

(2) Summary of Joint Research

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

Early Detection of Water Stress by Analysis of Chlorophyll Fluorescence Distribution and Suppression of Photoinhibition by Row Cover

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To obtain basic knowledge on chlorophyll fluorescence of water-stressed plants, chlorophyll fluorescence was measured during the daytime for coffee and cabbage plants under different water treatments. Chlorophyll fluorescence parameters, F_v/F_m which is the dark-adapted quantum yield of photosystem II, and $\Delta F/F'_m$ which expresses the actual quantum yield under light conditions, were determined at several leaves in each plant using a pulse-amplitude modulated portable chlorophyll fluorometer.

$\Delta F/F'_m$ was lower in water-stressed coffee and cabbage plants than that in non-stressed plants. Variation in the values of $\Delta F/F'_m$ inside each plant of coffee increased with increasing the water stress level. F_v/F_m was lower in both water-stressed and non-water-stressed coffee plants than the normal level. This suggests that coffee plants exhibit photoinhibition in the daytime.

A Prediction Model for Daily Gravitational Water at a Sand Dune Field

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Gravitational water with eluviation of fertilizer is an important problem for the conservation of groundwater. It is remarkable at a sand dune field because it has large permeability and little available water. When the timing of irrigation and rainfall is mismatched, gravitational water is greater than only rainfall. It is essential for the sustainable agriculture at the field to establish the irrigation method minimizing gravitational water. In this study, the prediction model for evaluation of gravitational water at a sand dune field is developed and performed some simulation to clear the irrigation method minimizing gravitational water. The results are summarized as following: 1) The model has good prediction accuracy. 2) It is cleared that the gravitational water at a sand dune field is reached 60% by supply water into it. 3) It is suggested that irrigation method with high flexibility have possibility to decrease the gravitational water.

Estimation of Evapotranspiration Efficiency under Mulching Culture

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Experiment was conducted from July 6 to August 18, 2000 to compare the influence of various rates of Straw mulch on evapotranspiration, soil moisture, soil temperature and root distribution. Treatments included Straw mulch, Black film, Paper, Control, and Bare soil. Evapotranspiration was highest in Bare soil and lowest in Straw II in the initial stage but in the later stage it became higher than that of other treatments due to its higher transpiration. Evapotranspiration efficiency was highest (98%) in Bare soil and lowest (59%) in Straw II mulch. In this study, in case of Black film mulch only transpiration occurred. Evapotranspiration efficiency decreased in the order as follows: Bare > Straw I > Paper > Straw II. The soil moisture content at 2 cm depth of all treatments except Black film was less than 30 (vol.%) and at that time evapotranspiration efficiency started to decrease. The diurnal range of soil temperature of Straw II mulch was the lowest and highest in Bare soil. The minimum temperature of Straw II mulch was high at night. Root density was high only on the surface layer in Straw mulch but other treatments it grew uniformly up to bottom.

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

Fundamental Studies on the Relationship between Salinization and Evapotranspiration of Agricultural Lands in Arid Area

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We measured water pressure of 1 mm glass beads media. We control water pressure as connecting water table, and lower it gradually. Lower than the critical water level, water pressure becomes independent from the water level. In that condition, water in porous media consisted of pendular ring and film water, and film water does not transmit any pressure, and hydraulic conductivity becomes zero (hydraulic disconnection). We conclude, that in the condition of hydraulic disconnection, water movement depends upon thermal gradient, and water moves with phase transform from liquid phase to gas phase, v.v.

Measurements of Water and Salt Behavior in Soils Using TDR Method

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A small TDR probe was designed and its characteristics were examined. The probe was made of an electric circuit board on which serpentine wave guide was drawn. The calibration of the probe was investigated for three different soils. Each probe showed appropriate relationship between soil water content and apparent dielectric constant, though data scattered a little bit for sand soil. Furthermore, from a numerical analysis, it was found that the sampling volume of the probe is about few mm over the board.

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 conditions. Heat pulse system was applied on cotton stem for measuring root water uptake. Cotton is a salt-tolerant crop and a threshold soil salinity level at which initial yield declines gave an EC_e of 7.7 dS m^{-1} ; a 50% reduction in yield occurred at an EC_e of 17 dS m^{-1} (Ayers,1977). Exp.1) Salinity levels of irrigation water to reduce transpiration rate of cotton were investigated using potted plants. Frequent irrigation with saline water ($EC_{iw}= 15\text{dS/m}$) reduced 20% of transpiration rate and soil salinity showed an EC_e of 11.0 dS m^{-1} . According to the figure of Ayers (1970), this soil salinity level is supposed to reduce 20% of yield. An agreement of these values was convinced. Exp.2) A relationship between ground saline water table and root water uptake was investigated using root boxes. In case of wetted soil condition with evenly distributed, root distribution and salinity distribution in the soil profile were similar. In case of high water table, there was no significant similarity between root and salinity distributions because of dominant root water uptake occurred near water table.

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

**Environmental Responses and Varietal Differences of Cereal Roots
in Their Tissue Structures**

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1. Dynamics of Cell Length in Maize and Rice Roots under Different Water Conditions.

Length of roots is an important factor to establish a deeply-developed root system that is expected to have high ability to acquire soil water under drought conditions. Response of cell elongation pattern in root apical part to water content of soil could be a factor to determine the root length under drought conditions. Maize and three varieties of rice seedlings were grown with vermiculite mediums with different water content. Longitudinal sections of apical 5cm of primary seminal roots were observed to investigate the length of cortex cells. In maize, final cell length (at more than 40mm from the root apex) did not differ with water conditions, but the cell elongation in the elongation zone (at 5-40mm from the root apex) seemed to progress more slowly under drought conditions. In rice, final cell length was different among the three varieties under drought conditions - drought tolerant varieties had larger cell length than sensitive variety.

2. Silicon Accumulation in Root Endodermis of Rice.

Silicon (Si) is an important chemical element to rice. Rice seedlings were grown by solutions with and without silicon. The content of silicon in cell walls was investigated using X-ray microanalyzer (EDAX) attached to ESEM in the Arid Land Research Center. Silicon accumulation was clearly detected in cell walls of root endodermis and leaf surface by EDAX. Moreover, a treatment to supply silicon in the solution after five days cultivation without silicon was conducted. The result suggested that matured part of roots (more than 10cm from the root apex) still accumulating silicon into the cell wall of endodermis.

