Constraints on Food Production and Perspectives for Solution: Water Resources

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ABSTRACT

In terms of water resources, floods and droughts are considered to be the main factors affecting stable food production. In recent years, extreme cases (various extents and severities of such natural disasters) have been occurring at an alarming rate around the world, apparently due to recent climate changes and human activities such as changes in land use, agricultural practices, etc. In Monsoon Asia, distinct dry and rainy seasons coexist and both floods and droughts occur irregularly in the same areas, yet sustainable rice cultivation has been carried out for centuries due to various types of unique water uses which are totally different from those in dry and/or arid regions. However, the mechanisms of water use and the effects of changes on food production in this area have not been fully elucidated.

The speaker, therefore, presents and outlines the differences in hydrologic conditions between arid (including semi-arid) and monsoon regions, and the sustainability of rice production by analyzing the unique characteristics of water use in Monsoon Asia. There is also an attempt to determine the effects of such water use on food production and vice versa.

First, the unique features of paddy irrigation in humid regions are illustrated by comparing hydrological environments, types of irrigation, and characteristics of paddies with those in arid and semi-arid regions (examples of Australia and USA). About 54% of the world population lives in the Asian monsoon region, which covers only about 14% of the world land area. The majority of Asia large population is supported by intensive paddy rice cultivation, which is not only an outstanding form of agriculture with high land productivity, but can also be considered as a sustainable and environmentally friendly economic activity suited to the climatic and topographical conditions of the region. This economic activity has continued to evolve for hundreds or thousands of years in various areas, as witnessed by the archaeological vestiges of 7,000-year-old rice cultivation in China.

Second, although agriculture in Monsoon Asia accounts for a large part of total water use, a sustainable water supply and use mechanism derived from various water use patterns, has been developed there. That is, from the viewpoint of watershed management, not only do the paddy areas regulate floods by functioning as retarding basins (ponds), but the water resources are used effectively by optimizing the natural hydrologic conditions. While this function is commonly found in low-lying paddy areas such as paddies in Japan, Cambodia, Vietnam and other countries, it is especially noticeable in the Mekong River Basin (drainage area: 790,000km2, river length: 4,400km).

Third, an attempt was made to refine a water use model and to combine it with global water and food analyses in order to examine the effects of changes in water circulation on food production in terms of agricultural land use, water use, irrigation patterns, etc. Unfortunately, the above-mentioned unique characteristics of water supply and demand as elements of water use have not yet been appropriately

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considered in many "world water and food" models that have been developed since 1990 at many research institutes, such as JIRCAS, IFPRI, and IWMI.

FOOD PRODUCTION AND EXTREME EVENTS

Extreme events such as floods and droughts are the main factors affecting stable food production, and changes in climate, land use, and agricultural methods are contributing to an upsurge in their frequency.

The numbers of disasters have increased remarkably around the world over the last three decades, as well as the numbers of people they have affected and killed. Among the many types of disasters occurring, catastrophic droughts and floods have accounted for the largest share of the increases seen.

In Monsoon Asia, the availability of water resources fluctuates sharply, as distinct dry and rainy seasons cause severe droughts and major floods in the same regions. In order to prevent such disasters and eliminate their momentous effects on agricultural production, unique practices of water use were developed in Asia. Notwithstanding, the mechanisms of water use and the effects of changes on food production have not been fully examined.

The following pages will cover three main topics.

- The different hydrologic environments and unique features of food production, particularly the sustainability of rice production, in humid and arid or semi-arid regions;
- The mechanisms of sustainable and integrated water use for rice paddies, with specific examples from Japan, Cambodia, and Vietnam;
- A trial to refine a water use model and incorporate that model into global water and food analyses.

MONSOON ASIA

While Asia covers only 24% of the world's land area, about 6 billion people, or 60% of the world population, live in the region. By far the highest concentration of Asians live in Monsoon Asia, where 54% of the world's population occupies an area covering only about 14% of the world's land mass.

