RICE CULTIVATION: ENVIRONMENTAL ISSUES AND WATER SAVING APPROACHES

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Introduction

Globally, rice is the most important food crop with more than 90% produced in Asia. In most of Asian countries, rice is not only the staple food, but also a source of employment and income for the rural communities. In several Asian countries, rice provides 50 to 70% of the energy and protein dietary requirements. Moreover, rice is also a staple food in many Latin American and Caribbean countries and is the most rapid growing food source in some African countries with Nigeria as a major importer of rice. Rice represents about 45 percent of all irrigated crop areas in Asia where 59 percent of the rice is irrigated (FAO, 2002).

Rice demand in year 2030 is projected to be around 533 million ton of milled rice. With water being the most important component for rice production, producing more rice with less water is therefore a formidable challenge. There will be great difficulties to increase the rice area due to growing competition for land and water from both industrialization and urbanization activities.

Due to its high productivity, irrigated rice makes up approximately 75% of the total rice production. Rice is known to be a high water consuming crop. In Asia, irrigated rice consumes 150 billion m^3 of water. This high water consumption results in a low water use efficiency of approximately 20,000 m^3/ha. Assuming an average yield of 5 t/ha, the water productivity of irrigated rice is only 0.15 kg of milled rice/$m^3$of water (FAO, 2002). This low productivity of irrigated rice makes the crop non-competitive with other uses of water.

Rice irrigation

Surface irrigation is by far the most widespread irrigation technique in Asia. It includes all paddy rice cultivation and most of the other crops. The total area for rice cultivation in Asia is 111,495,121 ha of which 65,321,714 ha are irrigated (59% of the total area) and 46,173,407 ha are rainfed (41% of the total area). The total area of rice cultivation worldwide is estimated to be 153,783,818 ha. In India only 47 percent of the total harvested area for paddy rice is irrigated, while more that 92 percent of the harvested paddy rice in China is irrigated (AQUASTAT, FAO, 2006).

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The most common system of lowland rice cultivation in Asia is transplanting or direct seeding in a field that is kept continuously flooded with 10±5 cm throughout the growing season. Land preparation includes soaking, ploughing and puddling, i.e. harrowing until a soft muddy layer of 15±10 cm is formed in saturated conditions. The water requirement for land preparation is estimated at 200 ±150mm, but can reach as high as 900± 650 mm for long duration, i.e. 48±24 days. Field water application during crop growth periods varies from 500 to 800 mm to more than 3000 mm. Most wet season rice irrigation is by gravity (cascades from plot to plot) while dry season rice cultivation would require pumping in some places (Bouman and Tuong, 2000).

In most of Asia, drainage is usually linked to irrigation. In traditional terraced paddy cultivation, water flows from one plot to another and it is difficult to draw a line between irrigation and drainage. In addition, in several humid countries of the region, large parts of lowland or wetland are used for paddy cultivation.

Rice water requirements and productivity

The average total water requirements (m^3/ha) and specific water use (m^3/kg) for rice production under different conditions can be roughly estimated based on an evapotranspiration, which is the water actually consumed by the plant, of 550 to 950 mm/crop and any additional water used. Following figures were obtained by Facon (2000):

- rainfed upland rice: 5500 m^3/ha (evapotranspiration only) for 1.25 t/ha, specific water use: 6.5 m^3/kg
- rainfed lowland rice: 10,000 m^3/ha (evapotranspiration + impounded rainwater) for 2.5 t/ha, specific water use: 4.0 m^3/kg
- irrigated upland rice: 10,000 m^3/ha (evapotranspiration + supplementary irrigation) for 2.5 t/ha, specific water use: 4.0 m^3/kg
- irrigated lowland/deepwater rice: 16,500 m^3/ha (evapotranspiration and full irrigation) for 4.5 t/ha, specific water use: 3.7 m^3/kg

Irrigated lowland is the dominant system. It is the most productive system in terms of yield and it produces the highest yield per m^3 of water but, it is also the least efficient if one considers water use per ha or the amount of water required for evapotranspiration divided by the amount of water diverted into the system.

The average rice yield for 2004 for the world and Asia was 3.97 and 4.08 t/ha, respectively. World rice production in 2004 was just under 610 Mt. At least 114 countries grow rice and Asian farmers produce 90% of the total with India and China growing more than half of the total crop (IRRI, 2006).

