Project Homepage ● http://www.chikyu.ac.jp/iccap/

Impact of Climate Changes on Agricultural Production System in the Arid Areas

This research project aimed at identifying the direction and dimensions of the potential impacts of climate changes and ensuing adaptations in the agricultural production systems of arid regions, where water resources are limited, based on the projection of future regional climate changes on the eastern coast of the Mediterranean Sea, the case study region. While the relationship between climate and agriculture in the past and present was analyzed, the impact of climate changes, including rise in air temperature, decrease in precipitation and sea-level rise, on agricultural production systems were assessed. The project was implemented as an international joint project in cooperation with the Scientific and Technological Research Council of Turkey.

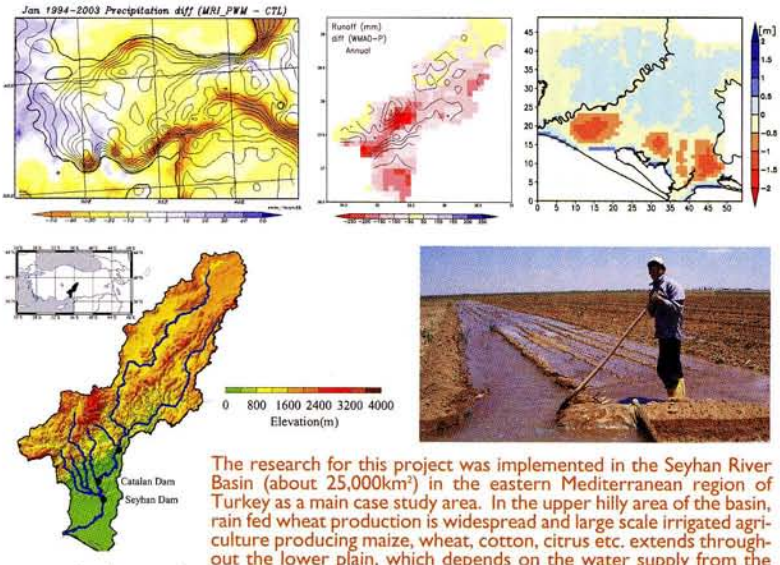
Project Leader ■ **WATANABE, Tsugihiro** RIHN

Summary of Research Outcomes

Climate change in the 2070s in the Seyhan River Basin was projected by using the latest climate model, and impacts of climate change on the condition of the river basin and agricultural production were assessed through generated climate change scenarios. The results showed the possibility of temperature increases of 2 to 3.5 degrees throughout the year and decreases in precipitation of about 20% except during summer.

The developed crop model predicts future increased wheat yields, which is a main crop in the region, with higher temperature and increased CO_2 in the 2070s. The projected decrease in precipitation will not affect the yield of wheat significantly. And, a decrease in precipitation will cause a decrease of water resource availability, resulting in water shortages and crop damage according to selection of crops and the expansion of the irrigated area.

Figure Assessment of Global Warming Impacts in the Seyhan River Basin of Turkey



The research for this project was implemented in the Seyhan River Basin (about 25,000km²) in the eastern Mediterranean region of Turkey as a main case study area. In the upper hilly area of the basin, rain fed wheat production is widespread and large scale irrigated agriculture producing maize, wheat, cotton, citrus etc. extends throughout the lower plain, which depends on the water supply from the reservoirs that receive run-off of winter precipitation in upper mountainous areas. The climate scenarios for the 2070s were generated by using the developed local climate model. (Top-left: an example of the future precipitation change in January. Blue shows increases and brown shows decreases). The basin model predicted the future changes of the hydrological regime along with the climate scenarios. (Top-center: predicted changes in annual runoff yield. Blue shows increases and red shows decreases). The future crop growth and water balance in the farmland were predicted based on these conditions. (Top-right: change of average groundwater table in the lower basin. Blue shows future rise and red shows decline).

"Projection" or prediction is a discussion with piling up probable conditions and available information, and it could be recognized as a kind of thought experiment. An adaptive management approach like "Mitameshi" (watching and trying-out) is essential to account for the uncertainty of a human-nature system, when its resultant changes can not be simulated and predicted precisely since repeated experiments are not possible.

