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Rice Production Status and Irrigated Rice in Ethiopia, a Review

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Abstract: From a historical perspective up to the present and the future, an analysis of recent research on Ethiopia's irrigation systems and advances was done. The Ethiopian irrigated rice is discussed in this assessment in light of its historical context, present-day development and economic contributions, difficulties and opportunities, and potential for future growth using different scholars. Irrigation techniques are thought to have been used for a very long time during the prehistoric period, with an undefined commencement period. The development of ancient civilization in Ethiopia, however, was probably not fueled by irrigation. Modern irrigation has been used in the Rift Valley basin since the 1950s to produce commercial crops. Governments, foundations, and NGOs are making investments in the creation of irrigation systems, particularly for small-scale irrigations. Irrigation technology is therefore evolving quickly. In contrast to rain-fed agriculture and its potential for irrigation, nevertheless, it makes a relatively small economic contribution to the country. Similar to this, Ethiopia's rice production is primarily rain-fed, and it is not more adaptive to Ethiopian agricultural output than rice's capability for irrigation. Since there are no widely accepted studies or widespread consensus, there is a dearth of detailed research on Ethiopia's water potentials and its developmental implications. Potentially, there are field accounts that have been thoroughly researched and documented. The improvement of Ethiopia's food security and economic growth will undoubtedly be aided by irrigation, provided that water is used efficiently.

Keywords: Rice Production, Status, Irrigated Rice, Ethiopia

1. Introduction

Ethiopia's economy and food-security are primarily supported by agriculture [1]. The technique employed by emerging nations to support agricultural production heavily relies on irrigation [2]. Area of Ethiopia is 112 M ha, and from this, estimates for cultivable land range from 30 to 70 M ha. Only 15 M ha of land are now being farmed, according to conservative estimates. Our estimation is that just 4 to 5% of the already cultivated area is irrigated, with the 640,000 ha covered by currently in place irrigation systems. This indicates that Ethiopia's agricultural land is currently not irrigated to a substantial extent [1].

Rice is the principal crop globally and rice introduction in Ethiopia is relatively new, which is related to the Derge regime's efforts to alleviate the many problems caused by various public initiatives. Settlement and food security were the two key issues. Gambella, Pawe, and Fogera were the initial rice-introduction locations (early 1980s). Fogera Plain was the only one of these areas to have undergone the substantial variations in farming kindred and community changing aspects brought on by the outline of rice and that one successive commercialization. Only one of these regions, Fogera Plain, continues to be a major rice-producing area [3].

To supply the rapidly expanding demand, here is cumulative dependence on bring in rice. Around, a growing trust on imported rice to encounter quickly rising request [4]. Despite the resources being less available, rice production, processing, and marketing in the future will need to be done in a more environmentally friendly and sustainable manner due to the global decline in environmental quality (land, water, labor, and energy). Gains in yield per unit of land and water must account for the majority of increases in rice production required to fulfill future demand. It aspires to lessen poverty and hunger, enhance human health and nutrition, adapt rice-based farming systems to climate change, support youth mobilization and women's empowerment, and lessen the environmental impact of rice production.

2. General Overviews of Irrigation Potential in Ethiopia

Ethiopia is the Horn of Africa's water supply [5]. According to the nationwide main strategy research, Ethiopia has 12 river basins with an probable yearly surface runoff of 122 BM^3 and groundwater potential ranging from 2.6 to 6.5 BM^3 [6]. Ethiopia has 5.3*106 ha of potentially irrigable land, according to Awulachew, Erkossa [7], including 1.6*106 ha from rainwater collecting. The most realistic approaches to ensure food security are to increase cropping intensity in irrigated areas and produce in rain-fed and irrigated agriculture using a variety of technologies [8]. Irrigation and drainage expansion, as well as rehabilitation of degraded areas and the smart use of water resources, are all major difficulties in establishing and maintaining a sustainable environment.

