Improving Water Availability and Use in Rainfed Systems

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Abstract

As an essential component of world food security, agricultural productivity needs to be maintained in Southeast Asia, a major source of the world's food supply,. Water is the most important technical limiting factor for agricultural production even in this region, most of which receives a sufficient amount of water during the rainy season but lacks suitable management systems for its effective usage, particularly in rainfed areas. Development of improved systems for water resource management must be a focal point for agricultural development in this region. To improve economic options for farmers in Southeast Asian countries, it is essential to provide them with appropriate technologies for water management. Incorporation of value-added approaches for high economic returns is also needed for the future development of agriculture in Southeast Asia.

JIRCAS has been conducting collaborative research in this region, with a focus on Thailand, for more than three decades. In its most recent collaborative research project, from 1995 to·2002, a number of key component technologies for sustainable agricultural production were developed in Northeast Thailand. These now need to be adapted to meet farmer conditions in Northeast Thailand, and the individual technologies need to be combined into new production systems and tested under real farm conditions. There is increasing recognition of the value of participatory methods for closing the gap between research results and farmer practices. Based on the above perspectives, a new seven-year research project titled "Increasing economic options in rainfed agriculture in Indochina through efficient use of water resources" has now been launched. An overview of this new project is provided in this article, together with a discussion of several key issues in water resource management in rainfed areas.

Introduction

Although 80% or more of water resources is currently allocated to agriculture in the Asian region, in the next 25 years, water availability for agriculture will be rapidly reduced by injudicious use of water resources and competition with other sectors of the economy, and become a serious problem even in well-irrigated areas (Seckler *et al.*, 1998). It is foreseen that one-third of the population in developing countries will be exposed to conditions of serious water shortage in the first quarter of the century (Seckler *et al.*, 1999). Considering present water availability and use, the need to increase water resource use efficiency in agricultural production is critical if we are to avoid serious water shortages that are otherwise likely to occur in the near future.

About 60% of world food production is derived from rainfed agricultural areas that account for 80% or more of arable land (FAO, 1996). Productivity in rainfed agriculture is much lower than that of irrigated agriculture and also displays larger annual variations. Thus, food production necessary to meet population increases in the near future will inevitably have to depend heavily on production from irrigated agriculture.

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Considering the tendency towards stagnation in productivity increases in irrigated agriculture, however, irrigated agriculture alone cannot meet all the expected demand, and it will be essential to increase the contribution of rainfed agriculture to overall food production through the stabilization and improvement of its productivity. Moreover, in the majority of rainfed areas, it would be either technically impossible or it would require huge sums of government funds to construct irrigation systems with efficient water management based on extensive canal networks from permanent water reservoirs. In the majority of rainfed areas with these limitations, the only realistic option for agricultural development is to improve the productivity of rainfed uplands and lowlands.

In rainfed agricultural areas that are widespread in the central part of Indochina, crop production has remained low and the gap in living standards between rural farmers and urban people has widened. The slow progress in agricultural development despite the introduction of new crop varieties and improved technologies can be attributed primarily to unfavorable environmental conditions of these rainfed areas, including unpredictable rainfall patterns and soils with low fertility and inadequate water-holding capacity.

Following the completion of its most recent project titled, "Comprehensive studies on sustainable agricultural systems in northeast Thailand," JIRCAS has started a new project for seven years from April 2002 titled, "Increasing economic options in rainfed agriculture in Indochina through efficient use of water resources." The overall objective of this project is to develop technologies capable of efficient water use and combine them into high value-added production systems.

Biophysical Environments and Agricultural status in Northeast Thailand

Northeast Thailand receives annual rainfall ranging from 700 to 1600 mm, depending on location and year. Total rainfall tends to be higher and exceed total pan evaporation in the northern part. In the southern part, however, rainfall is significantly lower and pan evaporation exceeds rainfall. More than 90% of the annual rainfall occurs between May and October. Most agricultural activities are carried out during the rainy season. Soils are often sandy or skeletal, and problems of salinity are extensive in this region (Lindsay, 2000).