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**Physical and Chemical Modification of Root Cell Walls by Humidity,
Environmental Ions and Plant Growth Regulators**

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Viscoelastic properties of cell walls are important factors to control the growth of plants and to control the mechanical strength of cell walls. Since the apoplast of roots is open to outer environment, the cell walls of roots may directly be affected by drought and acidification of outer environment by which water absorption and turgor pressure are influenced resulting in physiological responses of symplast.

In this research, we investigated the extensibility of root cell walls under several water conditions such as pH and humidity surrounding the cell walls.

Viscoelastic properties of cell walls were measured *in vitro* by a creep meter (Yamaden, Tokyo) equipped with a constant humidity supplier (Fuji Electric, Tokyo). The elongation zone of lateral roots of Alaska peas were used for an experimental material.

Low pH buffer solution drastically decreased viscosity coefficient of cell walls (*Plant and Soil* 226:21-28, 2000). Dehydration of cell walls increased both elastic moduli and viscosity coefficients, whereas hydration by high-humidity air stream decreased these mechanical parameters. One of candidates for trapping water molecule in the cell walls is a pectin component. Cell walls with pectin partially removed was more extensible than untreated cell walls. Preliminary results showed that pectin-removed cell walls are less responsible to hydration and dehydration. These results indicated that the mechanical property of root cell walls could be controlled by surrounding water conditions, such as low pH and dryness. It was suggested that drought and/or acidification of root environment may affect viscoelastic properties of root cell walls, which then regulate the root growth.

Analysis of Crop Root Formation Using Acoustic Emission (AE) Method

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Non-destructive methods for measuring crop root system are highly needed to evaluate elasticity of root morphology under various stressful conditions. However, few non-destructive methods are used under the field condition. We are developing a non-destructive method for measuring root system using acoustic emission sensors. The objects of this study are to adapt AE method to various soil types and to arrange installation of wave guide with AE sensor for measuring elongation angle of nodal roots. Results in this study are summarized as follows: 1) Low sensibility to detect root elongation in paddy soil was improved by putting sand on the wave guide. 2) The elongation angle of nodal root could be measured by inserting the wave guide (40 cm length) with AE sensor into soil at 20 cm apart from the plant.

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

Study of the Genes for Water Transport in Relation of Salt Tolerance in Plants

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In order to reveal the molecular and cellular mechanisms of salt tolerance and drought tolerance in plants, water channels, that regulate water transport at the plasma membrane and at the tonoplast, are one of the important factor to be analyzed. In this work, the author isolated 3 putative plasma membrane type water channel genes from barley, designated as bpw1, 2, and 3. Among them, the expression of bpw1 is highest and changed after salt stress. Now transgenic rice with barley bpw1 is established and is under investigation. The author also identified a water channel gene in *Salicornia*, one of halophytes. This is most homologous to barley bpw3.

Effects of Salt Water Irrigation on Growth of Bulbous Plants

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Drought tolerance in 45 species/ cultivars of 29 genera of seven families of geophytes was surveyed from autumn of 1998 to early summer of 2000 by means of salt water irrigation at different concentrations. Fourteen species/ cultivars with 0% salt treatment (control) did not flower or flowered in very low rate, probably because of no initiation or abortion of flower buds in high temperature in greenhouse conditions. The remaining well-flowered 29 species/ cultivars were finally classified into eight categories by three flowering characteristics (flowering rate, plant height and days to flowering) and their combinations responding salt treatments. All these flower characteristics were not affected in *Muscari armeniacum* with 5,000 mg/L salt treatment, proving that the plant is the most drought tolerant. At least one characteristic in other geophytes examined was much or less affected by the treatment. Generally, spring-flowering geophytes tend to be more tolerant than summer-flowering geophytes. However, no clear relationship between family and classified categories and between the types of storage organs (bulbs, corms, etc.) and the categories were found. Salt (drought) tolerance in geophytes seems to be species or cultivar dependent.

The Effect of the Water Conservation Rate on the Crop Growth

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In this year various crop water requirements data were collected. For selecting of crops with strong ability on arid land, the data were collected in respect to soil water content, salt concentration and meteorological environment.

On the bases of collected data Egypt was selected as a representative of hot desert and Inner Mongolia of China was selected as a representative of cold desert. It is under progress for what these please

people request, because the objective of the study is to provide practical water saving culturing measures for the local farmers.

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

Ecophysiological Responses of Three *Salix* Species under Different Water Conditions

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Ecophysiological responses under different soil water conditions were compared among three *Salix* species including *S. Matsudana* Koidz, which is used for the afforestation in semi-arid areas in China, and two Japanese *Salix* species (*S. subfragilis* Andersson and *S. sieboldiana* Blume). In this study, photosynthesis rate, transpiration rate and leaf water potential were measured using 1-year-old cuttings of those three *Salix* species grown under flooding, drought (pF2.4) and irrigated (pF1.4) conditions. *S. subfragilis* inhabiting river side tolerated flooding stress and *S. sieboldiana* inhabiting hill slope showed drought tolerance. The ecophysiological characteristics of these two species corresponded with their natural habitat. The habitat of *S. Matsudana* is riverside in northern China but the cuttings of this species tolerated drought stress.

Effect of Soil Microbes on Salt Tolerance of Trees

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Influence of arbuscular mycorrhizas and actinorhizas with *Casuarina* trees to the growth of seedlings and to the salt tolerance was investigated in pots. The growth, photosynthesis rate, transpiration rate and stomatal conductance were greater than controls. Ergosterol biomass of infected fungi in pots after 6 months increased and the extrahyphae of arbuscular mycorrhizal fungi extended to the soil.

Salt tolerance of *Frankia* symbionts was high, but their photosynthesis rate was decreased. Though leaf color of symbionts kept green, controls changed autumn color. Though shoots of well-grown

symbionts were highly caught by powdery mildew (*Uncinula* sp), controls were lower infection.

Fundamental Studies on the Technical Improvement of Afforestation

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The studies were carried out for improvement of the bad soil condition and maintenance of the green resources or recovery. Consequently, the saline tolerance plants are introduced into deteriorating soil or deteriorated soil and the salinity is absorbed. After then, leaves and branches of plants are required to take away by cutting or pruning and to dispose. It was proven that the soil improvement became possible by repeating these actions. And it was proven to be the application of the continual subsurface irrigation method that it maintains the green resources, and that as recovering and effective water management technology, the irrigation water does not permeate it in the deeper soil layer.