2.1. Irrigated Rice Production System

Rice production is affected by differences in environmental and socioeconomic conditions that vary by region. Rice production ecologies include irrigated lowland, irrigated upland, rain fed lowland; rains fed upland, and deep water/floating ecosystems, which are all based on soil water conditions [14]. Rice is farmed in irrigated systems in Australia, Bhutan, Central Asia (Kazakhstan and Uzbekistan), Chile, China, Japan, Korea, Nepal, Russia, Turkey, the United States, and Uruguay in temperate climates [15]. The productivity of 8–10 t/ha or greater is obtained in moderate climatic zones where a single irrigated rice crop is cultivated each year [16]. Because aerobic rice has the potential to significantly enhance eco-efficiency in rice-based systems where water, labor, and energy are becoming increasingly scarce, it is gaining popularity in South Asia as a viable alternative to the traditional transplanted flooded rice system [17]. In dry-DSR and TPR production systems, irrigation at 20 kpa resulted in a considerable reduction in irrigation water input as compared to daily irrigation. The dry-DSR production technology saves irrigation water, which is especially beneficial in fine-textured soils [18, 19].

Irrigation with a twist many rice farmers all over the world can benefit from water-saving methods such as alternating wetting and drying (AWD). Irrigation is administered every 6–8 days for heavy soils and every 4–5 days for lighter soils in AWD [20]. The crop can be dry direct-seeded or transplanted in an aerobic rice system, and the soils are kept aerobic for most of the growing season. When additional irrigation is required, it is applied. Aerobic rice cultivars offer higher yield potential than typical upland cultivars because they are acclimated to aerobic soils. The aerobic rice system can produce grain yields of 5–6 t ha^{-1} [21]. As a response to water scarcity in northern China, aerobic rice farming is currently being performed on a small scale in freely drained fields. About 80,000 ha in China and 250,000 ha in Brazil were projected to be planted with aerobic rice cultivars [14]. In India, states such as Karnataka have begun to embrace the aerobic rice system [22].

2.2. Overview of Rice Production Trends

2.2.1. Global Rice Production

Rice is the world's most common food, consumed by almost 3.5 billion people [9]. Rice is a staple food in seventeen Asian and Pacific countries, nine North and South American countries, and eight African countries [10]. Rice provides 20% of the world's dietary energy, whereas wheat and maize provide 19% and 5%, respectively [11]. Rice (Oryza sativa L.) is the most frequently produced cereal crop in the world, with the biggest planted area. Asia produces the majority of the world's rice, with China leading the way with 1, 45,500 million tons, followed by India (1, 03,500 m tons). Rice crop area and yield will increase by 3.8, 7.2, and 11.3 percent globally by 2025-26, according to USDA (2016), (the base year 2015-16). Japan had the highest rice productivity (4.91 t/ha) during 2015-16, followed by China (4.79 t/ha). With an output of 145,500 million tons, China ranks first among the top ten rice-producing countries. Even though, India has the biggest land area [12]. India is ranked second in the world in terms of output, with 103,500 million tons produced [9].

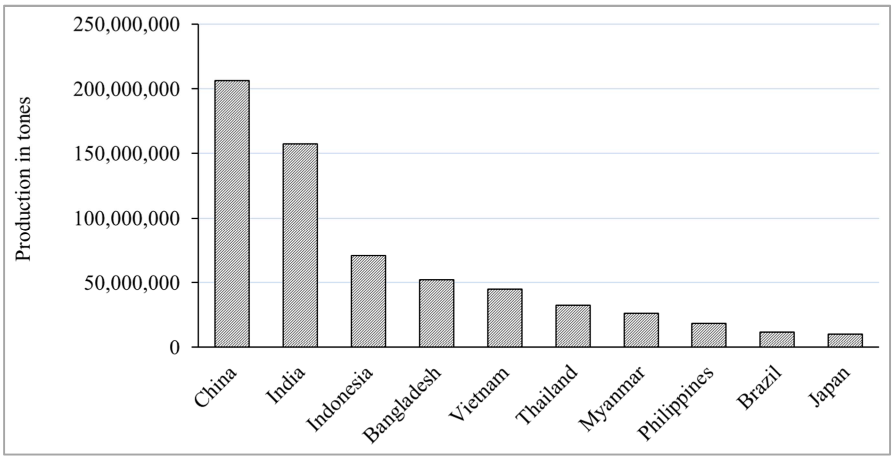

Figure 1. *World's top ten countries in rice production (Source: FAOSTAT, June 2017).*

As the report of Jeong, Kim [13], in 2013, Asia used 77.8 kg of rice per capita, Africa 23.9 kg, and America 18.5 kg. In particular, Africa's annual rice consumption per capita has risen steadily over the previous 20 years, from 16.9 kg in 1994 to 23.9 kg in 2013. Korea's per capita rice consumption declined by 2.48% per year, while rice consumption for processing climbed by 9.5% each year. Rice consumption for food and processing has risen by 1.37% and 3.68%, respectively, over the world. Because of the major reason for such a growing human population, an extra 116 million tons will be required in 2035, up from 439 million tons in 2010.