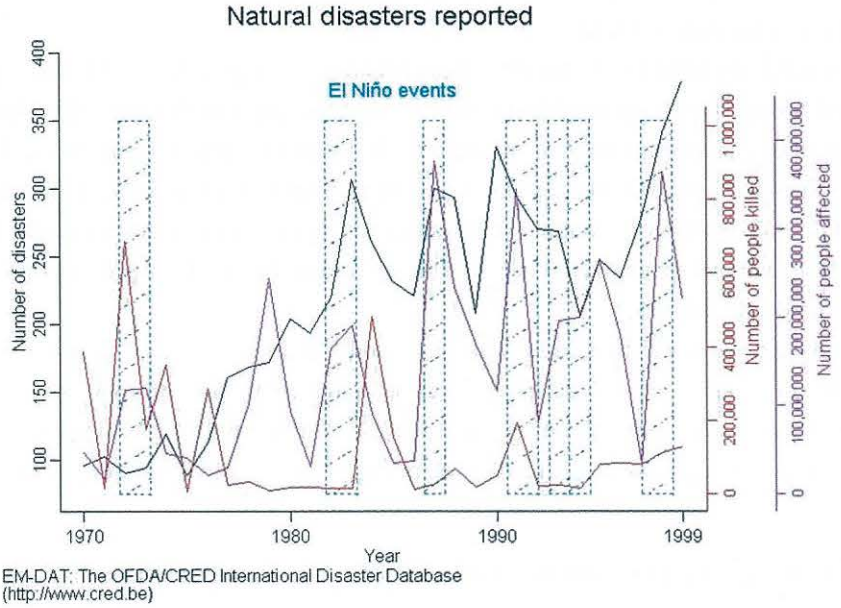


Fig. 1. Extreme disastrous events in last three decades in the world

Most of Asia's massive population is supported by intensive paddy rice cultivation, a practice that is not only highly productive, but sustainable and environmentally friendly as an economic activity as well. Were it not so, evidence of rice cultivation dating back 7,000 years in China would never have been discovered.

Needless to say, the features of rice cultivation differ markedly between arid and semi-arid regions.

As a world region, Monsoon Asia is very rainy. Most parts of the region have a warm climate with high precipitation averaging 1,500 mm or more annually. As a result of the high precipitation, the water balance in the region (annual precipitation minus annual potential evapo-transpiration) is also very high (over 500 mm).

Monsoon Asia can be considered a homogenous region, in that paddy rice cultivation extends over almost the entire area. In fact, 90% of the world's rice is produced in Asia. At the same time, irrigation is used for the 2nd and 3rd rice cultivations (replenishment irrigation), as large seasonal and short-term fluctuations in the supply of water resources exist in those areas.

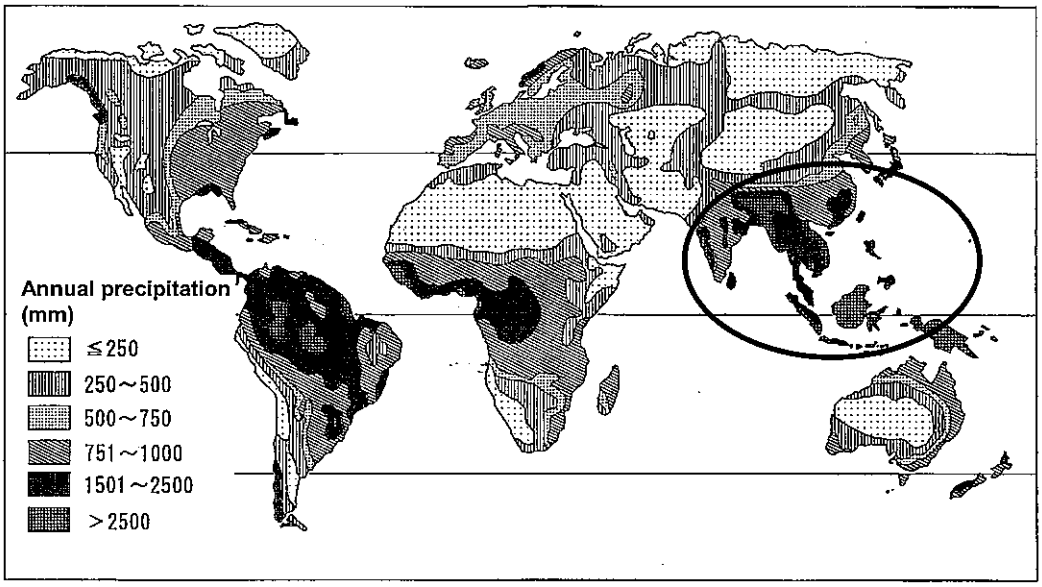


Fig. 2. Characteristics of paddy irrigation in Monsoon Asia

PADDY IRRIGATION IN ARID AND SEMI-ARID REGIONS

Paddy irrigation is practiced in arid and semi-arid regions in places such as the USA, Australia, Italy, and Spain. In the Murray River Basin in Australia, for example, 100,000 ha of paddy fields are cultivated in an area where precipitation only reaches about 400 mm. This makes paddy irrigation essential.