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

On the Characteristics of Rill Patterns Generated on the Salinity Soil - Effect of Surface Soil Compactness on Soil Erosion -

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This study aimed at investigating the effect of surface-soil-compactness on erosion in a laboratory experiment. From this experiment, the following results were obtained:

- 1) In the case where the same volume of surface flow occurs, comparing the loss of surface soil with different dry densities, erosion was most severe on the soil with low dry density.
- 2) In the case of sheet erosion, soil loss decreased with the passage of time, showing no relation to the dry density and the volume of surface flow. However, when rill erosion occurs, the outflowing of soil reaches its peak in the existing time-interval. This peak became higher in accordance with the increase of soil loss as the dry density becomes lower.

3) Clay and fine sand showed the tendency to be heavily eroded by surface flow. This tendency was noticeable just after the surface flow starts and it became most noticeable on the soil with a high dry density.

Effects of Soil Chemical Amendment on Stability of Soil Structure

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Soil chemical status affects behavior of clay particles and then stability of soil structure. Chemical amendment widely uses to prepare land for agricultural production. It may affect soil physical properties, but details are still not clear. This study aims to the first step to answer this question. Here we employed chemical improvement of acid soil as a model of chemical amendment. Kunigami Mahji soil from Okinawa Japan was packed into plastic acrylic pipe with 1.15 g/cm^3 . At the beginning, three pore volume of 30 mol/L NaCl solution was percolated to attain standard condition. Following to this Ca electrolyte solution, CaCl_2 , of the same electrolyte concentration was supplied. During the experiment, EC of the soil solution and electric conductivity (EC), pH and ion concentrations of effluent were measured. Calcium and Na solutions showed similar EC outside of the soil column. However, when the front of the Ca solution leached to the EC censor, it showed lower EC. It was interpreted ion exchange and hydration and precipitation of Al cations in the Mahji soil was a reason of this drop of the EC.

Prediction of Soil Erosion in Different Bare Plots

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The study was carried out to investigate the applicability of a soil loss equation (proposed equation) in various plots with bare surfaces (bare plots) while estimating the amount of soil erosion using the proposed equation. Data used in the analyses were recorded from several fields under the natural rainfall (standard type test field and free type test field) as well as experimental plots/erosion boxes under an artificial rainfall simulator and a surface runoff generator. The result showed that in each and every type of experimental plots (bare plots), the applicability rate of the proposed equation ranged within 48.5% to 60.1%. Moreover, the type of erosion (sheet and rill erosion) found in each plot was different. The study identified that the variation in the amount of soil loss, which lately affected the applicability of the equation was occurred because of the variation in size and configuration of each test plot. The data and analytical results of the study would be used as useful referential materials for any individual and or an integrated general research to predict the soil erosion in farmlands.

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

Evaluation of meteorological environments of the Loess Plateau by Satellite data

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The basin of Huang He River has scarce rainfall about 400 to 700mm. Dry-up of the river began in 1972 and occurred frequently year by year. It causes 26.8 billion Yuan worth damage. The dry-up was supposed to occur by three reasons below. 1) Reduction of rainfall for the basin; it has no clear tendency partly because precise rainfall data for the basin has not made. The data will be made by data by GMS, which is Japanese meteorological satellite. 2) Increase of water consumption by farm and industry; it has clear tendency for 27 years. 3) Insufficiencies of water management; this is room for improvement in the future. Especially, 2) is caused by improper use of water and land resources. Proper crop planning and water management is necessary for the water shortage of Huang He River.

Improvement of Estimating Method for the Aboveground Biomass Using Landsat-5/TM Data

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Our study has been conducted to develop the estimating method for the aboveground biomass using satellite data. Many researchers reported to evaluate the standing tree volume using satellite data. Spectral reflectance of the tree canopy was measured by handheld spectral radiometer for several tree ages and tree heights at Takakuma Experimental Forest Station, Kagoshima University. We tried to estimate the biomass with NDVI using Landsat/TM data. These results were reported last year. In this study, we eliminated the geometric and atmospheric effects on the Landsat/TM data. NDVI and pattern expanding method were adapted. The relationships between the calculated values on composite images, corresponding to the ground truth points, and actual values were analyzed by multi regression method. This result shows the higher correlation than the previous results.

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

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The arid to semi-arid region, with its very limited fresh-water potential, has generally used saline water such as brackish groundwater as major water supply source for either drinking or irrigation. Quality of drinking water sometimes exceeds the maximum limit of WHO standard of 1,000 ppm of T.D. S. Salinity of groundwater in the deep aquifer increases by steps owing to over pumping exceeding the safe yield. After exploiting almost all the renewable fresh water resources in the country, it is essential to adopt the management policy for sustainable development. A case study of non-conventional water resources management, which is carried out by tri-lateral international cooperation among Jordan(MOWI), Germany (GTZ) and Japan (JICA), is shown In this paper.

**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.

Hitao Irrigation Project is a large-scale irrigation project, which takes 294,000,000 m³ of water annually (just less than 300 m³/sec) from Huang Ho River covering 500,000 ha of farm land. In this area, irrigated agriculture had been practiced since the time before Christ but a full-scale irrigation project was started about 100 years ago. At present, the project is said to be in a critical situation due to serious

problems of water shortage and saline soil in addition to decrepitude of irrigation facilities.

In the present study, we analyzed land-use changes in the respective irrigation blocks in the recent year using satellite image data to grasp the actual state of irrigation in this big project and to find a clue for solving problems in future.

Land Cover Classification by Using Remote Sensing Data and Material Spectral Characteristics

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In continuation with my efforts on researches involving land cover classification using remotely sensed data, I would like to summarize here the results from an experiment with Masa soil.

The spectral characteristics of Masa soil samples were investigated in the laboratory using spectrometer. It was found that:

1. With dry soil samples, reflectance values were not affected by temperature and illumination of the surroundings.
2. With the increase in water content of soil samples, the reflectance values increased.
3. In case of weathered dry soil, both when dry and wet, strong absorption was observed in a region approximately corresponding to band 6 of the radiometer ASTER flying aboard Terra satellite.

