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Water Resources and Irrigation in Rwanda

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ABSTRACT

The main objective of the study is to assess the agricultural water resources for irrigation potential in Rwanda. Rwandan agriculture national reports, irrigation expert documents, and various published articles were used in the preparation of this study. Rwanda is a small, land-locked, and fertile country in East Africa. Rwanda has a total area of 26,338-km2 and a population size of 12.7 million. Agriculture accounts for 24% of the total GDP (Gross Domestic Product) in 2020 and accounted for 64% of the working population. The country has 1.4 million ha of agricultural land, of which 43% (0.6 million ha) is irrigable land. Approximately 10% (63,742 ha) of the irrigable areas in the country are irrigated. Rwandan's average annual precipitation is 1200 mm, and the total amount of usable water is 6.8 billion m3/year. The percentage of the irrigated plots by surface irrigation, sprinkler, and drip irrigation systems with an average of 49.7%, 6.7%, and 2.5%, respectively in 2017 to 2021. In 2021, the agricultural production of cereals, legumes and pulses, tubers and roots, and vegetables-fruits were 491,130 tons, 288,018 tons, 1,826,018, and 184,944 tons, respectively.

Ruanda'da Su Kaynakları ve Sulama

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ÖZET

Bu çalışmanın amacı Ruanda'nın tarımsal su kaynaklarını ve sulama potansiyelini değerlendirmektir. Çalışmanın hazırlanmasında Ruanda ulusal tarım raporları, sulama konusunda uzmanlaşmış kişilerin raporları ve konuyla ilgili yayınlanmış çeşitli makaleler kullanılmıştır. Ruanda, Doğu Afrika'da, yüzölçümü nispeten küçük, denize kıyısı olmayan tarımsal potansiyeli büyük bir ülkedir. Ruanda toplam 26.338 km2 yüzölçümüne ve 12.7 milyon nüfusa sahiptir. Ülkede tarım, 2020 yılı rakamlarına göre GSYİH'nın (Gayri Safi Yurtiçi Hasıla) %24'ünü oluşturmakta ve çalışan nüfusun %64'ü tarım sektöründe istihdam edilmektedir. Ruanda'nın sahip olduğu 1.4 milyon hektar tarım arazisinin yaklaşık %43'ü (0.6 milyon ha) sulanabilir niteliktedir. Mevcut durumda sulanabilir alanların yaklaşık %10'u (63.742 hektar) sulamaya açılmıştır. Ruanda'nın yıllık ortalama yağış miktarı 1200 mm, toplam kullanılabilir su miktarı ise 6.8 milyar m3/yıl'dır. 2017- 2021 ortalamasına göre, yüzey sulama, yağmurlama ve damla sulama yöntemleri ile sulanan alanların oranı sırasıyla % 49.7,% 6.7 ve% 2.5'dir. Sulanan alanlarda 2021 yılında hububat, baklagil ve bakliyat, yumrular, sebze ve meyvelerin tarımsal üretimi sırasıyla 491.130 ton, 288.018 ton, 1.826.018 ton ve 184.944 ton olmuştur.

1. Introduction

Rwanda is a land-locked country in the Great Lakes region of East Africa. The surface area of Rwanda, including water bodies, is 26 338 km^2 (REMA, 2017). The population of Rwanda is 12.7 million (RDB, 2020), and the population density of 415 inhabitants km^2 (REMA, 2015). Out of this population, 64% working in agriculture and related sectors in 2020. Agriculture contributes to the National Gross Domestic Product (GDP) of 24% (MINAGRI, 2020). Rwandan agriculture has been driven by a Strategic Plan for Agriculture Transformation Phase 4 (PSTA-4) from 2018 to 2024, which has four priority areas; innovation and extension, productivity and resilience, inclusive markets and value addition, and enabling environment and responsive institutions (MINAGRI, 2018). Agricultural land is the primary component with almost 1 475 385 hectares, It is approximately 60% of the total area of the country (NISR, 2021). The country has an irrigation potential of 600 000 hectares (Malesu et al., 2010). Out of this potential, only 10% are irrigated (MINAGRI, 2020). Agriculture despites more contributions, poor rural households with small plots are the most food insecure and the most vulnerable to shocks that disrupt food production (REMA, 2015). Agriculture is also dependent on rainfall and implies low productivity and high vulnerability to climate shocks (FAO, 2021).

The main objective of the study is to assess the agricultural water resources for irrigation potential in Rwanda. The specific objectives are to assess agricultural crop production of Rwanda, The water resources and irrigation water potential distribution of Rwanda, to assess irrigated agriculture development and irrigation methods used in Rwanda, and irrigation organization status. There is also highlighting the challenges of agriculture in Rwanda by addressing the solution to overcome.