Yet percolation due to paddy irrigation increases the water levels of saline groundwater, a change that harms the environment in various ways. In the case of the Murray River Basin, some paddies have ended up as barren piles of salt of no further use for agriculture. Nearby forests converted to farmlands have met with a similar fate. The use of the forestland for cultivation has decreased the rate of evapo-transpiration and increased the groundwater level, filling rivers with salt and killing off trees.

These unwelcome changes in Australia effectively show the big differences in rice cultivation between Monsoon Asia and arid areas. While paddy irrigation brings about positive effects on the groundwater in Monsoon Asia, it produces a serious salinity problem in arid areas. This is why rice cultivation is sustainable in Monsoon Asia.

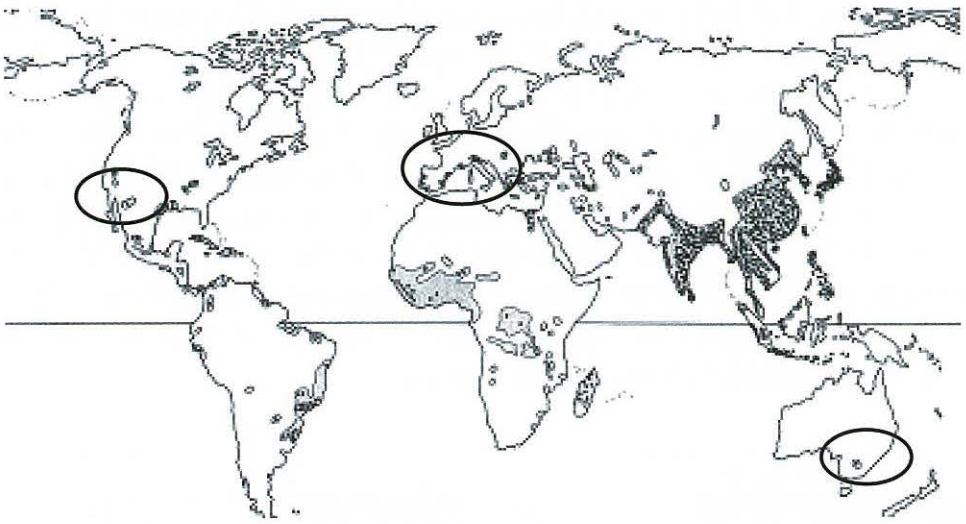


Fig. 3. Paddy irrigation in arid and semi-arid regions

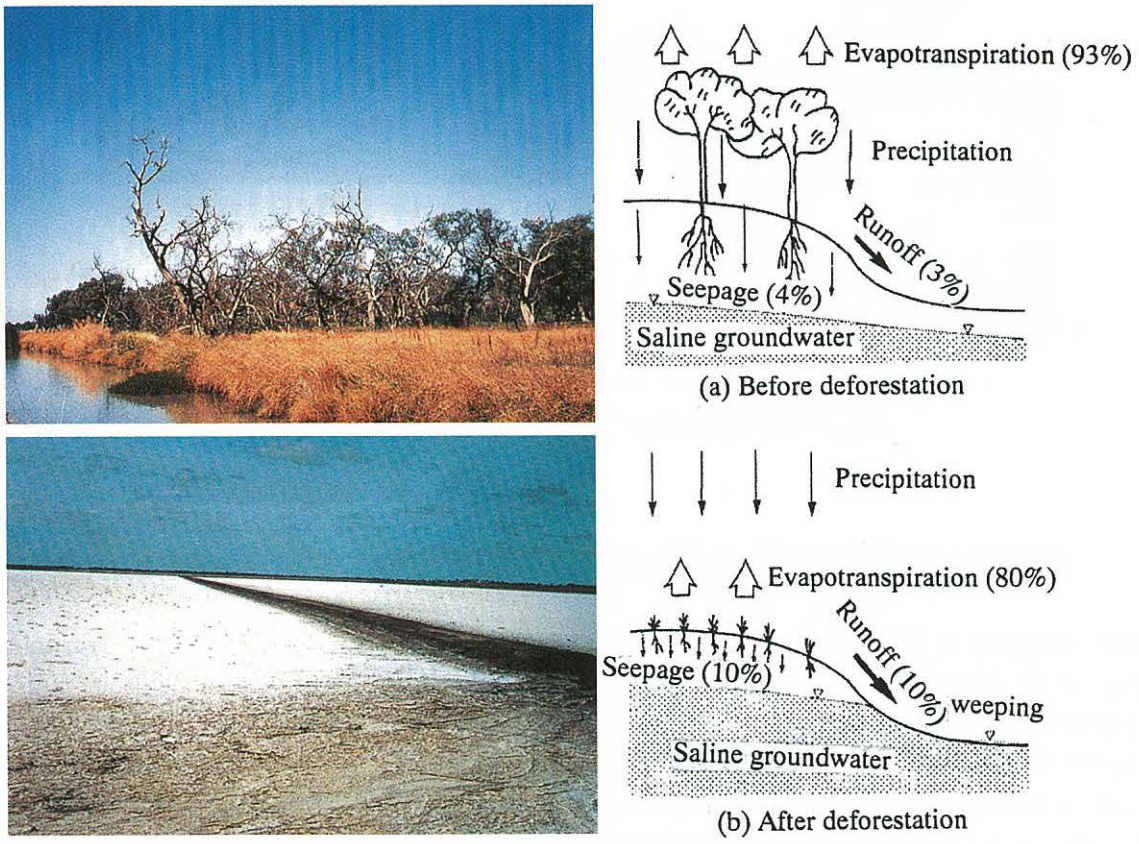


Fig 4. Paddy fields in Australia

INTEGRATED WATER CONTROL FUNCTIONS

In addition to being sustainable, rice paddy cultivation is a multifunctional and integrated form of water use. In the past, paddy fields were thought to serve solely for rice cultivation, whereas now they integrate "water cycle control functions" such as flood protection and the fostering of water resources.

When comparing observed changes in runoffs in hilly areas in Niigata Prefecture in Northern Japan, we

