2.7 Activities of Foreign Researchers

(1) Associate Professor Mehmet Aydin

Visiting Associate Professor (September 2002-August 2003)
Mustafa Kemal University, Faculty of Agriculture, 31040, Antakya, Turkey.
Title: *Modelling impact of climate change on agricultural production*

My activities have been performed mainly in the Subdivision of Water Resources, headed by Prof. T. Yano.

Summary of research activities

My research activities have been focused on two major topics: 1) Modelling impact of climate change on agricultural production in arid areas, 2) Effects of saline irrigation on root water uptake. These topics are related to the ongoing research program at the Arid Land Research Center (ALRC).

Seminars

1. Quantitative description of root-water uptake under field conditions. Department of Agricultural and Environmental Biology, Graduate School of Agricultural and Life Sciences, the University of Tokyo. February 13, 2003.
2. Estimation of actual evaporation from bare field soil. Arid Land Research Center, Tottori University. February 26, 2003.
3. Quantification of water uptake by roots from individual soil layers. Arid Land Research Center, Tottori University. March 19, 2003.
4. A model for evaporation from bare soil and experimental verification. ICCAP Research Meeting for Impacts of Climate Changes on Agricultural Production in Arid Areas (ICCAP). Research Institute for Humanity and Nature (RIHN), Kyoto. May 08, 2003.
5. The relationships between soil hydraulic conductivity and zeta potential. Department of Agricultural Sciences, Saga University. July 11, 2003.
6. Experimental evidence for soil hydraulic conductivity and electrophoretic mobility relation. Arid Land Research Center, Tottori University. July 16, 2003.

Lectures

A series of informal lectures were given to graduate students of the Water Resources Subdivision:

1. Soil-water content/potential
2. Saturated and unsaturated hydraulic conductivity
3. Quantification of soil-water flux in plant rooting zone
   a) Water flux through the soil matrix (upward flux, downward flux)
   b) Water flux through the plant roots

Assistance to students, and editorial activities

1. Advising the M. Sc. thesis research work of one student (Mr. Yoshihiro Egami).

2. Editing the Ph. D. thesis (in English) of Mr. S. L. Yang.

Participation in national and international meetings

1. Annual Joint Research Symposium of the Arid Land Research Center, Tottori University. ALRC, Tottori-shi, December 3, 2002.
2. International Workshop: Impacts of Climate Changes on Agricultural Production in Arid Areas. Research Institute for Humanity and Nature (RIHN), Kyoto. January 22-23, 2003.

Professional meeting

1. Round-table discussions: Impact of climate change on agricultural production in arid areas. RIHN, Kyoto. September 26-27, 2002.
2. The University of Tokyo, Graduate School of Agricultural and Life Sciences. Exchanged information on root water uptake with Dr. J. Abe (Department of Agricultural and Environmental Biology) and Dr. A. Kamoshita (Field Production Science Center). Met with Prof. T. Miyazaki and his research students. Exchange concepts and views in zero flux plane. Department of Biological and Environmental Engineering. February 13, 2003.
3. Discussions with Prof. A. Yoshinaga and Dr. Md. A. Hossain on water saving techniques in arid areas, Faculty of Agriculture, University of the Ryukyus, Nishihara-cho, and technical tour to erosion control parcels near Nago-shi, Okinawa. March 25, 2003.
4. Meeting with Prof. J. Chikushi on environmental issues in Japan and Turkey. Kyushu University, Biotron Institute, July 11, 2003.
5. Visited Department of Agricultural Sciences, Saga University. Met with Drs. H. Cho and N. Toride, and technical tour to the polder land around Ariake Bay, western Kyushu. July 12, 2003.
6. Visited Faculty of Environmental Studies, Nagasaki University. Met with Dr. T. Shimomachi and exchanged concepts and views in research activities of mutual interest. July 13, 2003.

Participation in preparation of proposals for an international project

The following project proposals were prepared in close collaboration with Turkish colleagues and Prof. T. Yano for submitting to the Scientific and Technical Research Council of Turkey (TUBITAK): Impact of Climate Change on Agricultural Production in Arid Areas (Joint Research Project of RIHN-Japan and TUBITAK-Turkey): (1) Simulation of soil-water-climate and plant relationships in Seyhan Plain under changing global climate, (2) Quantification of C and N dynamics in croplands of Seyhan watershed in changing global climate and land uses.

