1.5 Theses of Graduate and Undergraduate Courses

(1) Doctoral Theses

Division of Climatology and Water Resources

Munkhtsetseg, E.

Study on partitioning evapotranspiration into transpiration and soil evaporation

The exchange of heat, momentum, moisture, and gases with the atmosphere regulate and are regulated by microclimate, the physiology of plants, and soil processes. To address issues raised in relation to the impact of ongoing and future climate change on terrestrial ecosystems and human activities requires a deeper understanding on the interactions between vegetation activity and land surface processes. This is the central problem of the present dissertation, focusing two climatologically contrasting regions. Two study areas highlighted here includes the arid region of Mongolia and the humid region of Tottori, West Japan.

The present study used a unique long-term agrometeorological measurement from 1971 to 2000 in order to investigate the pasture yield response to precipitation and high temperature at the desert steppe zone, Mongolia. The result showed that precipitation is most strongly correlated with the pasture yield, while high temperature had a considerable negative effect on the yield. Moreover, the study established a new aridity index combining the precipitation and high temperature index, which is more strongly correlated with the yield than the precipitation only. That is, a reduction in precipitation with an increase in high temperature results in a lower yield, whereas sufficient precipitation with a reduction in high temperature results in greater production.

The evapotranspiration measurement from 2002 to 2004 was conducted to examine the environmental controls of evapotranspiration in the typical steppe zone, Mongolia. Latent heat flux was several times higher during wetter growing periods compared to during drier periods. A seasonal variation of evapotranspiration was affected by snow melting and precipitation events.. The irrigation experiment demonstrated that a clear response of evapotranspiration to the irrigation. In summary, the results obtained at the two vegetation zones in Mongolia revealed that pasture yield was sensitive to soil moisture derived from precipitation, snow, or irrigation. We concluded that the grassland ecosystems in Mongolia are regarded as water-controlled ecosystems.

Water and carbon flux was measured over the soybean field in the humid region of Tottori from July 2005 to October 2005 in order to examine the environmental control of leaf stomatal conductance and evapotranspiration on a seasonal time scale and to understand the mechanisms of inter/intra-seasonal variations of carbon exchange between the soybean field and atmosphere. In general, stomatal conductance, evapotranspiration, and carbon uptake (namely, photosynthesis) were all controlled by net radiation. The results obtained at the humid region indicated that vegetation growth was sensitive to radiation rather than soil moisture and precipitation. In brief, the ecosystem at the humid site of Tottori is characterized as a radiation-controlled ecosystem.

In conclusion, the results of the present dissertation demonstrated the difference of controlling factor of plant growth; water for the grassland ecosystems of Mongolia and radiation for the agricultural ecosystem in Tottori. The research provided data sets and the new and modified methods that have considerable application in assessment of aridity in the dry region of Mongolia, and in predicting of stomatal conductance at the humid region of Tottori.

Division of Biological Production

Zhang, B.

Monitoring and simulation of long-range mineral dust from China and Mongolia

Dust sources and transport in China and Mongolia were studied using a coupled method of satellite remote sensing and trajectory analysis. Identified dust by satellite images was further modeled by importing into atmospheric radiative transfer model, and methodology for retrieving optical property was presented and discussed. Next, a dust event was studied by satellite monitoring, in-situ observation, and synoptic analysis. This integrated method revealed the mechanism responsible for dust emission, transport and deposition. This dust event was then simulated by running a regional climate model. The accuracy of the model was tested and necessary improvements of the model were discussed.

Division of Afforestation and Land Conservation

Yamazaki, S.

Subsurface irrigation with saline water at two depths in a sandy soil

Agricultural water use should be more efficient because of the water shortage in the world. Especially in arid region, water has been a precious resource since ancient times. Therefore, water saving and water harvesting technologies have been developed. Many developing countries are also located in arid areas and use these technologies. Though they can correct and use water efficiently, agricultural water use has much high proportion of total water use. High rate of agricultural water use is found all over the world. The global average of agricultural water use is over 70%. Therefore, the need to reduce agricultural water use is increasing and efficient water use becomes a duty for farmers. They are forced to reduce and save irrigation water and to use marginal water for agriculture. Recently, subsurface irrigation becomes remarkable practice for water saving, but it has some negative impacts. For example, it makes root to concentrate around irrigation pipes and in shallow layer beneath soil surface, and cannot supply water near soil surface without capillary rising, which is lacking in sandy soils. No water supply near soil surface can be crucial at early growth stage. In this study, in order to solve these problems, we proposed and evaluated an improved subsurface irrigation method, which has two depths of irrigation source, hereafter referred as 2D.In addition, some numerical simulations were done to find the best condition of 2D in sandy soil. We also made some suggestions to save water with 2D.