2.2.2. Rice Production in Africa

In terms of both quantity and quality, African rice production is failing to meet demand. Even big rice producers like Cote d'Ivoire, Guinea, Madagascar, Mali, Nigeria, and Tanzania are powerless to spread food independence (Figure 2). By 2025, African rice production would only meet around two-thirds of the landmass's request if current trends continue. Imports of mostly Asian rice will be required to cover the remaining one-third [23]. According to the report of Ravichanthiran, Ma [24], Rice consumption was predicted to be over 488 million tons (MT) in 2018, with Asia accounting for 90% of production and consumption. Rice consumption, on the other hand, is fast expanding in Sub-Saharan Africa (SSA). In 2018, SSA's rice consumption was predicted to be at 33.2 MT of milled rice, which was partially met by the importation of about 15.5 MT, or about 33% of what was sold on the global market. Rice is the fastest-growing food staple in Africa. In Sub-Saharan Africa, where rice is farmed and consumed in 38 nations, the demand-supply gap reached 10 million tons of milled rice in 2008, costing the area an estimated $3.6 billion [25]. By getting admission to better efforts and manufacture techniques counting first-class seeds, irrigation, and limited farming technology productivity can be increased by about 80%. By improving storage and processing effectiveness, which will include milling facilities, warehouses, and logistics, the remaining 20% will be used to raise rice quality [26].