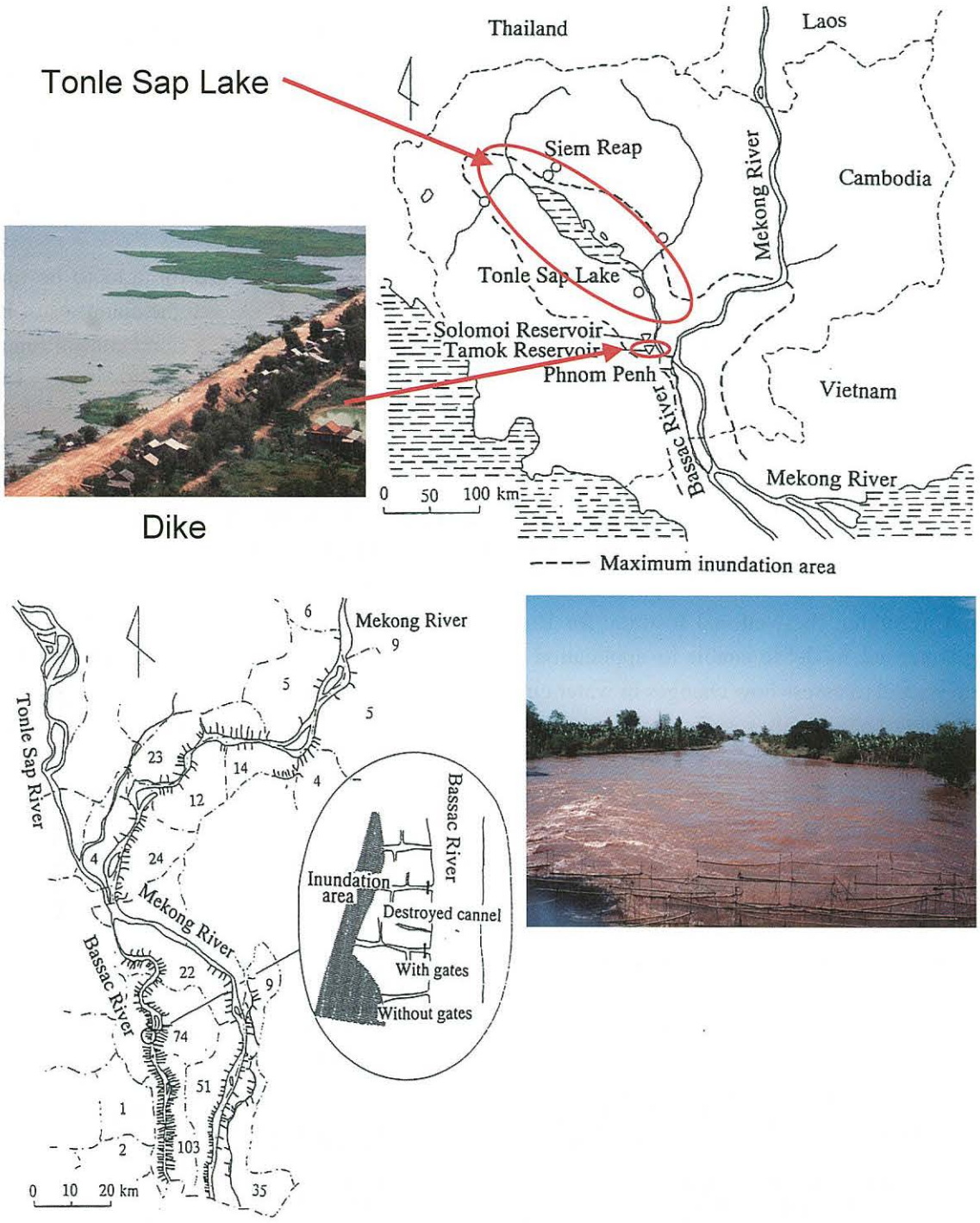


Fig. 5a and 5b. An example of flood prevention function in the Mekong River Basin

find that if paddies are abandoned, the peak amount and total runoff volume both increase when the paddies are wet. As long as the paddies are cultivated, the flood prevention function is provided.

In the Mekong River basin, paddies work to secure irrigation water and prevent floods at the same time. They do so through three different mechanisms that can be illustrated here.

The first mechanism is water storage by Tonle Sap Lake. Since the discharge of the Mekong River is still unregulated, the water level fluctuates drastically between the dry and wet seasons (by more than 7 meters). When the water rises in the Mekong it creates a reverse flow into Tonle Sap Lake, flooding the entire area and submerging the rice fields. Cultivation, which begins when the water starts to recede, is highly dependent

on the floods.

The second mechanism is water storage by a dike near the city of Phnom Penh, about a 100 km south of Tonle Sap Lake. The dike protects the city from floods and provides water that can be stored in reservoirs behind the dike and used for rice cultivation.

The third mechanism is provided by Colmatage, an agricultural method developed by the French. When the Mekong and Bassac rivers start to rise, a natural levee carved into the ground feeds the surplus water into the floodplains. Part of the water stored during the floods remains in the area, where it can be used for irrigation later during the dry season.

These flood protection mechanisms used in the Mekong River basin are thought to be outdated compared to the technologies used in advanced nations such as Japan, the USA, and the countries of Europe. From the viewpoint of watershed management, however, the paddy fields provide a flood control function as retarding basins (ponds), while supplying rational water resources simply by taking advantage of natural hydrologic conditions.

INCORPORATING THE WATER USE MECHANISMS IN FOOD AND WATER MODELS

Working within the National Institute for Rural Engineering (NIRE), our group has been refining an existing water use model to enable its application in global water and food analyses. Ultimately, our goal is to use the model to assess how changes in water circulation affect food production.

Our study began with a review of a number of water and food models currently used throughout the world, including the IMPACT-WATER model developed by IWMI and IFPRI in the late 90's.

IMPACT-WATER, likes many other global water and food models, has various weaknesses, but one stands out before the others. That is, the factors of water use within the model need to be refined by adjusting the categories of land use, growing duration, cropping patterns, irrigation practices, and so on.

