Rice Research: Open Access
ISSN: 2375-4338

Review Article | Open Access

20 Years of Water Management Research for Rice in Sub-Saharan Africa

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Abstract

Rice is one of the major staple foods in sub-Saharan Africa (SSA) and is mainly grown in three environments: rain fed upland and rain fed and irrigated lowlands. In all rice-growing environments, the yield gap (the difference between the potential yield in irrigated lowland or water-limited yield in rain fed lowland and upland and the actual yield obtained by farmers) is largely due to a wide range of constraints including water-related issues. This paper aims to review water management research for rice cultivation in SSA. Major water-related constraints to rice production include drought, flooding, iron toxicity, and soil salinity. A wide range of technologies has been tested by Africa Rice Centre and its partners for their potential to address some of the water-related challenges across SSA. In the irrigated lowlands, the system of rice intensification and alternate wetting and drying significantly reduced water use, while the pre-conditions to maintain grain yield and quality compared to continuous flooding were identified. Salinity problems caused by the standing water layer could be addressed by flushing and leaching. In the rain fed lowlands, water control structures, Sarah rice production system, and the Smart-Valleys approach for land and water development improved water availability and grain yield compared to traditional water management practices. In the rain fed uplands, supplemental irrigation, mulching, and conservation agriculture mitigated the effects of drought on rice yield.

Keywords: *Oryza spp*.; Productivity; Sustainability; Water

Introduction

Food and nutrition insecurity remains a severe drawback in most Social Security Administration countries, with a high prevalence in rural areas. Rice is one among the necessary staple foods in Social Security Administration. Rice consumption has up speedily since the 1960s, as a result of the triple result of rising per capita consumption, urbanization, and demographic growth. The per capita consumption has steady exaggerated from ten metric weight unit in 1961 to fifty four metric weight unit in 2017, and in some countries, like Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, and African country, annual per capita rice consumption exceeds one hundred metric weight unit per capita. By 2028, Social Security Administration is anticipated to possess the world's second-highest annual per capita rice consumption when Asia. Despite increasing rice consumption, domestic production solely meets fifty three of demand, and imports principally from Asia fill the void. The lean production of rice in Social Security Administration is thanks to restricted rice production space and low yield. Farmers' yields area unit low (on average two.2 t/ha in two017) compared to the planet average (4.6 t/ha in 2019). Previous studies attributed the lower rice yield in Social Security Administration to sub-optimal crop management practices, climate-related stresses (drought and flooding), soil constraints (salinity, alkalinity, iron toxicity, nitrogen, and phosphorus deficiency), and organic phenomenon stresses[1-3].

Literature Review

Inland Valleys (IVs) area unit outlined because the higher reaches of rivers systems, comprising valleys bottoms and their hydromorphic fringes In rain fed lowlands, fields area unit flooded by rains and groundwater for a part of the rice-growing season, though in some seasons, fields might not be flooded thanks to lack of rain. Rain fed lowland rice is additionally fully grown in flash-flood areas, wherever the water level is exaggerated throughout the rice-growing season, inflicting short-run immersion [4]. A fuzzy transition exists between rain fed and irrigated lowland rice-growing environments, wherever a water-management time exists starting from strictly rain fed (no water control) to totally irrigated lowlands, which can evolve with investments in water management. Deep rice is found within the flood plains on the main rivers and coastal wetlands. Water depth remains high (up to three m) for AN extended amount. Within the mangrove-swamps, rice field area situated on periodic event estuaries near to the ocean. Rice will be fully grown throughout the amount once fresh floods wash the land and displace periodic event flows [5-7].

Major water-related challenges for reducing yield gaps within the major rice-growing environments embrace water insufficiency, soil salinity, and iron toxicity in irrigated lowland, drought, flooding, and iron toxicity in rain fed lowland, and drought in rain fed upland. Here, water insufficiency in irrigated systems happens once there are unit technical failures within the irrigation infrastructure, like once there's a collapse of a canal bank, inadequate canal cleansing resulting in a shortage of water within the fields that area unit at the very best elevation at intervals the irrigation space[8]. Another technical style of water insufficiency happens once there's lean water that may be tense into the higher a part of the irrigation space. Drought in rain fed systems happens once the rain quantity in an exceedingly given season isn't enough to satisfy the crop water demand or once the temporal arrangement of rains shifts leading to drought spells at intervals the season.

