Fu-do and Food in Monsoon Asia: A Brief Agro-Environmental Outlook

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Abstract

Monsoon Asia is blessed with natural resources for agriculture by the warm and seasonal humid climate and the fertile large alluvial plains. The dominance of rice cultivation and family-owned small-scale agriculture in this region, which is the consequence of longstanding human activities in its unique *fu-do,* has led to the development of agro-ecosystems with long-term sustainability of food production and biodiversity conservation. However, Monsoon Asia is facing rapid changes in both socio-economical and natural aspects, causing changes of land use and management systems over the region. Climate change is an additional source of risks to the region. These changes have significantly impacts on the status of agriculture and food production in the region, and have resulted in substantial negative ecological consequences, including increased greenhouse gas emissions, a loss of biodiversity, deteriorated air and water quality, and soil degradation. The impacts of environmental constraints may limit future increases of food production to meet the demands in the region. Therefore, researchers, engineers, and administrative authorities in this region must develop close international collaborations to meet the region's growing agricultural needs, while harmonizing the human systems with the natural systems that support them.

Keywords: agriculture, climate, environment, impact, sustainability

1. Introduction

The Japanese word *fu-do* (風土) literally means "Wind and Earth (or Soil)" as a general term for the natural environment of a given land, including the climate and weather, geological and productive nature of the soil, and the topographic and scenic features. The significance of *fu-do* was extended by the Japanese philosopher Tetsuro Watsuji (1889–1960) to the concept of an entire interconnected network of influences that together create entire attitudes and values of people (Watsuji, 1961). This concept sees *fu-do* not merely as a collection of natural phenomena, but also as the agent by which human life is objectified. In particular, *fu-do* is even more obvious in the case of agriculture and food as it is, along with the climate, most intimately connected with the production of food.

Monsoon Asia, which includes countries in the regions of East, Southeast and South Asia, is blessed with natural resources for agriculture because of the warm and seasonal humid climate and can therefore sustain large populations within its limited land area. The dominance of rice cultivation and family-owned small-scale agriculture in this region, which can be recognized as the consequence of human activities for thousands of years in its unique *fu-do*, has led to the development of agro-ecosystems with long-term sustainability of food production and biodiversity conservation. On the other hand, the agro-ecosystems in Monsoon Asia have been intensively disturbed or managed by human activities for many centuries and are now suffering from rapid economic, social, and environmental changes. As a result, drastic deterioration of some of these ecosystems has been observed recently because of the combined effects of climate change, urbanization, pollution by toxic chemicals, and invasion by alien species. Therefore, these problems must be solved to meet the region's growing agricultural needs, while harmonizing human systems with the natural systems that support them.

This introductory chapter of the book briefly looks at the present status of agriculture and the environment in Monsoon Asia, while discussing the major environmental impacts and issues on agriculture in the region.

2. *Fu-do* of Monsoon Asia

Most of the areas in the Asian region are strongly influenced by the Asian monsoon, which is a seasonal reversing wind accompanied by corresponding changes in precipitation. Thus, this region is often called "Monsoon Asia." The Asian monsoon is a most significant component of the global climate system, and it influences lifestyle and livelihood while providing water resources in the region (Salinger et al., 2014). The East Asian monsoon carries moist air from the Pacific Ocean and Indian Ocean to East and Southeast Asia in summer. Reversely, it carries cold and dry air from the Eurasian Continent in winter. In South Asia, winds blow from the southwest direction from the Indian Ocean onto the Indian landmass during the months of June through September, which brings rain to most parts of the subcontinent. Subsequently, around the month of October, the winds reverse direction and start blowing from a northeasterly direction from the subcontinent to the Indian Ocean, which carries less moisture and brings rain to only limited parts of India. However, the dry area extends to the northwestern interior parts of the region because of the decreased influence of oceanic winds.

The region is stratified into different agro-ecological zones (AEZs) because of the wide diversity of climates. Figure 1 shows the AEZs in Monsoon Asia as classified by the global AEZ methodology, which is based on principles of land evaluation developed by the Food and Agriculture Organization of the United Nations (FAO). The map shows the AEZs in the region by the number of days that are available in 1 year for a standard crop to grow, based on the conditions of temperatures >5 °C and the availability of sufficient water. Based on the results shown in the figure, the crop cultivation potential clearly increases from the northwest to southeast in the region. Moreover, it is important to point out that the area that has more than 180 available days for a standard crop to grow extends to more than half of the region, which is notably larger than other regions in the world.