2. Material and Method

2.1. Study area

Rwanda has four administrative provinces. Such as Northern, South, East, and West province plus a capital city, Kigali. The border countries are Uganda to the north, Tanzania to the east, Burundi to the south, and the Democratic Republic of the Congo to the west (REMA, 2015). Rwanda has a tropical-temperate climate with an average temperature of 20 ^{0}C and a total annual average rainfall of 1 200 mm (NISR, 2020). The average elevation is 1 250 m. The highest point is 4,507 m at the Karisimbi volcano, and the lowest point is 900 m in the southwest (REMA, 2011).

2.2. Source of information

For achieving the objective, the study was reading technical and methodological surveys reported by the National Institute of Statistics of Rwanda (NISR), National Seasonal Agricultural Survey (SAS), and Irrigation Master Plan (IMP-2010). The study was also reading annual reports of the Ministry of Agriculture and Animal Resources (MINAGRI). These documents are accessible from the government of Rwanda official websites. Other published papers and documents containing information for the agriculture of Rwanda were used. The detailed study has the following indicators; Agricultural crop production of Rwanda, water resources and irrigation water potential distribution of Rwanda, irrigated agriculture development, irrigation methods, and irrigation organization used in Rwanda.

3. Results and Discussions

3.1. Agricultural area and crop production of Rwanda

Agricultural area in Rwanda includes arable land, land under permanent crops and permanent pasture. The total country land area, excluding only rivers and lacs, is estimated at 2 480 100 hectares (NLUDMP, 2020), for which 1 475 385 hectares (60% of total country land) is used for agriculture. Out of the total agricultural land, 1 096 956 hectares were used for Seasonal crops in season 2021A, nearly 0.6 million hectares are area under permanent crops (tea and coffee), while 0.131 million ha under permanent pasture (NISR, 2021). The hillside agriculture is dominated with 41.6% of total land area and cropping pattern of radical terraces and progressive terraces. Table 1 shows the agricultural area for hillside, irrigation area and land use for non-agricultural potential.

Table 1. Agricultural area and land use of Rwanda

Land cover in 2019	Area in km^2	Percentage
Hill side agriculture	10 949	41.60%
Total irrigation potential area*	6 000	43%
Total irrigated area**	637.42	10%
Forests	7 242	27.50%
Bare high slopes	1 554	5.90%
Built up areas & infrastructure	2 888	11.00%
Water bodies	1 637	6.20%
Wetlands	2 068	7.8%
Total Country area	26 338	100%

Source: NLUDMP, 2020, MINAGRI, 2020

*Total irrigation potential and **total irrigated area included on agriculture area and not affected the total country area.

In season A of 2021, 91 percent of farmers practiced anti-erosion activities, 37.1 percent of farmers used improved seeds, 67 percent of farmers applied organic fertilizer in their farms. While 22.4 percent of farmers applied pesticides (NISR, 2021). The crop productions of cereals, legumes and pulses, tubers and roots, and vegetables and fruits are discussed in the following paragraphs.

Figure 1 provides the cereal productions (maize, paddy rice, sorghum, and wheat). The total agricultural area of cereals is 290 069 hectares, with a total production of 491 130 tons in 2021. Maize production increased by 78 311 tons, from 300 330 tons up to 378 641 tons in 2016 and 2021, respectively. However, the yield (production per hectare) was decreased by 9% from 2016 to 2021. The area of maize was increased by 39%. The Paddy rice production is 63 950 tons in 2021. The crop area dropped down by 10%.

However, rice yield production per hectare was 4 160 kg ha^{-1} in 2021 and it increased up to 43% from 2016 to 2021. The sorghum production decreased by 3 483 tons because the harvested area decreased by 6%. However, the yield production per hectare was slightly constant at an average of 1 300 kg hectare^{-1}. Wheat production increased by 135 tons (+3%) in 2021. The yield of wheat was up to 1018 kg ha^{-1} from 850 kg ha^{-1} (increased up 20%) from 2021 to 2016, respectively.