B-2) Studies on Salt Accumulation and Leaching

Reclamation of Salt-affected Soils through Leaching

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In this research, salinization process was studied as a preliminary experiment to improve the salt-affected soil through leaching and to make salt affected soil for leaching experiment.

Four different states of the stratification were made filling sandy and clayey soil to small column ($\phi 5\text{cm} \times 20\text{cm}$) as follows: upper half sandy and lower half clayey (SC), upper half clayey and lower half sandy (CS), whole sandy (SS) and whole clayey (CC).

Water, whose quality assumed that of the Syr Dar'ya river (Kazakhstan republic), was supplied from the bottom of the soil column with a Mariott bottle. The columns were set in the air-conditioned room (35□ in temperature, 25% in humidity, and 80,000lux in illuminance).

The results are as follows,

- (1) The amount of salts which accumulated on soil surface has increased in proportion to the amount of

evaporation from the column.

- (2) The amount of evaporation from the surface was the least in SC, and the salt accumulation was lowest. The amount of evaporation and accumulated salt have increased in the other three columns in order of SS<CC<CS.
- (3) It seemed that the salt accumulation to the surface was suppressed, if sandy soil in the upper layer controlled evaporation even if the clay soil existed in the lower layer. However, when the composition of the layer was opposite, salt accumulations were promoted most.
- (4) When underground water level was shallow like this experiment (depth of 20cm from the surface), the sandy soil of the lower layer effectively move moisture to the upper layer.
- (5) First, Na and Cl accumulated to the surface. And increase in the amount of accumulation of Ca, Mg and SO₄ was the following continuously.

From the above-mentioned, it was confirmed that the situation of the salt accumulation changed depending on the soil texture and the stratification condition of the soil. It is scheduled to verify the effect of reclamation of salt-affected soils through leaching with no disturbance soil, based on these results.

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. Time-domain reflectometry (TDR) is a promising technique to monitor water content and bulk electrical conductivity (EC) of soil simultaneously and nondestructively. Firstly the performance of down-sized TDR sensors having 0.5 to 10 cm in length was evaluated. TDR measurements of the dielectric constant ϵ and EC for Na- and Ca-bentonites were also investigated. Bentonite samples though prepared by distilled water provided considerable magnitude of EC having a maximum peak value at volumetric water content $\theta = 0.60 \text{ m}^3 \text{ m}^{-3}$, the lowest limit of θ for saturation: 3.88 dS m^{-1} for Na-bentonite and 1.45 dS m^{-1} for Ca-bentonite. Due to energy loss, TDR waveform was almost completely attenuated between $\theta = 0.45$ and $0.87 \text{ m}^3 \text{ m}^{-3}$ for Na-bentonite and between $\theta = 0.36$ and $0.50 \text{ m}^3 \text{ m}^{-3}$ for Ca-bentonite.

Study on the Measurement of Subsoil Permeability

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An applicability of the Guelph well permeameter (WP) method was examined by in-situ tests in sand field. The WP method, which was developed by the researchers of Guelph University, Canada, around

1985, is an in-situ permeability test to determine a field-saturated hydraulic conductivity of soil, K_{fs} , by measuring steady-state infiltration rate from a bored well into the soil to maintain constant head of water within the well. The in-situ tests in the sand field showed that an apparatus of the WP method as well as a procedure to measure the steady-state infiltration rate is quite simple. Accuracy of K_{fs} was successfully evaluated by comparing with saturated hydraulic conductivity of soil cores sampled from the test sites without disturbance. K_{fs} along the vertical line from the soil surface to 140cm in depth were measured by the WP method and plotted together with the soil profile along the vertical section of a trench in the soil. Comparison between K_{fs} along the soil profile and the saturated hydraulic conductivity of the soil cores sampled from the soil layers revealed that, in the case of layered soil, the WP method provides a weighted average value of K_{fs} of layered soils included within some region around the well. It was also shown that the vertical component of hydraulic conductivity is preferably measured by the WP method in sand soil.

Mechanics of Simulation Transfer of Water, Solute and Heat

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Simultaneous water, salt and heat transfer experiments were conducted using in large soil columns with 798 mm in diameter that were installed at the Arid Land Research Center of Tottori University. The behavior of water, salt and heat were monitored on condition of no-plant (1999) and plant (2000). The following result was obtained. (1) It was confirmed that salt concentration at soil surface influences evaporation phenomena. And the method to predict the evaporation rate was developed. (2) It was clearly that the salt transfer caused by the difference of solution density, usually it was negligible, exists. Therefore, it was impossible that convection-diffusion equation was applied to these experiments. A modified salt transfer equation considered the effects of the density flow was developed.

C) Free Subject on Arid Land Studies

Characteristics of Subsurface Water Movement in Sand Dune

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It is important to understand the behaviors of water soil and infiltration processes in sand dune. However, a few studies have been conducted outdoor. At the same time, almost all studies of outdoor experiments focused on one dimensional phenomena in this issue. In this study, we paid our attention on the whole sand dune and considered the water movement in two-dimensions. A typical sand dune has been chosen in Tottori, Japan to study the behaviors of soil movement and temperature in sand dune where the water table is 20m in depth. TDRs, thermometers and tensiometers have been set in 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.

The following conclusions can be expressed:

- (1) There is a very close relationship between temperature and moisture distribution in the sand dune. Temperature variation caused by infiltration water will become smaller and smaller with the depth. As a result, it is possible to trace infiltration with temperature in the sand dune where there exists a large temperature gradient during snow-smelt period.
- (2) In the suspended water zone, the wetting front made by snow-smelt water moves downward through the surface is faster in bare site than tree site since the existence of humus soil which field capacity is much higher than sand.
- (3) Vegetation can control water infiltration in sand dune by topsoil layer and well as transpiration. As a result, soil water content in sand dune with vegetation was higher at the topsoil and lower in the sand below 15 cm in depth than that without vegetation.

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 soil in domestic and overseas are possessed. Digital image of surface I the arid land soils was measured by digital camera. Spectral data of surface in the arid land soils was measured by spectrometer. Recorded digital image and spectral data made the database by adding the comment of picking places, picking persons, picking dates, etc.

