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Production of Rice in Water Deficient Regions

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Abstract

In Asia, rice production must increase in order to feed continuously increasing population. Although the water deficit for rice in Asia continues to be fully assessed, evidence suggests that a decline in water quality and water availability is putting the irrigated rice system at risk of sustainability. One of the main reason behind rain-fed rice high yields is Drought. There is a need to find various ways to grow rice with little available water in order to provide food security and meet hunger demand of world. The paper explores a systematic approach which involves genetics, breeding and integrally controlled capital, to growing rice yields and reducing water necessities for the production of rice. The various irrigation methods intended to save water, like cultivation of saturated soil as well as alternative wetting - drying can minimize unproductive water discharges while continuously growing water productivity. Additional modern methods are being studied to increase water efficiency without losing returns. In order to increase yield per unit of water, incorporate the C4 photosynthetic route in rice, use molecular biotechnologies to boost the resistance of droughts, and grow "aerobic rice" in non-flooded soil to achieve a healthy and safety yield.

Keywords: Drought, Irrigation, Irrigated Rice, Rain-Fed, Water Management.

Introduction

In recent years, worldwide water shortages have been increased. The huge pressure is put on Asian countries to minimize water usage, where 90% of the total fresh water is diverted. Rice is considered as a simple objective for water management since it grows on more than 30% of irrigated soil and represents 50% of water for irrigation. By minimizing the use of water in rice production it will benefit society and the atmosphere if the saved water is exported to high-competitive areas. The 10% decreases in the water volume used for irrigating rice will save 25% or around 150,000 million m^3 of the projected fresh water utilized for non-agricultural uses worldwide. Rice, on the other hand, is highly vulnerable to water tension. The numerous ways to minimize the consumption of water in rice manufacturing will lead to lower performance and further endanger the food safety of Asia. Reduced water intake for rice would result in a transition in soil aeration from submergence to aeration. Our aim is to create novel rice-based systems that are socially appropriate, economically feasible, and environmentally friendly, enabling rice production in the face of decreasing water availability to be sustained or increased. This paper analyses the current state of rice supply in rice regions as well as the advantages and inconveniences of rice growing with less water [1].

As a result of the implementation of various irrigation technologies intended to save water will lead to a change in rice field from constantly anaerobic to entirely or partly aerobic. These will undertake major improvements for the protection of water, the turnover of organic soil, the dynamics of fertilizer, carbon sequestration, soils, and biodiversity of weeds and pollution of greenhouse gases. These improvements are considered as beneficial, for example, water reuse and reduced emissions of methane, some of which may be seen as negatives, e.g. surface release of nitrous oxide or agricultural soil decrease. The goal would be to establish successful integrated natural resource management actions that allow rice to be grown profitably with increased soil aerations while preserving rice-based production, environmental services and sustainability.

1.1 Rice-Producing Areas and Available Water Resources:

Approximately 45% of the global rice supply comes from the rain fed rice. Drought was among the major limitations in the area of rainfed lowlands and all the rain-food mountains prone to drought, which currently stand at an average of 2.3 t ha^{-1}. Extreme and moderate droughts are commonly seen in predominantly precipitated rice regions like Laos, northeastern Thailand, Central Myanmar, northeast and east India [2].

About 75% of rice supplies come from irrigated lowlands of 79 million hectares. Rice production mainly relies on wet-season plant precipitation with additional irrigation in the various regions of Northern and Central China, Northwest India and Pakistan. Irrigated rice in Southeast and East India, South-East Asia and in South China is present throughout the dry season. There is a lack of a detailed evaluation of water supply for irrigation in the irrigated rice region. The dry-season irrigated rice regions in Pakistan, north China, and north and central India are likely to face the shortage of physical water by 2025. Also, over two million hectares of irrigated grown rice in the dry season in central India would be physically scarce. The 'economic water shortage' region encompasses the majority of the approximately 22 million hectare of dry season irrigated rice fields in South and Southeast Asia. However, as forecasts of water scarcity are concentrated on the annual groundwater recharge, overestimation of dry season water supplies can occur. In the dry season, the water is always scarce, because the absence of rain makes irrigation difficult. In the dry season, physical water shortages can affect the rice fields in the commercial water scarcity zone [3].

Data has shown that rice growing areas are now dominated by water shortages. Over recent decades, the over-exploitation of groundwater in China and South Asia has created significant problems. This has contributed to higher pumping costs, saline penetration, fluoride pollution, land reduction and cracks and sinkholes[4]. The rice-wheat growing areas of northern India as well as the rice-growing areas of Tamil Nadu, Pakistan, and China are affected by these big groundwater-depletion areas. In the Bangladesh, groundwater's overdrawing causes rice areas to dry during the summer months, but water is recovered during the monsoon season. The appearance of poisonous arsenic is a particular problem linked to declining groundwater level in this region[5].