Figure 2 shows legumes and pulses production (beans, peas, groundnuts, and soya beans). The total agricultural area of legumes and pulses is 443 736 hectares. The total production was 288 018 tons in 2021. The beans production increased up to 9 906 tons; the cultivated area also increased up to 42%. However, the yield per hectare was dropped down by 27% and an average yield of 800 kg ha^{-1} from 2016 to 2021. The peas have a small area of 11 116 hectares in 2021. The pea production decreased by 3 056 tons (decreased by 26%) from 2016 to 2021. Even if the yield of peas per hectare increased by 6% in 2021. The groundnuts production was 6 054 tons to 6 313 tons in 2016 and 2021, respectively. 34% of the cultivated area increased and 22% of the yield of groundnuts decreased from 2016 to 2021. The maximum production of

groundnuts was 12 546 tons in 2018. Soja beans production has increased by 1 891 tons from 2016 to 2021. The sojabeans area has increased by 32%. However, the yield per hectare has decreased by 13%.

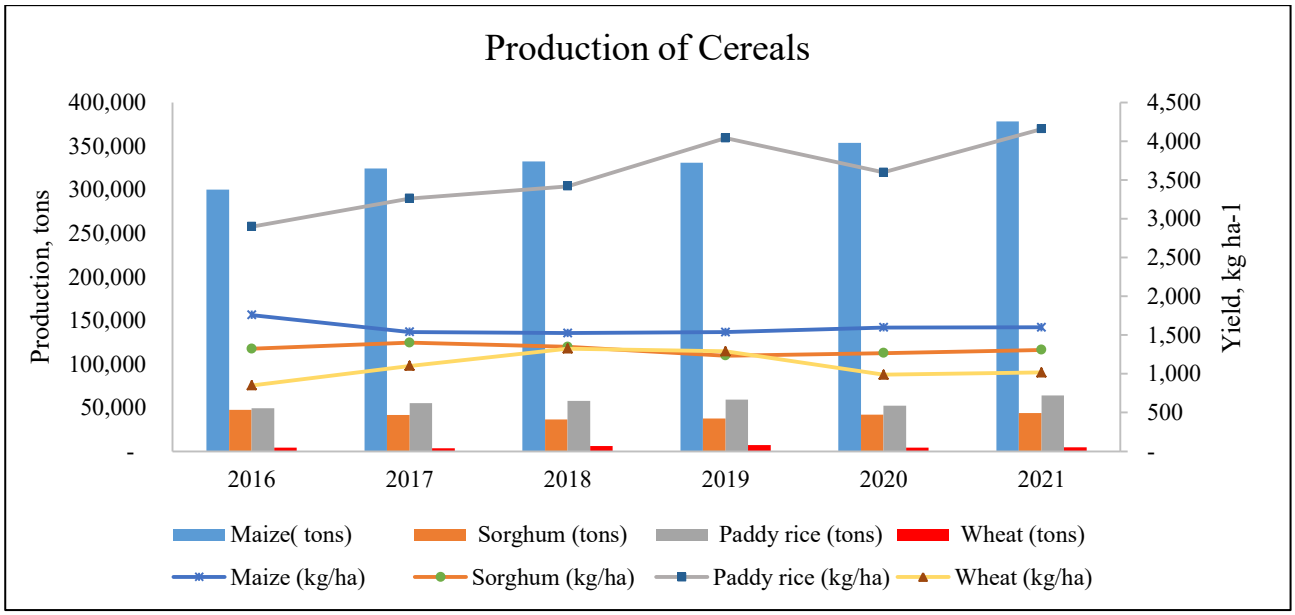

Figure 1. Production of cereals
Source: NISR,SAS, MINAGRI, 2016-2021

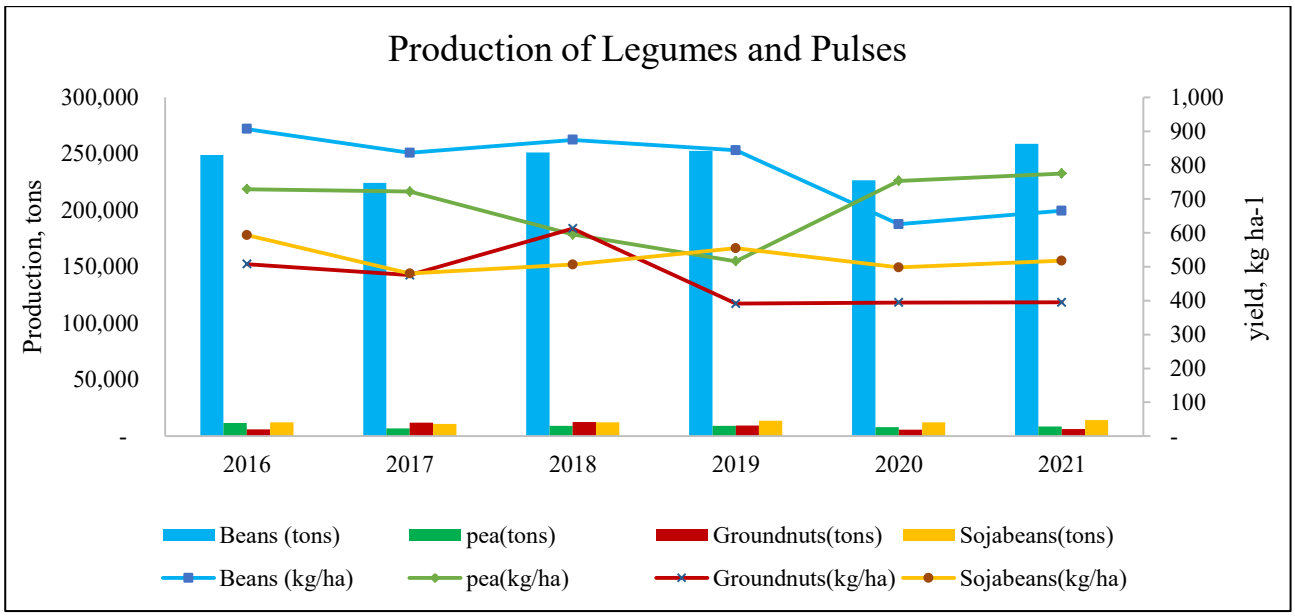

Figure 2. Production of legumes& pulses
Source: NISR,SAS, MINAGRI, 2016-2021

Figure 3 provides the yield of tubers and roots (cassava, sweet potatoes, Irish potatoes, and yams &taro). The total agriculture area of tubers and roots is 209 589 hectares, with a total production of 1 826 018 tons in 2021. The cassava production increased up to 195 330 tons from 2016 to 2021. Improved seeds and pests control for cassava leads to a reach of 909% of yield production ha^{-1}, from 2016 to 2021. However, the cassava area decreased from 288 049 ha to 42 284 ha (a decrease of 85%), from 2016 to 2021, respectively. The sweet potato production was 667 346 tons in 2021. Production has increased by 163 586 tons (an increase of 32 %) from 2016 to 2021. The crop area of sweet potatoes has increased by 53%, and yield per hectare was decreased by 13% from 2016 to 2021. The Irish potatoes production was 463 562 tons in 2021 and increased by 93 871 tons, and yield per hectare increased by 30% from 2016 to 2021. The crop area of Irish potatoes was 54 051 to 52 196 hectares in 2016 and 2021, respectively. Yams and taro (cocoyam) had 93 819 tons in 2021, and 11 575 tons were increased from 2016 to 2021. The yield of yam per hectare has increased by 29%. However, the area of yams and taro has decreased by 12%.