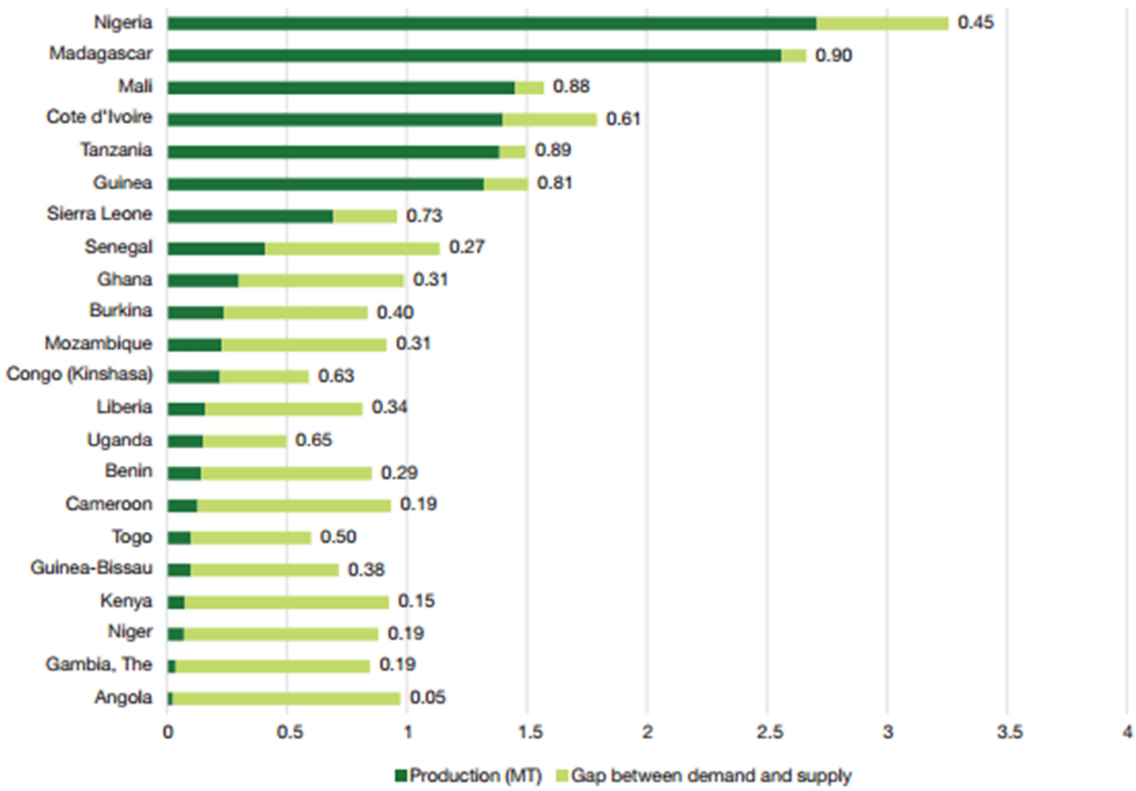

Figure 2. *Rice self-sufficiency for selected Sub-Saharan African countries (Source: Africa Rice 2018a).*

2.2.3. Rice Production in Ethiopia

As the report of Hegde and Hegde [25], Ethiopia is a multi-faceted country that serves as a gateway to the world's sole rice-producing region. In 2006, yields are expected to be 2.32 tons per hectare, compared to 5.80 tons in Europe, 4.93 tons in the Americas, and 4.22 tons in Asia. Africa's average rice yields are barely 57% of those in Asia. Yields have increased slightly over the last two decades, but not enough to make a substantial difference. The majority of the increase in production has come from increased harvesting areas rather than increased yields from many externalities.

As the report of Alemu and Thompson [4], Rice is a relatively new addition crop to Ethiopia, which is tied to the Derge regime's efforts to overcome the numerous issues posed by various public initiatives. The majority of the issues were related to settlement and food security. The profound variations in agricultural families and communal subtleties caused by the outline of rice and its following commercialization, only the Fogera Plain continued to be one of the main rice-producing regions. Rice's importance in the country is well acknowledged, as the area covered by 18,000 ha and total production of 42,000 tons in 2006 has climbed to 155,000 ha and 496,000 tons in 2009 [27].

As the report of Farmer Research Groups Alemu, Kiyoshi [28], Upland rain-fed rice grows in only three districts (Amhara, SNNPR, and Tigray) in 2009, with lowland rain-fed rice growing in all districts except Somali and Afar. Irrigated rice was exclusively planted in the Gambella Region until 2009; however, by 2014, it will be grown in all districts except Tigray. The discovery of wild rice in the Fogera plain and Gambela areas has prompted several governmental and non-governmental organizations to begin cultivated rice adaptation trials around the country [29, 30]. The Ethiopian Institute of Agricultural Research (EIAR) recognized the importance of rice and built the Fogera National Rice Research and Training Center (Fogera NRRTC) in 2013. The Fogera NRRTC is responsible for coordinating rice research in the country, and irrigated rice should be given special attention to meet the country's growing irrigated agricultural [31].

According to Alemu [32], Rice is regarded as Ethiopia's "Millennium Crop" for ensuring food security. As shown in figure 3, Ethiopia's projected potential rice production areas are as follows: upland is 30 million hectares, with 5.6 million hectares extremely suitable and 25 million hectares appropriate and irrigated is 3.7 million hectares. Rice may be grown successfully in various sections of the country. The West-central highlands of Amhara Region (Fogera, Gonder Zuria, Dembia, Takusa, and Achefer), North West lowland areas of Amhara and Benshangul Regions (Jawi, Pawi, Metema, and Dangur), Gambella regional state (Abobo and Etang Woredas), South and southwest Lowlands of SNNPR (Beralee, Weyito, Omorate, Gura Ferda (Illuababora, East and West Wellega, and Jimma Zones). Rice output has been expanding at a rapid rate, particularly since 2006. Rice-producing farmers increased from 32 thousand in 2006 to 119 thousand in 2013, with an increase in area allocated from 6,000 ha in 2006 to 58 thousand ha in 2013, and an increase in production from 11 thousand tons in 2006 to 184 thousand tons in 2013. In Ethiopian agriculture, rice is still a minor crop (Figure 4).

