Chapter

Rainfed Rice Farming Production Constrains and Prospects, the Kenyan Situation

Al-Imran Dianga, Ruth N. Musila and Kamau W. Joseph

Abstract

Kenya experiences huge production-consumption deficit in relation to rice. This is due to changing eating habits that has adopted more rice in the menu and rapidly rising population. Rice production has remained low being unable to meet consumption. Rice ecosystems in Kenya include irrigated, rainfed lowland and rainfed upland. Irrigated ecosystem has over the years been given more emphasis despite rainfed rice farming having double the potential over irrigation system. Ecologically rice grows well in abundant water supply, warm to high temperatures and in Clay sandy to loamy soils with slightly acidic to neutral pH. Rice varieties grown in Kenya are mainly traditional, introduced improved, hybrids and land-races. Rainfed rice farming faces constraint's key among them being; drought and erratic rainfall, weeds, pest and diseases, cheap imports, land ownership and poor infrastructure. Mitigating against drought and erratic rainfall, improving farm inputs and equipment, increasing germplasm production and distribution, credit support and marketing to farmers, improving farmers skills through technological transfers and infrastructural development are prospects that if adopted could increase rainfed rice productivity. More attention towards improvement of rainfed rice farming could greatly contribute to bridging the production-consumption deficit that is bridged through imports. It is with this, that this review updates our understanding of rain fed rice farming in Kenya in terms of ecological conditions, ecological systems, varieties, constraints and prospects.

Keywords: Rainfed, rice, rainfed, ecology, constraints

1. Introduction

Cultivated rice is grouped in to the genus *Oryza* taxonomically. The genus *Oryza* (*O.*) contains 23 species of which two are cultivated while the rest are wild [1]. The two cultivated species, are *Oryza glaberrima*, commonly referred to as African rice, and *Oryza sativa* L., commonly referred to as Asian rice [2]. *O. glaberrima* is indigenous to sub-Saharan Africa and its domestication is believed to have been from *Oryza barthii* (which used to be referred to as *Oryza brevilugata*). On the other hand, *O. sativa* was domesticated independently probably in China [3]. Cultivated rice is not limited to the two *Oryza* species, other inter-specifics for example the New Rice for Africa marketed as NERICA'S that arose due to crossing of *O. sativa*, and *O. glaberrima* are also cultivated [2].

Rice is an essential food crop that provides for most of world's population. It is also the second most consumed among cereal crops that include maize, wheat, barley, sorghum and millet. Rice is a major cereal crop with high economic and nutritional importance [4, 5]. Worldwide the leading producers of rice are Indonesia, India and China who together account for 50% world production [6]. Africa accounts for only 3% of the world's total production, with biggest producing countries being found in West Africa and they include Cote d'Ivoire, Nigeria and Mali. Mozambique and Malawi are the leading producers in Southern Africa. Madagascar and Egypt are also other substantial producers. In East Africa Tanzania ranks top in production followed by Kenya then Uganda [6].

In Kenya rice is mainly consumed as food with byproducts having other roles, for example rice hull is used as animal feeds, rice straw is also used as animal feed and substrate for growing mushrooms, while rice husks are used as cooking fuel [7]. In Kenya rice consumption has increased tremendously at an annual rate of 12% in comparison to wheat and maize that have increased at about 4% and 1% respectively. This is credited to changes in eating habits mostly among people living in urban centers [8]. Therefore, demand for rice is expected to increase further. In 2019 the annual rice consumption in Kenya was approximated to be 800,000 metric tons compared 130,000 metric tons produced the same year (**Figure 1**), the deficit was met through imports [6]. Current rice imports are estimated to be about $87.5 million consequently stretching other parts of the economy [6].

Irrigated rice production land potential is about 540,000 ha while the production land potential for rain-fed ecology is 1.0 million ha [7, 9] currently area under production is estimated to be 30,000 ha. This indicates that if rain fed ecology potential is fully explored it will contribute to towards bridging production and consumption gap. Rice yield for irrigated rice is approximated at 4–6 t ha^{-1} while for rain fed is 1 t ha^{-1} which are below optimal production capability of about 10 t ha^{-1} and 7 t ha^{-1} respectively [7].

