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UPLAND RICE: A NEW HIGH POTENTIAL NON-TRADITIONAL CASH CROP FOR AFRICA

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ABSTRACT

Rice is the main staple food for almost half of the world's population and leading cereal in terms of production area and consumption. Rapid urbanization and changes in consumer preferences have led to a concomitant increase in consumption which so far exceeds any other crop in Africa. Therefore, upland rice cropping has become a common sight in Africa as farmers engage in diversification and respond to demand for the crop. Interspecific hybridization of African rice (*Oryza glaberrima* Steud.) and Asian rice (*Oryza sativa* L.) produced upland rice NERICA varieties that combine adaptability, tolerance to stresses and high production potential. Traditional African rice varieties though adapted to the continent are prone to lodging, shattering and comparatively low yielding which adversely affects production and consequently their adoption. Some of the poorest farmers are found in Africa where there is dependence on biomass cooking fuel and upland rice has greater significance. There is, therefore, need to re-evaluate the role played by the crop, identify gaps and proffer solutions that will make it productive and widely cultivated. Accordingly, this review intends to examine upland rice production patterns and strides which can be made to sustainably increase its productivity so that there is food and nutrition security. Some of the pertinent issues that need to be considered include prioritization of farmer preferences in quality and agronomic attributes to enhance adoption. Upland rice breeding programs can go beyond traditional breeding for stresses and yield but focus on genetic biofortification to use the crop as a conduit for vital nutrients. Ultimately, for sustainable rice productivity, there is need to have affordable infrastructure to lessen labor requirement particularly during production and post-harvest processing. Moreover, there is need to build institutional capacity to conduct more research and offer extension services to support production of the crop. A wider product portfolio for the crop will subsequently have a multiplier effect and enhance adoption of rice production by many farmers in Africa. The ultimate aim is to spread awareness of upland rice as an alternative cash crop that can be produced in suitable agroecologies in Africa.

Key words: Crop diversification, NERICA, *Oryza glaberrima*, *Oryza sativa*, Upland rice



INTRODUCTION

Rice (*Oryza spp*) is the leading cereal that supports numerous households in developing countries. Furthermore, in Africa it has the greatest yield potential compared to most traditional cereals such as millets [1]. African rice, is a domesticated rice species cultivated in production systems characterized by minimal agro-inputs and direct seeding [2]. Rice has wide adaptation with the most prominent production systems being lowlands and uplands. Asian rice, predominates lowlands where fields are flooded during part or all of the growing season; lowland rice includes rain-fed lowland, irrigated lowland, deep-water and mangrove swamp [3]. Upland rice is grown on level or sloping, natural terrain fields without flooding. In some cases, supplemental irrigation may be provided to ensure adequacy of soil moisture. Furthermore, upland rice can be grown under crop rotation systems with other crops making it compatible with crop production systems in Africa. Despite the existence of these diverse production systems, rainfed upland and rainfed lowland are predominant in Africa. The dominance of these two systems predisposes the rice crop to droughts and floods particularly in the face of climate change and variability that is manifesting in the continent.

Africa accounts for about 4% of the world's total rice production with West and East Africa producing over 90% of rice in sub-Saharan Africa (SSA). The main producers are Nigeria and Mali in West Africa, Mozambique and Malawi in Southern Africa. In East Africa, Tanzania ranks top in production followed by Kenya and Uganda [4]. Of note is that rice as a food crop is currently more relevant in West Africa with Nigeria and Ghana leading in terms of *per capita* consumption at 32 and 48 kg yr⁻¹, respectively. Other SSA regions are well below the projected 2024 *per capita* consumption of 28.6 kg yr⁻¹, with East Africa (Tanzania 26 kg yr⁻¹, Kenya 14 kg yr⁻¹) increasing significantly spurred by the uptake of NERICA varieties and Southern Africa (Namibia 8 kg yr⁻¹, South Africa 15 kg yr⁻¹) currently lagging in the continent [4,5].

