(2) Summary of Joint Research

A-1) Micrometeorological Improvement of Agricultural Fields in Arid Lands

Studies on Characteristic of Turbulence Transfer of Heat, Moisture, Momentum and Scalar Quantity in and above Canopy under Dry Condition

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Most of meteorologists have reported that high order closure model is better than K-theory model for estimation of meteorological factors in the canopy, but solving high order closure model needs boundary condition for turbulence by sonic anemometer that is very expensive, and then few scientists in agriculture use that model. Estimation of wind profile in and above Sorghum canopy was carried on by using 2nd order closure model with only one height mean wind above the canopy without the observation of turbulence. Basically the calculation profiles were fit well for observed, and it was suggested that it is possible for estimation of wind profile in the canopy with the use of 2nd order closure model without observation of turbulence. It was revealed that most of turbulence was produced at the part of head in Sorghum canopy in heading by analyzing turbulence. It was also suggested that plant area density should be measured in observation of meteorology at canopy if area of stem and head etc. is not negligible.

Estimation of Soil Moisture in the Shallow Root Zone Using Simple Meteorological Observation

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Measurement of Evapotranspiration in Arid Fields by Micrometeorological Method

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Study on Crop Coefficient for Estimating Actual Evapotranspiration

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Crop coefficient (Kc) is a correction coefficient for calculating actual evapotranspiration (ETa) from potential evapotranspiration (ETp). Prediction of ETa using Kc is used for the determination of amount of irrigation water and estimation of ETa on irrigation scheduling. Therefore many empirical number of Kc are accumulated in the world. However there are few studies on crop coefficient's self. Crop coefficient is a correction number influenced by many factors. Therefore it is important for increasing accuracy of prediction and expanding application area of the crop coefficient method to investigate the feathers of Kc.

In this study, soil moisture, micrometeorology, leaf area index (LAI), and crop height were observed in a sorghum field. Moreover it was discussed the daily and hourly changes of Kc and the relationships between Kc and soil moisture, LAI, canopy resistance (rc) and stomatal resistance (rs). The rc and rs were estimated by the Penman-Monteith method.

Results in this study are summarized as follows: 1) The hourly average of Kc is 1.12. 2) The hourly change of Kc is steady in daytime and change greatly in nighttime. 3) The daily average Kc is 0.995. 4) There are weak correlation between Kc and the resistances.

A-2) Irrigation Management for Water and Salinity Control in Soil

Numerical Study on Water and Salt Transport

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Hydrological modeling of water and salt transport under soil-plant-atmospheric continuum is indispensable for adequate management and control of valuable water resources in arid and semi-arid agricultural lands. The purpose of this study is to present a numerical model of water flow and salt transport in a soil-root system, and test its validity against the experimental results in a cropped sand column. The root contact model formulated by Herkelrath et al. (1977) and the Nimah-Hanks Model (1973) were applied to the mathematical description of root water uptake in the presence of salinity. The computed salt profiles by the root contact model are in good agreement with the measured data, while the profiles by the Nimah-Hanks model differ from the data in the upper layer of the root zone. Further works will be required to apply the root contact model to actual situations because of unknown plant parameters such as root permeability and plant water potential.

Physical Definition of Residual Water Content in Unsaturated Soils

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The residual water content is a one of the most important parameters for the predicting soil water characteristics and for hydraulic conductivity in unsaturated zone. However, in the physical viewpoint, we don't have clear and rigorous description of residual water content, yet. Therefore even the fundamental thing, that capillary height of soil water, is still involved.

In this study, we focused on the pressure head profile in equilibrium condition of glass beads and sandy soil. Under the condition of controlled evaporation, soil water remains at the contact point of solid in the form of pendulous ring. We found that though pendulous rings have continuity to film water at which solid surface, pendulous rings are not able to transmit water pressure.

Water content that composed pendulous ring could be thought the minimum limit of Darcy's law in the respect of liquid phase water movement.

Evaluation of Root Water Uptake Characteristics under Water and Salinity Stress Condition

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The objective of present study is to evaluate root water uptake characteristics of crops under water and salinity stress condition. Sap flow measurements were applied for measuring root water uptake of sweet pepper and citrus. Exp.1) Sweet peppers were grown in long pots (h=77cm,d=20cm) filled with four types of soil which has different water holding characteristics. After water stress treatment, root distribution and water content in each depth was surveyed for coupling root water uptake with soil water holding. Results indicated that used pots restricted root developing for horizontal direction, root system was deviated from natural condition. In case of soil that has high water holding capacities, plants utilized only upper layer water and leaf area was small. In case of sand with low holding capacity and high permeability, root developed more deeply for seeking water in lower layer and plant size was large. Exp.2) The root water uptake characteristics of citrus tree were investigated during salinity irrigation and the leaching period using weighing lysimeters. Although there was significant reduction of root water uptake caused by salinity irrigation, reduction of yield could be avoided by executing appropriate leaching based on monitoring plant behaviors.

A-3) Analysis of the Eco-physiological Characteristics of the Root System under Arid Land Condition

Study on Root Characteristics in Cereal Crops with Aspects of Functional Morphology

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Anatomical properties of roots in upland rice cultivars were investigated in comparison with lowland rice cultivars. Cross sections of rice roots were observed by light microscope in University of Tokyo and by SEM in ALRC.

Upland rice cultivars had thicker cell walls at their exodermis and endodermis than lowland rice cultivers had. In addition, there was genetic variation in the number of cell layers with thickened cell wall at exodermis. The thickened cell walls with lignification could be a barrier to water leakage from root to soil, and may protect the inner tissues of roots. These varietal differences in cell wall structure may have some relation to the variation in drought resistance among rice cultivars.

The anatomical observation was also conducted with ESEM in ALRC successfully. The use of ESEM allows easy observations of fresh samples of plant roots.

Study on Salt Tolerance of Pear Rootstocks

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The objective of this study is to select salt tolerant pear rootstocks and understand the mechanism of salt tolerance in pears.

After incubating mature leaves of wild pear species in water containing different NaCl concentrations, the extent of toxicity symptoms was compared. Toxicity symptoms were lighter in leaves of *P. betulaefolia* and *P. calleryana* than in those of *P. communis* and *P. pyrifolia*, which indicates that *P. betulaefolia* and *P.calleryana* are more tolerant to salt stress *than P. communis* and *P. pyrifolia*.

To investigate changes of H_2O_2 scavenging enzymes responding to salt stress callus derived from the base of current shoots of wild pear to species mentioned above was treated with different concentrations of NaCl. Salt tolerant *P. betulaefolia* showed an enhanced activity of ascorbate peroxidae (APX) and superoxidase dimutase (SOD). In contrast, a decreased activity of APX and SOD was observed in salt-sensitive *P. communis*. It seems that salt tolerance in pears may be connected with H_2O_2 scavenging enzymes.