In Kenya like in many other sub-Sahara Africa counties rainfed rice farming has not been given priority [10]. With a potential of over 1 million ha about only 250, 000 ha are under rainfed rice crop [11]. Increasing Rain fed rice production is likely to increase the national rice production thus decreasing the rice import bill. This

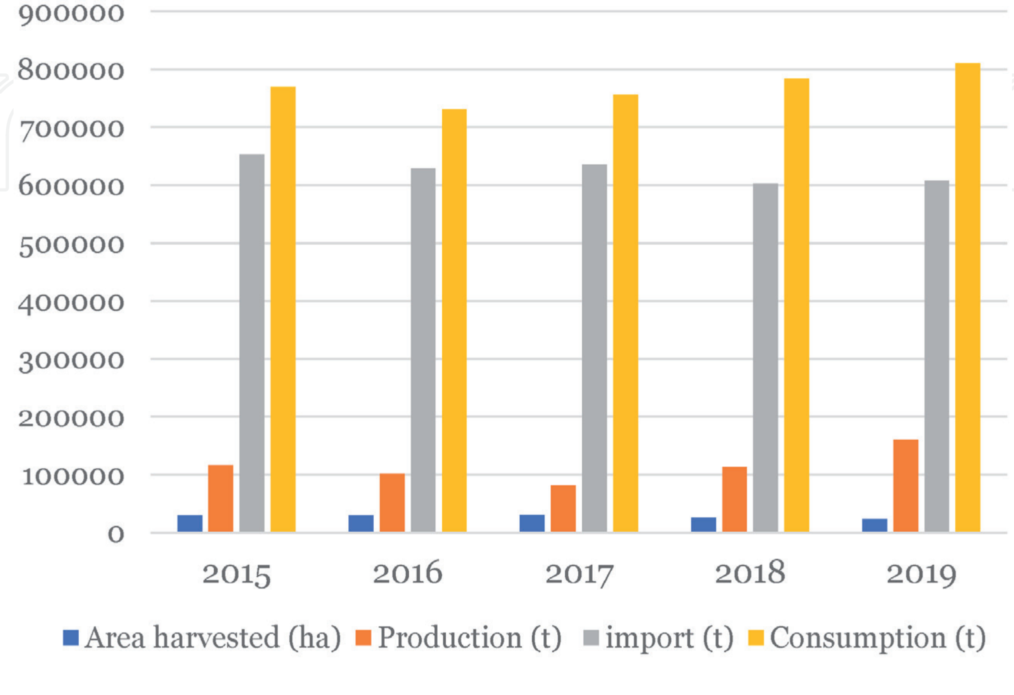

Figure 1.
Rice production, imports and consumption in Kenya between 2015 and 2019.

chapter aims at reviewing rainfed rice farming in Kenya by highlighting ecological conditions, ecological systems, the constraints faced by rainfed rice farming and discussing their potential solutions which if adopted can increase rice production in Kenya.

2. Rice ecological conditions

Rice plant water requirements is based on ecosystems under which it is cultivated. When it is grown as an upland crop under rain-fed conditions it needs 100 mm monthly rainfall and when grown as lowland crop it requires 200 mm rainfall per month. Rice can also be grown as lowland crop with standing water. Rice crop will need 125 mm monthly rainfall during vegetative stage while during ripening stage no standing water is needed. It is thus best adapted to grow with abundant water supply [12]. Rice grows in different soil conditions ranging from black clay that is heavy to sandy loam with a pH range of 4.5–7.0 and can tolerate water logged soils. Hot and humid condition with temperature ranging between 22° centigrade to 40° centigrade is the ambient climatic condition of rice. It grows well in altitudes of between 0 and 1700 meters above sea level [13].

3. Rice ecosystems

Based on IRRI, rice farming is categorized into four ecosystems depending on source and water supply. This are irrigated, flood prone, rainfed lowland and rainfed upland and [14].