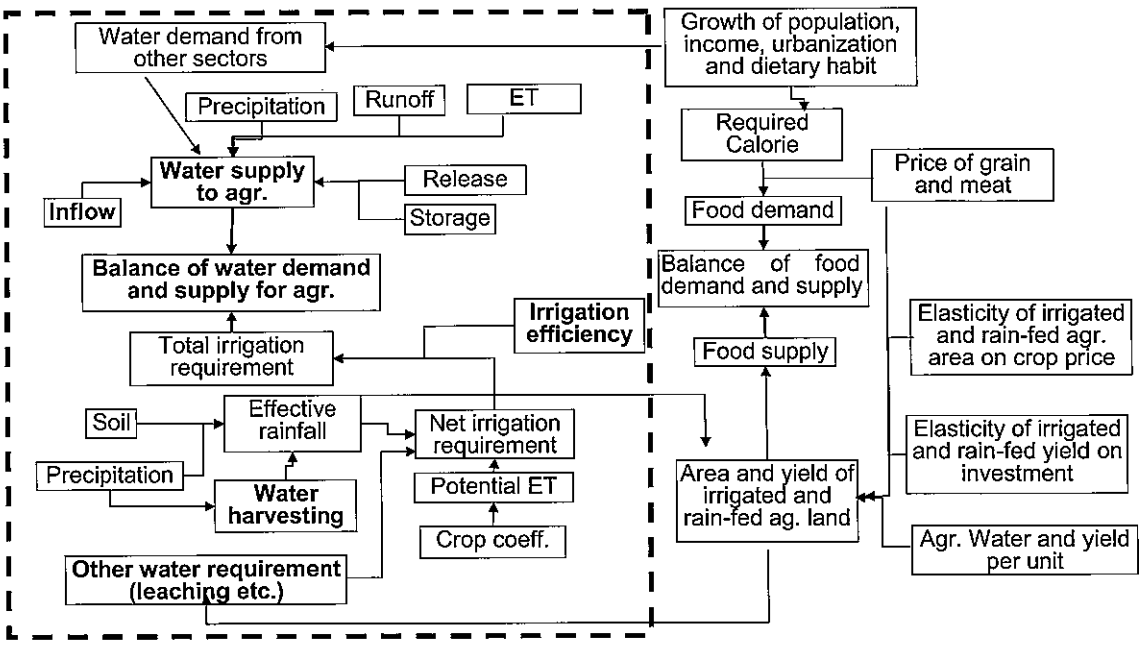


Fig. 6. Basic concept of 'Water and Food' Models

COLLABORATION ON A REFINED MODEL

This year, the Japanese Ministry of Agriculture, Forestry, and Fisheries began sponsoring a five-year study to establish a refined water use model integrating several sub-components more closely, with a chief focus on water supply and water management. Uniquely, this refined sub-model will be coupled with the JIRCAS model, as well as other global water and food models now in use.

The study is also unique for the high level of collaboration it embodies, with tightly integrated contributions from important institutions such as the National Institutes for Rural Engineering (NIRE), the National Institute for Agro-Environmental Sciences (NIAES), JIRCAS, and the Forestry and Forest Product Research Institute (FFPRI). Unlike other cases seen before, this study is not merely a patchwork of earlier research results stitched together. The framework is changing, and the cooperation will certainly contribute to the CGIAR consortium in the future.

TRIALS ON WATER USE MODELING

Water use models incorporate factors such as topography, rainfall and water levels, land use, area and duration of inundation, irrigation patterns, soil types, climate conditions, and rice varieties. These factors have recently been defined and examined under the GIS platforms.

When areas were downsized to provincial levels in an analysis of the changeable factors in water use relating to rice yields in Cambodia, we found important effects of stress due to water shortage, as well as both positive and negative effects of floods. Overall, floods seem to be a more important factor than droughts on the water supply side.