Water shortages downstream are being exacerbated by strong upstream water consumption along some of Asia's main rivers. The last 600 kilometers were dried for more than four months in 1997 as a result of the heavy demand for its water. China's government has made it illegal to grow flooded rice in the Beijing region. The reality that strong competition between states and various sectors for rice growing areas causes water shortage in the Chao Phraya delta in Thailand and in southern India's Cauvery is not so drastic, but more significant[6].

Furthermore, irrigated rice cultivation is faced with competition from other industries. Between the 1970s and 1990s, China's irrigated rice field fell by 4 million hectares. Although the decrease in irrigated rice area cannot be said solely because of the water shortage, signs indicate that the decreased area of water transported into irrigated rice is related to a decrease in water. The irrigation system of 160,000 ha in Zhanghe was dominant until the 1980s, when the water was diverted to irrigation[7]. In the 1990s, the area irrigated rice decreased by around 20% compared to the 1980s (Figure 1). Rice yield was also limited as a result. Similar instances of intensified rivalry can be seen in Asia. Water is being increasingly diverted to Manila from the Angat River in the Philippines, which reduces supplies of water downstream for irrigation. Degraded water quality, which is compounded by human pollution, is threatened in other regions. The water throughout the Agno River, Pangasinan Province has been polluted with sediments and toxins from mine activities upstream.

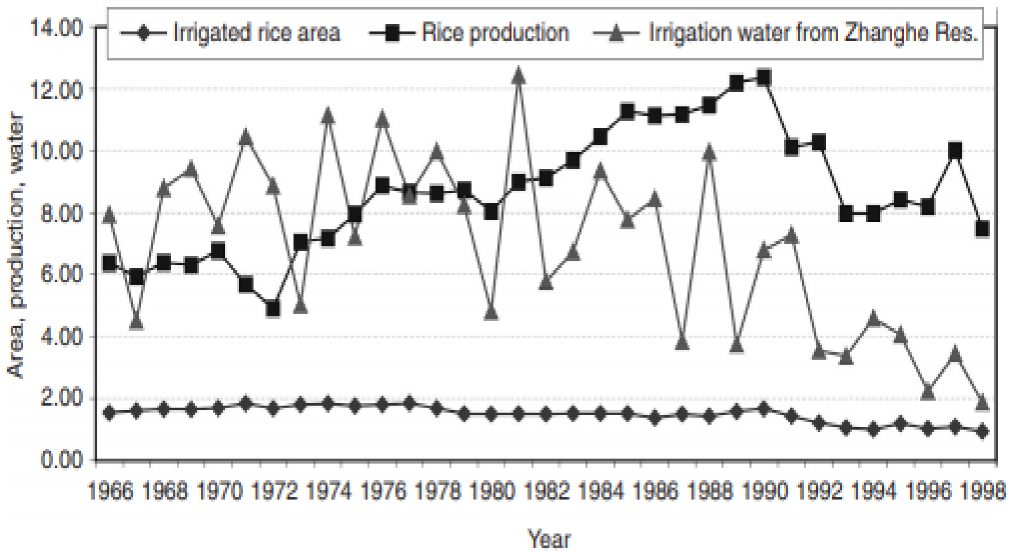

Figure 1: Irrigated rice area, irrigation water and rice production in Hubei province, China[8]**.**

2. LITERATURE REVIEW

Yasuhiro Tsujimoto et al. explains the optimization of agricultural productivity return, e.g. an improvement of yield in grain per kg of N relevant (AE_N), by the use of fertiliser input for rice production in Sub Saharan Africa. Experimental results show that soil spatial differences, both irrigated and rainfed, can increase the value of AE_N in the soil. In rainfed production systems, too, are major differences in small-sized topography that impact AE_N through complex hydrological shifts and changes in the contents of soil organic carbon and clay. These capabilities include the use of low-cost, UAV-systems for micro-topography collections, a high-resolution soil nutrient data base, improved SSA fertilizer mixing and immersive decision support instruments using cell phones. Another way to enhance AE_N is the small-dose fertilization of nurseries in difficult terrain conditions in sub-Saharan Africa [9].