In addition to the climatic factors, Monsoon Asia is also blessed with great advantages to

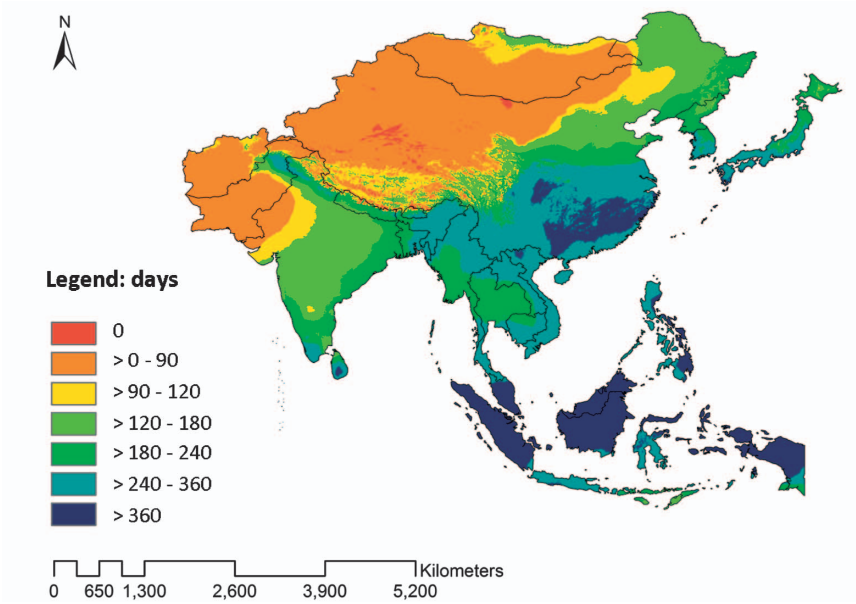

Fig. 1 Agro-ecological zones in Asia categorized by the number of days that are available in one year for a standard crop to grow (i.e., T > 5 °C and sufficient water available: source: IIASA/FAO, 2012).

agricultural production by the geographical and topographical features of the region. The map of Asia shows many vast rivers, including the Yellow, Yangtze, Mekong, Chao Phraya, Irrawaddy, Ganges, Brahmaputra, and Indus. Many of Asia's major rivers have their source in the Himalayas and adjacent plateaus, of which the main range runs for more than 2,400 km and separates the Indian subcontinent from the rest of Asia. The rivers create fertile land for farming with large alluvial plains and deltas. Although the scale is relatively smaller, such fertile land is also developed in a number of chain islands (or island arcs) located at the east and southeast shores of the continent, because of mountainous landscape with volcanic activities and high precipitation.

3. Food Production in Monsoon Asia

If we appoint the area of Monsoon Asia to be all Asian countries on the east side of Afghanistan, then this area will host approximately 4.0 billion people, which represents 54% of the world's current human population (Table 1). Like most of the world, Asia has a high growth rate in the modern era. For instance, during the 20th century, the population in Monsoon Asia nearly quadrupled, as did the world population. Although the rate of population increase in the area is gradually decreasing, the area is projected to host an additional 0.3–0.6 billion people by 2030, which represents nearly 40% of projected increase in population in the world (United Nations, 2015).

If we focus on the rural population, it is remarkable that Monsoon Asia has a larger proportion

Table. 1 Trends of population in Monsoon Asia and other regions of the world

Region	Population (millions)						Average rate of annual increase (%)	
	2000		2015		2030¶		2000–2015	2015–2030
Monsoon Asia	3450	(56)	3990	(54)	4434	(52)	0.97	0.71
East Asia	1504	(24)	1612	(22)	1650	(19)	0.46	0.16
South-East Asia	534	(9)	633	(9)	725	(9)	1.15	0.90
South Asia	1411	(23)	1744	(24)	2059	(24)	1.42	1.11
Other Asia	311	(5)	404	(5)	489	(6)	1.75	1.29
Africa	834	(13)	1186	(16)	1679	(20)	2.38	2.34
Europe	726	(12)	738	(10)	734	(9)	0.11	-0.04
LAC*	534	(9)	634	(9)	721	(8)	1.15	0.86
North America	317	(5)	358	(5)	396	(5)	0.81	0.68
Oceania	31	(1)	39	(1)	47	(1)	1.49	1.25
World total	6204		7349		8501		1.14	0.97

Numbers in parentheses are the proportion of population at each region to the world total
* Latin America and the Caribbean
¶ Prospects by medium fertility variant
Source: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition.

of rural population to the total population than other regions of the world, with the exception of Africa. As a result, the average value of arable land area per rural population in Monsoon Asia is calculated to be as high as 0.19 ha person^{-1}, which is much lower than that in other regions of the world (Table 2).