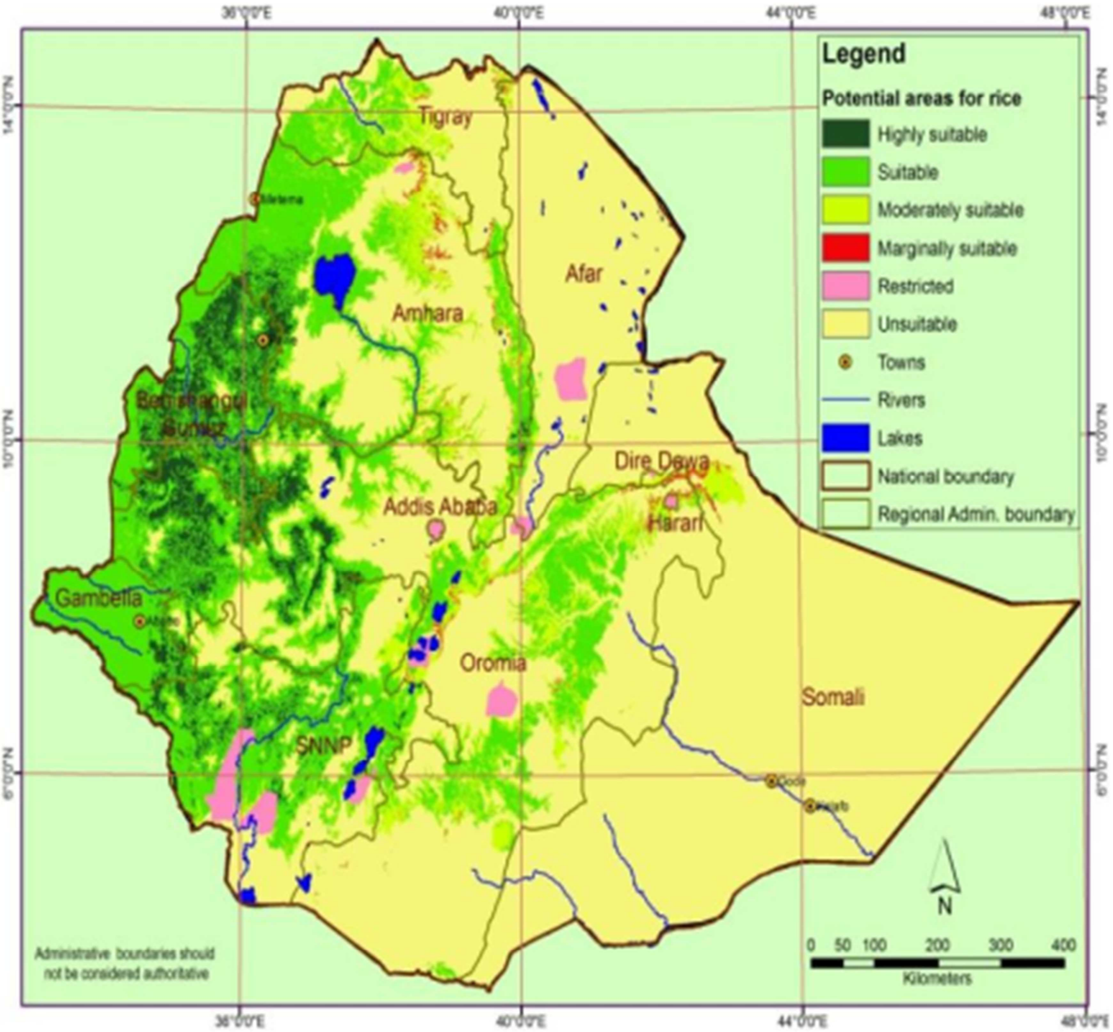

__Figure 3.__ Rice Suitability Map: Rain-fed (Source: MoA, 2010).

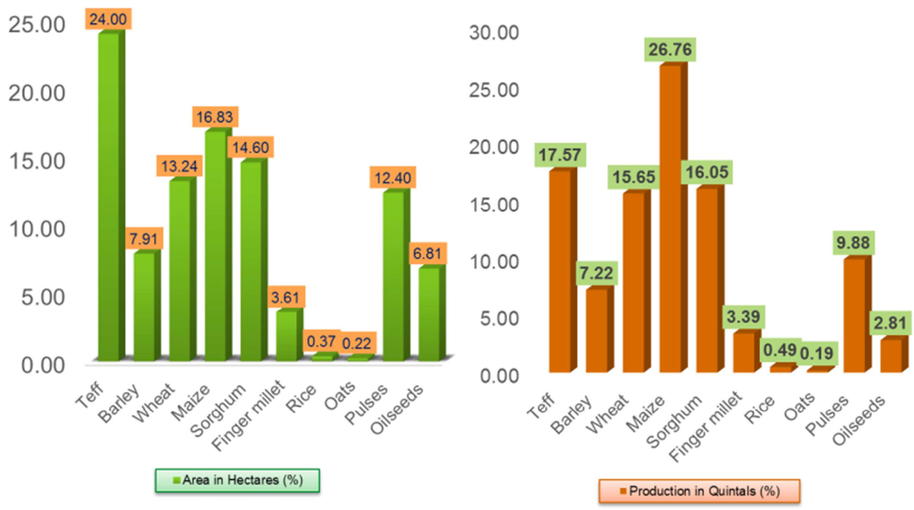

Figure 4. *Percentage Distribution of Area and Production under Major Crops (Source: Dawit Alemu, 2015).*

Rice production has significantly improved farmers' livelihoods and offered work chances for some residents in various parts of the country. Different stakeholders' need for enhanced rice technologies is increasing over time [33]. It has also become a crucial item for internal use as well as an export market for economic development in much of Ethiopia. As a result, a strong research and development system is required to construct a productive, sustainable, stable, and profitable rice farming system in the country.

Rice is the "millennium crop" projected to contribute to the country's food security, and it is one of the target commodities that has received special attention in the promotion of agricultural output. As a result, it has been classified as one of the Ethiopian Institute of Agricultural Research's (EIAR) nationally coordinated research programs. Because the crop is new to the country, study on it is still in its early stages. Almost all research activities are focused on variety development, with only a few research activities on crop management, and the other research disciplines are still mostly unexplored [27].

Adet (national coordinator), Gonder, Bako, Bonga, Gambella, Gode, Maytsebri, Humera, Pawe, Assosa, and Werer Agricultural Research Centers are all involved in rice research as collaborating centers, primarily in national variety and adaptation trials organized and coordinated by the national coordinating center. Until now, variety development has primarily focused on pure lines, to address mostly highland and lowland rain-fed, and to a lesser extent irrigated habitat. Rice germplasm is only obtained through introductions. Rice germplasm is introduced by the coordinating center from many sources, primarily IRRI and Africa Rice [34, 35].