Contribution to Better Solutions for Global Environment Problems

Climate change due to global warming will affect the natural conditions for agriculture like land and water resources and consequently impacts agricultural production. With these impacts, humans may act to adapt to the changes or to mitigate the damage caused by climate change. These human reactions may result in other changes in the environmental problems. Therefore, for better solutions to the problems, it is essential to understand and project the impacts of climate change on agricultural production, and to let local knowledge and systems react to the changes. In this project, a method to diagnose the problems of land and water use and identify the crucial points was developed. In Turkey, where the case study area was located, the project provided the opportunity to establish new research organizations and a cross-disciplinary approach to the problem, and promoted enhanced consciousness of the importance of impact assessment of global warming on basin hydrology and agriculture.

Disseminations of the Project Outcomes

The outcomes of the project are disseminated to the public, in the shape of books, lectures, reports, etc., inside and outside Japan. The project participants have published scientific papers on the research results in academic journals and international conferences, and will continue to do so as well. In Turkey, the project held a symposium on land and water management, and provided a television program with the research outcomes. In addition, the method developed by the project and the results are being supplied to international organizations and research initiatives.

Project Homepage● http://www.chikyu.ac.jp/Project2-1/index.html

Emissions of Greenhouse Gases and Aerosols, and Human Activities in East Asia

The recent growth of economy in East Asian region is being watched with keen interest. The relationship between human activities and emissions of greenhouse gases and aerosols in this region are studied with collaboration of socioeconomic analysts and atmospheric scientists. This research project consists of macro-analysis of economy, development of emission inventory, analysis of atmospheric transport by using model and satellite data, and ground-based observation around Japan and China.

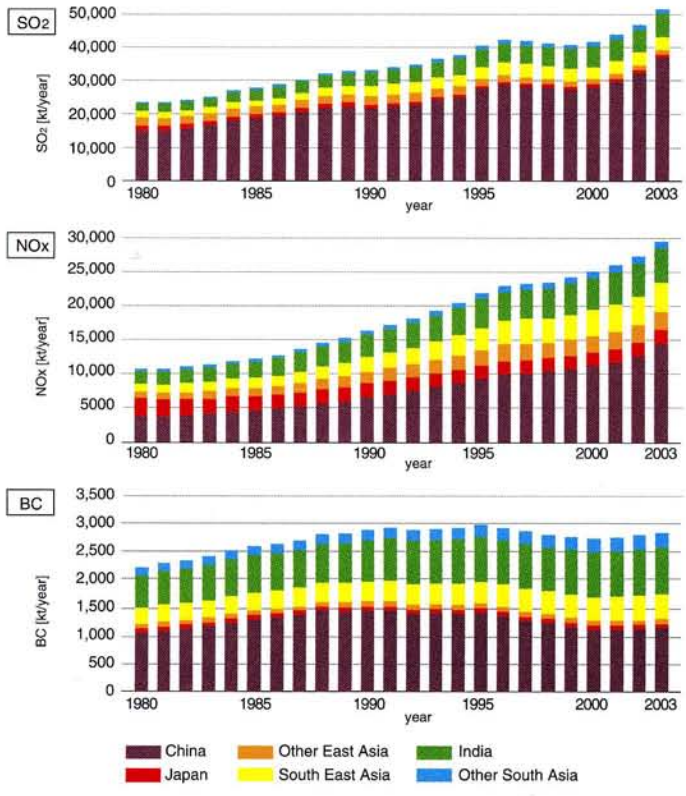
Project Leader ■ **HAYASAKA, Tadahiro** RIHN

The present study focused on East Asia, especially China, for the past few decades to investigate (1) the relationship between changes in human activities such as economy and industry and the change in emissions of anthropogenic gasses and aerosols, and (2) the influence of the emitted gases and aerosols on climate change and air pollution.

The macroanalysis of economy was performed as planned. The economic development in East Asian countries led by industrialization brought increases in energy consumption and emissions of CO_2, SO_2 and others. However, SO_2 emissions have not increased as much as expected. The emission density of CO_2 has not increased or has decreased due to an improvement in energy efficiency.

The emission inventory was developed according to the initial plan, which includes anthropogenic greenhouse gases, aerosols, and precursors of aerosols for the period, 1980-2003. Figure 1, for example, shows changes in the amounts of emitted SO_2, NOx, and Black carbon (BC) in Asia.

Figure 1 Changes in the Amount of the Emission of SO_2, NOx, and Black Carbon (BC) in Asia



The analysis of emitted anthropogenic gases and aerosols was performed with observations and atmospheric transport models. The observations of greenhouse gases were carried out in China and around Japan. The observations of aerosols were carried out mainly in Japan. The results of those observations were consistent with the emission inventory.