Another distinctive feature of Monsoon Asia is the very high share of the area and production for rice. The unique combination of the monsoon climate and the exceptionally large lowland area is the driving force that makes this region rightly deserve to be named the “rice granary” of the world (Kyuma, 2004). Approximately 90% of the total acreage, as well as annual output of rice, are concentrated in the region. The large amount of precipitation that is generally concentrated during the rainy season and the occurrence of extensive lowlands are the two determining factors for the dominance of rice cultivation in Monsoon Asia. Particularly, the vast expanse of lowlands that result from the combination of geological instability and large precipitation is a unique feature of the region. Rice cultivation emerged as an adaptation to the extensively inundated lowlands, but with time it was expanded even to the land that could support rice only with irrigation. High productivity and high sustainability are the outstanding advantages of rice cultivation, and this has assured the sustainability of staple food production for a long time and has further enabled these countries to sustain a large population within limited arable land.

Rice production in the sub-regions of Monsoon Asia has increased by 2.8, 4.4, and 3.1 fold in East, Southeast, and South Asia, respectively, from 1961 to 2011. Nonetheless, the per capita

Table. 2 Rural population and arable land area in Monsoon Asia and other regions of the world in 2013

Region	Rural population (millions)	Proportion of rural population to total (%)	Arable land area (Mha)	Arable land area per rural population (ha)
Monsoon Asia	2170	55.4	406	0.19
East Asia	683	42.8	115	0.17
South-East Asia	332	53.6	70	0.21
South Asia	1155	68.0	221	0.19
Other Asia	114	29.2	76	0.67
Africa	671	59.5	231	0.34
Europe	199	26.9	277	1.39
LAC*	128	20.6	172	1.35
North America	66	18.9	198	2.98
Oceania	11	29.3	47	4.22
World total	3359	46.8	1408	0.42

* Latin America and the Caribbean
Source: FAOSTAT, http://faostat3.fao.org/home/E

production of rice has remained almost constant in East and South Asia during this period (Fig. 2(a)), indicating that the rice production has increased in parallel with the population. In contrast, the per capita production of rice in Southeast Asia has steadily increased during the same period, because of the rapid increase in the quantity of rice exports from countries such as Thailand and Vietnam. The same statistical analysis was applied to the total cereal production and increasing trends were confirmed in East Asia with some fluctuations, and slight increases were observed in South Asia (Fig. 2(b)).

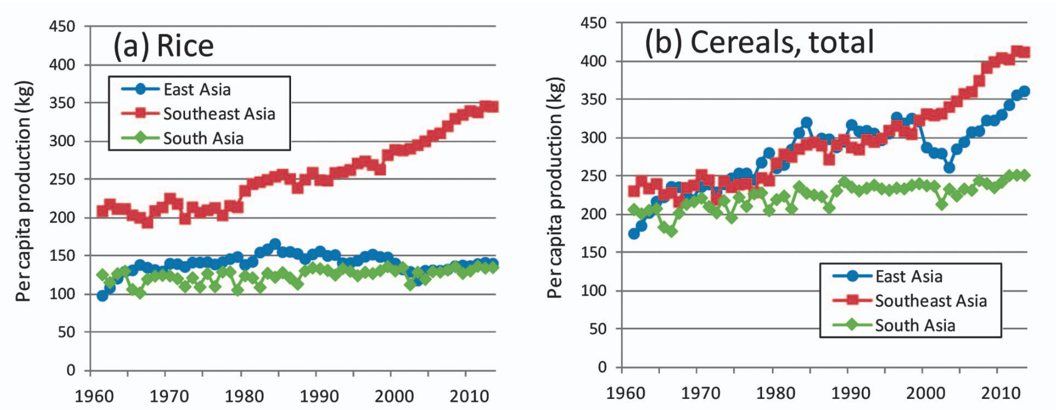

Fig. 2 Trends of per capita production of rice (a) and cereals (b) by sub-region of Monsoon Asia (original production data were obtained from FAOSTAT, http://faostat3.fao.org/home/E).