Rice nutritional value, consumption and production

Africa accounts for 4% of world rice production with an average yield of 2.6 t/ha compared to 4.6 t/ha in Asia [6]. Additionally, a significant portion of the continent's nations import rice with the ever-increasing demand spurred by rapid urbanization and increasing incomes. Rice grain is mostly consumed as a food crop in Africa but some of its byproducts serve other uses. For instance, rice straw can be used as animal feed, substrate for mushroom growth, rice hull can be used as both animal feed and



fuel for cooking [7]. Besides providing calories, rice is a significant source of other vital nutrients and minerals such as proteins, folic acid, iron and zinc that are key to human wellbeing. The most nutritious portions which are important source of essential amino acids, vitamins, minerals and antioxidants are confined to the aleurone layer and germ [8, 9, 10, 11].

Nearly half of the world's population in developing countries depend on rice as a source of carbohydrate. By 2024, rice *per capita* consumption in developing countries is projected to increase to 68.4 which is 10 kg yr⁻¹ more than the world average [12]. More so, in sub-Saharan Africa, the quantity of rice consumed nearly tripled between 1990 and 2018 [5]. This makes the crop more relevant to African countries where population growth is also expected to increase this decade. To avert hunger and starvation, rice production growth should keep ahead of population growth.

Furthermore, promoting rice production is in-line with the two Sustainable Development Goals (No hunger, No poverty) aimed at eliminating hunger and poverty in the poorest communities. Despite the importance of rainfed rice in Africa, yield is comparatively lower than lowland rice that dominates Asia and Latin America. Low yields of rice are frequently linked to poor crop management techniques, lack of improved varieties, shortage of quality seed, biotic stresses such as pests and diseases and abiotic stresses such as droughts and floods [13, 14, 15, 16]. The development of New Rice for Africa (NERICA) varieties was a significant milestone in ensuring food security in Africa particularly for resource constrained farmers. NERICA varieties are interspecific hybrids between *Oryza sativa* and *O. glaberrima* combining yield potential, disease and drought tolerance into one genetic background. Generally, NERICA varieties mature earlier and give better yield under low moisture, low nutrient, high weed pressure and have better taste than other varieties grown in the continent. Regional contribution of rice in Africa (Figure 1) is, however, relatively small when compared to other cereals making it a suitable crop of choice due to its dietary constituents and rising in demand among the populace. Maize has been a dominant crop (Figure 1), but there is need to diversify to non-traditional crops such as rice to increase productivity and generate income for smallholder farmers. Furthermore, given the adaptation of NERICA varieties to rainfed agricultural systems that typify Africa, there is scope for its wider production to ensure self-sufficiency.



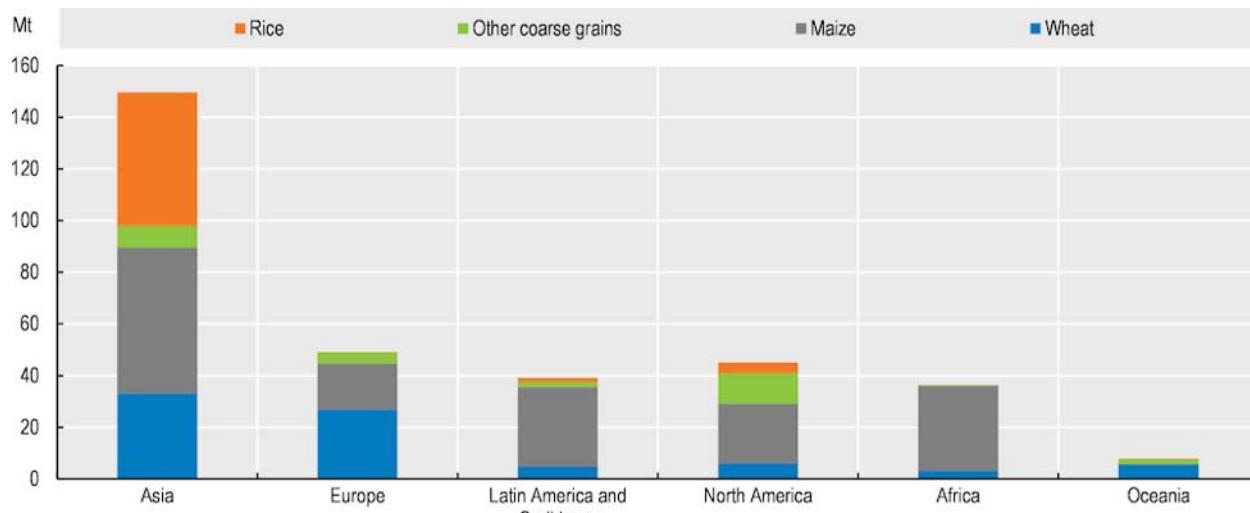


Figure 1: Comparison of continents in cereal crops production [17]