Viscoelastic Properties of Root Cell Walls affected by pH and Humidity *in vitro*

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The water environment of roots such as ion balance, pH and drought strongly affects root growth. Since the cell walls of roots are naked to the outer environment, these conditions may directly affect the mechanical extensibility of root cell walls. We analyzed the effect of low pH and humidity on the viscoelastic properties of root cell walls *in vitro*. We used the creep method and measured six viscoelastic parameters of elastic moduli and of viscosity coefficients in *Pisum sativum* L.

Low-pH treatment of the cell walls *in vitro* remarkably and specifically decreased the viscosity coefficient among six parameters. Humidity also affected the viscoelastic properties. Increasing the relative humidity around the cell walls proportionally decreased the elastic moduli, while viscosity coefficients did not proportionally decreased but declined quickly even at low humidity. It was suggested that cell wall components, which bear viscosity elements, are highly hydrophilic to absorb water molecules from environment. Thus we suggest that the low pH- or high humidity-induced increase in cell-wall extensibility is mainly due to the decrease in the viscosity coefficient.

A-4) Studies on Water-Saving Cultivation of Crops in Arid Lands

Study of Genes for Water and Potassium Transport in Crops

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Genes for water transport in barley and in Salicornia sp. were investigated to reveal the molecular mechanism of water transport under drought/salt stress. Three plasma-membrane type water channel genes were isolated from barley. Expression of one of them (designated as bpw1) was regulated under salt stress, but two others (bpw2, bpw3) expressed constantly. Transgenic rice overexpressing bpw1 was generated. Activity of water transport and drought / salt tolerance in these transgenic plants are under investigation. One PCR fragment was sequenced as putative water channel in Salicornia sp., indicating that this gene shows high homology to barley bpw2. Other putative water channel genes in Salicornia are now being sequenced.

Effects of Salt Water Irrigation on Growth of Bulbous Plants

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Effects of salt concentration in irrigation water on growth of bulbous plants (six families, 21 genera and 35 species/cultivars) were investigated. The bulbs of Lycoris and Rodophiala were planted in August, and the other bulbs or corms were in October 1998 in sea sand in plastic pots. They were grown in a greenhouse and 0, 500, 1000 or 5000 mg/L salt water was applied when the pot surface was dried. Five to 12 plants were used for each species/cultivars per treatment. Most species/cultivars survived up to the concentration of 5000 mg/L except two Lilium species. In many species/cultivars plant height was shortened and flowering was delayed at the concentration of 5000 mg/L. There was no species/cultivars specific tolerance in this experiment, but it can be said that the bulbous plants investigated are generally tolerant to salt stress.

A-5) Eco-physiological Studies on Tree Tolerance to Water Deficiency and Salinity

Growth and Morphology of *Salix Psammophila* Planted on the Sand Dunes of Mu Us Desert in Inner Mongolia, China

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Growth and morphology of *Salix psammophila* planted on the slopes of sand dunes were studied in the Mu Us desert of Inner Mongolia, China. Stem lengths and basal diameters of *Salix psammophila* were greater at the mid-slope of dunes than at the top or the bottom. The thickness of leaves was the thinnest at the mid-slope. The size of them at the hilltop was the smallest and increased with a decrease in ground level. The density of adaxial stomata was greater at the wet area near the bottom than that of the dry area near the hilltop. In contrast, the stomata density on the abaxial side was the greatest at the hilltop. The rate of the adaxial to abaxial density of stomata was the greatest at the mid-slope.

Effect of Soil Microbes on Salt Tolerance of Trees

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Casuarina trees which forms multipartites symbiosis with actinorhizal root-nodule bacteria, ectomycorrhizal fungi and arbuscular mycorrhizal fungi are well known as one of the most useful trees grown on poor soils at beach sites. The purpose of this study is to investigate how symbiotic functions of *Casuarina* are effective to the torelance of high salt conditions.

Some mycorrhizal fungi isolated and cultured were followings; some strains of *Pisolithus tinctorius* var. *turgidus* as ectomycorrhizal fungi, and *Glomus leptotichum* from *Miscanthus sinensis* and *G. clarum* from *Raphiolepis umbellata* as arbuscular mycorrhizal fungi. *G. clarum* was inoculated to *Casuarina* seedlings. After 3 months, all seedlings were infected.

Casuarina equisetifolia seedlings having numerous root nodules from Okinawa were collected. The root-nodules were used for isolating root-nodule bacteria, *Frankia*. *Frankia* was isolated from new root-nodules of *Casuarina* seedlings and inoculated to the seedlings using crushed nodules.

A-6) Studies on Farm Land Conservation in Arid Areas

On the Characteristics of Rill Patterns Generated on the Salinity Soil -On the Effect of the Saline of the Soil on Soil Erosion and Soil Physical Properties -

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In order to examine erosion behavior of the salt accumulation soil, as a second stage of this study, the single shear test of soil, liquid test and plastic limit test were conducted. Experiments were carried out by using artificial slope model while supplying water flow on the two slope models that were composed of non-salinity soil and salinity soil. The time variations of sediment rate were measured. As well, time variations of plane and sectional patterns of rills were measured.

As a results of physical soil test, plastic limit become NP. Liquid limit of saline soil was any lower in comparison with the soil that did not do the saline soil. The result of the single shear test tended to lower in comparison with the soil that did not do the saline. There was not large difference on the aspect of the formation of the rill pattern between the saline soil and not so soil.

Effects of Soil Stability and Water Quality on Erosion during a Rainfall

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Two soils from well-drained upland field (Fukaya-A soil) and water logged upland field (Fukaya-B soil) were used in this study. Soils were packed into the soil box of 30cm×50cm×10cm with bulk density of 1.1 g/cm^3. Initial moisture condition of the soils was 20 to 27%. Gypsum (2.5 t/ha) was spread onto the soil prior to the rainfall. The deionized water and tap water (EC = 0.16 dS/m) were used for simulated rainfall in the Arid Dome of Arid Land Research Center. Rainfall intensity was 38-40 mm/hr which was smaller than saturated hydraulic conductivity of the soils. When tap water was used for the simulated rainfall, gypsum amendment seemed not to be effective to stabilize soil structure. However, gypsum application clearly enhanced infiltration of the rainfall when deionized water was used. The Fukaya-A and B soils did not show the difference in infiltration during a simulated rainfall while both soil showed completely different feature in permeability at the field. It needs further study to clarify the reason of discrepancy between the result under the simulated rainfall and at the upland fields under natural rainfall.