Upland New Rice for Africa (NERICA) rice varieties include NERICA-4 and NERICA-3, which were released for the rain-fed upland habitat, and NERICA-1, NERICA-2, NERICA-6, NERICA-14, and NERICA-15, which were released for the upland-irrigated ecology. Africa Rice (the ex-WARDA) scientists produced NERICA rice varieties, which are expanding and delivering the rice green revolution to other African countries, including Ethiopia. Four irrigated kinds, two lowland rain-fed varieties, and seven upland rain-fed varieties are among the remaining 13 varieties issued [35]. Farmers have paid close attention not only to rice production but also to variety development since two kinds (one-upland and one-lowland rain-fed type) have been developed through selection [36, 37].

2.2.4. Rice Production in Fogera

Based on the report of Asmelash [38], rain-fed, naturally well-drained soils with no surface water accumulation are used to grow upland rice. The cropping season for upland rice types in the Fogera district begins in May. Upland rice may grow in any area that receives at least 15 to 20 mm of rain over five days throughout the growing cycle. Rainfall of 15 mm every five days is sufficient during the germination and early growth stages. National efforts have been made to develop upland rice varieties, and the MOARD has established a rice strategic plan. ARARI, non-governmental organizations, JICA, and SG-2000 are collaborating with WOARD to increase rice output and productivity, as well as upland rice production. Farmers in non-water-logged locations benefit from the NERICA (NERICA-3 & 4 and SUPERICA-1) types that have been released. However, of the released types, NERICA-4 is frequently used in the district's hilly parts. Despite the extension system's and other stakeholders' efforts, the adoption of improved upland rice varieties is still low in the research area. Farmers have their adoption criteria for newly released varieties, which are rarely taken into account by research and extension personnel. The majority of sample farmers (90%) liked NERICA-4 because of its market demand, grain production, taste, and other desirable characteristics. The NERICA-4 cultivar produced higher yields in upland and non-flooding zones in the research area.