At first, a field experiment was implemented to evaluate the possibility and usefulness of 2D to cultivate crops. We cultivated sorghums (*Sorghum bicolor* L.) in a greenhouse with 2D and sprinkler irrigation using saline water (4000ppm NaCl solution) and measured dry matter, leaf area index (*LAI*), water use efficiency (*WUE*) and soil water content and electrical conductivity of soil water (EC_{sw}) distribution. As results of saline irrigation condition, it was indicated that 2D produced more dry matter than sprinkler irrigation. *LAI* and *WUE* also increased with 2D. On the other hand, salt accumulation at soil surface was larger with 2D treatment than sprinkler treatment. However, salt concentration at 0.05 to 0.40m depth decreased on 2D treatments. It could be considered as the tool to manage soil salt environment, which differ from the conventional way of leaching.

At second, we cultivated soybeans (*Glycine max*) in the greenhouse using 2D and normal subsurface irrigation method (hereafter referred as 1D) with saline water (3000ppm NaCl solution) to evaluate advantages of 2D. Dry matter, LAI, WUE, water content and EC_{sw} with 2D were measured and compared with 1D. Results showed that dry matter, *LAI* and *WUE* with 2D were larger than 1D.

Even in summer season, 2D had deeper soil moisture than 1D, and promoted growth of soybean and water percolation. Both irrigation method made salt accumulation at soil surface, but 2D also made additional salt concentrated zone around irrigation pipes.

As a consequence of above experiments, the capability and the usefulness of water saving irrigation with saline water of 2D were demonstrated. Field experiments, however, could not provide enough information about water and salt distribution and dynamics in soil. Therefore, some laboratory experiments were carried out to observe water and solute movements in soil with 2D and 1D. Changing irrigation intensities and irrigation points, distribution of soil water and solute were monitored. Increasing irrigation intensity induced lateral and upward extension of the wet domain. Surface evaporation might be accelerated by excessive upward flow. In the case of 2D implementation and the lateral distance of neighbor two pipes were enough apart, two wet zones extended independently. While with 2D, two wet zones were overlapped. The water content of overlapped zone might be described as a simple addition of two water content found at same position with independent wetting. In addition, it was implied that solute delayed and trail behind soil water. These solute movements suggested that soil chemical properties, e.g. adsorption or ion exchange, could not neglect for the solute dynamics even in sandy soil.

The laboratory experiments showed some water content and EC_{sw} distribution as results of irrigation under certain condition and these results were obtained on certain point and at certain time after the end of irrigation. Using these point and momentary data, inverse analyses were conducted to calculate some model parameters applied to describe soil water retention curve (SWRC) and solute dynamics (Convection-Dispersion Equation, CDE model). The SWRC model was van Genuchten model, the most popular model to describe SWRC. Some numerical simulations were carried out to predict soil water and solute dynamics under many conditions. Validity of the calculated parameters was evaluated by duplication of previous laboratory experiments with obtained parameters. As a result, three parameter sets were obtained by three patterns of inverse analyses. One more parameter set collected from some literatures were added to these three parameter sets, so that totally four parameter sets were assessed by the validity test. Due to the validity evaluation, it was concluded that one parameter set, calculated by the method considering hysteresis with initially wetting, made the best match to the observed result.

Finally, some numerical simulations with crop cultivation using 2D were conducted as the integration of above experiments. A calculation of this simulation was consisted of nine days and evaluated the effect of changing irrigation pipes position and irrigation intensity to *WUE* and balances of moisture and salt amount in the rootzones. Daily evapotranspiration and irrigation quantity were determined with referring evapotranspiration data of sorghum cultivation experiment. Model parameters (van Genuchten model parameters, CDE model parameters) were applied the values achieved by the best fitting inverse analysis. As results of these simulations, it was indicated that *WUE* increased with narrow pipes distance. However, the condition of narrow pipe interval brought salt accumulation in the rootzones. It means that irrigation designs depend on the priority, which belongs to water saving or land conservation.