Soil Erosion Prediction for Farmland Conservation

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To estimate the amount of eroded soil from farmlands is an important pre-criterion for selecting proper soil conservation measures. In Japan, an equation for estimating soil loss from water erosion due to rainfall and runoff had been proposed by a researcher based on a series of laboratory and field experiments done over the years at the Faculty of Agric., Yamaguchi Univ. This equation is of a practical type which considers the growth of vegetation and the pattern and intensity of rainfall. The present report focuses the results of the study as well as the process of investigating the rate of applicability of the equation in different types of fields (bare and vegetative). For the study, several crops had been cultivated in different experimental plots within the university campus. Then, 2-years observations had been carried out on soil loss and surface runoff in each cropping plot. With the measured values of soil loss in each field at different growing-stages compared, an attempt is made to determine the constant values of two unknown coefficients for each crop. The equation in question has further been revised to be an extended form, which considers the effect of small quantity of rainfall with the intensity of 1mm≦/10min, and the effect of lateral width of a field. With this newly developed equation, investigation has been made into soil loss in each cropping-plot of the experimental fields under rainfall both natural and artificial, and into the applicability-rate of the equation. The results obtained from using the effect of small rainfall and the lateral width of slope in that the applicability-rate proceeding from the equation shows higher values than from the basic form of the equation. Finally, the values of each coefficient and exponent of the soil loss equation have been categorized according to the types of the crops.

B-1) Integrated Researches on Soil-Water-Plant Monitoring by Remote Sensing

Estimation of Evapotranspiration using Remote-Sensing

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It is important to estimate evapotranspiration of large area for monitoring of water balance and adequate planning of water use. So the evapotranspiration is calculated using some meterological elements, air and ground surface temperature and water vapor pressure are required. In this study, ground surface temperature and soil water content are measured by remote sensing apply to Penman and bulk method. The results show the following. 1.In the wet condition (evapotranspiration efficiency is full), the results of calculation obtained agreed. 2.In the dry condition, the results of each method show too much value than real one especially dry sand layer has grown. The largest problem in estimation of evapotranspiration is water vapor pressure of boundary layer. In the dry condition, boundary layer is saturated but water supply from under ground surface to boundary layer cannot meet evapotranspirate demand. It is necessary to measure soil temperature and water contents at several points of vertical direction for estimate boundary water vapor pressure. One of the following two methods should be used, because only shallow area will be measured by remote sensing currently. First, new method, which estimates boundary water vapor pressure with another data sets (solar radiation, albedo et al), should be taken. Second, measure soil temperature and water contents at several points of vertical direction with other wavelength.

Change of Spectral Reflectance due to Mist-irrigation for Plants by Remote Sensing

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In this research, a method is presented for detecting the damage of young green leaf due to rainfall stress, using a spectral reflectance. The experiment was conducted with using kidney bean, cucumber, and Chinese mustard in growth chamber. Remarkable changes in the spectral reflectance due to the each stress were found in the near-infrared region and the short wave infrared region. This may be arisen from the fact that a transmission was increased by increment of leaf water content due to rainfall intensity. Using this result, the spectral vegetation vigor index was developed for detecting a stress of plants.

There have been numerous studies related to the method for detecting the water stress by remote sensing. However, the research about a change of spectral reflectance due to rainfall has not been considered in the past. On this point, this study will present a new possibility of remote sensing about the water condition for plants.

Estimation of the Aboveground Biomass Using Landsat-5/TM Data

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This study was conducted to develop the estimating method for the aboveground biomass using satellite data. We selected standing tree volume as the aboveground biomass, as the ground data were easily obtained. Spectral reflectance of the tree canopy were measured by handheld spectral radiometer for several tree ages and tree heights at Takakuma Experimental Forest Station, Kagoshima University. After analyzing the relationships among the spectral reflectance, tree age, and tree height, image analyzing indices, NDVI and RVI, for Landsat/TM were determined. These indices were adapted on the identified forest areas in Takakuma Experimental Forest Station artificial forest and Yakushima island natural forest. For discussing the analyzing accuracy, these results were compared with ground truth data.

Time Series Change Study in Tottori Sand Dune Using Remote Sensing

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Tottori sand dune consists mainly of sand but vegetation is also an important component of its land cover. A ring of protected forest surrounds the sand dune. Recently this sand dune is facing a serious problem from the uncontrolled growth of exotic grass and shrubs. In this report, the spectral characteristics of the distribution of heat and vegetation over the sand dune region are investigated employing Landsat/TM data. The result is that there are differences between the eastern and western parts of the sand dune regarding growth of vegetation and temperature conditions.

Basic Study on Saline Water Resources Assessment in the Middle East Based on Integrated GIS Database

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This study was performed to delineate the status of degradation of water resources owing to the increasing salinity. The Hashemite Kingdom of Jordan, which has been suffered from the sever drought in 1998-2000, was selected for the case study to review the outcome of GIS data base in the digital national water master plan study by GTZ (German Government Technical Cooperation). It is noted that the salinization of existing water resources as well as potential use of brackish groundwater are to be integrated in the relational data base to facilitate the digital balancing model for water resources management.

Application of Remote Sensing and GIS Technology for Water Management/Landuse Change in Large Scale Irrigation Project in Aridland

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In the arid land of southern part of Iran, large scale irrigation projects each exceeding 100,000 ha such as Dez irrigation project, Zahyande irrigation project and Drudzen irrigation project are in progress in the downstream of a large dam constructed in the Zakros mountain range. Large-scale irrigation projects have also been implemented adjacent to the arid areas in Hetao and Yingchuan areas, in Inner Mongolia of China, and in Kazafstan. In the present study, we make full scene use of remote sensing data (satellite data) and apply GIS techniques to grasp the whole pictures of these projects through case studies and discuss the monitoring system so that these projects shall be managed soundly for a long time and contribute to the local development considering cooperation with global irrigation technology system.

We have just sorted out satellite data related to many of the irrigation projects in the semi-arid areas mentioned above. We are planning to expand observation image data in these areas from now on. Meanwhile, we have constructed a cooperative utilization system with more than ten national universities under a floating license by getting ERDAS Imagine and ENVI＋IDL, which are efficient and high-performance image processing software. Now, we can display the whole satellite image of 120× 110 cm size relatively easily and this will be a great power in the field survey of developing countries not provided with a map.