Publications

1. Aydin, M., Yano, T., Kilic, S., 2003. Dependence of zeta potential and soil hydraulic conductivity on adsorbed cation and aqueous phase properties. Soil Sci. Soc. Amer. J. (accepted for publication).
2. Aydin, M., 2003. Modelling impact of climate change on agricultural production. Proceedings of the International Workshop for the Research Project on the Impact of Climate Change on Agricultural Production System in Arid Areas (ICCAP). Research Institute for Humanity and Nature, Kyoto. January 22-23, 2003. pp. 13-16.
3. Evrendilek, F., Kilic, S., Aydin, M., 2003. Quantifying ecosystem productivity of Seyhan watershed under human disturbances. Proceedings for the ICCAP Workshop. Research Institute for Humanity and Nature, Kyoto. January 22-23, 2003. pp. 17-21.

4. Kanber, R., Aydin, M., Unlu, M., Koc. M., 2003. Implementation project involved in ICCAP on simulation of soil-water-climate and plant relationships in Seyhan plain under changing global climate. Proceedings of the ICCAP Workshop. Research Institute for Humanity and Nature, Kyoto. January 22-23, 2003. pp. 22-30.
5. Yang, S. L., Yano, T., Aydin, M., Kitamura, Y., Takeuchi, S., 2002. Short term effects of saline irrigation on evapotranspiration from lysimeter-grown citrus trees. Agric. Water Manage. 56(2): 131-141.
6. Yang, S. L., Aydin, M.**,** Yano, T., Li, X., 2003. Evapotranspiration of orange trees in greenhouse lysimeters. Irrig. Sci. 21: 145-149.
7. Aydin, M., Yang, S.L., Kurt, N., Yano, T., 2003. Test of a simple model for estimating evaporation from bare soils in different environments. Ecological Modelling (submitted).

Articles under preparation

8. Yano, T., Aydin, M., Yang, S.L., Zero flux plane in a dune sand cropped with maize.

Research results

1. Modelling impact of climate change on agricultural production

This study deals with the interrelationships among regional climate change, basin hydrology, crop production, irrigation system, and agricultural economics. A flow chart (framework) was built to develop a simulation model for quantitative analyses of relationships among climate change prediction, regional hydrological regime, micrometeorology, soil salinity, crop response (water consumption and growth), irrigation water demand and farming system. Within this framework, conceptual models of all topics were designed to get necessary feedback from others. (The outcomes of the study were presented at International Workshop: Impacts of Climate Changes on Agricultural Production in Arid Areas. Research Institute for Humanity and Nature (RIHN), Kyoto. January 22-23, 2003).

2. Evaporation from bare soils: model and experimental verification

A simplified model originally developed by Aydin (Proc. International Symposium and 2nd Chinese National Conference on Rainwater Utilization, Xuzhou-Jiangsu, China. pp. 283-287, 1998) for estimating actual evaporation from bare soil was tested under different environmental conditions. Field experiments were carried out on clay soils in a semi-arid region of Turkey. A sandy soil column-experiment in a drying chamber and a study with the same sand media in a greenhouse was conducted at Arid Land Research Center, Tottori University – Japan, in order to test the performance of the model. The model is based on the relations among potential and actual soil evaporation and soil water potential at the top surface layer of the soil, with some simplifying assumptions. Input parameters of the model are simple and relatively obtainable viz. climatic parameters for the calculations of potential soil evaporation and matric potential measured near the soil surface. Despite of some differences between calculated and measured soil evaporation, the agreement was reasonable at all sites. This agreement seems to support the model assumptions, and the model is potentially valuable, but the objective measurement of soil water potential near the surface of the profile is difficult especially for drier upper layer.

3. Effects of saline irrigation on water uptake by maize roots

A lysimeter experiment was designed in order to investigate root water extraction under saline conditions. This research is currently performed with Professor Yano and the master student, Mr. Egami. Three weighing lysimeters installed in a greenhouse were filled with sandy soil. The soil is an Arenosol

(siliceous sand, Typic Udipsamment). Average dry bulk density of the sand in lysimeters is 1.50 g/cm^3. The Maize will be planted in the lysimeters and surrounding area in spring. Three treatment regimes (two salinity levels of irrigation water, and control) will be applied to three respective lysimeters equipped with TDR sensors and soil moisture probes. The results will be reported in a M. Sc. thesis (Mr. Yoshihiro Egami).

