biodiversity	Some of the harmful repercussions of poorly constructed and maintained water resources infrastructures are as follows: a. Destruction of diversity and distinct environments. b. In certain areas, water tables are fast falling due to decreased storm holding capacity, contamination of water sources, and changes in microclimate management. c. Major irrigation projects cause salinization of the soil and create moisture environments, lowering the agricultural season for example productive capacity.

5. Conclusions

This study outlined the key issues of watershed and groundwater resources management and development in Africa, which stem from poor river basin management, which results in limited access, destructive erosion, wildfires, flooding, persistent drought, and desertification, particularly in the north. Continuous use and deterioration of watersheds, rivers, lakes, and other linked watercourses bring these challenges to the forefront. Countries recorded high precipitation while others recorded low, as the study indicates average annual precipitation of 17,000 mm over 733,350 ha of land, with the Republic of Sierra Leone recording the highest of 2525 mm/year while the Islamic Republic of Mauritania receives 92 mm/year each year. Lack of organized water resources regulations and development master plans, very old data (if available), civil conflict, and disputes along international seas are also factors to consider. Sustainable watershed and groundwater resource management, on the other hand, necessitates a well-organized and well-coordinated structure including all important stakeholders, as well as an institutional framework designed to produce beneficial results. The following recommendation and conclusions were made in this paper:

a. Create a framework for simplifying and building synergies between national, regional, and intercontinental activities aimed at maximizing the effectiveness and sustainability of Africa's existing waterways and natural resources;
b. Slowing the rate of urbanization and population increase near river basins; c. Water infrastructure investment using contemporary technologies;
c. Experts and human resources providing up-to-date data to counteract misuse;
d. Cooperation among nations sharing water basins and strict adherence by all African countries that are signatories to the 1997 United Nations Convention on non-navigational and transboundary uses of international watercourses.

By 2030, there will be a sustainable and strategic IWRM guideline as well as water safety and management measures as part of the envisioned United Nations Sustainable Development Goal 13 (Climate Action), targeted at combatting climate change and its impact through prompt global actions. There has to be mutual understanding and synergies between initiatives, programs, and projects at the national, regional, and continental levels. The current state of integrated watershed management, river basin frameworks, and groundwater resources requires a comprehensive, community, and multidisciplinary approach. All the Africa sub-region (the six regions; Western, Eastern, Central, Northern, Southern, and The Western Indian Ocean Islands) within the continent must consider the IWM conceptual framework in this study, which reveal the natural (environmental), institutional, sustainability, as well as human systems, coordinated developmental approach and strategies towards a sustainable watershed and groundwater resources management of Africa.

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