Shaobing Peng et al. analyzed the difficulty in rice production faced by Chinese farmers. Over the past five decades, Chinese rice production has more than tripled mostly due to increased grain yields and more seeding areas. The production of high yielding crops and better crop management practices including nitrogen fertilization and irrigation has contributed to this rise. In the last ten years, though, rice has stagnated in China. China would have to grow 20 percent more rice by 2030 with its increasing population in order to satisfy domestic needs if per capita rice intake remains at its present level. It is a challenge because a number of innovations and challenges in the rice production system in China restrict the country's ability to sustainably grow rice overall. Both trends are important, such as arable land degradation, rising water scarcity, global climate change and work shortages. Chinese rice development primarily includes a limited genetic history, over-use of pesticides and fertilizers, deteriorating irrigation facilities, overly simplistic plant management and poor expansion schemes. In spite of these challenges, effective research strategies would allow China to improve rice production. The production involves developing new rice types that produce high potential returns, improved tolerance to major diseases and insects, and abiotic stress including drought and heat and integrated crop management. With the advent of new technologies and rice science, we think China will achieve a long-term rice production rise [10].

T.P. Tuong et al. reviewed innovative techniques for using genetic engineering, integrated resource management as well as breeding to improve the production of rice and minimize water demands for irrigation of rice. Irrigation, like moist soil irrigation and alternate watering and drying, would greatly minimize the unproductive outflow of water and maximize the productivity of water. However, most of the present rice varieties of the lowlands produce a decrease in yield. Additional new methods to growing water productivity without losing yields are being examined. In this way, the C4 photosynthetic mechanism is incorporated into the rice to enhance unit water efficiency, increase the drought tolerance using molecular biotechnology, and grow "aerobic rice" in order to produce good and stable yields in non-flooded soil. As a result of the adoption of water-saving irrigation methods Rice fields can move from continuously anaerobic to partly or even totally aerobic. The trends in soil-organic-matter turnover, nitrogen dynamics, carbon-sequestration, soil productivity, and crop biodiversity and greenhouse-gas pollution would all affect water management and investment. Although some of these modifications are useful, such as water efficiency and decreased methane emissions, other improvements are detrimental, such as releasing nitrous soil oxides and removing organic soil. To feed an increasing population, rice production in Asia must increase. While there is still a lack of a detailed evaluation of the water shortage rate in Asian rice production, indicators indicate that deteriorating water quality and a reduced water supply threaten to maintain the irrigated rice scheme. Drought is a major restriction in rain-fed rice yield [8].

3. METHODOLOGY

Lowland rice is frequently transplanted onto puddled lowland paddy grounds in Asia. Soaking, ploughing, and puddling are the steps involved in paddy land planning. Puddling is mostly used to combat weeds, but it also helps with soil permeability reduction, water absorption, and transplanting and field leveling. Soaking is considered as a one-time process that causes penetration of water and a pounded water surface to be formed on top soil. There are sometimes "idle periods" between laboring and transplantation in major irrigation systems, which can prolong the land preparation period by up to 12 months. Commencing the time of transplanting to the time of harvest, the crop is growing. Fields are usually filled with 5-10 cm of water at this period, with the final runoff taking place 10 days before harvest.

Water is needed in flooded environments to go with outflows (percolation (P) and seepage (S)) to the surroundings as well as depletions (transpiration (T) and evaporation (E)) to the atmosphere. The flow speeds S and P are determined by the water head on the ground and the water resistance movement throughout the soil. S and P are sometimes merged as a single word. SP, since in the domain they are hard to discern. Because during ground soaking, soil breakage cannot close completely, SP can exceed 25 mm a day in the preparation of the land. During land planning, only E occurs, while during crop development, both E and T occur. As the difference amongst E and T is difficult to determine during crop forming, evapotranspiration is also known as ET. In Asia, rice ET prices are normally between 4 and 7 mm a day.

3.1 The Productivity of Water:

Water productivity is known as the amount of cereal results acquired per unit of water. Water productivity can be defined as total grain yield per unit water input (WP_{IP}) or grain yield for unit water evapotranspired (WP_{ET}), which depends on the type of water flows under consideration. WP_{ET} Values in the field vary between 0.4 and 1.6 g kg^{-1} considering normal lowland conditions, while (WP_{IP}) values range between 0.20 and 1.1 g kg^{-1}. The broad range of WP_{ET} illustrates the wide variance in rice yield and ET caused by variations in growing conditions. Rice's WP_{ET} levels are just marginally smaller than those of other C3-type food crops like wheat. Rice, on the other hand, has a (WP_{IP}) that is about half of the value of wheat. The lower (WP_{IP}) value of rice is primarily because of strong infertile discharges described earlier as SP and E. Aside from size and yield of the field water outflows, the boundary and scale of the region considering which the productivity of water is measured have a significant impact on its importance. This is because S, P and wastewater outflow losses at one place in the sample area can be repeated at another. Data on water efficiency can be used at different scales to assess if upstream water outflows are reused downstream efficiently. Till now very little number of reliable evidence regarding the quality of water at dissimilar levels have been found for irrigation systems (Table 1). Results demonstrate that higher than in the field the productivity of water differs significantly and is below the spectrum of productivities on the ground floor. Water efficiency data are sparse at scales above field level because:

a. Data on produce, flows of water, or both at certain scales; and

b. Collaboration among agricultural and water-management professionals.

