Growing more rice with less water

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Rice (Oryza sativa) is the staple food of more than half of the population in the world. It is an important target to provide food security and livelihoods for millions. Imminent water crisis, water-demanding nature of traditionally cultivated rice and climbing labour costs have necessitated the search for alternative management methods to increase water productivity, system sustainability and profitability. Considering the food basket of India, rice cannot be replaced by other arable crops. To withstand the scarcity of water, growing direct seeded rice (DSR) is one of the best options for areas where rainfall does not support the cultivation of conventional rice. DSR refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery. Direct seeding avoids three basic operations, namely puddling (a process where soil is compacted to reduce water seepage), transplanting and maintaining standing water; thus it saves water, labour and time.

The amount of freshwater available on the planet is limited, but demand for that finite water is growing. For at least part of the year, four billion people – or 66% of the world's population faces extreme water shortage. One billion of these people live in India, while 0.9 billion live in China. A staggering 180 million people in India face severe water scarcity all year round[1]. Burgeoning population and changing food habits from vegetarian to non-vegetarian make this limited resource scarcer day by day. Therefore, the pressure to reduce water use in irrigated agriculture is mounting, especially in Asia where it accounts for 90% of total freshwater consumption. Rice as a main food crop for more than three billion people[2] supplements the major carbohydrate and even protein demand not only in Southeast Asia, but also in some parts of Africa[3,4], and thus becomes an obvious target when it comes to agricultural water conservation. It is grown in more than 30% of irrigated land and uses 50% of irrigation water. According to Toung and Bouman[5], 39 m ha of irrigated rice in Asia can face physical or economic water scarcity by 2025. If the water saved can be delivered to areas where consumption is high, reducing water input in rice production can have a significant societal and environmental effect. A 10% decrease in the amount of water used in irrigated rice will free up to 150,000 million m^3, or around 25% of the total freshwater used for non-agricultural purposes globally.

When the International Water Management Institute's (IWMI) water scarcity atlas and International Rice Research Institute's (IRRI) rice region maps are combined, it can be clearly observed that wet-season irrigated rice areas in North China (2.5 m ha), Pakistan (2.1 m ha), and North and Central India (8.4 m ha) will face physical water scarcity by 2025. The groundwater table is also decreasing at an average rate of 1–3 m/yr in the North China plains, 0.5–0.7 m/yr in the Indian states of Punjab, Haryana, Rajasthan, Maharashtra, Karnataka and northern Gujarat, and about 1.0 m/yr in Tamil Nadu and hard rocks of southern India resulting in water shortage and rising pumping costs[6–9].

Dry direct seeded rice

Irrigated lowland rice is the most important agricultural system in Asia, wherein the rice is transplanted into puddled paddy fields. Soaking, ploughing and harrowing of saturated soil are the steps involved in land preparation. The fields are kept submerged with 5–10 cm of water after crop establishment. Since the water is used for wetland preparation and due to huge losses by seepage, percolation and evaporation, the production of lowland rice needs a significant amount of water (~150 cm), of which 15–20 cm is used for puddling[10]. According to Chauhan and Opena[11], puddling in transplanted–flooded rice systems consumes up to 30% of the total rice water requirement. The conventional method of rice cultivation (transplanting in puddled fields) uses about 5000 l of water to produce 1 kg of rice, rather than the actual requirement of 3000 l (ref. 12). Due to constant flooding of the fields, about 2000 l of water is lost by evaporation and seepage[13]. However, in rice–rice cropping systems, puddling is beneficial because it decreases soil permeability, creates hardpans and reduces water loss by percolation. Nonetheless, repetitive puddling operations damage the successive non-rice upland crop in rotation by dismantling soil aggregates, decreasing permeability in subsurface layers and forming hardpans at shallow depths[14,15]. The continuous submergence of soil also encourages the anaerobic decomposition of organic matter which produces methane, an important greenhouse gas.