Water productivity in continuous flooded rice was typically 0.4±0.2 g grain per kg water in India and 1.1 ±0.3g grain per kg water in the Philippines. Total rice production can be increased by using water saved in one location to irrigate new land in another.

Environmental issues

Agricultural activity is considered by many as the main user and abuser of natural resources. Irrigated rice production is particularly known for the excessive use of irrigation water, pesticides and inefficient use of fertilizers. Rice is a suspected to be a large contributor of carbon dioxide, methane, nitrous oxide and ammonia emissions (FAO, 2002).

Carbon dioxide is emitted especially during the burning of crop residue which is a standard practice in much of the world. Methane emission is associated with irrigated rice due to the long periods of flooding and the decomposition of incorporated organic matter under anaerobic condition. It is estimated that irrigated rice contributes around 20% of the global emission of methane. Methane is considered to be approximately 20-fold more potent as a greenhouse gas when compared with carbon dioxide. However, it seems possible to reduce methane by introducing a short dry fallow period or by including rice cultivation in rotation with an upland crop to allow the organic matter to decompose under aerobic conditions before subjecting the soil to anaerobic conditions for irrigated rice cultivation.

Nitrous oxide can be emitted in irrigated rice when soils were allowed to dry then flooded after application of urea. Continuous water application following the applications of urea on dry soil can significantly reduce nitrous oxide emissions. In irrigated rice, ammonia emission is a direct result of inefficient use of urea. The application of urea in water or on mud can lead to approximately 70% of the urea volatilizing as ammonia. This loss can be reduced by at least 30 to 50% without affecting yield by efficient and simple methods of fertilizer management.

Water saving

It has been estimated that a 10% decrease in the water use for irrigated rice could lead to water saving of approximately 150,000 million m^3, almost one-fourth of all the fresh water used world-wide for non-agricultural activities. Several studies have indicated that irrigated rice can be easily cultivated using 8,000 to 10,000 m^3/ha, which is approximately 50% of current use, without affecting yield. The main difficulty with saving water is that the water is not priced properly, especially in schemes where they charge the user by irrigated area and not by volume of water used. With such schemes, there is no economic incentive to save water.

There are several ways to reduce irrigated rice water consumption including:

- limiting rice cultivation to only the rainy season,
- using and developing more water efficient varieties (C_4 type plants),
- promoting upland rice,
- developing drought tolerance rice,
- changing the crop planting date and making more effective use of rainfall,
- changing rice planting practices, wet seeding of rice uses about 20-25 percent less water than in traditional transplanted rice methods and drastically reduces

labor for establishing the crop from 30-person days per ha for transplanting to 1-2 person days,

- replacing transplanting by direct seeding (dry seeded rice saves even more water, especially during land preparation),
- reducing water use during crop growth: Intermittent flooding, maintaining the soil in sub-saturated condition, alternate drying and wetting can reduce water applied to the field by more than 40 percent compared with continuous submergence methods without affecting yields,
- supplementary irrigation either for crop establishment or at critical growth stages, particularly flowering, can improve yield,
- water recycling and conjunctive use to enable farmers to reuse seepage, percolation losses from canals and fields as well as groundwater (to compensate for the lack of reliability, inequities in distribution, and rigidity of canal water distribution systems),
- using alternatives to flooding techniques, e.g. use of overhead sprinklers, furrows, etc. with newly developed aerobic varieties,
- adopting simple conservation; that is, maintaining only supersaturated soil conditions during cultivation of the crop, significantly reducing land preparation in water (puddling) and keeping water within the field by reducing outflow discharges.

The farmer's acceptance to the above practices depends on economic and other factors. Farmers will need technical support in upgrading irrigation systems for efficient water distribution and agricultural support in adapting agricultural practices such as modified irrigation methods, using new varieties and new water management practices.

In order to compete with alternative uses of water, improved efficiency of rice production is crucial.

Conclusions

Integrated water resources management is vital for producing more rice with less water. There is a range of options to increase the productivity and efficiency of water consumption in surface irrigated rice. With economic incentives and adequate production tools and irrigation services, farmers can adopt substantial changes in their water management practices.

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CONTENTS

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