Upland rice acreage in Asia which accounts for less than 9% of Asia's total rice acreage has been declining with the expansion of irrigated fields [44]. In Latin America, including the Caribbean countries and West Africa, on the other hand, upland rice cultivation is a major part of rice production, covering approximately 46% and 47% of the total rice acreage, respectively [45]. In particular, in sub-Saharan Africa, where rice consumption has been increasing rapidly every year [46, 47, 48], upland New Rice for Africa (NERICA) varieties have been disseminated even to areas where rice had not been cultivated in order to fill the gap between supply and demand [49].

Production constraints for upland rice

A significant obstacle in most of Africa that challenges upland rice production and results in low yield is drought and irregular rainfall patterns [18,19,20]. For example, in coastal and central regions of Kenya, drought is a major obstacle to the country's rainfed rice production [18, 21]. During drought periods, yield is halved from a potential of between 2.7 t ha^{-1} and 5.4 t ha^{-1} in a normal season. Drought is the greatest environmental barrier to rice production in SSA [22]. A study in the Sudan Savannah, Nigeria noted that water stress causes a significant reduction in plant height, leaf number, biomass and grain yield [23]. Furthermore, peduncle elongation, and booting stage duration were reduced and spikelet sterility ultimately compromised grain yield [24].

Weeds contribute to a significant yield reduction in rice, which poses a great challenge compared to any other field crop. More so in NERICA varieties, the weed

competitiveness from the African rice genetic background is not as prominent, making them highly susceptible to weed competition [25]. Yield losses of at least 2.2 million tons per year, valued at \$1.45 billion due to weed pressure are incurred in Africa [26]. Accordingly, in cases where weed management is ideal, yield losses are rarely greater than 1 t/ha [27, 28]. There are several devastating diseases including blast caused by *Magnaporthe oryzae*, rice yellow mottle virus (RYMV), brown spot (*Helminthosporium oryzae*), bacterial blight caused by *Xanthomonas oryzae* pv. *oryzae*, that cause significant damage to rice. Yield losses of up to 100% have been reported in both lowland and upland rice production due to blast [29, 30] which is the greatest threat to rice productivity.

Opportunities for upland rice production

Compared to other staple crops, rice has the greatest potential for expansion in the African continent both in terms of production technologies and area under cultivation. Moreover, given the energy constraints in the continent such as low electricity production capacity and firewood scarcity. Rice requires less energy for preparation compared to other cereals and food crops such as beans, cassava, yams and potatoes. Hence, rice consumption can bridge the gap of poor access to biomass fuel and electricity and contribute towards food security in areas where such fuels are scarce. Storability is another benefit that rice has compared to other food crops particularly tubers whose quality deteriorates the longer they are in storage.

Traditional African cereals such as finger and pearl millet similarly do not store well without proper post-harvest treatments, which is an important consideration in ensuring food security throughout the year.

Rice has higher returns per unit area, which is relevant for Africa where the majority depend on cropping a major source of livelihoods. Rice producer price is higher compared with other major cereals such as maize, wheat and other coarse grains (Figure 2). Livelihoods can be sustained through crops such as rice that can be readily sold at favorable prices. This makes the crop relevant to the African context where women are key in production. Accordingly, there is great scope for poverty alleviation and rural development through the introduction of upland rice which is greatly needed in most parts of Africa.