4. Major Impacts and Issues on Agro-ecosystems in Monsoon Asia

1) Land Use Change

Monsoon Asia has experienced dramatic land transformations within a historical context. In the last several decades, the demand for food to satisfy its growing population has resulted in dramatic changes in the composition and area of forests, the expansion and intensification of agriculture, and rapid urbanization (Collins, 2011). Southeast Asia has the highest deforestation rate of any major tropical region. In addition, 11 of the 19 megacities in the world that have more than 10 million inhabitants are in Monsoon Asia. The land use activities in this region have resulted in substantial negative ecological consequences, including increased anthropogenic CO_2 emissions, deteriorated air and water quality, alteration of regional climate, increases of disease, and a loss of biodiversity (Zhao et al., 2006).

Although land use change occurs at the local level, it prone to cause ecological impacts across local, regional, and global scales. A major challenge for most of the developing countries in Monsoon Asia is the reduction of the negative environmental impacts of land use change, while maintaining economic viability and social acceptability.

The monitoring of land use changes in the Monsoon Asia region is essential for the sustainable management of natural resources, environmental protection, air quality, agricultural planning, and food security. There is an increasing need to develop consistent land use products in this region with adequate spatial and temporal resolutions, so that scientific communities and resource managers can use them for proper development planning and policy-making.

2) Climate Change

Warming trends and increasing temperature extremes have been observed across most of the Asian region over the past century. The impacts of climate change on food production and food security in Asia will vary by region, with many regions expected to experience a decline in productivity (Hijioka et al., 2014). Comprehensive reviews in previous Intergovernmental Panel on Climate Change (IPCC) Assessment Reports have showed that higher temperatures will lead to lower rice yields as a result of shorter growing periods (Porter et al., 2014). However, carbon dioxide (CO_2) fertilization may at least in part offset the yield losses in rice as well as other crops. Hasegawa et al. (2013) reported a significant positive effect of elevated CO_2 concentration on the grain yield of rice, which averaged 17% over the four common cultivars based on free-air CO_2 enrichment (FACE) experiments at two sites in Japan.

Although the effects of climate change on precipitation are largely uncertain, water scarcity is expected to be a major challenge for most of the region as a result of increased water demand (Hijioka et al., 2014). Integrated water management strategies could help adapt to climate change, including developing water-saving technologies, increasing water productivity and water reuse.

Contrary to the negative impacts of climate change on agriculture, activities for agricultural production themselves may contribute to the changes of climate system by acting as sources or sinks of atmospheric greenhouse gases. Agriculture, forestry, and other land use (AFLOU) activities are responsible for just under a quarter (ca. 10–12 Gt CO_2eq yr^{-1}) of anthropogenic greenhouse gas emissions mainly from deforestation and emissions from livestock, soil and nutrient management (Smith et al., 2014). All of rice cultivation, enteric fermentation, and manure management systems are major sources of atmospheric methane, whereas fertilized agricultural soils and manure management systems are major sources of atmospheric nitrous oxide. Meanwhile, it is being shown that AFOLU emissions could change substantially in transformation pathways, with significant mitigation potentials provided by agriculture, forestry, and bioenergy mitigation measures (Smith et al., 2014). The enhancement of soil carbon sequestration in crop and forest lands is recognized as one of the promising options to mitigate global warming.

3) Biodiversity

Monsoon Asia encompasses some of the world's greatest biological, cultural, and economic diversity. The vast scale of human activities in this region poses a direct challenge to the resilience of the regional ecosystem. The serious negative effects of these activities are already evident today, as rapid economic development in this region has led to massive changes in lifestyle and increases in correlated indirect drivers of biodiversity loss. In 2008, the highest number of threatened species in the world was recorded in Asia and the Pacific. Many of the most serious problems are found in Southeast Asia, where 6 of the 10 countries in the region have the highest numbers of threatened animal and plant species (UNEP, 2010).