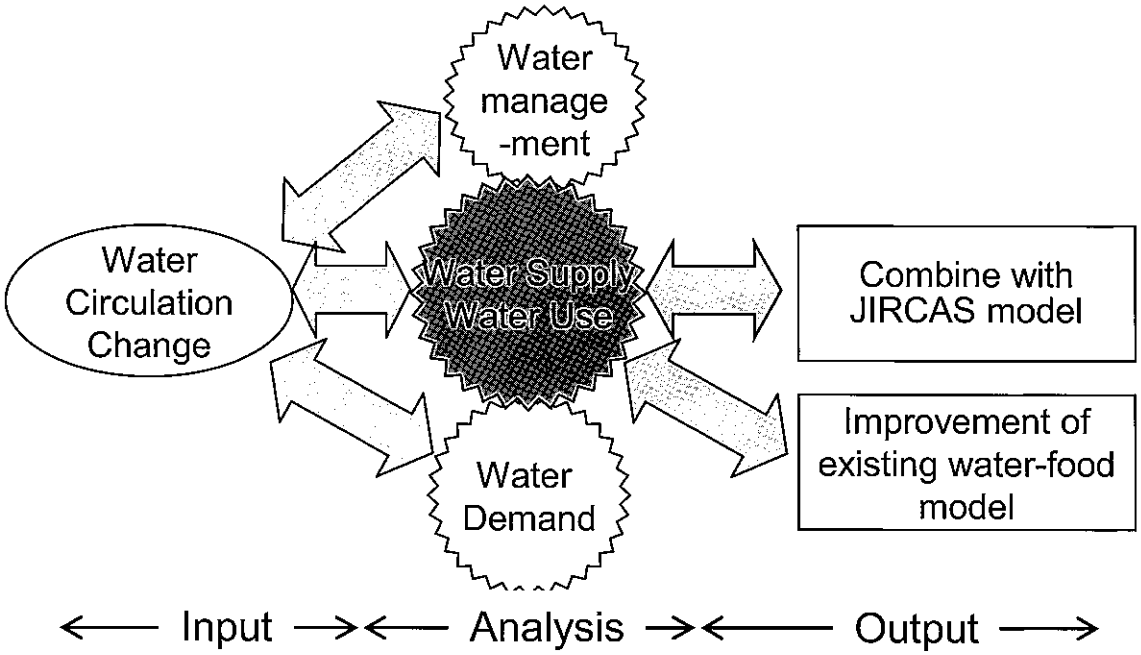
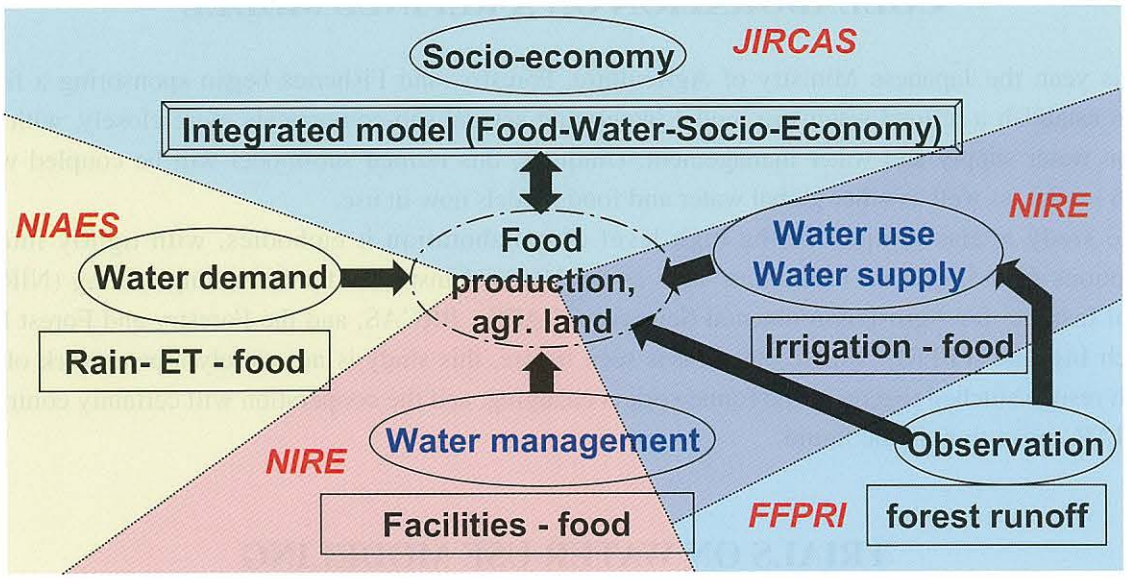


Fig. 7. Development of 'Water and food' model (2003-2007)



NIRE : National Institute for Rural Engineering
NIAES: National Institute for Agro-Environmental Sciences
JIRCAS : Japan International Research Center for Agricultural Sciences
FFPRI : Forestry and Forest Product Research Institute

Fig. 8. Research team and its contribution to the world (CGIAR)