As a result of deforestation, cultivable area expanded rapidly during the 1960's. Nearly 55% of the total land area in Northeast Thailand is already exploited for agricultural production (Fig. 1). However, less than 10% of the cultivated area is supplied with irrigation. This contrasts with central and southern Thailand that

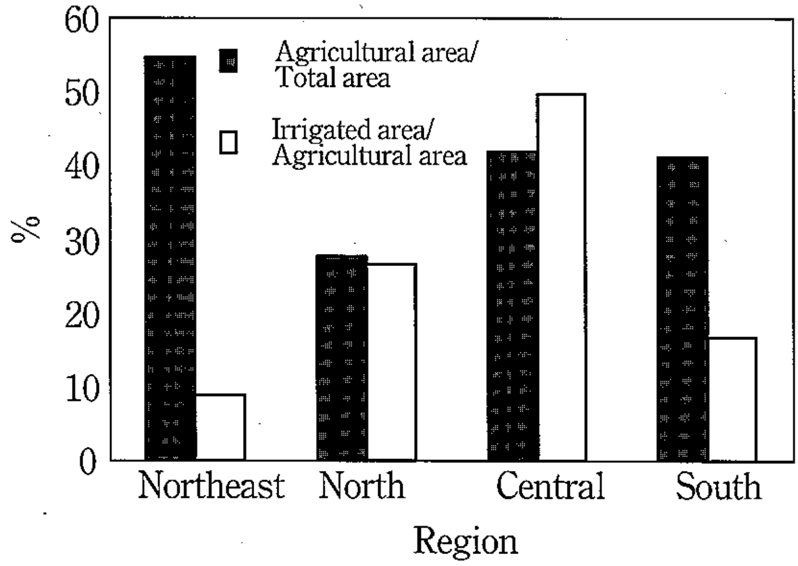

Fig. 1 Land use for agriculture in Thailand.

have less land exploited for agricultural production but more irrigation coverage. Agriculture in Northeast Thailand thus depends primarily on the quantity and pattern of rainfall received (Pattanee, 2000).

Rainfed lowland paddy, cassava and kenaf have been major crops since the 1960's, but in the last couple of decades, sugarcane has also become a major cash crop (Fig. 2). Deforestation has led to changes in the hydrologic environment and has caused widespread salinity problems in this region. Also, soil erosion and soil fertility deterioration are becoming serious problems in cassava growing areas. Because of these problems, the agricultural productivity is declining. Compounding this, international market prices for agricultural products from the region have also declined, thus further reducing the profitability of agricultural production in this region.

Water availability in Northeast Thailand seems to already be at a critical point in terms of both per capita availability and availability for agricultural production. The amount of fresh water currently available per person per year in Northeast Thailand is 2,398 m^3, which is fairly close to the amount of water needed to produce the food requirements per person per year (2,000 m^3 for a balanced diet with meat). Further decline in water availability may seriously threaten food security in the region. Assuming that the total watershed area, annual rainfall and usable runoff coefficient in Northeast Thailand are 170,000 km^2, 1,200 mm and 10%, respectively, usable water resources can be calculated as 20 billion m^3/year, which is equivalent to 1.7 million ha potential coverage of farmland. Northeast Thailand has approximately 2.0 million ha of farmland, so this already exceeds the potential coverage of available water resources (Mase, 1995). This indicates that there is already over-exploitation of land resources for agriculture using present crops and production technology. The two possible ways to address this unsustainable situation are either to increase the efficiency of water utilization per unit of land, or to return the excess farmland back to its original natural state.

Developing techniques to assure sustainable crop production requires a better understanding of the hydrology of this region, together with more efficient management and utilization of water resources (especially to minimize salinization problems), reforestation, minimization of soil erosion, arresting further decline in soil fertility, and crop diversification. Also, development of improved production systems that can utilize local resources and create employment opportunities for the local population should be promoted in this region. Milk production has become a major economic activity in Northeast Thailand, and rapid economic