B-2) Studies on Salt Accumulation and Leaching

Mechanism of Simultaneous Water, Solute and Heat Transport

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An advantage of an experiment using a large column was that it enabled to monitor the transport of water, solute and heat, with growing plants on it. Especially, in this study, we discussed the effect of the different salt concentrations in irrigation water on behavior of water, solute and heat transport. The soil columns were 798 mm in diameter and 1200 mm in height. Tottori dune sand was packed. Irrigation water concentrations were set at 5000, 2000 and 200 ppm NaCl solution. The experiment was continued for about two months in greenhouse. Water, solute and heat transports were monitored by three kinds of sensors. Sorghum was planted. The following result was obtained.

When salt concentration in irrigated water was high, concentration in lower point of soil profile increased. On the contrary, when the salt concentration was low, it did not vary with time. This suggested that high salt concentration of the solution had more driving force because of the difference of the density of the solution.

Mechanism of Salt Accumulation in Soil

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Salt precipitation from bulk solutions was examined to understand the characteristics of salt crystallization phenomena. Solutions of 2mole for seven kinds of salts were subjected to evaporation in the laboratory condition. In the solutions, a small acrylic-board was set vertically for observing salt crystallization on it. Experimental results showed several characteristics depending on salt type. Salts of $NaHCO_3$, $CaSO_4$ and Na_2SO_4 had low solubility and thus precipitated steadily as evaporation proceeded. On the other hand, $CaCl_2$ and $MgCl_2$ caused no precipitation during about month observation. For NaCl salt crystal appeared on the acrylic-board 3-dimensionally. These characteristics could affect the behavior of salt accumulation in soil, especially in soil physical and chemical facets.

Relationships between Ground Water Level Variation and Precipitation

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Ground water level is an important factor for salt accumulation in regions of salinity soils. In order to investigate the relationships between variations of ground water level and precipitations, the groundwater level and precipitation were observed in the Miyazaki University farm-land, which is layered by several volcanic ash soils.

In result, ground water level varied in the 2.5 m range in response to 2500 mm precipitation for about one year, and capillary upward moisture movement in the shallow soil surface layer seldom occurred, because high groundwater level was caused due to much rain in one time or long spell of rains. That is to say, high ground water level due to much rain seldom causes salt accumulation in soil surface layer, while in such condition the quality of ground water in deep soil layer is considered to be consequential.

Water Flow and Solute Transport in a Heterogeneous Soil

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Water flow and solute transport are heterogeneous due to the inherent nature of soils. An intensive flow and transport monitoring system in a laboratory soil column was constructed to monitor flow and transport in an unsaturated soil. Water content was monitored using time domain reflectometry (TDR) while hydraulic pressure was measured with tensiometers. Soil electrical conductivity was also monitored using TDR and four-electrode salinity probes. Unsteady flow and transport experiments were conducted for disturbed and undisturbed soil columns. Tottori dune sand and volcanic ash clays were used in this study. The validity of the conventional Richards equation with the convection-dispersion equation (CDE) was discussed for heterogeneous unsaturated flow and transport conditions.

Undisturbed Measurement of Water and Salt Movement in the Large-Scale Soil Columns (II)

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In order to prevent salinization problem in arid and semi-arid regions, it is essential to clarify the mechanisms of salt accumulation in soil. An experiment was carried out to evaluate the leaching process using continual or intermitted irrigation on the growth of grain sorghum. An experimental set up consisting of three large-scale soil columns was used to monitor dynamics of salt and water in a sand dune soil. The columns were 798mm in diameter and 1200 mm in height. Three kinds of sensors at different depths were installed in it. It was attached to monitoring system for water flow and solute transport. The monitoring was carried out in the Arid Land Dome for the period of 56 days. Irrigation water was used at 1500 mg/L NaCl solution. The results are shown as follows. For the purpose of reducing the quantity of irrigation water, the intermitted irrigation was more effective method to remove accumulated salt from rhizosphere than the continual irrigation. But the salt accumulation in the soil surface increases at the long intervals of irrigation. If we consider the salt tolerance of plants, we can apply the intermitted irrigation.

Soil Water and Salt Movement in Upland Fields Under Salt-Affected Groundwater Conditions

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In low-lying lands near the sea, tidal intrusion occurs in the groundwater. However, salt accumulation can be avoided by taking advantage of capillary rise characteristics of the soil. In this study, the critical depth of the groundwater table was investigated using laboratory experiments and simulations for Kawauchi (Tokushima prefecture) upland fields where sand is dressed.

A soil column of length 66 cm was filled with Kawauchi sand, which was wetted from below with a 3 % NaCl solution. The water table was maintained at 65-cm depth. Water and solute movement above the water table and evaporation were monitored. Water rose about 50 cm (15-cm depth) after one month. Relatively uniform salt concentrations (between 46 and 56 dS/m) were noted throughout the 25- to 65-cm depth, suggesting dissolved salts rise in accordance with the capillary rise of water.

A reasonable agreement among the numerical results, experimental data and field data was seen in water movements. Field data showed lower EC values above 15-cm depth of the groundwater table because rainfall had leached and transported the salts. The results show the critical depth for Kawauchi sand is around 50 cm under long drought conditions and about 15 cm under rainy or irrigated conditions.

C) Free Subject on Arid Land Studies

Characteristics of Subsurface Water Movement in Sand Dune

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Sand dune can be found in many regions with different climate conditions. How water infiltrates and temperature responds is the key to understand the hydrological processes and also the soil water parameterization in sand dune. A typical sand dune has been chosen in Tottori, Japan to study the behaviors of soil water movement and temperature in sand dune where the water table is 20m in depth. TDRs, thermometers and tensiometers have been set at the depths of 10cm, 20cm, 50cm, 100cm, 150cm, 200cm, 300cm and 380cm, respectively. Observations started from May 1998. Variations of water contents and temperature have been recorded at the loggers for every 10 minutes.

Observation results show that water contents respond to rainfall quickly in the layer from the surface to 2m in depth, but have little changes in the depth below 2m. However, from the results of tensiometers, it was found that the hydraulic gradients in the depth below 2m keep downward throughout the year. It hints that the sand dune seems a buffer to control the water content in unsaturated zone and maintain a constant recharge to groundwater. During the rain events, water infiltration in sand dune is not smooth but in a style like step pulse, which means that the water movement in dry sand cannot be explained by so call modern infiltration theories.

Variations of temperature distribution in sand dune have a very close relation with the water content. As a result, vertical temperature marched well with the water movement in sand dune during rain events. Comparing of water content with temperature, we can find out the possibility to trace water movement in sand dune with temperature.

Study on the Simulation of Sand Dunes Variation

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This study was carried out through field survey to make the mathematical model to simulate the variation of Tottori great sand dunes. As to the wind field measurement carried out last year, the wind field has characteristics according to the wind speed and direction. Applying the CFL (constant flux layer) model to the wind simulation model, the wind field at Tottori great sand dunes could be calculated.