Irrigated ecosystems are the most widely utilized rice farming ecosystems accounting for over 75% percent of total yield. The ecosystem includes lager parts of Europe, Australia, America, Asia and Africa. Irrigation ecosystem is again grouped into irrigated wet season and irrigated dry season. Irrigated wet season involves cultivation of rice during the wet season and irrigation water supplements rainfall. Irrigated dry season involves planting rice when rainfall is usually low and water is majorly supplied by irrigation in places that usually experience high solar radiation and evapotranspiration. In irrigated ecosystem the fields are bunded and leveled, water level maintained at between 2.5 cm to 1.5 cm determined by availability of water. Rice seeding is by either transplanting or direct seeding. In Kenya irrigation farming is done in irrigation schemes under the management of the National Irrigation Board (NIB). Major irrigation schemes include Ahero, Bunyala, West Kano, Perkera, Hola, Bura and Mwea. Small holder irrigation farming is practiced along river valleys namely; Kore, Alungo Nyachoda, Wanjare, Anyiko and Gem Rae in Western Kenya and Kipini, Malindi, Shimoni and Vanga at the coastal region [11]. Dry irrigation entails continuous flooding and it is practiced in Mwea, Ahero, Bunyala and Western Kano irrigation farming. Dry irrigation must have continuous water supply and soils must have high water retention capacity. During drought water is rationed hence reducing productivity though currently, System Rice Intensification (SRI) has been introduced.

Flood prone ecosystems involves paddy-fields being subjected to unbounded flooding for a duration that is about 5 months and water depth might range up to a maximum of about 5.0 M during plant growth. In this deep-water condition rice plants, mostly floating rice varieties outstretch their stems to get to the water surface. Flood prone ecosystem is largely practiced in Africa and Asia and accounts for 7% of the world land under rice cultivation. The cultivation is mostly located in river deltas for instance the Ganges in India, Brahmaptura in Bangladeshi, the Mekong in Vietnam and Cambodia, Niger delta in Niger and Chao Phraya of Thailand. Deep water rice system is also extensively practiced in coastal areas of India, West Africa, Vietnam and Bangladeshi based on daily tidal inundation. Key constraint in this environment is soil and water salinity and flash floods. This ecosystem extremely variable due to unpredictable flooding and drought. Farmers in this ecosystem records about 1.5 t ha^{-1} average yield with the main stress being environmental making most applicable farming inputs ineffective [14].

Rainfed lowland ecosystem involves slightly bunded and leveled field where water supply is mainly by rainfall and the water depth and the duration depends on the rain season. The water level cannot be controlled and rice plants are severely exposed to drought, deep floods, and alterations between anaerobic and aerobic environments [14]. In Kenya Rain-fed lowland rice cultivation is practiced in Kwale, Kilifi and Tana River counties at the Coast region.

Upland ecosystems involve rice fields in straighten valley bottoms to hilly mountainous lands with slopes ranging from 40% to about 0% descend. In Upland ecosystem rice cultivation done by preparing fields that are seeded when dry. These ecosystems form about 13% of harvested rice areas worldwide but accounts for only 4% of the world's total production. Upland rice is largely for a subsistence crop with yields approximated at 1 t ha^{-1} in areas with little inputs to 3–4 t ha^{-1} in situations where fertilizer application and supplementary irrigation is practiced. An estimated population of 100 million people are believed to depend on upland rice as their staple food. Upland rice is mostly grown in Asia (Bangladeshi and India), Africa and Latin America. These ecosystems have many constraints, mostly attributed to insufficient soil fertility, weed invasion and disease infection. Worldwide, rain fed ecosystem accounts for approximately 54 million ha of rice, mostly found in Africa and Asia [14]. In Kenya rain fed upland is grown in Kisumu, Busia counties in western Kenya and Kilifi, Kwale and Tana river counties of Coastal Kenya [15].

4. Rice varieties under rainfed ecology in Kenya

Rice varieties under rainfed conditions are categorized as traditional, introduced improved and hybrid rice. Traditional varieties are characterized by late maturity, low yields, lodging. However, they are adapted and are able to tolerate stresses such as pests and diseases, drought, weeds, salinity and even bird's attack. Some traditional lines possess farmers preferred traits like aroma and good gelatinization temperature.