Numerical Study of the Movement of the Sand Dune in the Arid Land

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In this study, we proposed one method to simulate the sand movement by the wind and investigate the flow over the typical sand dune and its movement assuming that the effect of the turbulence can be incorporated through the eddy viscosity of constant value. At first, the flow field is obtained without the movement of the dune in order to get initial condition for the computation. Then, using this result, the sand dune is deformed by the change of height of the surface. The flow field and the transfer of the sand are coupled through the relation between the friction and the transportation. The height of the dune becomes lower and the both side of the dune is spread out under the condition of uniform flow at the boundary. Finally, the shape of the sand dune approaches crescent shape like the actual barchan dune. The formation of the steep slope in the rear side is related to the large vortices formed behind the dune.

A Study on Photovoltaic (PV) Power System for World Deserts Using the Arid Dome

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We have been obtaining the meteorological data of Inner Mongolia using the Inmarsat mobile telephone system for more than one year. The data showed that averaged wind speed was relatively high and humidity low in April at Inner Mongolia. Total irradiation in Inner Mongolia in 2000 was about 1.25 times as much as that in Tottori in Japan. Irradiation at the inside of Arid Land Dome was 40% of the outside and sharp fluctuations in irradiation were observed inside of the Arid Land Dome because of the shadow of the framework. In order to control the irradiation at the inside of the Dome, we designed an artificial irradiation control system using a liquid crystal film (UMU, Nippon Sheet Glass Co., Ltd) and Fresnel lenses.

Hydraulic Design of Bypass Flow Meter Using the Bend Pipe

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In agriculture, to reduce the price of agricultural production, the low cost and low energy, in agricultural facility and production process, are requested. The typical flow meter in pipeline is orifice or venturi meter. In these meters, providing narrow cross section of constriction in the pipe creates a pressure difference. There is a head loss in pipeline using of these meters.

In this study, using the bend pipe, the hydraulic characteristics of flow meter are clarified.

The entrance of bypass flow was set at the straight part of pipe. To prevent the flowing of suspended matter in flowing water into bypass route, the filter was attached to the entrance of bypass flow. On the entrance of bypass flow, the bypass pipe stuck out into the main pipe to increase the bypass flow rate of water.

Measurement of Mass Transfer from an Agricultural Land Using the Energy Balance Flux Ratio Method

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Using the energy balance flux ratio method, the CO₂ fluxes from a paddy field were measured in two days a week from July to September, 2000. Estimated values of the CO₂ flux were similar to previously published data. However, clear relationship between the CO₂ flux and solar radiation or wind speed was not obtained. Reliable measurements of the CO₂ concentration in air are difficult to obtain outdoors, but the accurate estimate of the CO₂ concentration at two heights would be obtained by fitting the empirical equation to the measured concentration profile.

Ethnopedological and Ecotechnological Study for Sustainable Agricultural Development in Sahel Zone of Niger, West Africa

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The objective of the study is to establish an Ecotechnology based on indigenous knowledge in the Sahel zone of Niger. Soil, wind and indigenous knowledge were systematically surveyed to obtain necessary information. To arrive at the desired results, the following survey framework was set:

- 1) Determination of the characteristics of the soil in a benchmark site in which soil sampling was done and their physical, chemical, and biological properties were analyzed.
- 2) Indigenous soil knowledge survey to find out the system of soil evaluation by farmers and to establish the validity of indigenous knowledge by the application of scientific methods.
- 3) Survey on Harmattan dust and the effect of mulch to monitor the deposition of this dust in a benchmark site and to determine its characteristics. And this is also to find out the function of crop residue used as mulch for soil fertility management.

The physical, biological, and chemical properties of the soil were characterized. Longitudinal and

transverse sections of two transect lines were designed in the benchmark Matankari watershed (BMW). Soil samples were taken along these transect lines. The analytical results indicated that the difference in the soil characteristics is obviously according to each geographical unit although the soil in BMW is classified as one, Ferrisols. However, the soil fertility level of all sites on the plain is quite low compared with the results on Sahel savanna and West Africa by Buri (Buri, et al 1999), due to the high percentage of sand (90% \leq). These shows that it is important to establish suitable methods for soil fertility management based on a detailed soil distribution map in severe conditions like that of the Sahel zone. The indigenous knowledge on soils can be thought as an available information for the establishment of suitable technologies.

The indigenous soil classification system was surveyed at the BMW. It was revealed that the farmers used the factors of soil color, soil texture, and soil fertility level to evaluate the soil. Each factor was divided into 3 to 4 subdivisions, the headings for which were given in the local language in Hausa. 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 in BMW. The information derived from the farmers' evaluation was well confirmed through scientific comparison. For example, "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 soils. 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. These quantitative characterizations indicated that the indigenous soil classification and evaluation system has a valid background and even empirical basis, which can be corroborated scientifically.

To prove the effectiveness of crop residue mulch as a trap for Harmattan dust for soil fertility improvement as well as to suggest a practical method of mulch application based on the indigenous soil knowledge in this zone, a field experiment was conducted during the dry season (November 1997 to February, 1998). One set of 10m x 10m of two squares were set on different locations, the upper, middle and lower sites. A 20 kg millet stem were distributed on one small square as a 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 twice, before applying the crop residue and after the experiment. Three dust samplers each with a height of four meters were placed 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. In addition, mineralogical analysis results showed that the same components of dust were present in the soil of M from the upper site and lower site, which means that mulch functioned as a trap for dust. Although using crop residue as mulch has not been thought as a practical method, the result of the study proved the effectiveness of mulch for soil fertility improvement in this zone. Once mulch application is practiced in the upper stream where the soil is physically and chemically poor but still used for cultivation, the fertility of the soil can be improved by the incorporation of Harmattan dust. On the other hand, animal grazing can also be practiced in the down stream where nomad people can provide water for their animals. This combination can contribute not only to the regeneration of the degraded watershed but to the coexistence of different tribes in an ecosystem.

The Effect of Low Water Table on Carbon Distribution into Roots

and Respiration Loss in Rice

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We investigated whether carbon distribution into roots and respiration loss from a whole plant in rice changed by water deficit with low water table treatments. Low water table did not increase absolute amounts of carbon distribution into roots of two rice cultivars including drought sensitive and resistance cultivars, although partition percentage of carbon in roots increased. Respiration estimated from ^{13}C loss was accreted by the increase of carbon distribution into roots. Higher distribution of assimilated carbon into non-assimilation organs such as roots seemed to increase respiration of the whole plant.