Solar Photovoltaic Generation in Arid Land Environment Simulated in Arid Land Dome

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The goal of this study is to make clear the requirements for creating the simulated environment including the solar radiation in Arid Land Dome in order to develop the solar photovoltaic (PV) power generation facility suited to the arid land or desert. Meteorological measurement system and solar PV power system were settled in Inner Mongolia. The data (irradiation, temperature, generated power, etc.) can be transmitted to Arid Land Research Center by using Inmarsat mobile telephone. By comparison between the irradiation in Inner Mongolia and that in Arid Land Dome, the irradiation supply needed for simulating the condition of Inner Mongolia in the Dome was estimated. Several irradiation systems, such as natural sunlight concentrating instruments and a metal halide lamp system, were investigated.

Numerical Simulation of the Flow Field over the Tottori Sand Dune and the Estimation of the Effect of the Vegetation on the Flow Field

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Three-dimensional flow over the complex surface of the typical sand dune was computed by means of the numerical simulation. Incompressible Navier-Stokes equation is solved to compute the flow field. Boundary fitted coordinate system is employed in order to get high resolution near the surface of the sand dune. Although main calculations were performed using simple eddy viscosity model, large eddy simulation was also tested for the turbulent computations. Geographic data were obtained from the topographical map of the sand dune. Three-dimensional flow field up to 200m above the sea level was computed in this study. As a result, detailed structure of the flow field was obtained and the effect of the wind direction on the flow field was estimated. The results suggested the correspondence between the flow field and the shape of the sand dune. The calculations based on the Reynolds number around 900 gave the most adequate results among all the calculations using eddy viscosity model. The effect of the vegetation on the flow field was also investigated. These results were compared with the observation data obtained by the Arid Land Research Center of Tottori University and the agreement is satisfactory.

Spectral Analyze of Arid Land Soil by Visible and Near IR Range

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In Tottori Univ. Arid Land Research Center, many arid land soils in domestic and overseas are possessed. We photographed the surface in the arid land soil using the digital camera, and it was recorded as a digital image. Recorded digital image made the database by adding the comment of picking places, picking persons, picking dates, etc. The RGB analysis was tried using photographed digital image. However, the effective discriminant function was not obtained in order to distinguish the arid land soil.

Durability Tests of the Concrete in the Drainage Canal in the Salt Accumulated Field

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In the field where the salts accumulation is caused, most of the drainage canal is an unlined canal. However, because drain infiltrates the underground on the way of the pass, an unlined canal cannot be done in the excavation without timbering waterway. Then, the use of the concrete lining waterway where the drainage canal was paved with concrete is thought as a means to overcome this.

Here, concrete is deteriorated because of the sulfate and the chloride included in drain. If this deterioration extent is understood and the deterioration measures are considered, the life of the drainage canal made of concrete can be forecast. Then, the durability of the drainage canal made of concrete is experimentally examined by using the water quality data of Hetao Irrigation area Inner Mongolia in China in this research.

Ethnopedological and Ecotechnological Studies for Sustainable Agricultural Development of the Degraded Inland Valley Watershed in Sahel Zone of Niger

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The objectives of this study are to extract available information on indigenous knowledge and to fuse it into scientific information for establishing the sustainable agricultural development in Sahel zone of Niger. Field surveys were conducted in a small benchmark inland valley watershed Matankari village, Dosso City of Niger hereafter we described this watershed as BMW. After this basic survey, a field experiment taking the verified indigenous knowledge for the effective incorporation of the Harmattan dust to the ecosystem was conducted.

The results on the survey of indigenous knowledge revealed that the farmers in benchmark watershed, BMW, used the factors of soil color, soil texture, and soil fertility level to evaluate the soil as well as the location. Each factor was divided into 3 to 4 subdivisions, the headings for which were given in the local language in Haussa. The farmers identified the soil by a combination of these subdivisions or by the direct meaning of the subdivision. 'Hori-rairay', 'Lesso', 'Phara-kassa', 'Ja-kassa', 'Baka-kassa', 'Baringo', 'Jaka-laka', 'Kounkou', 'Tsagana' are the various names assigned to the soil. The soil evaluations on color, texture and fertility are based on their long-term experiences over the years, and are of considerable significance to their society. 'Hori-rairay', which was evaluated as the poorest soil by farmers, was of light color, quite sandy, and had a lower fertility level than any other soil. On the other hand, 'Baringo', which was evaluated as the most fertile soil for crop cultivation in BMW, was of darker color, clayey, and had high effective cation exchange capacity. Although the scientific classification of soil in benchmark watershed is generalized as Tropoudults, people who are living there differentiate the soils and use it in different purposes. This can be recognized as an environment conservation technique for making the people co-existing with the ecosystem. However, the result also showed that degraded soil named as 'Lesso' was found in benchmark watershed and it is apprehended that the poor fertility soil like 'Phara-kassa' changes into 'Lesso' because of population increase, continuous cultivation, among others. Therefore, it is necessary to establish the suitable agricultural system that should be sustainable.

In order to establish a sustainable agricultural system, a field experiment taking the verified indigenous knowledge for incorporation of the Harmattan dust to the ecosystem was conducted for the corroborative research in terms of ecotechnology in semi-arid region. Field experiment was conducted during the dry season from November to February 1998. One set of 10m x 10m of two squares were set on different locations; the upper, middle and lower sites. 20 kg of millet stem were distributed on one small square as mulch (M) while another was without mulch (NM). M was surrounded by iron fence for safeguard against animals while NM was without iron fence. Soil sampling was done two times, before applying the crop residue and after the experiment. Three dust samplers each with a height of four were put on different locations; the plateau, upper site and middle site, and then dust sampling was done. Physical, chemical and mineralogical properties of all soil and dust samples were analyzed. The result of the experiment revealed that silt and clay fraction increased on M on all sites while NM varied according sites. The fertility of the soil increased significantly on M and non significantly on NM. The chemical properties of the dust were extremely higher than that of the soil in the area. The result of the mineralogical analysis showed that the same components of dust were present in the soil of M from the upper site and lower site, which means the mulch functioned as a trap of dust. Although using crop residue as mulch has not been thought as a practical way in this zone, the result of this study still showed the effectiveness of mulch for soil fertility improvement. Once mulch application is practiced in the upper stream where the soil is physically and chemically poor but used for the cultivation, the fertility of the soil can be improved by incorporation of Harmattan dust. On the other hand, the animal grazing can be also practiced in down stream where nomad people can find the water for their animal. This combination can contribute not only to the regeneration of the degraded watershed but to the co-existence of different tribes in an ecosystem.