4.1 Rainfed lowland ecology varieties

Under rainfed lowland ecology traditional lines include Madevu, Kitumbo, Kichana chawa, macho ya wanda, kijego, Matako Nyeusi, Moshi and Mtumbatu. Introduced improved lines show improved yield, earliness and less lodging. Rainfed lowland introduced improved lines include Komboka and MWIR 2. Komboka was introduced by Kenya Agricultural and Livestock Research Organization (KALRO) in co-operation with International Rice Research Institute (IRRI) in 2013. It is high yielding, good grain quality, semi aromatic and has high tillering ability. Supaa, a local landrace that is aromatic and late maturing is also grown particularly at the Kenyan coast. Highbred low land ecosystem rice lines are Arize Tej Gold and Arize 6444 Gold from Bayer East Africa that were evaluated and found promising by National Irrigation Board (NIB) however, there adoption remain low.

4.2 Rainfed upland ecology varieties

Rainfed upland introduced improved rice lines include MWUR 4, *Dourado precoce,* NERICA 4, NERICA 1, NERICA 10, NERICA 11 and NERICA 2. *Dourado precoce* was introduced by Kenya Agricultural and Livestock Research Organization, and its attributes include good grain characteristics and early maturity. The NERICAS have been the most successful lines that have been introduced in Kenya. The NERICAS were developed from interspecific fixed lines *O. sativa* and *O. glaberrima.* The NERICAS combine the hardiness of the African rice *O. glaberrima* in terms of pest, diseases, and weeds resistance with the high yielding trait of the Asian rice *O. sativa*. The NERICAS are; high yielding with small amount of fertilizer application, they are suitable for African soil and matures faster shortening growth cycle by 30–35 days enabling double cropping and minimizing drought effect [16, 17]. Improved rice lines offer a feasible option to traditional rainfed varieties. Yield of up to 4.4 t ha^{-1} was realized from on farm field test in Kerio Valley for the NERICA lines, this showed promising results. Though NERICA 4 emerged as the best line for most parts of Kenya, others like NERICA 1, NERICA 10 and NERICA 11 performed quite well [8].

5. Rain-fed Rice production constraints in Kenya

A wide range of constraints affect rice production in Kenya mostly a biotic, biotic, socio-economic and management [18]. Abiotic constraints include drought and erratic rainfall. Biotic constraints comprise of pests, diseases and weeds while socio-economic includes land ownership, unfavorable trans-border trade, high cost of machineries and inputs, poor infrastructure, unskilled farmers, slow technological advance transfer, poor access to credit and uncoordinated marketing.

5.1 Drought and erratic rainfall

In Kenya drought and erratic rainfall is a major constraint that has limited production and led to low yields for rainfed rice farming [19, 20]. In reports done by [19, 21] at the coastal and central regions of Kenya, they both conclude that drought is a constraint of great importance in rain fed rice production in the country. During drought years in Kenya rice yield in the paddy system potential drops to 1.4 t ha^{-1} from a potential of between 2.7 t ha^{-1} to 5.4 t ha^{-1} in a good year. Rice is very sensitive to drought especially during the reproductive stage where if there is drought then it leads to significant yield losses. Drought stress reduces peduncle rate of elongation and length at the booting stage. Reduction in peduncle elongation majorly predisposes reduction in panicle exertion rate [22, 23]. This results in either incomplete or failure of the panicles to exsert from the boot. Moreover, there is spikelet sterility from the damaged and abnormal development of the reproductive organs [23].

5.2 Weeds

Weeds compete for vital nutrients with rice plants. Weeds serve as alternative hosts for diseases, pests and rodents. Weeds have a cumulative effect of suppressing rice plants growth thus reducing yield. Common weeds in Kenya include; *Echinochloe colona* and *Echinochloe crus-galli* of family Poacea, *Ishaem rogusum*, *Leptochlea chinesis*, *Cyperus deformis*, *Fimbristylis miliacea*, false finger millet and striga. Weeds also reduces harvests quality and makes farmers to utilize more resources in terms of time and money to control weeds which reduces returns [24].

5.3 Diseases and pests

Diseases are also a major constraint to a Kenyan rainfed farmer. Common diseases include; Blast caused by *Pyricularia oryza*, Rice Yellow Mottle Virus (RYMV), Brown Spot (*Helminthosporium oryza*) Sheath rot caused by *Sarocladium sp*., Sheath blight caused by *Thanetophorus cucumeris*, Bacterial blight caused by *Xanthomonas oryzae* pv. oryzae, Glume discoloration caused by *Sarocladium sp*. and *Curvularia sp*., Leaf scald caused by *Rhyncosporium oryzae.* Pests also have a major effect on rice yield, major pests that attacks rice include Stem Borers, Leaf Miners and Root Cutting Insects. Others are Rice hispa, termites, Rice root aphid, seed corn maggot, cut worm, Rice water weevil, Rice leaf beetle, and rice green caterpillars. Birds e.g., quelea and rodents such as mice and rats also cause a substantial field loses [25].