Analysis on Crop Physiology in Arid Region of China

--- Effect of Water Deficit on Physiology of Cotton Canopy ---

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The relationship between drought resistant and dry matter production was analyzed for cotton canopy in the dry land field at the Experimental Farm of Shihezi Dry Land Agricultural Institute, Shihezi, Xingjiang China. Transpiration rate, leaf temperature, photosynthetic characters were measured for crops in drought or irrigation plots. Leaf temperature was high for the drought crop, which was grown in drought plots, and its leaf water potential is especially low in the afternoon. The drought crop had lower leaf, stem and bud dry weight than the irrigation crop, although it had higher seed ball. This suggests that cotton leaf increase its temperature as it decrease its transpiration rate which is induced by water deficit. The increase in leaf temperature declined the photosynthesis activity and the productivity on cotton canopy. On the other hand, moderate drought made the partitioning rate to seed ball high.

The Relationship between Desaturation of the Fatty Acid and Salt Tolerance in Plants

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The relationship between desaturation of the fatty acid and salt tolerance in salt tolerant plant sugar beet (*Beta Vulgaris* L.) which can grow in the medium contained 0.2 M NaCl. Lipids in 0.2 M NaCl treated and non-treated plants were separated by silica gel chromatography and thin-layer chromatography, and fatty acid in the lipids was separated and measured by gas chromatography. Fatty acid desaturation in galactolipids monogalactosyldiacylglycerol (MGDG) and digalactosyldiacylglycerol (DGDG), phospholipid phosphatidylcholine (PC), phosphatidylethanolamine (PE) and

phosphatidylinositol (PI) isolated from salt treated plants were detected. These results suggest that fatty acid desaturation involve salt tolerance in plants.

Relationships between Structure and Function of Plant Root System under Dry Conditions

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Knowledge on structure and function of plant root system as well as their relationships is essential to improve crop production in arid and semi-arid areas. Electric potential of plant roots was examined as an indicator of their physiological activity. Throughout whole developmental period, there was intimate relationship between electric potential and xylem sap rate, the latter of which is an established index of root activity. Thus, electric potential is thought to be a useful indicator for long-term and non-destructive method monitoring function of plant root system. In addition, electric capacitance of plant root system was measured to estimate root mass non-destructively. During vegetative phase there was linear relationship between root mass and electric capacitance, though the relation was unclear during reproductive phase. Therefore, electric capacitance seems to be an index to monitor root mass non-destructively. Using above mentioned methods structure and function of plant root under stressed conditions are examining.

Screening Seed Germination Stimulants for Parasitic Weeds

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Effects of temperature and duration of conditioning (pre-incubation) on seed germination of a root parasitic weed, *Orobanche minor* Sm., were examined. In addition, effects on germination of phytohormones added during the conditioning period were evaluated. The exposure to supraoptimal temperature above 30 °C within 24 hours before or after the terminal treatment with strigol, a natural germination stimulant, significantly reduced the germination rate. The seeds, however, could recover from the inhibition caused by the supraoptimal temperature treatment when they were kept at the optimal temperature (23 °C) after terminal treatment. Fluridone, an inhibitor of abscisic acid (ABA) biosynthesis, and GA₃ could also ameliorate seed germination after the exposure to supraoptimal temperature. Endogenous ABA level in the seeds dropped rapidly after imbibition and remained at a constant level

irrespective of the supraoptimal temperature or fluridone treatment. Therefore, it is likely that *de novo* ABA biosynthesis does not occur during the conditioning period even if the seeds are exposed to a supraoptimal temperature of 30 °C. Consequently, GAs seem to play an important role in both conditioning and germination of *O. minor* seeds.

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

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Striga hermonthica (Del.) Benth is an economically important root parasitic weed that causes considerable losses in yield of several cereal crops including sorghum, maize, millet and rice in the arid and semiarid tropics. Germination of a *Striga* seed requires an exogenous stimulant exuded by roots of host and some nonhost plants. Induction of seed germination in absence of host plants is one of the most effective methods for *Striga* control as well as usage of specific germination inhibitors.

In an attempt to develop effective natural germination stimulants to enhance depletion of *Striga* seed reserves in soils, 500 fungal isolates were screened, *in vitro*, for metabolites with activity as *Striga* germination stimulants. As a result, a strain of *Cercospora kikuchii*, a pathogen of soybean, was found to produce germination stimulants. These stimulants were purified from the culture filtrate of the fungus to afford two active fractions. Purification of one of them by HPLC gave no active fractions, but the mixture of these HPLC fractions showed the activity. Further purification of the other fraction resulted in isolation of an active substance, C₁₂H₁₀N₄O₅. A strain of *Fusarium solani* f. sp. *radicicola*, a pathogen of potato, was also found to produce a germination stimulant. The active substance was found to show the same chromatographic behavior as *p*-hydroxyphenylethanol, but its yield was too low to get sufficient spectroscopic data.

In the course of screening search for metabolites with activity as *Striga* germination inhibitors, 63 fungal isolates were screened, and three fungal isolates were chosen. From these fungi, penicillic acid, harbarumin, putaminoxin and a new metabolite, C₈H₁₂N₂O₂, were isolated as *Striga* germination inhibitors. Harbarumin was not a Lettuce germination inhibitor, indicating its selective inhibition against *Striga*.

Search and Synthesis of Water-Soluble Germination Stimulants to Regulate the Germination of Parasitic Plants in Semi-Arid Land Regions

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Striga, a parasitic plant found in semi-arid land regions, strongly damages the plants growing under drought stress and the agriculture in these regions. Strigol secreted by host plants induces germination of the seeds of *Striga*, and thus starts the parasitic life. It is effective to induce the germination at the point far from host plants. Strigol analogs have been chemically synthesized as artificial germination

stimulants. However, most of the strigol analogs including representative GR24 show low solubility to water. In order to circumvent the difficulties, we started the search and synthesis of water-soluble GR24 analogs replacing D-ring of GR24 to saccharide moiety.

We prepared the ABC-ring of GR24 and formed the enol group which acts as an acceptor in the subsequent glycosylation. Acetobromo glucose and ribose were coupled with this enol to afford the desired glycosylated products. Thus, we synthesized new types of GR24 analogs and developed the synthetic methodology to form enol glycosides. On the other hand, we tried to synthesize the analogs having high activities in short steps. Based on the proposed electronic mechanisms of the C-D ring cleavage during germination procedure, we selected some commercially available carboxylic acids and esterified with the enol.