Flow Meter in Micro-irrigation System by using the Bend Pipe

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In Agriculture, to reduce the production cost, the low cost and low energy are requested in agricultural facility. In this paper, the flow meter using the bend pipe is investigated. The bend pipe is very common in irrigation system, so if we use the bend pipe as a flow meter, its facility cost is very low. By the centrifugal force of flowing water in curved pipe, the pressure head of the outside of curved pipe is higher than that of the inside. By the application of this force, the characteristic of bypass flow across 90-degree curve pipe was investigated. The relation among the main pipe flow rate, the bypass route flow rate, and the pressure difference between inside and outside of curve pipe are clarified. Under the above result, the hydraulic design method of flow meter using the bend pipe is proposed.

Measurement of Mass Transfer from an Agricultural Land Using the Micrometeorological Methods

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To establish the accurate method by which the water vapor flux from an agricultural land can be measured, various problems concerning the energy balance estimated by Bowen ratio method and the flux ratio method were examined using data from a paddy field. In the flux ratio method, the water vapor flux was obtained using the known sensible heat flux measured by the eddy correlation method.

Then, the energy balance flux ratio method was proposed to remove some problems of the flux ratio method. The water vapor flux was estimated from the energy balance equation using corrected net radiation, soil heat conduction and the heat change of flooding water. It is considered that the water vapor flux from paddy fields can be estimated accurately by this method.

Perspective of Root Biology for Sustainable Agriculture

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Knowledge on structure and function of plant roots is quite important for improving agricultural production, especially in dry area. Perspective of root biology is examined getting information through Arid Land Research Center of Tottori University. Root biology has two related and different aspects of a single root and a whole root system. Regarding to a single root, researches from the viewpoints of morphogenesis, growth physiology and functional morphology should proceed further. At the same time, filed surveys are essential after establishing appropriate viewpoints and indices for structure and function of whole root system. In addition, methodology of approaching to a whole root system as an integrated system has to be established. Furthermore, contribution of whole root system to development as well as yield has to be examined based on stress biology and rhizosphere ecology.

Synthesis of Novel Abscisic Acid Analogues and Their Effect on Plant Growth

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Abscisic acid (ABA) and its glucosyl ester (ABAGE) strongly affect metabolism of plants: e.g. suppression of growth, closure of stomata, and inhibition of germination. It is remarkable that contents of ABA and ABAGE in plants increase under drought stress. In order to elucidate the action mechanism of ABA, many analogues have been synthesized so far. However, effective synthetic strategies of ABA glucosyl ester and following resolution of the diastereomers have never been reported.

We focused our project on two points: 1) effective synthesis of ABA glucosyl ester and 2) separation of the diastereomers on quaternary carbon of ABA residue. We resolved the first point by employing levulinated glucosyl donor to synthesize ABA glucosyl ester stereoselectively. The levulinoyl esters could be removed without affecting the glucosyl ester linkage. However, the two diastereomers could not be separated each other, even if we used HPLC with ODS or chiral columns. Optimization of the HPLC conditions will be needed for further procedures.

Effect of Na on Nitrogen Absorption of Rice

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In the University Farm of Tottori University, the water of Koyama Lake is used for irrigation of paddy rice field. The water contains about 200 ppm NaCL. This study was conducted to clarify the influence of 200 ppm NaCl on the growth of paddy rice. Eight cultivars were grown under nutrient solution without or with 200 ppm NaCl. Addition of NaCl tended to accelerate the growth and nitrogen absorption of two cultivars, Pokkari and IR36.

Changes of Water Use Efficiency in Rice Subjected to Depth of Different Water Table

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It is unknown whether root developments affect water use efficiency in rice under soil-desiccated conditions. Five levels of water depth in pots were set to change root growth in two rice cultivars having different drought resistant score during vegetative and reproductive stages. Root mass decreased depending on reduction of water level and water use efficiency increased a little regardless of cultivars. Water use efficiency as a result decreased with reductions of total root mass. Dry matter increase of whole plants however dominantly accompanied that of transpiration rate. The root mass almost changed dry matter production through alteration of transpiration rate. We suggested that total root mass scarcely affects water use efficiency of whole plant of rice when the mass is changed by water table.

Study on Mineralization of Organic Materials in Sandy Soil

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Mineralization test for waste compost of dye works sludge (N1.57%) treated with anti-high temperate bacteria, dregs of rape seed oil (N5.59%) and cow dung compost (N1.65%) was conducted in sand dune soil, light heavy soil and sandy field soil at 25℃, for 6 to 8 weeks, for humus enrichment in soil, and recyclable utilization of biological waste. Results of the investigation were as follows: Nitrogen of waste compost of dye works sludge was more slowly released than dregs of rape seed oil and cow dung compost. Humus enrichment in arid soil: sand dune / desert was basically the more important factor for greening.

Effect of Transpiration Ability on Productivity of Cotton Canopy in Arid Region

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Crop production and its physiological response to the regional climate were investigated for cotton plant in the dry land field at the Experimental Farm of Shihezi Dry Land Agricultural Institute, Shihezi, Xinjiang, China. Dry matter growth and transpiration rate were measured for some cotton cultivars. Significant difference in transpiration rate was found among the cultivars. The higher water potential was observed in the inner than the outer part of the cotton leaf, the higher it transpirated. Moreover, the higher it transpirated, the higher the cotton canopy produced dry matter. This suggests that the productivity of cotton depends on the transpiration ability in the dry field condition.

Screening Novel Germination Stimulants for Parasitic Weed Seeds

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Structure-activity relationships of cotylenins and fusicoccins in germination stimulation of *Striga* and *Orobanche* seeds, and effects of phytohormones and their biosynthetic inhibitors on conditioning were examined. In the structures of cotylenins and fusicoccins, the positions and number of the hydroxyl groups and stereochemistry of the 5-8-5 membered ring were found to affect their germination stimulation activity dramatically. In *Striga asiatica*, the addition of a brassinosteroid biosynthetic inhibitor, brassinazole, to the conditioning medium greatly reduced the germination after terminal treatment with *dl*-strigol, and this reduction could be canceled by brassinolide, indicating that brassinosteroid biosynthesis during conditioning period is necessary for germination or to became ready to perceive germination stimuli. In *Orobanche minor*, exposure to high temperatures over 30℃ even as short as a few hours during conditioning resulted in a significant reduction of germination after terminal treatment. This may be due to a rapid accumulation of abscisic acid (ABA), since an inhibitor of carotenoid biosynthesis (and thus inhibiting ABA biosynthesis), fluridone, could restore the germination.