As the report of Alemu and Thompson [4], the discovery of wild rice in the Fogera Plain's wetlands, followed by the introduction of a cultivated rice variety, changed the major land use activity from cattle grazing to rice farming. As rice cultivation grew, the amount of land available for grazing Fogera cattle and growing other crops shrank, causing dramatic changes in local farming systems. Farmers initiated to devote mostly in additional irrigation for rice production as their rice income increased. This goes to pave the way for the production of other crops under irrigation, boosting household earnings even more. To optimize farmers' returns on investment, the Office of Irrigation prioritizes gardening crop. Over the same period, the goal is to increase attention of limited irrigation systems since 2.3 to 4.1 M ha, as well as medium and large-scale projects from 658,000 ha to 954,000 ha. Farmers typically employ irrigation, for the improvement of rain fed rice production, as well as horticultural crops, which is usually done after rice and grass pea harvesting. Farmers had greater chances to diversify and create additional income as a result of these developments.

3. Production of Rice Under Irrigation

As the report of Mandal, Thakur [39], Rice growth requires more attention to increase yield while also minimizing water consumption. Sprinkler irrigation, on the other hand, led to agronomic and environmental benefits, as well as economic benefits, in the central Sardinia rice region of Italy, where water requirements were reduced by 50% without a reduction in rice yield [40].

Drought-resistant rice varieties yielded higher than puddled rice types under drip irrigation in Shanghai, China; drip irrigation achieved more than 95% of the yield produced under puddle conditions [41]. In Pakistan's Potohar Plateau, rain-gun sprinklers are being modified to offer supplemental irrigation to dry land agriculture. However, widespread adoption has not been documented in the Indus Basin's canal-irrigated districts [42]. The irrigation regimes and irrigation intervals determine how much water is available to the crops. The furrow irrigated bed technique reduces soil erosion and enhances accessible soil moisture, resulting in increased water consumption and yield [43].

The study was conducted in the summer of 2011–12 at a red loamy/calcareous black soil using subsurface and surface drip-fertigation with conveyance through PVC pipe; NPK at 150: 50: 50 kg ha^{-1} yielded the following results: grain yield 3.74–4.25 tone ha^{-1} in drip with 647.5–692.9 mm water, i.e. 8–17% higher yield and 7–27% increased water productivity compared to flood; suggested for the nutrient [44-46].

In 2013, an experiment employing short-duration rice 'Khandagiri', puddled transplanted, and supplemental watering through a drip in sandy loam soil during the rainy season, grain yield was 4.27-, 4.39-, and 3.92-ton ha^{-1} in 100%, 125%, and 75% of ETc in drip, respectively. After three days of drainage of standing water, it was 4.48-ton ha^{-1} with surface irrigation; drip (108–179 mm) and surface irrigation (5 cm); surface irrigation (250 mm) by hose pipe; WUE 0.604 kg m^{-3} in drip at 100% ETc and 0.432 kg m^{-3} in surface irrigation [47].

Also, during 2013–14, drip at 1.5, 2.25, and 3.0 times pan evaporation (PE) in direct-seeded rice in the wet season utilizing medium duration 'PR-115'; N 120, 150, and 180 kg ha^{-1}. With 860 and 1455 mm water in drip and flood irrigation, grain yields of 7.3–8.0 and 6.6–7.6 ton ha^{-1} were obtained, with water savings of 40–42%; WUE 0.81–0.88 and 0.42–0.52 kg m^{-3} in drip and flood irrigation, respectively [48].

3.1. Response of Rice (Upland Rice) for Irrigation

For irrigated rice ecosystems to attain viable yields, irrigation scheduling and nitrogen feeding are critical [49]. The grain production of waterless sowed rice seen by day-to-day watering and at stress of -20 kPa stayed comparable but, decreased when the irrigation verge climbed near 40 and 70 kPa [18].