5.4 Land ownership

Land ownership system has led to land fragmentation in potential areas as population increases. This has made it difficult to utilize mechanization in rice farming processes leading to reliance on manual labor which rises production costs narrowing profits margins for farmers. Furthermore, women who are key players in rice production are traditionally not allowed to own land though Kenyan laws provide for women land ownership [26].

5.5 Unfavorable trans-border trade practices and cheap imports

There is a lot of informal trade with Tanzania and Uganda. There is uncertified rice seeds movement which presents challenges to the rice sub-sector development. With no harmonized tariffs on germplasm trade between the East African community neighbors controlling this type of trade has been a challenge. There has also been illegal importation of cheaper milled rice from other countries which leads to low prices for the Kenyan farmer hence hurting profits.

5.6 High cost of machineries and inputs

The cost of acquiring machineries such as tractors and farm inputs such as fertilizers and pesticides is so high. This has been a disincentive to farmers on use of machineries and farm inputs. This has driven production cost high reducing farmers profits margins.

5.7 Poor infrastructure

In Rainfed rice systems poor infrastructure has been a major constraint to farmers. Rice mills are unevenly distributed forcing farmers to rely on traditional milling methods which are labor intensive, and lead to low quality and low percentage of milled rice recovery from paddy rice. Poorly developed roads, drainage, communication and viable public-private sector partnerships contribute to low rice productivity. More improvement in rice milling value chain could improve rice production. A study done in Rwanda by [27] showed that the system of processing rice in small hullers did not to contribute to increasing domestic supply. This was attributed to hulled rice of poor quality that was demonstrated by 30% decrease in prices of domestic rice compared to imported rice. Other aspects in which millers affects rice production is in relation to their location. Rice mills located far from farms implies high cost of transportation and this drives up production costs. The high milling costs implies farmers being unable to recover their production costs since cost of transporting paddy rice which is bulky than rice that has been milled by about 40% is expensive [28].

5.8 Unskilled farmers and slow technology transfers

Most farmers lack modern rice farming skills instead relying on traditional farming methods that have been overtaken by time. As new advancements in technology in rice are made the rate at which the technology is transferred to farmers is slow. Extension staff services are inadequate and at times the staff themselves have limited capacity on educating the farmers.

5.9 Poor access to credit and uncoordinated marketing

Most rainfed rice farmers do not have access to credit as most are small scale and subsistence farmers. Marketing is done individual farmers unlike in irrigation ecosystem where it is coordinated. Individual uncoordinated marketing makes the farmer lose ability to bargain for better prices exposing them to brokers who exploit them.

6. Rain fed rice production prospects

6.1 Mitigating against drought and erratic rainfall

Breeding of drought tolerant lines can effectively address frequent droughts problem in rainfed lowland and upland rice ecosystems [29]. The technology is cheap; costs less to grow drought tolerant lines than to grow a susceptible one. Yield performance under both drought stressed and non-drought stressed environments are realized, with the drought tolerant line having the ability to be cultivated in all seasons with no yield penalties in the good years [20]. Farmers should be encouraged to adopt early maturing lines like the NERICAS. Breeding for early maturing lines can be used to come up with genotypes that mature faster thus evading drought stress especially in rain fed production [30]. Using improved water storage, harvesting and underwater could supplement rain in rainfed system avoiding total crop failure when rains fail or are inadequate. This can also increase irrigation potential to 1.3 ha [15].

6.2 Farm inputs and equipment

Enhancing access to farm inputs and equipment's could increase yields. The government needs to subsidize fertilizers and pesticides. Farmers must also have access to appropriate germplasm and variety maintenance. The government should ensure sufficient production, supply and marketing of high-quality equipment's. The County governments need to have facilities that allow for hiring of expensive equipment's and machinery e.g., tractors to farmers.