**Comparative Study on Soil Factor Affected to Biological Production at Desert.
Application of New Fertilizer Contained Iron Element in Alkaline Sandy Soil.**

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Generally plants can not absorb iron element in alkaline desert soil (namely iron deficiency disease).

New trial manufacture fertilizer contained iron element was applied to Chinese mustard *Comatuna* in alkaline sandy soil. This fertilizer was made of EDTA-Fe compound with plastic covering treatment, and then influence of this fertilizer to plant is slowly.

Application of 5g/m² was better growth, but excess over this quantity was made poor growth.

**Salt-tolerant Wheat Breeding by Transferring *Thinopyrum Elongatum* Chromatin
into Wheat Genome**

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A highly salt-tolerant wheat line W148 (2n=42) was obtained from the BC₂F₆ progenies between *Triticum aestivum* (2n=42) and a salt tolerant wheatgrass *Thinopyrum elongatum* (2n=70). In the cross of W148 × salt sensitive wheat variety Chinese Spring, the F₂ plants segregated into the ratio of 3 salt tolerant: 1 salt sensitive, indicating that the salt tolerance was conferred by a single dominant gene. Genomic in situ hybridization (GISH) analysis clarified that W148 had one pair of *Th. elongatum*-*T. aestivum* translocated chromosomes with the salt tolerance gene of *Th. elongatum*.

Study of Traditional Ways of Water Resource Exploitation in Sub-Sahara Africa

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This study aimed at exploring traditional water resource uses, its knowledge, techniques and customs, which have been however well developed in Sub-Saharan Africa. This region has suffered from drought and desertification, but not without any wisdom for combating against natural disaster. It is therefore dangerous to apply anti-desertification politics and development politics without knowing this wisdom subtly transported from one generation to others. From this point of view, I have first compared two kinds of so contrasted water resource use between one and the other, highly artificial foggara type oasis irrigation system in Sahara and almost natural exploitation system of the flood plains of the Niger Inner Delta annually caused by seasonal rainfalls. Trying to explain why many important human civilizations have been developed in dry and half-dry zones regardless of scarce water resource, I have also discussed about the importance of rich animal resource existing there, but not existing in tropical rainfall forest areas. Animals provide not only precious protein resource, but also ways of transportation which are vital for the development of inter-regional commerce as well as for the formation of cities and States, synonyms of civilization.

Medicinal Plants Cultivated for Inner Mongolian and Mongolian Arid Farming

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Our bibliographical survey demonstrated that about 29 species of medicinal plants intended to be planted for the protection of the desertification in Inner Mongolia and Mongolia were added to the list of last year, consequently these total numbers were 74 spp. (49 genus, 29 family), and woody plants of them were 16 spp. (8 genus).

The drugs prepared at Erdenet in the north of Ulaanbaatar carried into our laboratory, which were seemed to be Peony Root, Japanese name, Sensekisyaku made from *Paeonia* sp. (perhaps *veitchii* Lynch, *Paeoniaceae*). Actually, they contained paeoniflorin 1.93 % w/w, which is major constituent of Peony Root. But the Peony Root used in Japan contains it 2 ~ 6 % (described in Pharmacopoeia Japonica). So, it is necessary to cultivate the Peony contained the higher content of paeoniflorin. It will be possible, and be still more able to introduce the other many similar plants in that place.

Ecophysiological Studies on the Pine Wilt Disease Occurring in Coastal Dune

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Spreading manner of pine wilt disease has been compared between two 20x 20 m experimental plots settled in Japanese black pine forest distributing over coastal dune in Arid Land Research Center of Tottori University. One of the plots was fertilized every year since 1996, and the other one remained with no treatment and served as a control. The amount of pine trees killed by pine wilt disease was far more in the fertilized plot than in control one, suggesting that the fertilization might have promoted the death of pine trees by pine wilt disease. To reveal the reason why the fertilization promoted the pine wilt disease, mycorrhizal relationship has been examined as a possible cue to explain the difference. Because fertilization might suppress mycorrhizal synthesis which has been regarded to work as absorbing organ for pine trees especially when under water stress. Diversity and constitutions of mycorrhizae formed on young pine seedlings were compared between the two plots, and between three groups of pine seedlings with different watering regimes. We may conclude that mycorrhizal relation plays an important role to make pine trees survive the epidemic wilt disease.

A Study on the Production of Local Desertification Map

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In order to make the desertification map of the Mu-Utsunuma Sands, the current status of desertification was detected spatially with the satellite images. The causes of desertification were analyzed on the comparison between the desertification image and GIS-based thematic data and the results of interview to local people.

The denuded area ratio of each village was related to the sand dune ratio. Desertification in this area was strongly affected by the activity of sand dunes. The revegetated area ratio had a close relationship with the cropland ratio. The development of cropland and the surrounding forestation contributed to revegetation of denuded area. Denuded areas were mainly distributed in the pastoral area. The highest relationship between the denuded area and the animal population was seen in the density of goats.

The results of interview also showed that goat density was high in the denuded sites. Overgrazing by goat was considered to be the main factor of current desertification here.

Studies on Chlorophyll Fluorescent Response of Xerophytes under Low Temperature and Short Term Water Stress

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Water deficit and low temperature affect on the growth of tree species in marginal conditions of northern dry area. The objective of this study was to examine the effects of acute water stress and low temperature on the physiological characteristics of *Sabina vulgaris*, evergreen conifer tree growing in northern semi-arid region in China, by the chlorophyll a (chl-a) fluorescence response and the quantitative analysis of photosynthetic pigments. The chl-a fluorescence is an efficient indicator of photochemical activity of reaction center II. Some parameters were determined from chl-a fluorescence using a pulse amplitude modulation fluorometer (Model, MINI-PAM, Waltz).

Ten sample seedlings growing in small pots were stored in a growth chamber at two levels of air temperature (30-15°C and 15-5°C in day-night) with constant humidity (30%), light intensity and two levels of soil water content (pF2.0 and 5.0). Changes in chl-a fluorescence with decreasing soil moisture content were monitored.