The results show that aerosol loading increased with an increase in fossil fuel consumption in China and other Asian countries and air pollution also increased, and thus surface shortwave irradiance decreased. However, the surface air temperature increased in almost all regions of China for the past 40 years, because of increasing greenhouse gases and a complicated climate system.

Project Homepage● http://www.chikyu.ac.jp/biwayodo/index.html

Multi-Disciplinary Research for Understanding Interactions between Humans and Nature in the Lake Biwa-Yodo River Watershed

The differences in problem consciousness among various stakeholders occurring from "hierarchy" of a watershed could be a major hindrance to governance, leading to conflicts between top-down and bottom-up Management. We proposed a system of "hierarchical watershed management" to overcome the restrictions derived from these hierarchical characteristics (Figure). Based on this idea, we conducted research on the agricultural turbidity problem in the Lake Biwa watershed to develop a methodology for environmental diagnosis and consensus building with an emphasis on communication. Our project is unique in 1) developing a new methodology to promote governance and participation of residents by 2) our transdisciplinary approach to natural science and social science 3) practiced in three scales in the Lake Biwa watershed (Shiga prefecture as macroscale, Inae district as mesoscale, local communities in Inae district as microscale, 4) moving towards practical watershed and global environmental studies.

Project Leader ■ **YACHI, Shigeo** RIHN

Specific Research Findings

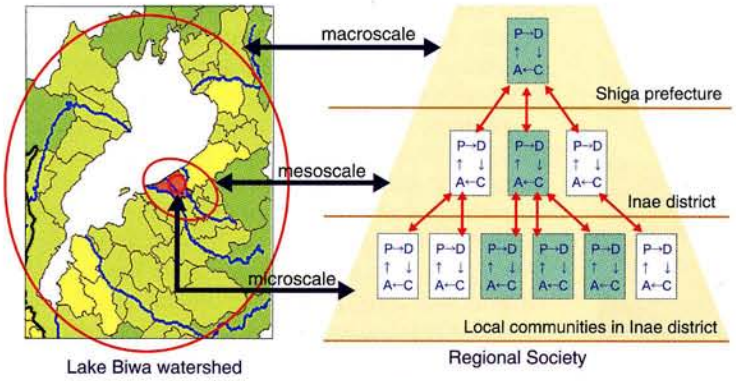
(1) A new watershed diagnosis method revealing the relationship between Lake Biwa and its rivers

The results of newly developed watershed diagnosis methods including stable isotope ratios and rare elements indicate that agricultural activities related to smaller rivers flowing into the eastern part of the lake have a large potential impact on the water quality and eutrophication of Lake Biwa, and that fine-tuned water management and water channel cleaning by local residents through a bottom-up approach is both effective and necessary for the environmental preservation of Lake Biwa.

(2) Clarification of an integrated picture of the agricultural turbid water problem and establishment of a communication methodology to support local residents' voluntary environmental preservation activities

In the background of the agricultural drainage issue, lies a drastic change of Japan's agricultural policy and agricultural community structure, which caused an increase in part-time farmers and decrease in young farmers. A workshop method was developed to support residents themselves discussing the local water environment and its future prospects using maps. Practical workshops were held to confirm how the provision of information related to the current status of the water environment or measures for water environmental preservation would affect the farmers' awareness of environmental considerations or their actions. These results indicate the need to develop a communication method based on the assumption of the individuality of the community and the importance of conditions such as social capital that allow such a method to work effectively.

Figure Hierarchical Watershed Management System Applied to Lake Biwa Watershed in the Case of Agricultural Turbidity Problem



Shiga prefecture, Inae district (region colored ■) and local communities in Inae district indicated by red circles (left) and green boxes (right) are regional stakeholders concerning the agricultural turbid water problem, however, their consciousness of the problem is not the same. The hierarchical watershed management system is a mechanism to promote watershed management by governance of the various stakeholders in the region by building 1) feedback mechanism (PDCA cycle) consisting of monitoring with diagnosis indicators at each scale, and 2) mechanisms to promote communication between hierarchies (indicated by red arrows).

Contributions to Global Environmental Studies

There are two important issues that must be dealt with if we are to solve global environmental problems: (1) a watershed area is important in terms of scale. Dealing with it not only solves regional environmental problems but also constitutes a test bed for specific solutions to global environmental problems; and (2) It is essential to appropriately coordinate various stakeholders with various patterns of involvement in the environment that are deeply rooted in the area. Although this project has the methodology for watershed management as its main theme, we believe the project provided a prototype methodology which can contribute to the way we consider and solve global environmental problems.