Over the last 3 decades, continent Rice Centre united with its partners has conducted water management analysis to beat the preceding challenges associated with water, scale back the yield gaps and guarantee property rice cultivation. Water management will be outlined as human interventions to set up, develop, distribute and manage the surface and subterranean water for agricultural functions to satisfy

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Received: 01-Aug-2022, Manuscript No. rroa-22-73276; **Editor assigned:** 05-Aug-2022, PreQC No. rroa-22-73276 (PQ); **Reviewed:** 19- Aug-2022, QC No. rroa-22-73276; **Revised:** 23- Aug-2022, Manuscript No. rroa-22-73276(R); **Published:** 29-Aug-2022, DOI: 10.4172/2375-4338.1000326

Citation: Duku SN (2022) 20 Years of Water Management Research for Rice in Sub-Saharan Africa. J Rice Res 10: 326.

community objectives. This paper focuses on the water management analysis for 3 major rice-growing environments: irrigated lowland, rain fed lowland, and rain fed upland. The most analysis topics addressed by continent Rice and its partner area unit list [9]. Though such accomplishments are reportable in an exceedingly form of publications, there's no comprehensive review of water management analysis for rice production in Social Security Administration. Orientating with this special issue on property productivity improvement of rice-based farming systems in continent, the main focus of this review is on water-related constraints in SSA's rice-growing environments, and aims at property water resources management and property intensification of rice-based systems. Therefore, the objectives of this paper area unit to produce a synthesis of water management analysis achievements over the last thirty years (1990–2010) and views for future analysis for development efforts in Social Security Administration. The paper is structured as follows. Firstly, we have a tendency to review analysis created on the constraints associated with water management for rice cultivation within the major rice-growing environments. Secondly, we have a tendency to review selected water management technologies developed over the last thirty years [10]. At the top of this paper, we have a tendency to gift the restrictions and analysis gaps within the past Understanding the constraints associated with water management for rice cultivation is crucial to line priorities for analysis and target technologies. Numerous approaches are wont to have a far better understanding of the water-related stresses to rice cultivation in Social Security Administration. In irrigated systems, field surveys, interviews, and environmental modelling were wont the factors poignant rice yield and therefore the results indicated that water insufficiency could be a major constraint to rice production.

Field surveys and experiments were wont to evaluate the factors poignant yield and yield variability in rain fed lowlands and uplands, and therefore the results showed that drought spells at the start of the time of year, violent rains throughout the season, and finish of season drought semiconductor diode to water stress for rice plants (deficit or excess in water), leading to low rice yield, and enormous yield variability between farmers' fields. These constraints were additionally reportable to limit the response of rice plants. Most of the previous on-farm surveys on the rice-growing environments didn't embrace direct measuring of surface water level and soil water convenience and heavily relied on the visual score for surface water conditions.

In SSA, iron toxicity is one of the major constraints preventing the growth of rice production. This phenomenon is ascribed to a nutritional disorder associated with a high concentration of ferrous iron (Fe^{++}) in the soil solution of poorly drained rice fields. Iron toxicity is commonly observed in rain fed lowland and irrigated rice systems. Field experiments were conducted in West Africa to evaluate the effects of iron toxicity on rice yield, and the results showed mean yield reduction of 35 – 80% in Togo, 16–78% in Côte d′Ivoire, Guinea, and Ghana, and 60 – 80% in Sierra Leon with the extent of the yield loss depending on rice cultivar, iron toxicity intensity and crop management strategy.

Soil salinity and alkalinity, both soil constraints that can be related water management, have been reported to affect rice production throughout the Shelia zone, rice area and yield loss. The strongest effects of salinity on yield were observed around panicle initiation, whereas plants recover best from stress at the seedling stage. Floodwater electric conductivity (EC) lower than 2 mS cm− 1 hardly affected rice yield, while for floodwater EC levels above 2 mS cm− 1, a yield loss of up to 1 t ha− 1 per unit EC (mS cm−1) was observed for salinity stress around panicle initiation. A rice yield decline due to soil salinity can be expected if the soil electric conductivity is higher than 0.8 dS m-1 in the 0 – 20 cm soil depth Regarding soil alkalinity, yield reduction of up to 75% was reported in the Senegal River Valley in Senegal, Niger and Forum Goleta scheme in Mauritania.,