(2) Associate Professor Kamal El-Siddig

Visiting Associate Professor (October 2002-September 2003)

Agricultural Research Corporation (ARC), Sudan

Title: *Biochemical responses to salt and water stress in seedlings of Psidium guajava, Grewia tenax* and *Tamarindus indica.*

Broadly, I am interested in physiological and biochemical characteristics of woody plants that confer salinity and/or drought tolerance. I work from the whole plant level down to the molecular level in order to identify physiological and biochemical variations in response to abiotic stresses. The results of this work are multifaceted: 1) to learn how physiological and biochemical processes are integrated into growth responses under stressful conditions, 2) to elucidate the role of organic and inorganic solutes in mediating osmotic adjustment during the stress, and 3) to integrate this information into a predictive model which will help identify rapid methods of clonal selection of tolerant genotypes under stress conditions.

Summary of experimental results

1. Response of Tamarindus indica L. to iso-osmotic solution of NaCl and PEG during germination

The effect of reduced external water potentials (0, -0.3, -0.6, -0.90, -1.20 MPa) generated by either NaCl or polyethylene glycol-6000 (PEG) on water uptake and germination characteristics of Tamarindus indica seeds were investigated under laboratory conditions. Water uptake and final germination percentage (GF) decreased, while number of days to 50% germination (D50) and mean germination time (MGT) increased significantly with reducing osmotic potentials of both NaCl and PEG. At each iso-osmotic solution, PEG appeared to be more inhibitory to water uptake than NaCl, especially at the lowest water potential (-1.3 MPa). At this water potential, no germination was observed in both NaCl and PEG solutions. At all other treatments, NaCl resulted in lower, GF and higher D50 and MGT values than did iso-osmotic solutions of PEG. These results suggest that the main effect of PEG occurred via an inhibition of water uptake while detrimental effects of NaCl may be attributes mainly to accumulated toxic ions.

2. Growth and photosynthesis of tamarind (*Tamarindus indica* L.) seedlings subjected to repeated cycles of water stress.

Growth, photosynthesis and water relations were studied in 4-months old tamarind (Tamarindus indica L.) seedlings exposed to 4 drought cycles extending over a period of 32 days. Each drying cycle lasted to

the point of passive leaf wilting. Total, leaf, stem and root dry biomass of WS seedlings decreased to approximately 69%, 70%, 72% and 83% of the control seedlings, respectively. Thus the growth decrease in WS plants was related mainly to growth inhibition of aboveground parts and, to lesser degree, to a decrease in root growth. In WS seedlings, root/shoot ratio was 0.25 compared to 0.21 for the control plants. This may indicate adjustment in biomass allocations pattern to favour root tissues at the expense of shoot tissues. Greater root biomass will tend to increase the capabilities of water uptake while at the same time lower shoot biomass would be expected to reduce the amount of water loss due to an expected smaller leaf area. Net photosynthetic rate (A), transpiration rate (E) and stomatal conductance (g_s) of WS plants decreased progressively with time while those of WW plants showed only minor changes (Fig. 3). A of WS did not differ significantly from that of the control plants until day 4 after withholding water, but E and g_s were reduced to about 65% and 68% of the control, respectively. The effect of drought stress on these parameters became evident on day 6 of both drought cycles. In the 1st drought cycle A, E and g_s of WS plants were reduced to approximately 75%, 63% and 58% of the control plants, respectively. The effect, however, was transient, and A, E and g_s returned to near pre-stressed levels 2 days after re-watering.