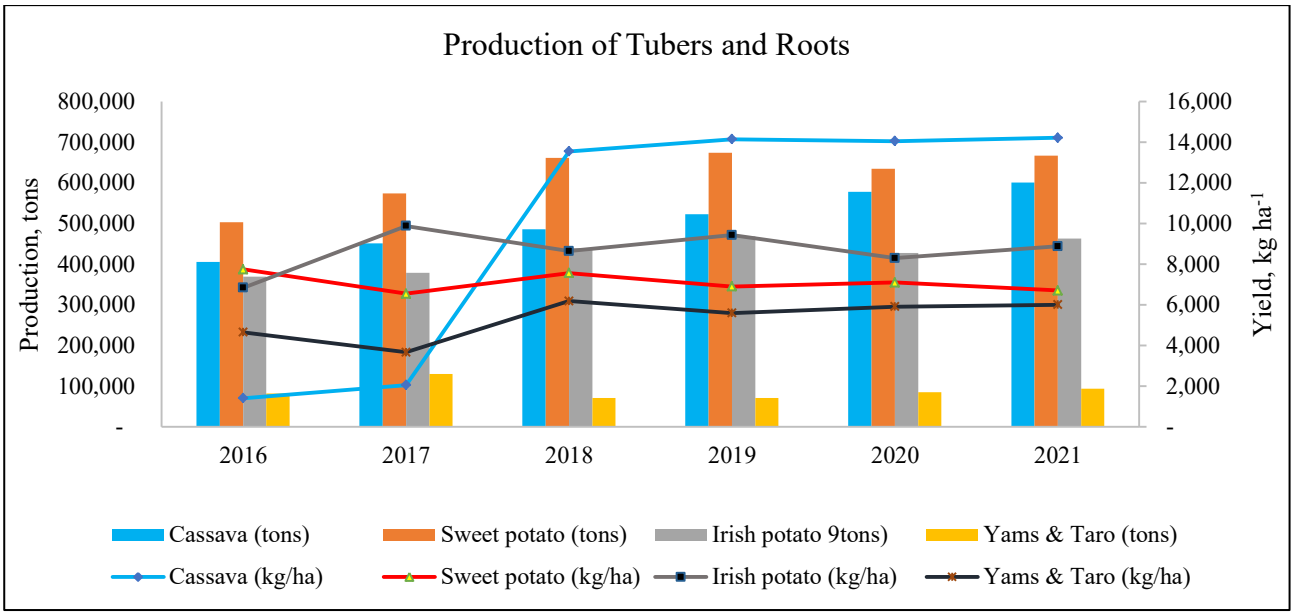

Figure 3. Production of tubers and roots
Source: NISR, SAS, MINAGRI, 2016-2021

Figure 4 indicates the production of vegetables and fruits. The total area production of vegetables and fruits is 24 780 hectares (201 181 ha of vegetables; 4 599 ha of fruits), with a total production of 184 944 tons. The vegetable has increased by 16% of production. However, decreased by 9% of yield per hectare, from 2016 to 2021. The fruits production has declined by 27 percent, from 34 438 tons to 25 275 tons, from 2016 to 2021, respectively. However, the productivity of fruits per hectare has increased by 32%.

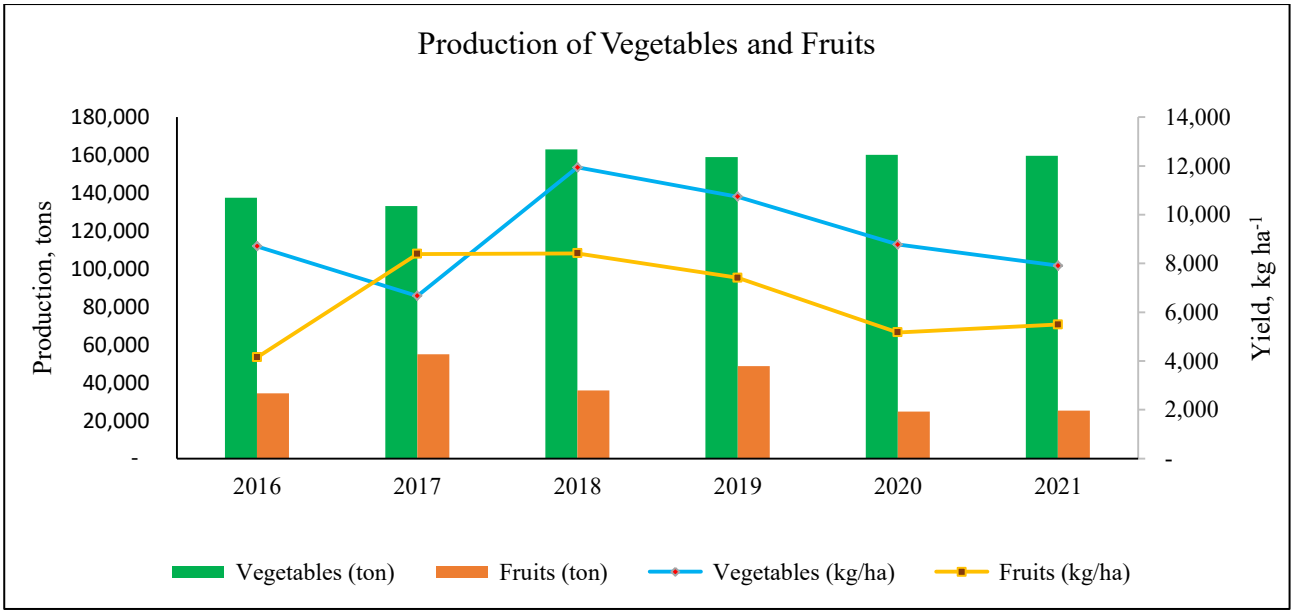

Figure 4. Production of vegetables and fruits
Source: NISR, SAS, MINAGRI, 2016-2021

About cash crop, the tea and coffee production was 34 735 506 kg and 20 958 306 kg, respectively. Out of these, 34 394 268 kg of tea were exported. 16 880 926 kg of coffee were exported during the fiscal year of 2020-2021 (NAEB, 2021).