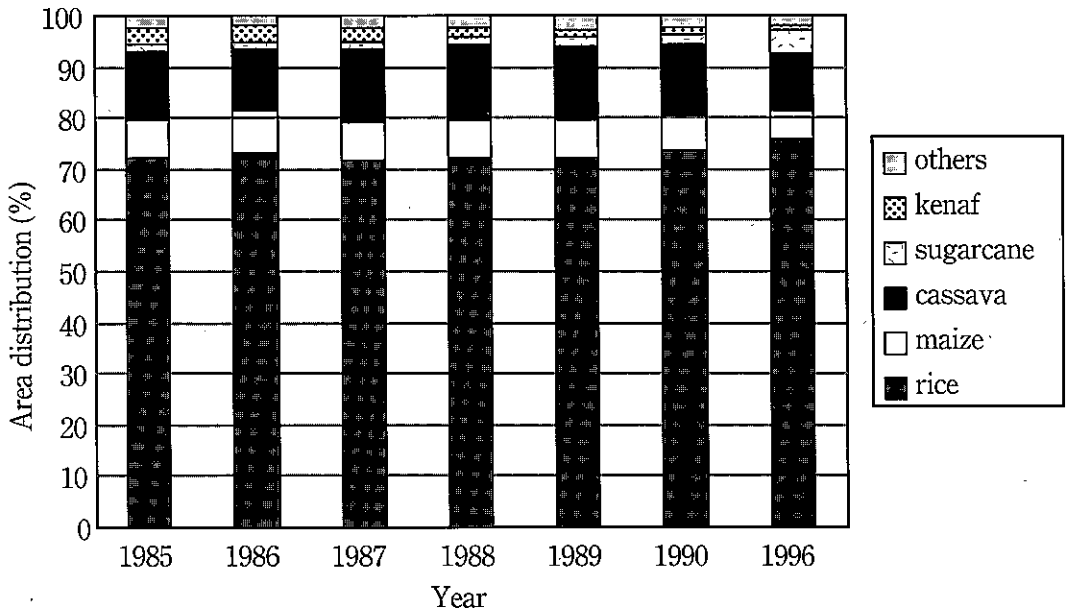

Fig. 2 Distribution of planted area for various crops in Northeast Thailand.

growth in other parts of this country is expected to create a substantial demand for milk and meat in the near future. Thus, integrated agricultural development that can functionally link agricultural crop production, livestock industry, sericulture, and vegetable and horticultural production should be the goal for the improvement in the overall productivity of this region.

Project Outline

The target area of the new project are the lowland-upland boundary zones of the central part of Indochina including Northeast Thailand and Laos, where the small-scale mixed farming is predominant. The project aims to develop component technologies for the collection, storage, and distribution of water, together with crop production technologies with high utilization efficiency. From the viewpoint of the optimization of farm management, tests of combinations of component technologies are carried out in farmers' field, and an integrated farm management model is presented. Considering biophysical and socio-economic conditions which surround each individual farming unit in the project site, farming systems that have high profitability and sustainability are proposed as a goal of the project. The project consists of three main themes as illustrated in Fig. 3, each of which is described in more detail below.

Assessment of regional water availability and identification of factors limiting more efficient use of water in existing farming systems

The overall size of water resources in Northeast Thailand can be calculated based on available estimates of runoff rates of the main rivers in the region. However, information on available water resource quantities disaggregated for different parts of the region is very scarce. Although many small-scale irrigation systems