The intensive use of pesticides may harm vital ecosystem services, particularly aquatic fauna like fish and waterfowl (Cochard et al., 2014), and continuing patterns of pesticide use will damage the biodiversity in production areas (Ramsar Convention, 2012). The challenge will be for farmers to intensify production in a sustainable way while meeting the increasing demand for food both in the present and in the future. These concerns have led governments to promote more efficient uses of diminishing resources by farmers (i.e., Save and Grow concept), and better management and use of agro-ecological processes for sustainable intensification of agricultural production. FAO launched the Regional Rice Initiative in 2013 in Indonesia, Lao PDR, and the Philippines to focus on the goods and services produced by and available from rice ecosystems and landscapes so that the farmers could identify and undertake sustainable rice production practices to enhance resilience and increase efficiencies in rice production to improve food security (Abubakar et al., 2015).

Invasive alien species, particularly plants and insects, constitute a substantial threat to agriculture and local biodiversity and their negative impacts can be widespread. The first step in managing invasive alien species is to identify them, including those that have stealthily entered the ecosystems and those that have the potential to do so.

There is an increasing tendency to introduce genetically modified (GM) crops both in domestic production and in imported food and feed crops, such as rice, soybean, and maize. In 2011, five countries in Monsoon Asia (China, the Philippines, India, Pakistan, and Myanmar) grew GM crops domestically, and GM crops might make their appearance in other countries in Monsoon Asia. The country growing GM crops has been improving its management and approval systems while making extensive research progress in developing GM crops and biosafety assessment protocols (Matsuo, 2012).

There are activities to evaluate the effects of environmentally friendly farming on the conservation of both the wildlife inhabiting the agro-ecosystems and the overall biodiversity. To address this issue, a manual that describes indicator animals and explains the survey and evaluation methods used was published as a product of a research project in Japan (Tanaka, 2016).

4) Contamination

Contamination in the agro-ecosystems is caused by the presence of chemicals at hazardous levels in the environment. Sources of contamination of arable land in most Monsoon Asian countries include parent materials, mining and smelting activities, agrochemicals and sewage sludge applications, and livestock manure uses. The causes of diffuse contamination tend to be dominated by heavy metals and other inorganic contaminants, persistent organic pollutants (POPs), and excessive nutrient and pesticide applications.

There is an urgent need to decrease the hazardous heavy metal concentrations of cadmium (Cd), arsenic (As), and other elements, especially in paddy soil and rice grains. Approximately 19% of the farming land in China has high levels of Cd, nickel (Ni), and As, causing an estimated reduction in the food supply of more than 10^7 t annually (Wei and Chen, 2001). In many regions of Monsoon Asia (Bangladesh, India, China, Vietnam, Taiwan, Thailand, and Nepal), the risk management of heavy metal contamination in rice grains is a priority issue posing a great challenge for the population of the region. Several risk minimization methods for Cd and As are introduced in a later chapter of this book as an overview of the state-of-the-art technologies that have been developed in Japan, including breeding cultivars, phytoremediation, and chemical remediation (Makino et al., 2016).

POPs are organic chemical substances that are very resistant to natural breakdown processes, and thus are extremely stable and long-lived. These pollutants accumulate in the fatty tissue of living organisms, and are toxic to both humans and wildlife. The eastern Asian region is a potential source of pollution, particularly by emerging contaminants such as polybrominated diphenyls ethers (PBDEs). This group of contaminants, together with polychlorinated biphenyls, exhibit either decreasing or increasing trends depending on the extent of industrialization in the Asian developing region (Tanabe, 2011). Comprehensive and long-term monitoring programs are still urgently needed with close collaboration and proper capacity building in developing countries to mitigate the emission of POPs and their risk on ecosystems and human health.

The increased use of nitrogen (N) and phosphorous (P) fertilizers has allowed for the increased food production necessary to support a rapidly growing human population, and for increasing the per capita overall consumption of meat and milk in particular (Galloway and Cowling, 2002). However, significant fractions of the mobilized N are lost through emissions of ammonia (NH_3), nitrous oxide (N_2O), and nitric oxide (NO). Also, large fractions of the mobilized N and P in watersheds enter groundwater through leaching and surface runoff, and are transported in freshwater toward coastal marine systems. This has resulted in numerous negative impacts on human health and the environment, such as groundwater pollution, loss of habitat and biodiversity, and eutrophication of surface water and coastal areas.