Table 1: The productivity of water with respect to irrigation, evapotranspiration and overall water input at various scales.

Area (ha)	WP_{ET}	(WP_{IP})	WPI	Location
30–50	0.5–0.6	0.25–0.27	1–1.5	Muda irrigation system, Kendal, Malaysia
287–606	1–1.7	-	0.4–1	Zhanghe irrigation system Hunan, China
Over 10^5	-	0.5–1.3	1–2.5	-

3.2 Techniques for Enhancing Productivity of Water:

Increasing water efficiency can be achieved by considering following points:

(i) ET accumulated increases in yield per unit;

(ii) Reduced water outflows and depletions that are not productive (SP, E); or

(iii) Ensuring the rainfall is best used. The final solution is economically as well as environmentally important because rainfall will complement or replace the water which needs to be supplied by irrigation.

3.2.1 Agronomic Practices and Germplasm Development:

Increased water efficiency in rice production has been aided by the invention of germplasm. In comparison to conventional varieties, new varieties have almost a threefold rise in productivity of water by raising yield while concurrently reducing the length of crop. However, cultivars launched before 1980 accounted for the majority of the growth in WP_{ET}. This is because the increase in yield was accompanied by a decrease in growth period between 1966 and the beginning of the 1980s. Water productivity will improve as tropical japonicas and hybrid rice become more established.

Breeders have had the most success exploiting drought relief in low-fertility, drought-prone rain-fed ecosystems. Drought exposure is reduced by decreasing crop length or reducing the likelihood of vulnerable crop phases coincident with water-deficit cycles. Drought resistance breeding has progressed more slowly, and the problems faced are often attributed to the trait's genetic variability and contact with the environment. In both upland and low-lying rain-fed areas drought-resistant varieties were produced and discharged.

Enhanced agronomic techniques, such as effective weed management, site-specific fertilizer control, and proper leveling of land, will greatly improve yield of rice devoid of affecting ET, potentially increasing water productivity.

3.2.2 Minimizing Inactive Periods Throughout the Preparation of Land:

Transplant rice seedlings will typically be nourished 2-4 weeks in the seedbed. During this time, most fields around seedbeds are tilled as well as flooded with tertiary and field-to-field irrigation systems. With access to the services, this land planning period can be shortened by encouraging farmers to:

(i) Provide water to the nurseries directly without the main fields needing to be submerged; and

(ii) Implement their agriculture activities irrespective of the climate.

Farmers in Muda irrigation schemes in Malaysia were able to reduce land preparation times by raising the drainage power of 10 to 30 m ha in 25 days, which saves 375 mm of water a year over two rice cultivation years. This is due to an increase in water preparation time.

Direct seeding seems to be another strategy for reducing idle time in irrigation systems without tertiary canals during the ground planning. However, transplanted rice has a shorter crop growth time than direct seeded rice in the main sector. Thus, a compromise between decreased use of water by means of reduced land planning and expanded use of water through a larger growth period in the main industry is calculated for the water saved by direct seeding.

Changing the physical properties of the soil will increase the resistance to water flow. Puddling creates a compact, well-compacted soil which prevents vertical flow of water. Heavy compaction machines have been demonstrated in North-East Thailand to minimize soil permeability of at least 5 percent clay in sandy and loamy soils. Physical walls, such as bitumen deposits and plastic covers, have also been tried under paddy soils by researchers. Soil compaction and physical obstacles, on the other hand, are costly and out of control for most producers.

3.2.3 Utilization of Rainfall More Efficiently:

Dry-seeded rice innovation provides a huge potential to save irrigation resources by more successfully using rainfall. Farmers in transplanted as well as wet-sowed rice schemes typically wait for canal water to be delivered until the field is drained. Dry-sowed rice preparation takes place in dry or humid soil, and starts with early monsoonal precipitation. Crop happens and early growth mostly early in the monsoon and the crop is irrigated later only when the water is adequate from the canal. In terms of total water production, however, all three crop-establishment activities were found to have comparable total water input and water productivity. Dry seeding also has the benefit of allowing farmers to grow an extra crop after harvest using remaining soil moisture or saved irrigation water due to the early establishment of the crop. Rice plants are able to prevent a later-season drought and improve yield and reliability in early establishment and harvesting of dry-seeded rice in strict rainfed systems.