Household interviews to evaluate the farmers' experiences of various constraints in rice-growing environments in 40 African countries and reported that drought, flooding, soil salinity/alkalinity, and iron toxicity was major constraints faced by farmers, affecting 32 – 37% of their rice area and leading to 27 – 32% of rice yield reduction. Mapping and crop modelling approaches were used to evaluate the abiotic constraints to rice production at the African continent level. According to drought-prone soils (with low soil water holding capacity) are a major constraint to rice production after low nutrient soils. Showed that 20–33%, 12%, and 2% of Africa's total rice area, were potentially affected by drought, iron toxicity, and soil salinity/alkalinity, respectively.

There are currently no long-term studies on the effects of water management practices such as AWD on soil fertility, soil salinity, and weed infestation, as well as the incentives for farmers to use water-saving technologies in the irrigated schemes of SSA.

Rice fields in irrigated systems have been identified as major sources of methane emission as they evolve under anaerobic conditions. In SSA, irrigated rice contributed to about 40% of the total rice production, and previous studies reported that achieving rice self-sufficiency in the region requires an increase in irrigated rice production. The question is whether such an increase in irrigated rice production can occur without greater greenhouse gas emissions. In Asia, water management technologies such as safe AWD were reported to reduce greenhouse gas emissions from rice fields, while maintaining rice yield compared to continuous flooding. The effects of water management technologies on greenhouse gas emissions may be different in Africa compared to Asia due to differences in soil types, climatic conditions, and management practices that are reported to significantly impact greenhouse gas emissions. However, in SSA, limited research exists on the effects of water management practices on greenhouse gas emissions and rice yield [11].

Water governance, defined as the institutions, processes, procedures, rules, and regulations involved in water management, plays an important role in efficient, adequate, and equitable water allocation in irrigation schemes. Several studies have linked the poor irrigation scheme performance in SSA to poor water governance, little is known about the indicators for assessing water governance in irrigation schemes, and how these indicators are related to the irrigation schemes performance.

Discussion

Although mulching and conservation agriculture have the potential to increase soil water use and mitigate the effects of drought on the rain fed crop, they can result in lower rice yields in the short term due to nitrogen immobilization necessitating more nitrogen fertilizer to compensate for the temporary nitrogen loss Other studies, however, reported additive nitrogen, phosphorus, and potassium uptake with a sustained application of rice straw, which may positively affect rice yield in the long term Furthermore, the scarcity of crop residues is a significant barrier to mulching or conservation agriculture adoption in many farming situations. Mulching with crop residues can alter resource flow in farms, where crop residues are used for a variety of purposes (e.g. fodder, fuel, or construction material). Besides, the typical farm sizes in SSA are small, and mulching materials are in short supply, making the reported application rates of 3 – 10 t/ha required to increase yield unrealistic. Mulch retention is not always possible, either. Farmers in some African countries, including Zimbabwe and Mozambique, have complained that leaving crop residue as mulch attracts termites, which feed on the following crop, causing lodging and yield loss, particularly in dry areas or during dry spell. In the humid and sub-humid climatic zones, the water-conserving effect of mulching can be detrimental when it exacerbates poor drainage, and water-logging conditions, or when it inhibits the necessary warming up of the soil especially in cooler environments. Further study is required for a critical assessment of the ecological and socio-economic conditions in which mulching or conservation agriculture are best suited for enhancing farmers' resilience to climatic stresses in Africa. Filling the research gaps identified in this study could contribute to sustainable water resources management and sustainable intensification of rice-based systems in SSA.

Conclusion

This study reviewed water management research for rice cultivation in SSA. Water-related stresses are a major driver for low rice yields and large yield gaps. A wide range of technologies has been tested by Africa Rice and its partners for their potential to address some of the water-related challenges across SSA. However, most of the research assessed a few indicators such as rice yield, water use, water productivity at the field level. There has been limited research on the cost-benefit of water management technologies, enabling conditions, and business models for their large-scale adoption, as well as their impact on farmers' livelihoods, particularly on women and youth. Besides, limited research was conducted on water management design for crop diversification, landscape-level water management, and iron toxicity mitigation, particularly in lowlands. Filling these research gaps could contribute to sustainable water resources management and sustainable intensification of rice-based systems in SSA.

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