Communication of Research Findings

The project final report (in Japanese, ISBN 4-902325-11-X) is now available at University libraries in Japan and at the libraries of cities and towns in the Shiga prefecture. In it, 5-year transdisciplinary research on watershed management is compiled as a first step to "watershed environmental studies" with close connection to global environmental problems. Readers will find not only the new research findings but also the message and dynamism of the project emphasizing the importance of practice in regional societies, the social meaning of transdisciplinary collaboration, d academic and social issues to be challenged.

Project Homepage ● http://www.chikyu.ac.jp/oasis/

Historical Evolution of the Adaptability in an Oasis Region to Water Resource Changes

The Oasis Project is a research project aiming at reconstructing the history of the interaction between people and nature for the last 2000 years in a Chinese arid region. The project adopts a trans-disciplinary approach, integrating the studies of history, archeology, ethnology, economics, hydrology, meteorology, climatology, glaciology, biology, and agriculture. The major research field has been in and around the Heihe region in central Eurasia, where outstanding human cultures have developed for the last 2000 years.

Project Leader ■ **Nakawo, Masayoshi** RIHN

Research Content

The history of the region has been reconstructed by examining historical documents, and a variety of proxies such as ice cores from glaciers, tree-ring samples, and lake sediment cores. The water circulation system in the basin, water resources and demands placed on them has been also studied.

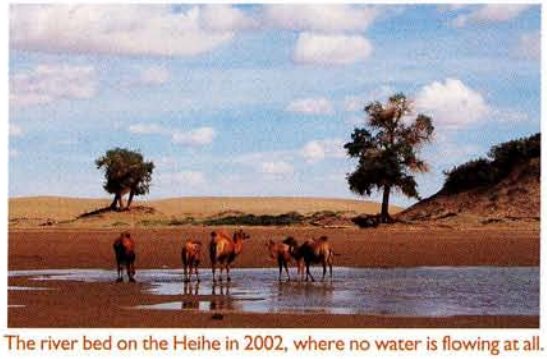
The Outline of the Research Results

The Heihe Basin is a region where farming was developed by numerous colonial soldiers sent there to confront the Huns during the Han Dynasty 2000 years ago. At that time, the area of the Juyanze Lake was as large as 1600 km^2. The lake area started decreasing thereafter, and this is considered to be due to the development of irrigated farmland. Thereafter, the region's population fell temporarily, but increased during each of the following dynasties: Tang, Xixia and Yuan.

Three-dimensional views helped identify the geographical extent of the agricultural lands around Kara Khoto during the Xixia and Yuan Dynasties in the period when Kara Khoto flourished. It was approximately twice the size of the modern Ejina Oasis.

Ice core analysis showed that the air temperature from the end of the Yuan through the early Ming dynasties gradually fell. In other words, the volume of river flow per annum became less than the total annual precipitation concomitant with the growth of the glaciers due to the cooling effect.

Also, it became clear that many large-scale water routes were constructed during the Yuan Dynasty, and were used to develop vast tracts of agricultural land. This development of farmland definitely increased the volume of water drawn from the river around the oases, and consequently the downstream region of Kara Khoto was visited with water shortages.



The river bed on the Heihe in 2002, where no water is flowing at all.

At present, water shortages are again evident. Nearby vegetation is on the verge of crisis. Juyanze is also a shadow of its former self. The cause, basically, is the increase in the volume of water drawn from the river for irrigation farming at the oases, since water supply from the mountains has increased lately.

Two countermeasures to this problem have been established: forestation, and limits to the water drawn from the river in the mid-flow basins. Accordingly oasis farmers, for whom the volume of water they can take has been reduced, have come to dig wells to use the subterranean aquifers to augment their shortages in order to maintain their arable land. For forestation, a policy of "Ecological Relocation", in which herdsmen from the foothills of the mountains are moved to the area around the oasis, has been adopted. The displaced herdsmen, however, have to develop fresh arable land to graze their animals. Although only natural, their new farming regions need water. Hence, the oases need more water now than ever, and shallow wells in the downstream area and even around the midstream region of Zhangye have started to dry up. To supplement this, an abundance of deep wells are now being dug. The water, however, has started to be used in abundance. This is considered the major problem at the moment.