3. Drought tolerance of *Grewia tenax*: A potential new small fruit for the Sudan

Six provenances from diverse geographical origins were chosen to represent the natural range of this species in the Sudan. When 4-month-old, half of the seedlings were watered regularly in order to keep the plants near maximum retention capacity (Well-watered, WW). The other half was subjected to repeated drought cycles by withholding water until at least one plant exhibited signs of wilting or leaf rolling, particularly in the morning, and then re-watered to near maximum retention capacity (Water-stressed, WS). There were 4 drought cycles ranging between 6 and 7 days in length and extending over a period of 26 days. Significant provenance variation was established in total dry biomass under both WW and WS conditions. Under WW, SK-C had the highest and ND-R the lowest dry biomass, while under WS treatment, SD-C had the highest and ND-R the lowest dry biomass. The magnitude of biomass reduction was not similar among provenances. It varied between 28% in SD-S to 9% in WK-R. These results suggest that under WW conditions seedlings from less dry sites grew faster than did seedlings from dry sites. An exception to this is the ND-C (xeric habitat) with dry biomass comparable with those from less xeric habitats. However, seedlings from less dry origins suffered more biomass reduction under WS than those from dry sites. Drought-induced reductions in biomass of ND-R and ND-C (dry origin) was most pronounced in above- than below-ground parts, causing an increase in root: shoot ratio. The ability of the provenances from drier sites to proportionally increase root growth in drought condition is crucial. Reallocating carbon away from shoots to roots seems to be a dehydration tolerance adaptation important for survival and natural distribution in dry habitats.

Manuscripts Submissions/ Preparations

El-Siddig, K., G. Ebert, A.M. Ali and S. Inanaga. Salt Effects on Emergence and Early Seedling Growth of Tamarindus indica L. (Europ. J. Hort. Sci.).

El-Siddig, K., B.A. El Tahir, G. Ebert and S. Inanaga. Grewia tenax: A potential New Small Fruit for the

Sudan (Appl. Bot.).

El-Siddig, K. and S. Inanaga. Response of Tamarindus indica L. to iso-osmotic solutions of NaCl and PEG during germination (J. App. Bot.).

El-Siddig, K., T. Inoue and S. Inanaga. Growth and Photosynthesis of Tamarindus indica L. Seedlings subjected to repeated cycles of water Stress (in preparation).

El-Siddig, K., S. Inanaga. Growth and photosynthesis of Grewia tenax subjected to repeated cycles of water stress (in preparation).

El-Siddig, K., S. Muranaka and S. Inanaga. Provenance variation in drought tolerance of Grewia tenax (in preparation).

El-Siddig, K., P. Gama and S. Inanaga. Promotive effects of auxins on rooting of stem cutting of Grewia tenax (in preparation).

Symposiums and Conferences

1. Salinity Problems in the Sudan. Special lecture delivered at the Joint Research Symposium, December 3, 2002. Arid Land Research Center, Tottori.
2. Grewia tenax: A potential New Small Fruit for the Sudan. Poster presented at the “Deutsche Tropentag”, Geottingen, Germany, 8-11 October 2003.
3. Drought Tolerance of Grewia tenax: A potential New Small Fruit for the Sudan. Poster presented at the “Deutsche Tropentag”, Geottingen, Germany, 8-11 October 2003.

Lectures and Seminars

1. An overview of scientific cooperation between the ALRC and ARC, presented on the occasion of the visit by H.E. the Minister for Science & Technology, Sudan. Arid Land Research Center, Tottori. December 15, 2002.
2. Use and Potential of Indigenous Underutilized Crops of the Sudan. A lecture presented at the Arid Land Research Center. May 30, 2003.
3. Tamarind (Tamarindus indica), A multipurpose tree for diverse environments. A lecture presented at the Arid Land Research Center. August 23, 2003.

Editing activities

During my stay I edited a large number of English manuscripts for the staff and students of the Center prepared for submission to scientific journals, conference presentations and reports.

Scientific Visits

1. Kobe University, Faculty of Agriculture, Water Environment Laboratory, Prof. Hata and Dr. Hadi. 16-18 March 2003.
2. Kyoto University, Attendance of the Third World Water Forum, Session on Participatory Water Management. 19-21 March 2003.
3. Tsukuba, Office of International Coordination National Institute for Environmental Studies (Dr. Shimizu and Dr. An, Ping) and JIRCAS, 27-30 August 2003.
4. Kobe University, Faculty of Agriculture, Water Environment Laboratory, Prof. Hata and Dr. Hadi. 01 September 2003.