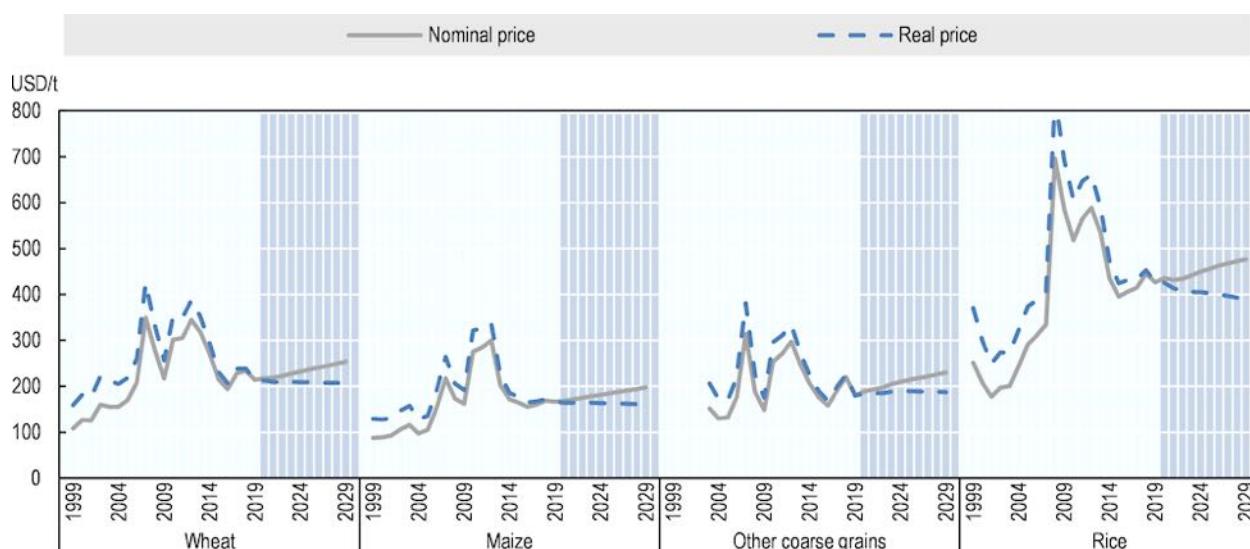


Figure 2: Comparative analysis of world major cereal prices over 20-year period [17]

Through effective management of nutrients from soil and fertilizers, the existing rice-based systems can be intensified particularly in those areas with a long production history. Economic Community of West African States (ECOWAS) has selected rice as a priority crop due to its potential productivity and market opportunities. Such efforts by other governments based on deliberate policies are instrumental in financial resource allocation and manpower development to serve the growth of rice production. Despite this potential, not all regions in Africa exploit the potential of the crop. Most countries in the Southern Africa Development Community (SADC) still rely on rice imports. Furthermore, no active breeding programs for the crop exist despite its significance and the availability of diverse upland rice germplasm. Existence of the Coalition for African Rice Development (CARD) and joint initiative between Alliance for Green Revolution in Africa (AGRA) and Japanese International Cooperation Agency (JICA) could be an opportunity that other African countries can exploit to promote rice production in their respective countries [5]. Currently the majority of Southern African countries such as Botswana, Eswatini, Lesotho, Namibia, South Africa and Zimbabwe despite their reliance on rice imports are not part of this coalition which consists of donors and research institutes, hence missing out on the rice collaborative network. In 16 African countries where NERICA varieties have been introduced, food security has been enhanced and poverty reduced for over 8 million households [31]. NERICA varieties have been introduced Africa wide with great success in countries such as Kenya, Uganda, Nigeria, Benin and Cote de'Ivoire. These adapted varieties are relatively high yielding compared to unimproved *O. glaberrima* germplasm requiring

less fertilizer application and suitable for African soil, and with a shorter growth cycle enabling double cropping and minimizing drought effect [32,33]. In south western Uganda, improved upland varieties, NamChe4 and NamChe5, showed yield of up to 10 t ha⁻¹, a clear indication of great potential for profitability by farmers [34].

To encourage use of improved rice germplasm and maximize yield, line development should ideally be agro-ecological zone-based and incorporation of farmer preferences. Commercial and subsistence farmer needs should be prioritized. Generally, subsistence farmers have a preference for stability and adaptability traits, whereas commercial farmers prefer responsiveness to input supply in their varieties. The creation of novel rice cultivars with high yield, resistance to biotic and abiotic stresses and consistent performance in a range of conditions is necessary for sustainable production [35]. Accordingly, genotype-by-environment (G×E) and stability studies need to be at the forefront to identify high potential NERICA and other upland rice genotypes for release as new varieties [36, 37]. Breeding programs can build on the genetic diversity that is now in existence to generate new upland varieties adapted to their peculiar agro-ecologies. Drought stress tolerance, resistance to devastating diseases such as rice blast should be prioritized for sustainable and environmentally friendly production.