In light of these contradicting demands and constraints scenario, the question arises whether rice needs standing water for optimal production. Flooding in rice is used as a management tool rather than a necessity. As a result, new rice-based systems that are socially appropriate, economically viable and environmentally sustainable must be developed for rice production to be sustained or increased in the face of decreasing water availability.

An alternative to puddled transplanting of rice could be aerobic direct seeding because it requires less water, labour and capital input[16]. The concept of aerobic rice was first developed in China. IRRI defines aerobic rice as a production system in which especially developed 'aerobic rice' varieties are grown in well-drained, non-puddled and unsaturated soils. Suitable areas for aerobic rice cultivation include irrigated lowlands where rainfall is insufficient to sustain rice production, delta regions where there is delay in water release from reservoirs, irrigated system of rice cultivation where pumping from deep borewell has become expensive and favourable upland system having access to supplemental irrigation. Accordingly, Tamil Nadu, Jharkhand, Chhattisgarh, parts of Bihar, Odisha, Karnataka and eastern Uttar Pradesh; the projected areas of uneven distribution of rainfall and frequent occurrence of soil moisture limitation have good potential for DSR cultivation.

Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery[13]. Seeds are sown @ 40–45 kg ha^{-1} with a spacing of 20×10 cm, directly in the main field. Direct seeding avoids three basic operations, namely puddling (a process where soil is compacted to reduce water seepage), transplanting and maintaining standing water. Thus it saves time, labour and water required for nursery raising and transplanting. Aerobic rice can be irrigated or rainfed depending upon rainfall distribution, soil type and surface hydrology. Unlike flooded rice, irrigation – when applied – is not used to flood the soil, but to just bring the soil water content in the root zone up to field capacity, thus avoiding unnecessary water loss through evaporation from the flooded fields. The required amount of phosphorus, potash and one-fourth of the nitrogen is given as basal and the rest of the nitrogen (three-fourth) is top-dressed in three equal splits at 10–12 days after emergence, active tillering and panicle initiation stage. Rice varieties CR Dhan 200 (Pyari), CR Dhan 201, CR Dhan 202, CR Dhan 203 (Sachala), CR Dhan 205 and CR Dhan 206 developed by the National Rice Research Institute, Cuttack, are found to be performing well under this system.

Since direct seeded crop does not undergo transplantation shock, it matures 7–10 days earlier than the transplanted crop, thus allowing timely planting of the succeeding crop and provides an opportunity for crop intensification in rice-based cropping systems[17]. It also allows practices of conservation agriculture as used in upland crops, such as mulching and minimum tillage. Water productivity is reported to be higher in aerobic rice by 64–88% (calculated as grams of grain produced per kilogram of water input).

Like all other technologies in agriculture, aerobic rice is also not free from constraints; these include high weed infestation, poor crop stand, crop lodging, high percentage of panicle sterility, infestation of root-knot nematode[18,19], and other soil-borne pests and diseases. High infiltration rates of water in aerobic soils, further lead to micronutrients deficiencies, especially of zinc and iron[20]. However, through improved agronomic management practices like integrated weed management, site-specific nutrients, insect pest and disease management, and timely irrigation, these constraints can be overcome and a yield potential of 4–4.5 t ha^{-1} can be realized.

The sustainability of aerobic rice is threatened by heavy weed infestation than conventional, flooded, transplanted system[18,21], in which weeds are suppressed by standing water and transplanted rice seedlings have a headstart over germinating weed seedlings[22]. Aerobic soil conditions and alternate wetting and drying in Dry Direct Seeded Rice (DDSR) are conducive to the germination and growth of weeds such as *Leptochloa chinensis* (L.) Nees, *Eleusine indica* (L.) Gaertn., *Eclipta prostrata* (L.) and sedges which compete for carbon dioxide, light, water and nutrients, and can cause grain yield losses of 50–91% (refs 18, 23, 24). More than 50 weed species have been reported to cause yield loss in DSR[18] that ranges between 30 and 98% (refs 25–27).