Negative soil nutrient balances have been reported for N, P, and potassium (K) in many South Asian countries, whereas large excesses of nutrients, in particular N, have caused serious environmental problems in water bodies and the atmosphere in most of the East Asian and some of the Southeast Asian countries (Xiong et al., 2008). Based on the results of a nitrogen flow model, Shindo et al. (2006) suggested that nitrogen loads due to food demand have shown drastic increases in the last several decades in East Asian countries, and these loads will continuously increase until at least 2020.

5) Soil Degradation

The majority of the world's soil resources have been reported to be in only fair, poor, or very poor condition (FAO and ITPS, 2015). Regional soil assessments, such as the Global Assessment of Human-induced Soil Degradation (GLASOD) in the 1980s and an Assessment of Human-Induced Soil Degradation in South and South-East Asia (ASSOD) in the 1990s, revealed that human-induced soil degradation in Asia was the highest amongst all global regions (Oldeman, 1991; van Lynden and Oldeman, 1997). Based on the report by Oldeman (1991), the GLASOD project estimated that the percentages of degraded soils by water erosion, wind erosion, chemical degradation, and physical degradation in Asia (including west Asian countries) were 59%, 30%, 10%, and 2%, respectively. Deforestation was identified as the most dominant causative factor for soil degradation in Asia, followed by agricultural activities and overgrazing.

Based on a recent qualitative assessment of peer-reviewed scientific literature, the most significant threats to the soil functions in Monsoon Asia are soil erosion, loss of soil organic carbon (SOC), salinization/sodification, and nutrient imbalance (Yagi et al., 2015). Serious water erosion occurs in areas of South and East Asia that have pronounced dry and wet seasons, particularly in hilly and mountainous landscapes. The change in SOC in Asian countries differs amongst sub-regions. Increases in nutrient inputs, crop yields, and biomass production result in a retention and sometimes an increase in SOC across the croplands of East and Southeast Asia, whereas the SOC is decreasing in South Asia through the removal of crop residues or through land use change, which presents a major threat. The degradation of grassland has also caused great losses of SOC stock. Throughout the region, the threat of salinization/sodification is very widespread, although to varying extents. In the semiarid and arid zones of central Asia, salt-affected soils are widely distributed. Salt-affected soils also develop in certain coastal areas in the monsoon zones of South and Southeast Asia, mainly through salt water intrusion. Negative soil nutrient balances have been reported for N, P, and K in many South Asian countries, whereas large excesses of nutrients, in particular N, cause serious environmental problems for water bodies and for the atmosphere. Contamination by heavy metals and pesticides, acidification, waterlogging, compaction, sealing, and loss of biodiversity are also identified as threats to the soil. Although limited information is available for soil biodiversity in the region, the greatest potential contributor to soil biodiversity loss in Asia is land use change.

The management of land and water resources has been identified as one of the priority issues for achieving sustainable food security in Monsoon Asia. This requires raising land productivity, reversing land degradation and water loss, and increasing biodiversity and the quality of the environment.

5. Conclusions

Monsoon Asia is blessed with natural resources for agriculture and therefore sustains a large human population. Food production in Monsoon Asia has steadily increased during the last 50 years to meet the demands in the region, as seen by the trends in the per capita production of rice and other cereals. However, as mentioned above, Monsoon Asian countries are currently facing rapid changes in both socio-economical and natural aspects, which have extraordinary impacts on the agro-environment in the region. Rapid economical development and urbanization are changing land use and management systems in many countries. Climate change is an additional source of the risks. These impacts have extended to the status of agriculture and food production and may limit the future increase of food production to meet the demand in the region. Therefore, the researchers, engineers, and administrative authorities of this region must develop close international collaborations to meet the region's growing agricultural needs, while harmonizing these human systems with the natural systems that support them.

To meet this requirement, the Monsoon Asia Agro-Environmental Research Consortium (MARCO) was organized through an agreement among the participants at an international symposium entitled "Evaluation and Effective Use of Environmental Resources for Sustainable Agriculture in Monsoon Asia: Toward International Research Collaboration," held in December 2006 in Tsukuba, Japan. Since then, MARCO has promoted international collaboration to advance research on agricultural and environmental issues in Monsoon Asia by hosting 40 international symposia or workshops in the last 9 years (see Annex of this book), setting up a website as a venue for exchanging information, and helping train the people who will carry on the activities proposed by the consortium. Because the challenges lying ahead of us are still immense, further promotion to strengthen the collaboration to address the agro-environmental challenges in Monsoon Asia is essential.

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