Fundamental Study on Natural Plant Growth Regulators for Enhancement of Crop Productivity in the Arid Land

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Dwarfism is a very important biological phenomenon in agriculture because it prevents crops from lodging on the ground and produces a better harvest. In the course of a screening-based search for natural plant growth retardants among the metabolites produced by soil fungi, we found an unidentified fungus (strain C-1 33) whose culture filtrate showed plant growth retardant activity to rice seedlings. Three active substances were isolated from the culture filtrate of the fungus and their structures were determined based on the spectroscopic data to be the cyclic peptides that are composed of proline, phenylalanine and two unusual amino acids. To elucidate structure-activity relationships some compounds were derived from the natural product by chemical reactions and their dwarfing activities were determined.

Wheat Breeding for Salt-Tolerance by Transferring *Agropyron Elongatum* Chromatin into the Wheat Genome

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Agropyron elongatum (2n=10x=70), a wild wheatgrass showing high salt tolerance, has been used to transfer its salt-tolerance into common wheat by using wide hybridization. In BC_2F_6 generation of *Triticum aestivum* × (*T. aestivum* × *A. elongatum*), a common wheat line W148 was selected according to its high salt-tolerance tested in the laboratory and on the field. Genomic in situ hybridization (GISH) analysis indicated that W148 is an *A. elongatum-T. aestivum* translocation line, and the salt tolerance of W148 originated from *A. elongatum*. The 3 : 1 segregation ratio of salt tolerance in the F_2 generation indicates that the salt tolerance of W148 expressed as a dominant gene. DNA sequences related with the salt tolerance in W148 will be cloned using differential display method in the future.

Study on Breeding Ostrich in Arid Area

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Investigation on Useful Plants for Arid Farming

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The useful plants, especially medicinal plants were intended for adoption as species to be planted for protection against desertification in Inner Mongolia and Mongolia.

Our bibliographical survey demonstrated that about 50 species of local plants around the arid land have been used for treatment of various diseases. Main examples of the species are *Glycyrrhiza uralensis, Cistanche* spp., *Saposhnikovia divaricata*, *Ephedra* spp., and *Astragalus mongolicus*, The crude drugs, dried licorice root and *Cistanche* herb were obtained at Hohhot and Alashan country of Inner Mongolia, respectively.

They were assigned or evaluated by the qualitative and quantitative analyses of major constituents, glycyrrhizin and phenylethanoids, respectively. The content was determined using HPLC. The latter species was identitied as the stem of *Cistanche derserticola* Y. C. Ma.

Ecophysiological Studies on Pine Wilt Disease Occurred in Japanese Black Pine Forests on Coastal Dune

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The progress of pine wilt disease have been compared between two 20×20 m experimental plots. One was supplied with fertilizer. The other was non-treated control. Both were established in Japanese black pine forests at the ALRC. Pine wilt developed more promptly in the plot treated with fertilizer, where mycorrhizal development of pine trees seemed to be prevented, and so pine seedlings when planted scarcely survived. Inoculation experiment with pathogenic nematodes revealed that propagation of pathogenic nematodes in pine seedlings was accelerated by fertilizer treatment of the seedlings. Thus fertilizer treatment seemed to prevent mycorrhizal development, thereby reduce host resistance against nematode virulence. Further experiments are needed to solve the question how fertilizer treatment influences on mycorrhizal growth and the physiology of pine trees.

Study on the Production of Local Desertification Map

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Though desertification is called as a global environment-problem, it is actually caused by local factors as climate, soil, vegetation and human impacts. To prevent the development of desertification, local environmental planning is required. The maps of vegetation, soil, land use and groundwater-level were compiled on GIS system. The spatial changes of land-use were studied using satellite data. The current status of land use was studied through extensive field survey. Revegetated (= vegetation - developed) area, desertificated (= vegetation - declined) area and newly cultivated area were identified with time-sequential satellite data. Classification of humid grassland, fixed sand dune, hilly grassland and crop-field was developed with the analysis of seasonal satellite data. The pavement of major roads and the construction of electric lines were developed during 1990's. Constructions of irrigation systems with deep wells were progressed in key areas. Tree planting was promoted around major roads and key developed areas.

Studies on Chlorophyl Fluorescent Response of Xerophytes under Short Term Water Stress

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Water deficit in terrestrial habitats have some effects on the growth of tree species in natural condition**.** The objective of this study was to examine the effects of acute water stress on the physiological characteristics of *Sabina vulgaris*, evergreen conifer tree growing in semi-arid region in China, by the chlorophyll a florescence response. The chlorophyll fluorescence is efficient indicator of photochemical activity of reaction center II. Some parameters were determined from chlorophyll a fluorescence using a pulse amplitude modulation fluorometer (Model, MINI-PAM, Waltz).

Eighteen sample seedlings growing in small pots were stored in a growth chamber at controlled air temperature (25-30℃), humidity (40-70%) and light intensity without any irrigation to experience acute water stress. Soil water condition changed from pF2.0 to pF5.0 for two weeks. Changes in chlorophyll a fluorescence with decreasing soil moisture content were monitored.

Yo value (optimal quantum yield), which could indicate photochemical light use efficiency, showed remarkable decrease with soil moisture shortage. The recovery of Yo value after water supply indicated a strong ability of drought resistance for short-term water shortage. Moreover, such prompt reaction of photochemical process to the changes in soil water condition suggested sensible response of physiological process to the changes in environmental factors.

Development of Low-cost Disdrometer and Observational Study on Precipitation Processes of Shallow Clouds Developing in Winter

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In order to understand the rain formation mechanism in clouds, it is important to know raindrop size distributions. Disdrometer is one of useful instruments to measure the raindrop size distribution at the surface. However, the existing disdrometer is expensive and heavy for field experiment. To improve these problems, a low-cost portable disdrometer was developed. The disdrometer consists of a CCD camera, an IR sensor, a strobe, and a signal control unit. When a raindrop interrupts the IR sensor beam, the strobe flashes and the image of the raindrop is recorded on a VTR tape. An experiment for the improvement of raindrop-capturing precision was carried out in use of the simulated rainfall experiment system that was constructed in the Arid Dome.

The continuous observation with the portable disdrometer was carried in the early March 2000. The rain/snow on the coast of the Japan Sea in winter is known to be from shallow convective clouds, in which cool rain process is dominant. The disdrometer was set on the rooftop of the Arid Land Research Center, and three different types of precipitation, which were rainy, sleet, and snowy weather, were observed. The maximum daily rainfall amount was 27.5 mm on Mar. 4, 2000. The data obtained from the disdrometer indicated that the raindrop size distribution was different from that of tropical maritime clouds. It also suggested the cool rain process at the upper level plays important role to the efficient formation of rainfall.