3.2. Water resources and irrigation water potential distribution of Rwanda

Rwanda has abundant water resources with uneven distribution. Water resources occupy 6.2 % (1 537 km^2) of the total country area (NLUDMP 2020-2050, 2020). The country has about 6 to 7 billion m^3 of annual surface water, 4.50 to 5 billion m^3 of groundwater, and 27.50 billion m^3 of rainwater. The total average annual precipitation is 1200 mm $year^{-1}$. The total renewable water resources are about 6.80 billion m^3 per year. The annual renewable water available per capita is 670 m^3 (NISR, 2017). According to the water threshold value of 1 700 m^3/inhabitant/year (Falkenmark et al., 1989), Rwanda is not rich in renewable water resources. The consumptive

water use for irrigation stands at 363 403 960 $m^3 year^{-1}$, representing 59.75%, domestic water use is scond with 38.61% (234.8 million m^3 $year^{-1}$) of the water use, followed by mining, industries, fish ponds, and coffee washing stations with 0.79%, 0.53%, 0.17%, and 0.4% respectively (RWB, 2021). The Irrigation Master Plan of 2010 indicated the country of Rwanda has an irrigation potential of nearly 600 000 hectares, which distributed into six domains (Table 2). The domain means the general guide for locating or dominant water resources for a given area.

Table 2. Irrigation potential of Rwanda

Water resources availability	Irrigation potential areas (ha)
Runoff for small reservoirs	125 627
Runoff for dams	31 204
Direct river and flood water	80 974
Lake water resources	100 153
Ground-water resources	36 434
Marshlands	222 418

Source: Rwanda Irrigation Master Plan, Malesu *et al*, 2010

Figure 5 provides the distribution of irrigation domains in the country according to the water resources accessibility. The total agricultural land for marshland resources is 219 793 hectares, for which 222 418 hectares are irrigated potential (Figure 6). The marshland is a wetland with a slope of up to 2%. The irrigation domain for the small reservoirs is dominant of a slope range from 2% up to 40%. One small reservoir capacity is up to 300-m3, which irrigates a plot of 2020 m2 (Figure 7).

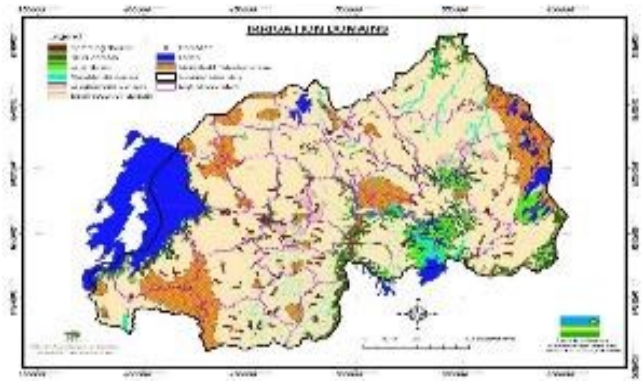

Figure 5. Distribution of irrigation domains in Rwanda
(Source: Irrigation Master Plan, MINAGRI, 2010)

Figure 6. Marshland water resources
(Source: World Agroforestry Centre, 2011)

Figure 7. Runoff for Small-scale irrigation
(Source: World Agroforestry Centre, 2011)

Figure 8. Lake water resources
(Source: World Agroforestry Centre, 2011)

Lake water resources irrigate the lands connected to the lakes, 50 m along the banks of lakes (Figure 8); irrigation potential for lake resources is 100 153 hectares. Runoff for dams has an irrigation potential of 31 204 hectares. The country has 107 potential dam sites for irrigation, for which 76 damming sites have ten up to 20 m of embankment heights (Figure 9). The groundwater resources have an irrigation potential of 36 434 hectares. Rwanda Irrigation Master Plan (IMP) indicted 652 boreholes. Out of these, only 100 boreholes have a water yield of 3 m^3 per hour.

Figure 9. Runoff for dams
(Source: World Agroforestry Centre, 2011)

Figure 10. Water harvesting on hillside irrigation
(Source: MINAGRI, 2011)

3.3. Irrigated agricultural development in Rwanda

Irrigation in Rwanda began in 1945 at Karongi district after the famine known as Ruzagayura (1943–44). An 8-km water channel was dug from Ntaruka towards Rubengera with its tributaries irrigating local people's farms. In 2003, the country developed swamp reclamation under the Rural Sector Support Project (RSSP) for large scale. In 2004, Rwanda initiated the Marshland Master Plan. However, in 2010, Rwanda developed an Irrigation Master Plan (IMP) for ten years of national sectoral planning (Malesu et al., 2010). In the fiscal year 2020, the total area of irrigation reached 63 742 ha (37 273 ha of marshlands, 8 780 ha of hillsides (Figure 10), and 17 689 ha of small-scale irrigation) (MINAGRI, 2020). Figure 11 shows the cumulative irrigated area development in Rwanda from 2012 to 2020.