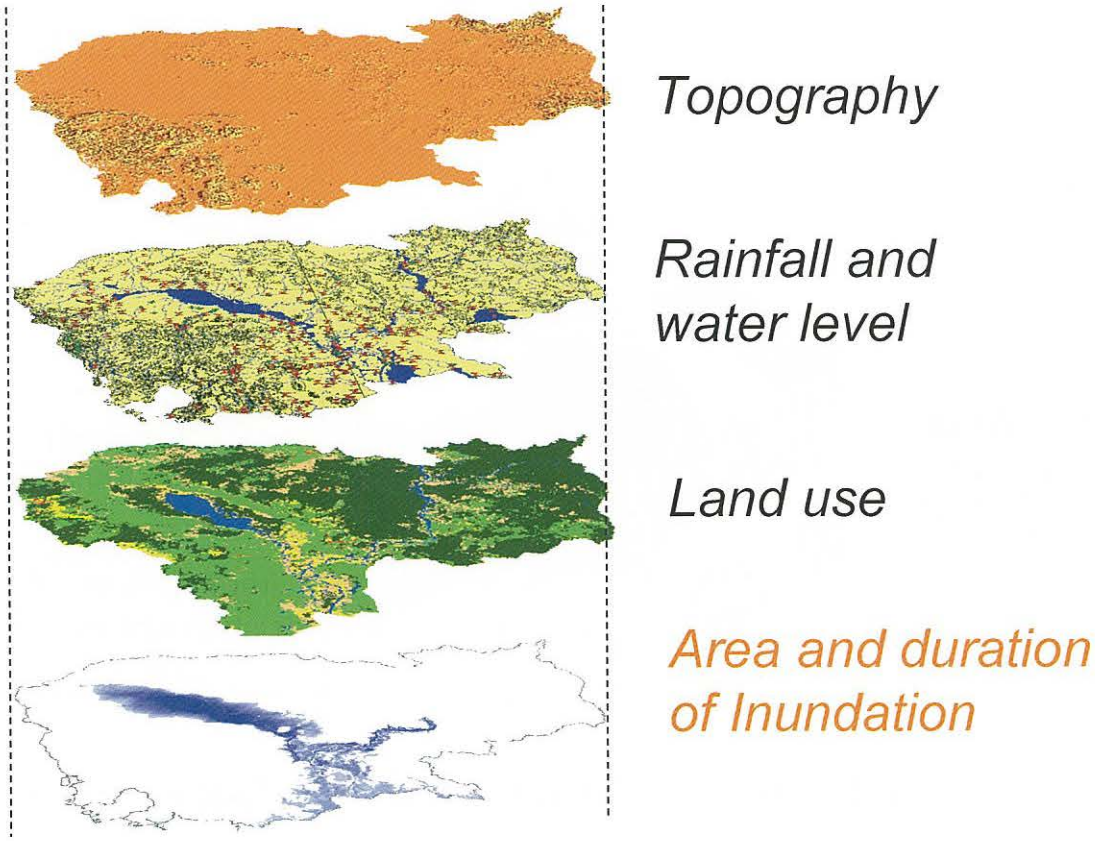


Fig. 9. Development of 'Water and Food' model

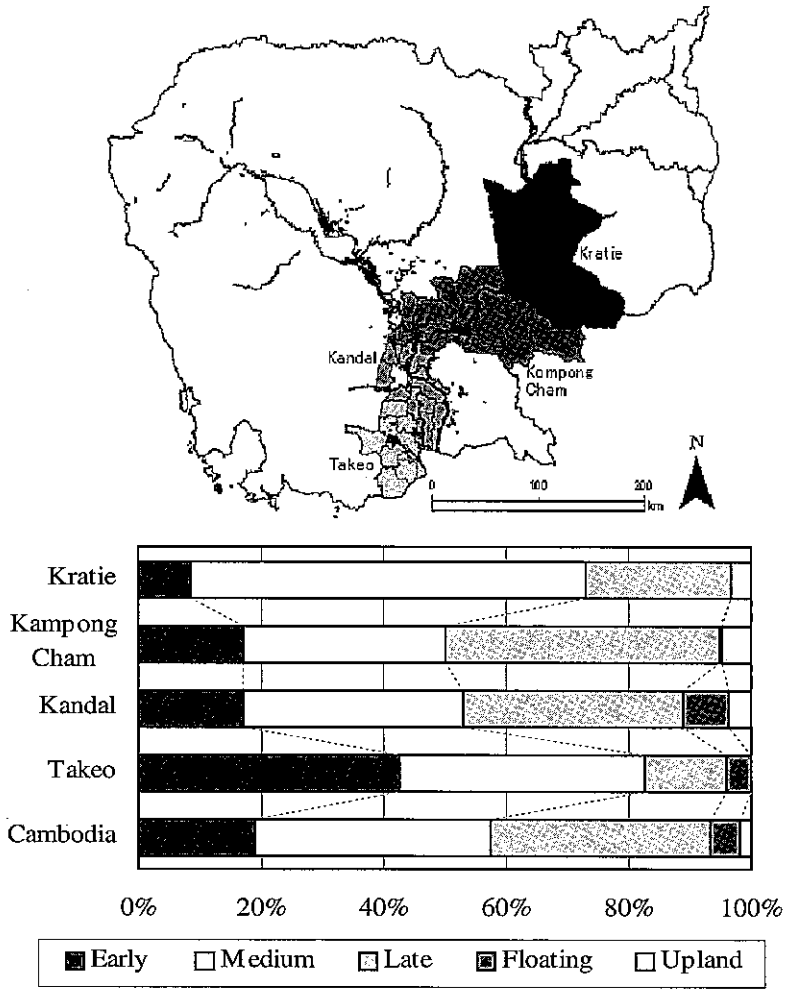


Fig. 10. Trials of water use modeling

CONCLUSIONS

Three main points have been discussed in the foregoing pages:

- Floods and droughts are expected to exact greater tolls as "constraints on food production" now that extreme events are increasing.
- The unique water use mechanisms in paddies of Monsoon Asia should be incorporated within the water and food models used throughout the world.
- Lastly, solutions in sustainable rice production in Monsoon Asia can be used to solve constraints in water resources by modeling integrated water uses such as the use of low-lying paddy areas for flood prevention. The same solutions can also be used for watershed management.