In the Heihe Basin, people have solved the problem of water shortages caused in the region (system) where they live, by expanding the area of the system. Drawing irrigation water from upstream of the Heihe River expands the area on which their livelihoods depend.

Recently, however, surface water has all been used up, and the system has been expanded to include the subterranean world as well. This fact also means that the range of the system on which people's livelihoods depends has expanded to a global scale. That is to say, our system has expanded as far as it can go, and it can only be said that we have now reached an era in which existing methods for solving problems by expanding the range of a system can no longer be used.

We have to find, therefore, completely different methods for solving problems that do not rely on solutions based on expanding the existing system. We are living in just such an age.

Global Water Cycle Variation and the Current World Water Resources Issues and Their Perspectives

It is alleged that the 21st century is the "century of water." Wars over water may occur, like those fought over oil in the last century. The rapid increase in population and the coming global climate change could cause water scarcity. This project attempts to develop global perspectives of such water resource issues by integrating field observations, predicting natural water cycles and human water usage in the future, and by establishing guidelines for sustainable development from the viewpoint of water resource issues.

Project Leader ■ **KANAE, Shinjiro** RIHN

Specific Research Findings

Regarding the primary goal, which is, "showing perspectives and making projections", we have succeeded in positioning our research on the cutting-edge, with the finest estimation and projection of global water cycles and resources in the world. For example, we successfully reproduced the daily fluctuation of land hydrological cycles through the past 100 years for the first time in the world. At the same time, we made a projection of land hydrological cycles for the next 100 years. Moreover, by estimating current and future water demands through an integration of all the estimations above, we have calculated current and future water stress on a global scale.

Contribution to "Earth-Environment Study"

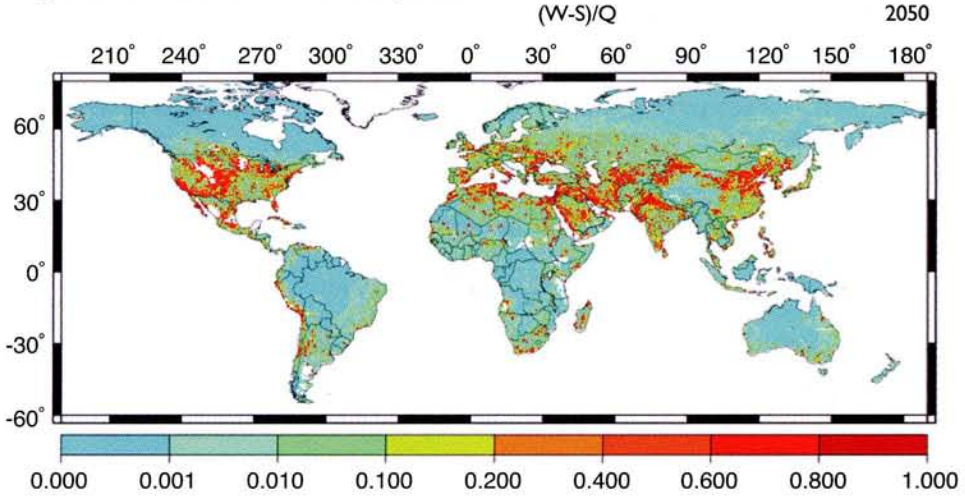
We have succeeded in making an estimation and projection of global water cycles and resources paying attention to the interaction between humans and nature. It is, however, on a local scale that such an interaction is considered in the study of water circulation and water budgets. This interaction, especially on a global scale, has been overlooked. In this sense, our results can be a model of "Earth-Environment Study." Besides, we also carried out research that dealt with specific areas with water problems, such as Thailand and California.

Studies that analyzed policy tools for preventing water conflict and water shortage are additional examples of an interdisciplinary analysis.

Communication of Research Findings

Dr. Taikan OKI, the former leader and currently a core project member, was chosen as the lead author of the IPCC AR4 and the Millennium Assessment. Also our paper in Science has effectively promoted the achievement of this project. Moreover, our achievement on virtual water has been widely disseminated in domestic society through multiple media and a "White Book" on water resources made by the Japanese government. We hope our research results (**Figure 1**) become a seed for ideas for coming water-related projects.

Figure Annual Withdrawal to Availability Ratio



The map shows the quotient obtained by dividing (expected water consumption for 2050) by (water availability forecast for 2050) of each geographic area. The quotient is high in areas painted red or yellow, in which available water is expected to be almost used up. In other words, red and yellow areas are candidate water crisis "hot spots."