Preferential Flows and Solutes Transport in Sandy Soils

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When fingered flow occurs during ponding infiltration in a fine-coarse-textured profile, a thin wet zone forms directly below the textural interface (induction zone). During the onset of wetting front instability, a thin induction zone develops from which many small fingers grow initially. Subsequently, a few of these fingers become dominant; they continue to grow at the expense of the remaining fingers that stagnate. Two possible mechanisms govern this process: (1) the pressure head gradient required to laterally transport water from any location at the soil surface to the nearest finger is such that the water entry value of the dry soil is exceeded at some distance from a finger, thus causing another finger to fully develop at that point, and (2) the flux density strongly amplified wavelength of perturbations of the wetting front or the pressure head. Finger spacing in the former case is determined by the properties of the induction zone, and in the latter case by the flux conducted by an individual finger as well as the water supply rate.

Natural Environment and Agro-Rural Development in Arid Zone of West Asia and North Africa
– Through GIS Analysis and Fieldwork -

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The measures of the desertification control and the prevention of water resources and soils combined with governmental support and villagers participation are the crucial factors for agricultural development and environmental issues in arid and semi-arid zones such as Iran.

Water spreading system for food and traditional artificial recharge facilities are small low cost and indigeous applied technology that harness and conserve floodwater in unusual rainfall events in spring season at dry areas. They are one way to replenish the badly depleted aquifers as well as to produce and preserve food, fiber and fuel for the lean years.

In February of 2000, we made a field trip to Erfoud region in Morocco where is located between the foothills of the Atlas Mountains and western fringe of the Great Sahara Desert. We did a survey on the traditional irrigation water system, khettaras, a network of underground channels and erosion control net for prevention of desertification that made from palm trees.

In March of 2000, we did a field survey on the utilization of floodwater of wadhi (rud-e khane khoshk) for the traditional drinking water tanks (ab-anbar) for villagers and nomad peoples at the dry areas of southern parts of Iran.

In-situ Measurement of Soil Permeability

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In-situ measurements of field-saturated hydraulic conductivity, K_{fs}, are essential for accurate prediction of water movement in soil. The practical applicability of the pressure infiltrometer method to measure K_{fs} of soil is examined using field and laboratory tests and numerical calculations. Sand and loam soils were selected for the study. Theoretical features of the pressure infiltrometer method are explained by the field permeability tests and the numerical calculations. It is shown that the pressure infiltrometer method can be an excellent practical in-situ permeability test. It is suggested that about 0.06 cm^{-1} or some smaller value of α^*, which is a soil parameter describing the unsaturated hydraulic conductivity of soil, may be more appropriate for sand and loam in calculating K_{fs} of soil, and that the measurement depth of the pressure infiltrometer method can be controlled by combining the radius and insertion depth of the ring, and the constant head imposed on the soil surface within the ring.

Analysis of Soil Water Movement by Using the Generalized Model for Unsaturated Hydraulic Conductivity

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The unsaturated soil hydraulic properties are represented by the relationship between the volumetric water content and the soil capillary pressure head, and the hydraulic conductivity function. Some models for water retention have been combined with pore scale models suggested by Burdine or Mualem for the purpose of deriving analytical expressions that can be used to predict the hydraulic conductivity. These combined water-retention-hydraulic-conductivity models have been widely used for the numerical modeling of soil water movement. In these models, it has been assumed that soils are unimodal, characterized by a single pore size distribution function. However, undisturbed soils may occasionally exhibit retention curves with more than one inflection point. This multimodality of pore size distribution may be the result of specific particle size distributions or be due to the formation of secondary pore systems (macroporosity) by various soil genetic processes such as soil aggregation or biological soil-forming. This study proposed to describe the retention function of these types of soils by a multi-model function, and developed the corresponding unsaturated hydraulic conductivity model. The developed retention and conductivity models were tested using observed data for some soils. The results showed excellent matches between the observed data and the model estimations.

Water Requirement of Vegetable and Fruit Trees Using Moisture Sensor

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The objective of this study was to measure water requirement of 3rd year-‘Kyoho’ grapes controlled by moisture sensor (UNSUC, SK-5500ET). The grapes were planted in pots in vinyl-house, and the pots were covered with polyethylene film in order to prevent surface evaporation. There were two treatments controlled by the sensor: treatment A (pF1.8 = 90% soil water) and treatment B (pF2.5 = 70% soil water). It was found that the water requirement of the grape trees during the cultivation period was 260 mL/g dry weight for treatment A and 176 mL/g dry weight for treatment B, and also the grape quality for treatment B was obviously better than that for treatment A. Thus, we suggested that the highest water requirement of 3rd year-‘Kyoho’ grape tree without the damage to grape yield and quality could possibly be less than 70% soil water.

Effect of Heterogeneous Water Flow on Unsaturated Hydraulic Conductivity Measurement

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Multi-step outflow experiment was applied to undisturbed structured soils that contained root channels or wormhole. Multi-step pressurized outflow experiments were performed for tree types of soils under different management such as paddy field; upland field; and forest soils. Optimized parameters showed non-uniqueness problem when saturated hydraulic conductivity (K_s) was applied as fixed value, however, the problem was settled when K_s was given as variable. Optimized K_s was smaller than measured K_s by about one order, which showed discontinuity in hydraulic conductivity near saturation. In saturated condition, macro-pore conducts water much faster than bulk soil, however in unsaturated condition, only bulk soil conducts water, making discontinuity from saturation to near saturation. Popular Mualem-van Genuchten equation contains K_s as one of the coefficient for unsaturated conductivity. In this case, K_s should be measured independently and K_s in parameter estimation should be applied as variable. Multi-step outflow experiment will be also useful for undisturbed soils through this procedure.

Research on Estimation of Unsaturated Soil Hydraulic Properties Using Genetic Algorithms

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A new filed experimental methodology of determining unsaturated soil hydraulic properties is proposed. In this method the unsaturated soil hydraulic properties are assumed to be represented by van Genuchten's closed-form expressions. Unknown parameters of this model are identified by Genetic Algorithms (GA) incorporating finite element analysis of non-steady axisymmetric seepage flow. GA is search algorithms based on the mechanics of natural selection and natural genetics, and one of the increasingly popular global optimization methods. Ponded single-ring infiltrometer technique, such as the Guelph Pressure Infiltrometer is performed. Simultaneously measured transient soil water content and cumulative inflow data are used to identify unsaturated soil hydraulic functions. The advantages of the proposed method are identifying the optimal unsaturated soil hydraulic parameters and diminishing experimental time. To evaluate availability of our proposed method, experimental results that are determined by proposed method and conventional laboratory method are compared for Tottori dune sand.