6.3 Germplasm production and distribution

To discourage farmers from using low yielding long durational lines, lines development should be specified based on agro-ecological zones though seed multiplication should be in areas that experience low abiotic stresses. Researchers should develop breeder and foundation seed that is maintained by research institutions. Scientist certified seed should be reproduced by seed merchants who should in turn sell it to seed stockiest in rice growing areas as per projected requirements to ensure they are easily accessed by farmers. This should be followed by massive sensitization of extension officers and farmers on the new lines in the market [25].

6.4 Credit support and marketing

Organize farmers into cooperative societies and common interest groups. This makes it easier to market their rice and access credit facilities. State funded credit agencies e.g., Agricultural Finance Cooperation (AFC) should be encouraged to lend to farmers.

6.5 Infrastructural development

Construction of modern mills will promote rainfed rice farming. Improving roads, construction of health facilities to provide health services to curb water-borne diseases are other infrastructural improvement that could promote rice farming. Furthermore, both national and County governments must provide incentives and formulate policies that encourages private sector partnerships. Temperature regulated bulk seed storage facilities should also be built. Fully equipped soil analysis laboratories as well as rice harvesting machines be made available to farmers.

Improving rice mills also contributes to improved income by offering employment. These mills support food security, and increase competition that will bring down milling costs to farmers [31]. There is need to put in efforts to modernize and improve rice milling subsector. Efforts should be put in place to promote setting up of mult-pass rice mills with recovery rate of about 70% of un-husked rice compared to single pass mills with recovery rate of about 57%. In addition to that, mult-pass mills have a lower split rice percentage of about 14% compared to 27% in single pass mills. To support farmers in this situations, possible approaches to be employed include; supplying multi-stage rice mills to farmers co-operatives societies, using rural social entrepreneur to supply rural mills, assisting millers and farmers to set up out grower agreements and developing models to upgrade central and decentralized local milling technologies [31, 32].

The government should commission studies on inventories on post-harvest facilities for rice, losses assessment and information gathering that supports government planning and other stake holder's intervention to the sub-sector. Better storage facilities need to be developed and promoted, to support the milling section further the government and county governments should promote technological knowhow on agronomic applications and post-harvest technologies that entails agricultural processing to reduce losses.

Furthermore, a need also arises to utilize other energy and drying technologies like solar drying systems and hybrid's systems that use both rice straws and solar, collapsible dryers, portable thermal dryers and other renewable energy technologies. This will greatly reduce post-harvest losses. Another way of pushing profits margin up for farmers is utilizing rice by-products mostly husks that make up to about 20% of paddy in animal feeds production, bio-fertilizers and briquettes [31].

6.6 Improving farmers skills and technological know-how

Researchers' farmers and extension officers should be trained on modern rice production techniques and utilization. Setting up new training institutions and revitalizing existing ones to undertake capacity building in rice specific courses. Extension officers be posted to rice growing areas to improve quality inspection and its enforcement. Fully functional research and extension infrastructure should be set up to promote development, packaging, and timely disseminating of appropriate technology to extension officers, farmers organizations and other stakeholders. Farmers-extension-research linkages should also be improved and strengthened.

7. Conclusion

To increase Kenyan rice production further emphasis, need to be on small scale rainfed farmers. By addressing the constraints like drought and erratic rainfall, weeds, pest and diseases, cheap imports, land ownership and poor infrastructure through; mitigation against drought and erratic rainfall, improving farm inputs and equipment, increasing germplasm production and distribution, credit support and marketing to farmers, improving farmers skills through technological transfers and infrastructural development. Rainfed rice farming production potentials could be unlocked resulting in improved rice production.

Conflict of interest

The authors declare no conflict of interest.

Acronyms and abbreviations

KALRO	Kenya Agricultural and livestock Research organization
IRRI	International Rice Research Institute
SRI	System Rice Intensification
AFC	Agricultural Finance Cooperation
NIB	National Irrigation Board
$t\ ha^{-1}$	Tons per hectare

Author details

Al-Imran Dianga[1*], Ruth N. Musila[2] and Kamau W. Joseph[1]

1 Department of Plant Sciences, Kenyatta University, Nairobi, Kenya

2 Rice and Maize Breeder, Kenya Agricultural and Livestock Research Organization, Kerugoya, Kenya

*Address all correspondence to: alimrandianga@gmail.com

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