Acknowledgements:

I wish to sincerely thank Prof. Dr. S. Inanaga, Director Arid Land Research Center, for offering me the opportunity to be associated with this esteemed center during 01 October 2002-30 September 2003. I should particularly like to thank all the students of the Ecophysiology Laboratory for their continuous help during my stay, I should particularly like to thank the staff of the Administrative section, who spared no efforts to make my stay enjoyable and successful. Special thanks go to Miss Kyoko Takahashi for helping us get started the day-today life in Japan, and thereafter.

(3) Professor Menachem Agassi

Visiting Professor (June 2003-May 2004)

Soil Erosion Research Station, Ministry of Agriculture, Israel

Title: *Improvement of salinity soil by mulching organic matter.*

Summary of research activities of 8 months

The basic principles and processes of soil's water evaporation was presented and discussed with the staff of the Division of Forestation and Land Conservation (DFLC), during several sessions. The idea of using aluminum coated plastic membrane (ACPM) as a mulch to reduce evaporation of soil's water and the consequences of this potential technique on the crops and the farming system was intensively discussed at the same forum. In cooperation with Assoc. Prof. Inoue, M. and Ms. Kurata, Y., a research program, studying the efficiency of ACPM in reducing evaporation of soil's water, was designed. At the first stage, the effect of ACPM on soil temperature was studied in Tottori sand dune field. At the second stage, the efficiency of ACPM in reducing evaporation of water from Tottori sand dune soil, under laboratory conditions, is recently under study.

Titles of articles which is related to my work in ALRC

1. Ravolonantenaina, A.H., Yamamoto, T., Dehghanisanij, H. and Agassi, M. 2003. Rural development with borehole project for potable water in Mahajanga, Madagascar. Paddy and Water Environment (submitted).
2. Yamamoto, T., Dehghanisanij, H. and Agassi, M. 2003. Soil degradation rehabilitation techniques for irrigated agriculture in arid lands. Journal of ISSAAS (submitted).
3. Dehghanisanij, H., Yamamoto, T., Inoue, M. and Agassi, M. 2004. Water flow and solute transport under drip irrigation in sand dune field. Irrigation Science Journal (submitted).

* Liu, Y., Yano, T., Nishiyama, S. and Kimura, R. 2003. Radiometric correction for linear change detection techniques: analysis in bi-temporal space. Journal of Remote Sensing (submitted). I reviewed

this article.

Results of my research work in ALRC

The summer field experiments in regard with the efficiency of the ACPM in reducing soil temperature were very successful. Mulching of the soil surface with ACPM reduced the maximum soil temperature, in the first 2 cm deep from 46 ° in the control to 42 and 37 ° in the 50 and 100% ACPM mulch, respectively. The ACPM was still effective in reducing soil temperature in the soil layer bellow 10 cm, and 36 and 32 ° in the control and 100% mulch, respectively. However, there was no effect in the 20 cm soil layer.

The laboratory winter experiments, in regard with the efficiency of ACPM in reducing soil water evaporation were very successful. After 168 hours the water loss by evaporation was 64 and 12% compare to the control for the 50 and 100% ACPM mulch treatments, respectively.

The winter experiments set up will be improved based on the experience we gained so far.

(4) Associate Professor Zhongmin Xu

Visiting Associate Professor (October 2003-September 2004)

State Key Laboratory of Frozen Soil Engineering,

Cold and Arid Regions Environmental and Engineering Research Institute, C.A.S., China

Title: *Study on the sustainable development in arid regions from the view of ecological economics –taking Hei river as a case.*

Summary of research activities of 6 months

I was invited to Arid Land Research Center, Tottori University for one year, working together with Prof. Hamamura. My research activities in the past half one year were as follows:

< Seminars presented >

1. Introduction to the integrated ecological economic research in Hei river. Arid Land Research Center, Tottori University. November 14, 2003. The same content presented at Research Institute for Humanity and Nature. November 19, 2003.
2. Assessing the benefits of restoring ecosystem service. Arid Land Research Center, Tottori University. December 18, 2003.

< Scientific visits >

1. Japan International Research Center for Agricultural Sciences, Prof. Kazuo Nakamoto. November 17, 2003.
2. Tokyo University, Prof. Keiji Ohga. Agricultural development. November 18, 2003.
3. United Nations University, Prof. Iwao Kobori. November 18, 2003.
4. Research Institute for Humanity and Nature. Prof. Masayoshi Nakawo.