Seed quality control should be prioritized since the seed is the primary input that determines productivity of all other inputs. In Kenya, for example, shortage of quality seed of some NERICA varieties has been a major constraint for their adoption [16]. Regardless of the seed system, timeous availability of plant material and extension support will be key in upland rice production and promotion. Besides resistance to biotic and abiotic stresses traits, there is need to use rice as a conduit of essential nutrients to prevent nutritional disorders that commonly plague the continent. Rice genetic biofortification for zinc and iron can be advocated for and prioritized by programs in the African continent as an alternative approach to enhance nutrition in a cost-effective and sustainable way.

Infrastructural development

Low levels of mechanization in Africa's agriculture have remained a significant barrier to increasing grain production, particularly for rice which has led to the high cost of growing this commodity due to manual post-harvest processing [38]. Given the unique rice production environments, there is need to acquire equipment that is compatible with such production systems to make operations more efficient. This will save time



and ensure that large areas are put into rice cultivation. Furthermore, subsistence farmers need to be considered in technology introduction so that adoption rates by this sector are high. In Africa, smallholder farmers are key drivers of crop production and as such technologies that suit their setups need to be prioritized [39]. Since post-harvest processing is essential in obtaining various byproducts from the crop, African governments may commission research on low cost but effective facilities for rice. Equipment for threshing, de-hulling and de-braning will lessen the labor burden on post-harvest processing. Furthermore, to cut down on storage losses, better low cost and effective storage facilities must be developed and promoted. Other energy and drying solutions, such as solar drying systems, hybrid systems that use both solar and rice straws, foldable dryers, portable thermal dryers, and other renewable energy technologies, are also required. This will significantly cut down on post-harvest losses. Utilizing byproducts of rice cultivation, namely husks and bran, which account for 20-22% and 5-8% respectively of the biomass can produce briquettes, bio-fertilizers and animal feed, consequently increasing farmers' profit margins [40]. One of the main byproducts of the rice milling process is rice bran, the outer brown covering of brown rice. Rice bran is mostly utilized as livestock feed and oil extraction because of its high protein and oil content [41]. Livestock feed is an important component of mixed production systems that typify Africa's landscape. Feed formulation using rice grain and its byproducts as the main carbohydrate source for ruminants and monogastrics can be explored. Other value-added products can also be explored to diversify the product portfolio and stimulate further adoption by other stakeholders. This will have a multiplier effect and initiate other downstream industries that will support rice production and create employment for the wider population.

Human resource capacity building

The use and production of upland rice requires training of researchers, farmers and extension agents. Extension services have been found to have a positive influence in West Africa [42]. It is also necessary to establish new training facilities and renovate existing ones in order to enhance tailored capacity building on issues specifically related to rice. Additionally, critical players in the rice value chain who are involved in quality assurance through inspection and its enforcement, extension officers must be stationed in rice-growing regions. Relevant government Ministries can encourage the creation, packaging and prompt distribution of relevant technology to extension officers, farmers' groups and other stakeholders. Functional research and extension infrastructure should be built or collaborations between nations can be fostered for rapid progress to be made in rice production.



Proposed perspectives

Rice consumption is increasing more rapidly than any other commodities and is driven by the triple effects of population growth, urbanization and changes of consumer preferences [12]. It is, therefore, ideal to ensure that, there is a sustainable development program for this crop to cater for the farmer and consumer needs. Requisite policies can be formulated to support rice production as strategic crop capable of emancipating millions from poverty and improve livelihoods. Policies can also curb cheap imports from the international markets that are threatening local production particularly in West Africa [43]. National agricultural research systems in countries without active rice research institutes can collaborate with established nations to build capacity to breed and undertake research in areas relevant to their needs. Where rice production is non-existent, stakeholders or possible beneficiaries in the rice value chain can be engaged to define the role of each and work towards promoting the crop. Weak value chains may need strengthening through stakeholder engagement and multinational collaborative initiatives within and across the globe. Overall concerted effort is needed by governments and private sector in ensuring that farmers are well informed and equipped with relevant technologies, skills and are assisted to market the crop and its byproducts.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Crop diversification to include rice can enhance food security and improve livelihoods for communities while minimizing risk associated with over-reliance on a few cereal staple foods in Africa. Coupled with this is potential for accelerated socioeconomic transformation associated with adoption, scaling up of rice production which dovetails with Africa's development agenda. Ultimately, to achieve this rice anchored transformation, a multi-stakeholder approach is required to initiate, harness and popularize activities to promote rice as an alternative cash crop.

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