Water, unlike fertilizers and pesticides, is seldom traded in the Asian markets, and Government-mandated irrigation water fees are often low or nonexistent. Consequently, farmers are discouraged from using water as a scarce resource. They do not implement water-saving technologies because conserving water does not lower farming costs or increase revenue. However, if the current rates of water extraction continue unabated, soon water will be considered a true economic good, forcing farmers to implement water-saving technologies. Literary evidences suggest that the farmers in Asia who face high water costs have already implemented such technologies. Various water-saving technologies have been widely implemented in China, where farmers are charged by the volume of water they use[28,29]. Water trading, which allows farmers to sell their water rights to others, has also been shown to enable farmers to implement water conservation measures in Australia[30–33].

Conclusion

Due to its low water use with reasonably higher yield, aerobic rice has great scope in areas where water availability is limited. Improving farmers' knowledge on improved methods of crop cultivation like integrated insect, pest, disease and weed management, and development of improved varieties for aerobic cultivation coupled with policy initiatives for water conservation will enhance their acceptance of this novel water-saving technology.

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Community-based approaches for wildlife conservation and livelihood options: a case study from Dampa Tiger Reserve, Mizoram, India

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The traditional practice of shifting cultivation in Mizoram, India is linked to the ecological, socio-economic and cultural lives of the over 86% of its population. Negative impacts are devastating and degrade the environment and ecology, a major concern in conservation biology such as large-scale deforestation, soil erosion, invasion by weeds and exotic species. Studies provide information on the nature and extent due to anthropogenic pressures on species diversity. Active participation of locals is pivotal. Workshops and awareness programmes were conducted with alternative livelihoods to reduce forest dependency. Efforts are on by educating people on preserving tropical forests at the Dampa Tiger Reserve, Mizoram.

Wildlife is an integral part of conservation as flora and fauna are the actual and true assets of any developing country. Conservation has evolved from a callow discipline to one of deep transformation. Finding solutions to conservation can be challenging as they require careful balancing of the wildlife along with the needs of local people. Therefore, involvement of the local community is pivotal. Since any protected area harbours and serves deep interests for the scientific community with functions like centre for eco-tourism; herein, we used Dampa Tiger Reserve (DTR), Mizoram, India as a case study for understanding the rational for developing a community-based approaches for wildlife conservation and livelihood upliftment in the region.

Brief background

DTR is the largest wildlife sanctuary in Mizoram covering an area of 988 sq. km (core 500 sq. km and buffer 488 sq. km) and stretching from 23°20′–23°47′N to 92°15′–92°30′E (Figure 1). Its elevation ranges from 235 to 110 m. The Sanctuary was declared a Tiger Reserve in 1994. Administration of DTR is managed under the Phuldungsei and Teirei ranges. It harbours rich flora and fauna and is natural home to leopards, Indian bison, barking deer, sloth bear, gibbons, langurs, slow loris, rhesus macaques, Indian python, wild boar and a variety of avifauna including reptiles and amphibians. It is the least explored area of North East India, with only a few records of fauna richness[1–4]. Forests are broadly categorized into three types; tropical wet evergreen, tropical moist deciduous and montane subtropical[5]. The site is dominated by mountain ridges with high-ground, non-floodable rainforest standing on a slightly undulating terrain[6–9]. Mizo, Bru and Chakma tribes inhabit the Reserve (buffer area) and practice jhum cultivation for their livelihood. Tribals around the DTR are predominantly meat-eaters. Primates are hunted in summer and winter and ungulates in winter and monsoon. Porcupines are hunted during winter and bears in summer. Villagers rear livestock for meat, but prefer bush meat due to its delicacy[1]. Non-timber forest products (NTFPs) such as wild edibles include vegetables, fruits (*Artocarpus heterophyllus*, *Emblica officinalis*, *Mangifura indica*, *Musa paradiasica*,