Title of articles which is related to my research here

1. Xu, Z.M., Cheng, G.D., Long, A.H., Loomis, J., Zhang, Z.Q., and Hamamura, K. Evaluating the Performance of Different Willingness to pay question format for valuing Restoration of Watershed services. Water Resource Research (submitted).
2. Xu, Z.M., Cheng, G.D., Zhang, Z.Q., Long, A.H., Hamamura, K., and Bennett, J. Choice Modeling and its application to managing the Ejina Region, China. Environment and development Economics (submitted).
3. Xu, Z.M., Ren, F.K., Ma, S.Y., and Guo, T.T. 2003. Comparison Analysis of the stated preference Techniques for valuing Environment. Journal of Glaciology and Geocryology. 25(6):701-707. (in Chinese with English abstract, revised in ALRC).
4. Xu, Z.M., Long, A.H., and Zhang, Z.Q. 2003. Virtual water consumption calculation and analysis of Gansu Province in 2000. ACTA GEOGRAPHICA SINICA. 58(6):861-869. (in Chinese with English abstract, revised in ALRC).
5. Long, A.H., Xu, Z.M., and Zhang, Z.Q. 2003. Water footprint of northwestern China. Journal of Glaciology and Geocryology. 25(6):692-700. (in Chinese with English abstract, revised in ALRC).
6. Costanza, R. and Jorgensen, S.E. "Understanding and solving environmental problems in the 21st century: toward a new, integrated hard problem science. (Xu, Z.M., Zhang, Z.Q., Zhao, W.Z., et al., translated into Chinese), Yellow River Water Hydraulic Press. 2004. (in press, revised in ALRC).

Result of research

1. Evaluating the Performance of Different Willingness to pay question format for valuing Restoration of Watershed services.

Based on a previous study on applying Contingent valuation Method (CVM) to analyze the total economic value of restoring Ejina ecosystem services by adopting the payment card format. To better mimic price taking in market behavior, se use dichotomous choice format, double bounded dichotomous choice to reevaluate the objective. This paper compares protest rates and willingness to pay for payment card, dichotomous choice and double bounded dichotomous choice contingent valuation question formats. Using a chi-square test, the payment card had a significantly higher protest rate (6.7%) than dichotomous choice question format (2.2%). The median WTP of the single bound and double bound dichotomous choice exceed the payment card by a factor of nine and seven, respectively. Two factors appear to influence this result: (a) the payment card allows for zero WTP, while dichotomous choice does not, and (b) responses to the dichotomous choice questions suggest that yea saying at high bid amounts is possible. Yea saying may be more prevalent in our case study (a developing country) due to the social context of surveys performed by government institutions in undeveloped countries and the novelty of surveys in general. Suggestions for reducing yea saying are provided.

2. Choice Modeling and its application to managing the Ejina Region, China.

Decision makers face a range of choices on how to manage ecosystems. Appropriate decisions should be based on weighing up the benefits and costs of alternative ecosystem management strategies, including some monetary and non-monetary benefits/costs. This paper reports an application of the Choice Modeling (CM) method in rural China. The CM method was used to obtain estimates of the monetary benefits for various attributes and changing scenarios in the Ejina Ecosystem. Application of CM is described including the goals of the valuation practices, questionnaire design and survey management. Model results are used to estimate sample non-monetary values of various attributes and changing scenarios. Significant non-monetary value estimates are reported for ecosystem management changes in the Ejina region. These estimates provide information to assist in choosing appropriate alternative management options.

3. Virtual water consumption calculation and analysis of Gansu province in 2000.

Demand for the increasingly scare water supply is rising rapidly with growing population in Chinese arid land. There is a pressing need for governments to manage water resources efficiently and adopt policy reforms. A recently emerging strategy concept developed as a developed as a prospective long-term solution for increasing stress on water resources is known as virtual water. Virtual water is the water 'embodied' in a product, not in real sense, but in virtual sense. It refers to the water needed for the production of the product. Trade of commodities brings along trade of virtual water.