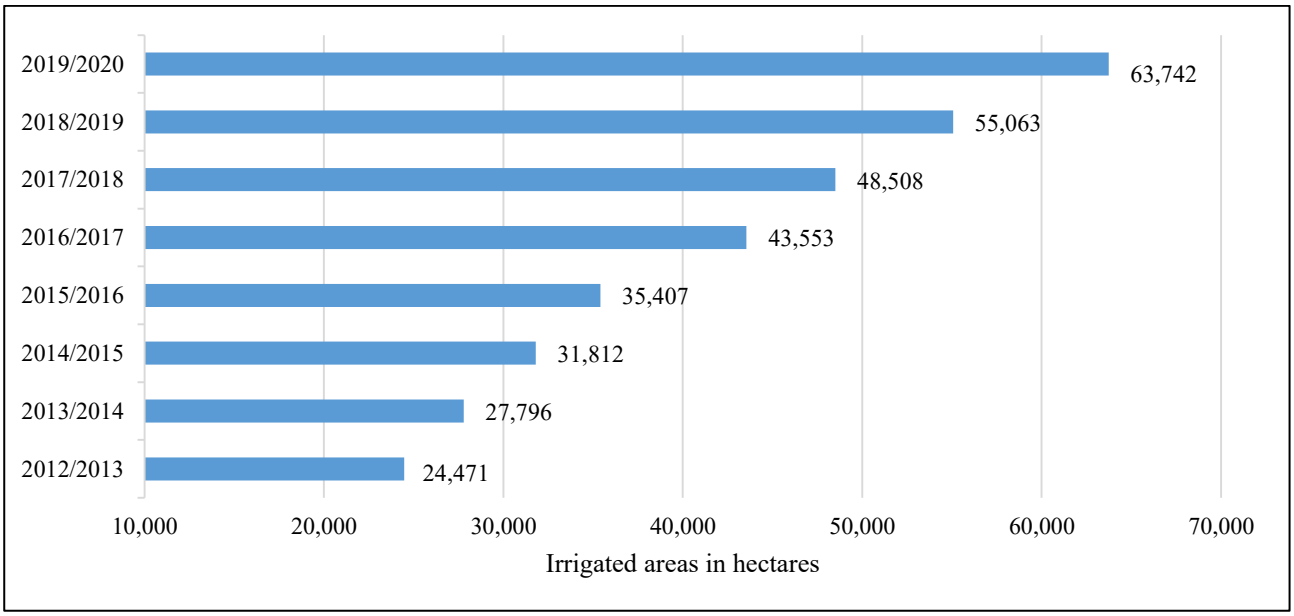

Figure 11. Cumulative irrigated area from 2012 to 2020
Source: MINAGRI, 2020

3.4. Irrigation methods in Rwanda

Figure 12 shows the average percentage of irrigation methods used in Rwanda. The furrow, basin, and border irrigation methods are classified into surface irrigation in this study, which has a water regulator, headwork, and other infrastructure with 49.7% of irrigation plots. The traditional method is flooding surface irrigation without a regulator. It means water diverts to the fields freely without control. This method has an irrigation area of 41%. Sprinkler irrigation and drip irrigation have an average of 6.7% and 2.5%, respectively. Therefore, the irrigation methods are applicable for three categories. Such as small-scale irrigation, medium irrigation scale as well large irrigation scale.

The small-scale irrigation area includes; ready to use 0.1 ha to 10 ha farms with complete drip kit/ sprinkler kit/rain-gun kits/rain pipe with portable diesel/petrol motor pump or solar powered irrigation system, and pipes and rain-water harvesting through tanks (plastic and concrete), and dam sheet technologies. The agriculture area for small-scale irrigation had 17 689 ha in 2020 (NISR, 2021). Medium irrigation scale varies between 10

and 100 hectares and is dominant in marshlands and hillsides. The agriculture area of a large irrigation scale is 100 hectares and above. Large scale mostly is mechanized. The main crop for this scale is the maize farm. The country has an overall 9.2% of farmers doing irrigation. Of which, 8.1% are small-scale farmers, and 57.3% are large-scale farmers (NISR, 2021).