At Utukuru, Andhra Pradesh, in three days irrigation interval given to aerobic rice registered higher grain and straw yield as equated to other, whereas the test weight did not vary due to the diverse quantities of water applied [50]. The water used in different irrigation schedules was between 675-775 mm, through effective precipitation of 325 mm, and the paramount water use effectiveness was detected with irrigation arrangement that maintained soil wetness pressure of -20 kPa to -30 kPa up to panicle beginning phase and -10 kPa to -20 kPa for the rest of the period, as opposed to additional programs that maintained IW/CPE percentage, and a decrease in water productivity was observed as irrigation levels increased [51]. And Mahajan, Chauhan [52], discovered that At Ludhiana, the WUE of aerobic rice was higher at -20 kPa than when watering at a soil water possible of -10 kPa. In Warangal, Andhra Pradesh, scheduling drip irrigation at 100% PE resulted in a 25 and 42% increase in water use efficiency over 150% PE and soil saturation, respectively [53]. Through minimizing aquatic usage through soil research and controlling leakage, filtration, and vanishing, aerobic rice cultivation saves water and promotes water production [21]. Water productivity can be boosted by either increasing yield or by maintaining production while reducing water input [43].

According to the report of Chandana [54], because the harvest discount was originally lesser than the quantity of water conserved, AWD boosted water productivity in terms of total water input. The grain yield of AWD is heavily influenced by variety. Under irrigated conditions, AWDI aims to generate an equivalent harvest as paddy rice by much-reduced usage (50% less water than regular paddy rice).

3.2. Factors Affecting Irrigated Rice

As the study of Nonvide [55], farmers age, sex, teaching, incidence of extension lead visits, loan admission, marketplace involvement, and remoteness of home to the irrigation system, tractor use, and fertilizer use are all factors that affect irrigated rice. The coefficients of the explanatory factors have the same signs as the marginal effects and comply with the predictions. Similar research has been reported [56, 57].

Farmers' age, expressed as a quadratic, has a large and non-linear impact on the likelihood of irrigation adoption. The likelihood of a farmer becoming an irrigator decreases as he or she grows older. One explanation is that older farmers may pass irrigated land ownership to their younger descendants. There is an inverse association between a farmer's gender and his or her likelihood of contributing in an irrigation project. Males are extra possible than women to use irrigated agriculture. This could be owing to irrigated farming's high labor request. Farmers who have completed at least primary education are more likely to use irrigation than farmers who have not completed primary school. The reason for this is that educated farmers may be better able to adopt modern agricultural technology [58]. The frequency of extension visits was found to have a positive relationship with the likelihood of irrigation adoption. Extension visits enhance the likelihood of irrigation adoption by 1.39% for every unit increase in frequency, implying that learning about new agricultural practices and technologies may have occurred through extension services and social networks [56, 59]. Access to credit has a positive impact on the likelihood of implementing irrigation. As a result, enhancing farmers' access to credit is critical to the irrigation policy's success. Farmers will tend to enhance rice supply by adopting new practices if they are aware that there is a demand for rice. The positive association between irrigation adoption and institutional variables like financing, market, and extension services demonstrates the government's support for the irrigation system among farmers [55]. As expected, the distance between dwelling and irrigation scheme exhibits a negative correlation with irrigation adoption. Being an irrigator is more likely if you live near an irrigation project. This could lower the cost of getting to the scheme in terms of time and effort, and then make management easier [60].

4. Conclusion

Because Ethiopia relies so heavily on rain-fed agriculture, production in that industry regularly fails as a result of unpredictable and frequently insufficient rainfall. Irrigation is a method for stabilizing agricultural productivity that also helps to mitigate the consequences of irregular or insufficient rainfall. Development in irrigation technology can help mitigate some of the negative effects of rapid population increase. As a result of agricultural expansion into marginal areas brought on by population development, land, water, and forests are degraded. This environmental damage in agriculture could lead to increased food insecurity and poverty. To meet the escalating demand for food, food production must increase. The three approaches to increase food production are to increase crop yield, increase the area of land that is arable, and intensify crop output (number of crops per year). In Ethiopia, rice has developed into a key crop for food security and a valuable strategic commodity during the past three decades as a result of a variety of causes. These are connected to the trend of increasing rice manufacture related to agro-ecological appropriateness and possible, compatibility of rice with regional agricultural practices and old-style diets, financial inducements of rice manufacture, the sharp rise in national rice feeding and the resulting load on far-off exchange owing rice introductions, and the supportive community rule atmosphere and expansion. As the major strategic interventions of the country, irrigation and investment in water control technologies is the main way to improve national food security by increasing irrigated crop production. So, evaluation of irrigation interval, water productivity, fertilizer rate, and economic return on irrigated rice in all irrigation potential areas of the country can fit the national strategy.

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