In this paper, we firstly introduce the concept of virtual water, discuss its role in managing water resources and its social, economic, and political implications. Virtual water strategy means countries or regions whose water is scarce achieve their water security and food security by importing water-intensive products from those whose water is abundant, which expands the solution of water resources scarcity to the political-economy system. The particular linkage of population, food, and trade has been the masterstroke of virtual water strategy research.

Secondly, we present the methodology to assess the virtual water content of crop product and livestock, and take Gansu province as a case to analysis the virtual water content in product and circulating field. Owing to lack of rigorous statistical data of trade among province, the above results are then combined with the index of consume amount of product to get a picture of virtual water circulating in social-economy system of Gansu province. The calculation results show that the total volume of total product-related and consume-related virtual water are 222.02×10^8 m^3 and 183.75×10^8 m^3, respectively.

Thirdly, we discuss the political implications and potential applicability of virtual water associated with water security, economic benefit and consumption structure in Gansu province, and examines the advantage and disadvantage of virtual water strategy. The results show that virtual water trade is an instrument to achieve water security and efficient water use, and make a link between consumption patterns and the impacts on water. Virtual water strategy have an added advantage of being

environmentally sound, at the same time, the reliance on trade can hold some risks, including the uncertainty of supplies, market price instability and increasing environmental stress if appropriate policies are not in place.

Finally, we put forward some suggestions on how to implement a viable virtual water strategy in arid land, and believe future efforts may apply virtual water strategy to alleviate the press of water resources shortage in arid land.

(5) Associate Professor Guoyu Qiu

Visiting Associate Professor (November 2003-October 2004)

Institute of Resources Science, Beijing Normal University, China

Title: *Separation of evapotranspiration into transpiration and soil evaporation.*

Summary of research activities of 5 months

During these 5 months, I have been concentrating in research and education related with above mentioned research title.

- Researches: 2 papers were written related with evapotranspiration.
- Seminar and lecture: 4 seminars were given. 3 of them were given in ALRC, Tottori University and 1 was given in Kagoshima University.
- International symposium: I joined an international symposium hold at National Institute for Environmental Studies, Japan and gave an oral presentation there.
- Supervision students: Gave supervision to students on their doctoral and master studies.

Title of article which is related to my research here

< Papers >

1. Theoretical Analysis and Experimental Verification of a Remotely Sensible Soil Evaporation Transfer Coefficient.
2. Remotely Detection of Soil Evaporation and Plant Transpiration by Surface Temperature.

< Seminars >

1. Researches on Evapotranspiration and Separately Estimating of its Two Components I. Determination of Soil Evaporation with Surface Temperature, ALRC, Tottori University. December 19, 2003.
2. Researches on Evapotranspiration and Separately Estimating of its Two Components II. Determination of Plant Transpiration with Surface Temperature, ALRC, Tottori University. January 16, 2004.
3. Researches on Evapotranspiration and Separately Estimating of its Two Components III. Determination of Evapotranspiration. ALRC, Tottori University, February 20, 2004.
4. Issues of Water Resources and Environment in Western China. Faculty of Agriculture, Kagoshima University, January 20, 2004.

5. Tendency of Desertification in China during Last 50 Years. International Symposium hold at National Institute for Environmental Studies, February 2, 2004.

Result of research

Theoretically, the boundary of h_a is $0 \leqq h_a \leqq 1$. With these clearly defined boundary of h_a, soil evaporation is determined between its maximum value (potential evaporation rate) when $h_a = 0$ and its minimum value (zero) $h_a = 1$. These well-defined boundaries of evaporation are much less apparent in the conventional evaporation models.

During the period when evaporation is dominated by aerodynamic resistance (r_a) and soil surface resistances (r_s), linear relation between ha and resistance term ($r_a + r_s$) is obtained with a regression coefficient of r^2=0.75. Meanwhile, a linear relation between h_a and r_a is obtained with a regression coefficient of r^2=0.76. These results can be considered that $r_a + r_s$ and r_s are well related with h_a because these are independent variables with huge difference in property and magnitude.

During stage 1 of evaporation, cumulative evaporation increases with time while h_a keeps as constants. After stage 1, h_a linearly increases with cumulative evaporation with high a regression coefficient (r^2 > 0.96). The relation between E_c and h_a will be useful for prediction purpose under the condition when E_c is not available.