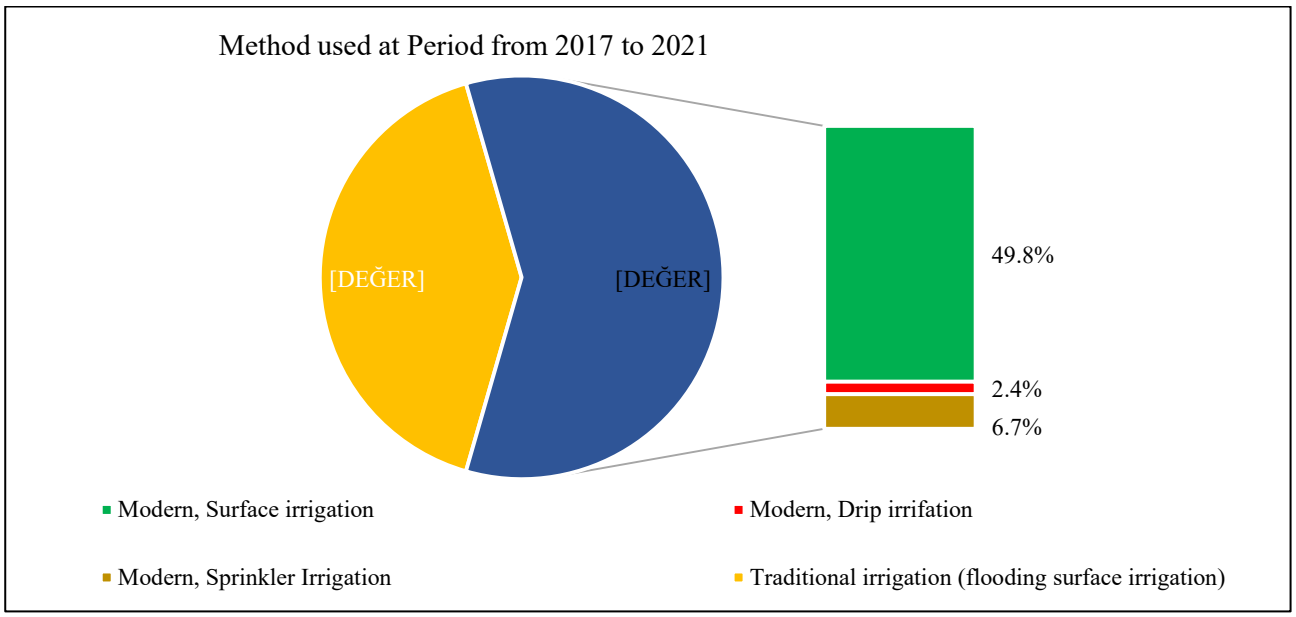

Figure 12. Average percentage of irrigation methods used in Rwanda
Source: NISR, SAS, 2017-2021, interpreted by Author

3.5. Irrigation organization in Rwanda

To provide effective and efficient irrigation under Irrigation Water Resources Management (IWRM), the Ministry of Agriculture and Animal Resources (MINAGRI) oversees and leads the planning of irrigation investment, legal and regulatory (MINAGRI, 2018). Rwanda Agricultural Development Board (RAB) is the agency of MINAGRI. RAB provides technical support for irrigation. The district-level leads to implementing irrigation infrastructures and overseeing the activities of Water Users Associations (WUAs). When there are heavy infrastructures, District irrigation steering Committee also collaborates with Service Provider and operator. On the level of farm or scheme, there are private sectors and Water Users Associations, Cooperatives, companies of farmers, farmers. Private is increasingly engaging to invest ın innovative irrigation and irrigation management. The Ministerial Order No 001/11.30 of 23/11/2011 formalizes the establishment of WUAs in all irrigation schemes within Rwanda. The main purpose of forming WUAs is to ensure efficient operation and maintenance of irrigation systems. WUAs and cooperatives are two independent bodies. The WUA is in charge of the Operation and Maintenance of the hydraulic infrastructure, while the cooperative focuses on production and marketing aspects (MINAGRI, 2011).

3.6. Challenges of the agricultural sector

The main challenges faced in irrigation of Rwanda are the high cost of irrigation development on the hillside projects, inadequate markets for the products, Small and fragmented private lands not attractive to big investors. The accessibility of farmers to public and private services, such as extension, capacity building, and farming technology along the irrigation scheme will increase productivity. Ensuring nature Conservation and water resources management will sustainably provide resilience in irrigated agriculture. Frequent monitoring and evaluation by promoting accountability bring importance to agriculture production and irrigation water use.

4. Conclusion

Irrigation increased the livelihoods of smallholders and contributed to national domestic products. Based on the irrigation potential in Rwanda, it is a good place for incentives of stakeholders and investors. Agriculture still contributes welfare of the livelihood in Rwanda. It will still be ahead for the contribution of food security as well as reduction of poverty.

Conflict of Interest

The article's authors declare that there is no conflict of interest between them.

Authors' Contributions

The authors declare that they have contributed equally to the article.

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