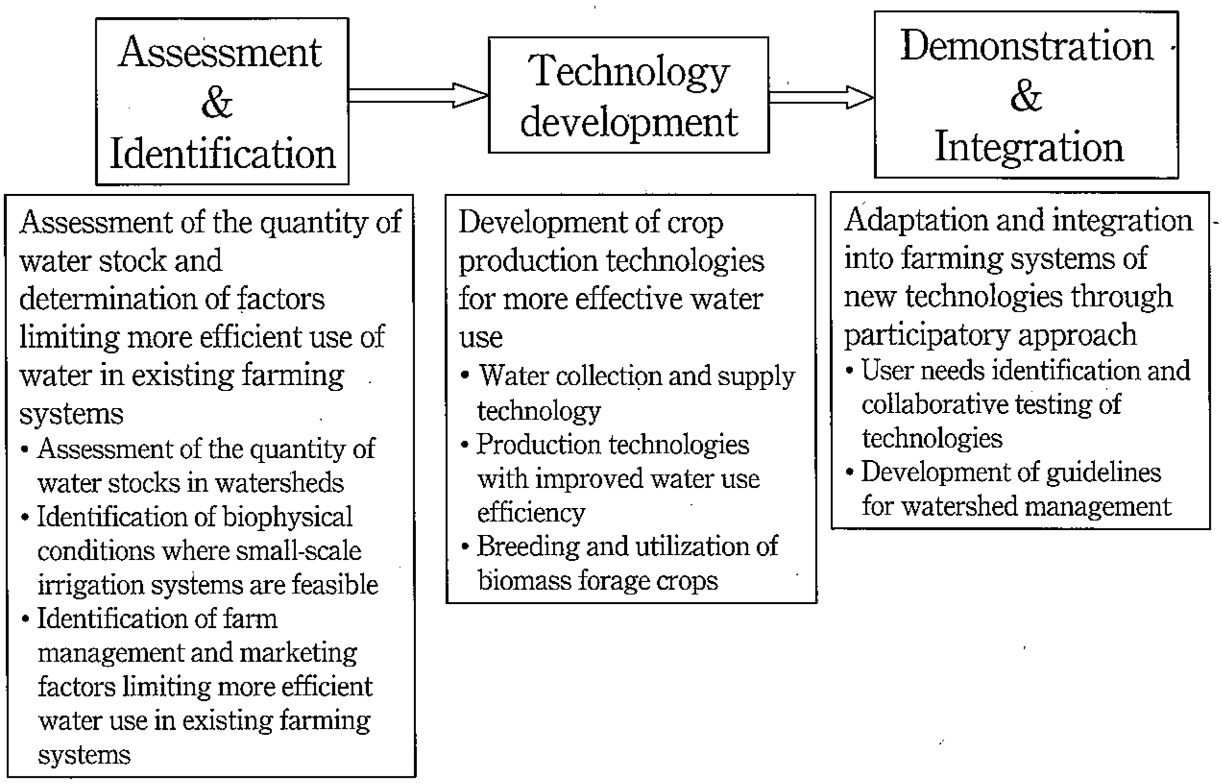

Fig. 3 Scheme of the project titled "Increasing Economic Options in Rainfed Agriculture in Indochina through Efficient Use of Water Resources".

have been constructed with the objective of increasing water resource availability for agriculture, in reality most of them have ended up being utilized simply as additional sources of domestic water, and only a limited number are utilized as a source of water for agriculture, the original purpose of their construction. .

To address the above constraints, the new project will begin with analysis of remote sensing data to estimate the amounts of water in different parts of the region and map water resource distribution over the entire region. Based on those results, types of small-scale irrigation systems that effectively utilize surface runoff and groundwater will then be designed. Site-specific investigations will be carried out to determine the status of water storage and utilization and land use patterns in the project site, as a basis for designing appropriate small-scale irrigation systems.

In rainfed agriculture, farming systems are pliable, and farmers adjust them depending on each year's rainfall pattern without being bound to a fixed form. Many aspects are still unclear in the relationship between difficulties in access to water resources and actual farming systems. Socio-economic research will compare farm management systems representative of the region with future potential farming systems, and assess the extent to which community control of water resources may restrict improvement of water resource utilization.

Development of crop production technologies for more effective water use

Rice cultivation occupies a central position in mixed farming in the region, and it is a cropping system in which water consumption (quantity of water needed for the production of unit mass) is very high. Much water is especially required during the land preparation period. Also, production based on transplanting requires more water than direct seeding. In order to develop a rice production system with improved water utilization efficiency, the early stage of rice production from land preparation to the young seedling stage will be re-examined from the viewpoint of water consumption. It is hoped that reduced consumption of water for rice production may lead to more water availability to the subsequent crop that can be introduced after rice.

Water loss that occurs not only through leakage in the vertical direction, but also leakage through bunds in the horizontal direction is high in the sandy soils prevalent in upland areas in region. Farmers in rainfed lowlands are also concerned about water losses from their field due not only to vertical and horizontal leakage but also destruction of parts of the bunds by heavy rain. Based on farmer assessment of a menu of technology options in a pre-project village meeting in the project site, highest priority was placed on a technology that can strengthen the weak part of bunds by mixing soil with magnesium oxide, a binding agent with a strength similar to concrete. If effective ways to use this technology at reasonable cost for farmers can be developed, water retention in rice fields will be greatly improved.