4. RESULTS AND DISCUSSION

Saturated soil cultivation (SSC) requires good field water management as well as repetitive, work-intensive, shallow irrigation turns. In Australia, the trial is being performed with elevated beds to promote SSC activities. The beds (120 cm wide) were held saturated by water in the furrows. When compared to flooded rice, water savings were 34% and yield losses were 16-34%. In southern New South Wales, Australia, the SSC was found to lower both the intakes and yields of irrigation-water by just over 10 percent, thereby maintaining water productivity. The new varieties grown with SSC are likely to decrease yields due to cold damage in this area. The results of the test show that further research is necessary in order to make up the water balance elements, which is responsible for the inequalities in the total use of water. In Malaysia, dry rice improves considerably irrigation water output in wet seeds and transplanted rice under the Muda irrigation scheme (Table 2).

Table 2: The Mean ± SE of waters productivity and grain yield. The new varieties grown with SSC are likely to decrease yields due to cold damage in this area.

Parameter	WS ISU	DS ISU	TP ISU
Yield	$4.50 \pm 0.23^{a,b}$	4.14 ± 0.17^{b}	4.79 ± 0.23^{a}
WP(I)	0.62 ± 0.30^{b}	1.48 ± 0.26^{a}	1.00 ± 0.30^{b}
WP(I+R)	0.26 ± 0.02^{a}	0.27 ± 0.02^{a}	0.25 ± 0.02^{a}
WP(ET+E)	0.42 ± 0.02^{a}	0.38 ± 0.02^{a}	0.39 ± 0.02^{a}
WP(ET)	0.53 ± 0.04^{b}	0.48 ± 0.03^{b}	0.61 ± 0.04^{a}

A crop after rice like wheat could benefit from the growing rice along with the SSC. Due to poor soil, spring irrigation and winter plant production after rice is constantly reduced in the physical structure and logging. A bed system could help with drainage for a post-rice crop.

Irrigated lowland rice habitats have a special feature: soil submergence. Lowlands growing 2 or 3 crops of rice every year on submerged soils are extremely functional as shown by continuous fertilizer availability, soil carbon levels and rice yield trends. The persistent submergence of soil, on the other hand, encourages the anaerobic decomposition of organic matter, which results in the creation of methane, a significant greenhouse gas. Methane emissions can be reduced by temporary soil aeration, such as those used in AWD. Long-term soil aeration, such as in aerobic rice, will reduce methane emissions even further. On the other hand, Soil aeration will increase nitrous oxide emissions, which is a greenhouse gas. The soil redox potential, an indicator of soil oxidation status, is closely linked to methane and nitrous oxide emissions. It is proposed that by keeping the soil redox potential between –100 and +200 mV, all methane and nitrous oxide emissions can be reduced.

The condition of Soil organic matter and the potential of nutrients will be affected by better aeration of AWD soil and aerobic rice. It may also complicate the retention of seed residues. A stronger reliance on herbicides could be required by more active weed flora associated with water-saving technologies, putting the environment at risk. The amount of water as well as soil essential for the resources and productivity of rice ecosystems might be important topics for water-saving techniques.

5. CONCLUSION

Rice growth has been expected for decades in indefinitely inundated areas, nevertheless the impending crisis of water will alter the cultivation technique of rice. Researchers are re-examining irrigation systems for saving water that were studied in the late 1970s, like Alternate Wetting and Drying (AWD). The fundamental elements for putting these inventions into practice seem to be in order. However, the introduction of these technologies was slow, with the exception of China. The task is to identify environmental as well as socio-economic factors which allow farmers to utilize them. Our analysis is far from finished in this area. However, we can identify main factors affecting farmers' readiness to use technology for water-saving use.

Water is seldom sold on Asian markets, and irrigation waters mandated by the government are either very poor or non-existent, as opposed to fertilizers and pesticides. Farmers are more likely to implement water-saving technology if water becomes a tangible economic good. According to data farmers in Asia facing high water costs are already using such technology. Farmers who use pumps to irrigate their fields in north-Central India use some kind of AWD to save pumping money. Water trade, which helps farmers to sell their water rights to others, has also been seen to enable farmers to implement water saving initiatives in Australia.

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