Only after one week from the beginning of stress induce experiment, Y_o value (optimal quantum yield), which could indicate photochemical light use efficiency, showed remarkable decrease and, on the other hand, the xanthophyll cycle pool size of needle ($V+A+Z/Chla+b$) and ratio of zeaxanthin ($Z/V+A+Z$) increased, which indicate effective dissipation of excessive excitation energy by thermal energy quenching. Since the short period of response in photochemical reaction, the pigment component in the xanthophyll cycle can be shifted quickly to adjust the intra electron transfer system to unfavorable environmental conditions.

Preferential Flows and Solutes Transport in Sandy Soils

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An unstable wetting front breaks up below a thin wetted layer: the induction zone. Many small fingers form initially, but only a few fully develop. The induction zone affected only the initial shape of the wetting front; finger size and spacing were governed by autonomous processes. The lateral pressure head gradients in the induction zone adapted to the location of full-grown fingers before these fingers were visible and remained stable afterwards. The water requirement and spacing of the fingers dictated the magnitude of the gradients. The pattern of the lateral pressure head gradients suggests that the fingers cause non-uniform infiltration from the ponded water layer.

Study about Fertility Conservation of Surface Soil in Arid Area

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A pot experiment was carried out to simulate soil disturbance in arid area. Soil samples at the surface and subsurface were collected at mining area in Western Australia to analyze chemical properties.

Annual and perennial shrub, *Atriplex* spp. called pioneer plants, were grown in the pot, whose soil condition were set from the chemical analysis of the Western Australian soil. Effects of the surface soil chemical properties on the plant growth were assessed.

In Western Australia, the site recovered with surface soil had good emergence of pioneer plants. However, the chemical properties, especially inorganic contents determined in the study did not have significant differences between surface and subsurface soil. Both of the surface and subsurface soils had low nutrients. Nitrogen deficiency treatment showed poor growth of *Atriplex* spp. Adaptation of *Atriplex* spp. to low fertility should be low. The results suggested good emergence of pioneer plants to recovered area with surface soil result from other soil properties.

**Natural Environmental and Agri-Rural Development
in Arid Zone of West Asia and North Africa
– Through G.I.S. Analysis and Fieldwork –**

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In October of 2000, we made a field trip to SHAFARE KORD Region in Iran where is located at the upstream basin of Karoon river in the highly elevated Zagros Mountain ranges. This is a JICA's Research project area "The study on Watershed Management plan for Karoon river in Iran".

In this region, debris flows, landslides and floods are prevailing because of the land degradation and subsequent soil erosion. These disasters seem to be caused from the over-grazing on livestock by the nomads with rapid increase of the population growth, cutting forest trees for fuels by the nomads and the inhabitants and dry farming without any counter measure for soil erosion. This area is suffering from a vicious cycles of natural-social environment: "Increase of population – Increase of demand for natural resources – Decrease of forest resources – Degradation of environment and decrease of productivity of land – Poverty". Natural disasters such as flood and debris flows accelerate the vicious cycles and the regional society is facing the danger of collapse.

It is necessary to break the above mentioned vicious cycle of natural and social environment and to formulate comprehensive natural-social sustainable regional development plan. Summer of 2001, we will do to field survey focus on socio-economic impact on the above mentioned study.

The Effect of Salty Crust on Soil Albedo

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Predicting salt accumulation in irrigated farmland in arid and semi-arid land requires knowledge about dependence of albedo on salty crust. Albedoes at various combination of surface water content and mass of accumulated salt near/on the soil surface were measured for two soils using soil slabs. Apparent albedoes measured from the soil slabs were first converted to those at a reference zenith angle of the sun, and then corrected to real albedoes expected for large extent surface using linear calibration equations predetermined. It was obviously shown that albedo increased with mass of accumulated salt under realistic degrees of salinization. An empirical equation for describing dependence of albedo on both surface water content and mass of accumulated salt above 5 mm depth, G , was presented in which the increment of albedo due to salty crust is assumed to be proportional to G . The value of the proportionality coefficient, that is the sensitivity of albedo to salty crust, determined for two soils of different texture and different color indicated that unit amount of G (mg/cm^2) increases albedo by 0.3-0.4, regardless of soil types.

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

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The soil moisture characteristic is represented by the relationship between the volumetric water content and the soil capillary pressure head, which is called the soil water retention curve. Undisturbed field soils occasionally exhibit retention curves with more than one inflection point. This multimodality of pore size distribution may 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 assuming lognormal distributions of soil pores. The developed retention model was tested using observed data for some field soils. The results showed excellent matches between the observed data and the model estimations. Estimated parameters indicated that secondary pore systems generally have larger mean pore sizes and greater widths of pore size distributions than primary pore systems.

Effect of Heterogeneity in Soil Structure on Unsaturated Hydraulic Conductivity

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Multi-step outflow experiments were performed to investigate unsaturated hydraulic properties of undisturbed Japanese soils under different management; paddy field, upland field, and forest. Cumulative outflow volume and soil water pressure head were measured to estimate the unsaturated hydraulic properties by inverse technique. Mualem-van Genuchten's model was employed to solve the Richard's equation. Relative error objective function showed best results, since care should be paid at high water content because of the deviation from log-normal properties. Repacked soils showed good

correlation between direct method and multi-step outflow method. On the other hand for undisturbed soils, effect of macropore caused abrupt changes in hydraulic conductivity near saturation. Because measured K_s showed macropore K_s whereas K_s in the models showed matrix K_s , it is appropriate to apply K_s as variable for undisturbed soils. Multi-step outflow experiment was acceptable as an unsaturated hydraulic conductivity experiment for Japanese soils except near saturation.

**Research on Field Techniques for Measuring the Unsaturated
Soil Hydraulic Properties.**

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A new field experimental method of determining unsaturated soil hydraulic properties is proposed. In this method these 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 transient axisymmetric seepage flow. GA are search algorithms based on the mechanics of natural selection and natural genetics. They have become a popular global optimization method. A ponded single-ring infiltrometer technique, such as the Guelph Pressure Infiltrometer is performed. Simultaneously the measured change of soil water content with time and cumulative inflow data are used to identify unsaturated soil hydraulic function parameters. The advantage of the proposed method is that it allows estimation of the unsaturated soil hydraulic parameters by quite simple in-situ permeability test data. The utility of our proposed method is demonstrated by using a numerical model and experimental data for Tottori dune sand.