If small-scale irrigation systems can be developed, it may become possible to extend the cropping period some time after the end of wet season. This will provide the farmers with more cropping options. This will, of course, depend on the water storage capacity of their farm ponds, the water requirements of the crop, and water efficient crop production technologies. Production of vegetables and tropical fruits that can be sold in higher prices in the market can help improve farm profitability. In the project, water-saving production technologies such as lowered seedling beds, foliar water spray, mulching, tunnel covering, drip irrigation, and others will be adapted and tested in on-farm trials. At the end, a set of farmer-tested and adapted production technologies with improved water use efficiency that fit well into local conditions will be available for wider use.

In fields located at the upper end of the watershed topography, water supply from small-scale irrigation systems is not possible because of distance, and farmers are forced to use cropping system that are entirely dependent on rainfall. In order to improve water use efficiency under such conditions, greater potential exists from crop improvement rather than from an approach focused on modification of production technologies.

Sugarcane and cassava are widely cultivated in Northeast Thailand. They are two crop species well adapted to local conditions, with higher tolerance to water deficiency and higher biomass production. The previous project identified *Erianthus* spp, a wild relative of sugarcane, as having the capability to maintain greenness in the plant to the end of dry season, probably due to its deep root system. The new project will produce breeding materials with a wide range of adaptability through interspecific hybridization between *Erianthus* spp and sugarcane species. Extensive crossing and screening for improved drought tolerance and dry mass production will be carried out using materials that have been collected, selected and produced in the previous project. The utilization of breeding materials so identified will then be explored, with a focus on their potential utilization as animal feeds.

Adaptation and integration into farming systems of new technologies through participatory methods

Since the lowland-upland boundary area that is the research target for the project has complex topography with gentle undulation, access to water resources can vary even among fields owned by the same farmer, so preferential cropping options will change depending on water resource availability in each particular location. This in turn means that overall water use efficiency for a given farm household can be increased by combining different cropping options that best fit each particular location. In the project, prototype production technologies developed by station-based research in the project will be tested in on-farm trials and compared with farmers' conventional methods from the viewpoint of water use efficiency. Combinations of technologies will also be tested, and further modifications will made to the technologies to improve their adoptability by farmers.

It is necessary to consider the water use efficiency not only at the level of a farm field but also at the catchment level. Improved water resource management depends on both technical and socio-economic factors. Technical factors will be defined based on detailed analysis of utilization efficiency and water budgeting in a minimum catchment unit. All the data collected from remote sensing, farmer interviews, and field surveys will be put together in a simulation model to optimize the water balance in the catchment unit of the project site. Based on the outputs of the model, the effects of improvements in water resource management on the overall water balance in the catchment will be assessed, and water resource and crop production management options with improved water use efficiency will be proposed.

Concluding Remarks

The Thai government has devoted considerable funds for various projects related to water security in order to revitalize agriculture in Northeast Thailand and make the rural areas of the region more economically self-sufficient, with more income from agriculture and less dependent on temporary work in the city. Although the Royal Irrigation Department and the Land Development Department have constructed many small-scale irrigation systems in the region, most of them have been used for domestic purposes or for animal water supply, and very few are used exclusively for crop production. In addition, in many cases pond maintenance is not properly done to remove sediments and repair side walls. Comprehensive, detailed investigation of the current status of the utilization of water resources is essential to identify realistic, workable solutions to these problems.

Developing countries have already entered the era of resource constraints for both land and water. Since wide-scale expansion of water resources is no longer feasible, effective utilization of existing water resources has become a common need for most developing countries. As pointed out by FAO, water resource management in Asian countries is shifting from the "age of construction" to the "age of management". Our project is motivated by the same spirit in its approach, aiming at the stabilization of crop production and improvement of profitability through integration of various production technologies well fitted to local conditions with higher water use efficiency. Moreover, the technologies developed in the project will be adapted and tested in on-farm trials using a farmer participatory approach. This approach, which has been widely adopted by many research centers belonging to the Consultative Group of International Agricultural Research (CGIAR), identifies farmers' needs and priorities from the initial stage in setting the agenda for subsequent research activities.

Since rainfed agriculture is characterized by production under water-limited conditions, in one sense it is intrinsically efficient in water utilization. The question is how to increase the availability to crops of water from rainfall. The fundamental technologies developed for rainfed agriculture in the new project are also expected to play an important role in the development of irrigated agriculture, for which serious water shortages are predicted in the near future.

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