Making a proposition of the new irrigation method (2D) is the result of this research.

Moreover, showing the process and way of this research is one of the method to make an irrigation plan and can be of some helpful for saving irrigation water planning.

Moritani, S

Irrigation scheduling and soil conservation on sloped soil layered green roof

The global warming is one of the most important environmental issues that affect the critical impacts on the human survival. Kyoto protocol entered into force in February 2005. Under the protocol, Japan makes a legally binding promise to reduce its greenhouse gas emission (GHGs) including CO_2 by 6% from 2008 to 2012 for 5 years. In order to achieve this target, Japanese government drive green roof on building to reduce CO_2. The green roof can be expected to moderate the heat island effect and also decrease the electric power supply. This greening has been paid attention especially in the city where the potential space of greening is limited.

The thin soil bed is used for green roof due to withstand-load restrictions in green roof. The sprinkler irritation is introduced on the sloped bed soil since it is easy to dry the upper part of a slope according to immediate drainage of rain and irrigation water. Water erosion is concerned even on the soil which is resistance of erosion due to decrease of infiltration rate as a consequence of destruction of soil aggregate by a sprinkler, and low rate of plant cover and clogging of drainage due to season and lack of management. Therefore the measurement of water erosion of the bare soil is important. However the method of conventional soil sampling consumed labor and time. The photogrammetry performed by remote sensing has possibility of measurement of water erosion in a wide scale of area from the sky on urban areas. However the accuracy of photogrammetry become worse when the distance from an object is long. Therefore it is important to asses the accuracy of photogrammetry.

Soil erosion was estimated by photogrammetry using the digital camera. The precision was first assessed by comparing the measured data against photogrammetry under no rainfall condition. The assessment was based on the statistical parameters, the absolute error (*AE*) and relative error (*RE*), which are 0.0946 kgm^{-2} and 8.59%, respectively. In the second step, the precision was assessed for under simulated rainfall on soil surface packed to two different dry bulk densities. At 1.20 gcm^{-3} density, the *AE* and *RE* were 6.62 kgm^{-2} and 1490%, respectively and corresponding values at 1.30 gcm^{-3} density were 0.675 kgm^{-2} and 86.0%, respectively. The soil saturated with water and whose bulk density was 1.38 gcm^{-3}, was subjected to rainfall of intensities of 40, 80, 120 mmh^{-1} continuously for 1 hour. They had *AE*(*RE*) of 0.0313 (36.1%), 0.0183 (26.4%), 0.0268 kgm^{-2} (29.8%), respectively, at each intensity.

Next, thin soil bed and low density of soil and artificial soil made of natural soil mixed with inorganic material such as the recycling are used well in green roof due to withstand-load restrictions. Therefore the evaluation of permeability and water holding capacity and fertility is important. Moreover, it is necessary to examine the irrigation scheduling to consider saving water by using the soil that has high water retention in irrigation of green roof. It can be also expected to decrease the water requirement of irrigation and increase the effective rainfall as a consequence of the saving water resource in urban area when dry-resistance plant such as Sedum plant.

Therefore physico-chemical properties of four artificial soils were monitored. The ability of soils to resist water erosion and efficient irrigation scheduling were also estimated. The studied soils were KS (Koka soil) which contains high value of organic matter, VS (Viva soil) made by poriferous pumice mainly, PP which is perlite in powder form and GP which is granular perlite. These soils had high percentage of sand particles with high value of hydraulic conductivity. The aggregate stability of VS was high with good structure for plant growth. Whereas, KS contained many nutrients and classified as a fertile soil. Soil erosion was not occurred when these soils were subjected to rainfall intensity of 40(mmh^{-1}). Moreover, when 30 years rainfall data was simulated for effective rainfall and net water

requirement, these soils were found to have high irrigation water efficiency. Generally, these artificial soils were expected to effectively resist water erosion and have high irrigation efficiency.

On the other hand, the drought-resistant plant have an effect of efficiency of irrigation scheduling although soil water retention is necessary. Therefore irrigation experiments on Sedum (Kirinsou) were conducted on sloped bed soil in glasshouse. At the same time, the pot experiment under the salt water condition was conducted to evaluate the tolerance of salinity of evergreen Kirinsou. The study was done during summer time. The result can be concluded as follow: 1) The evapotranspiration ratio of Kirinsou decreased after irrigation, leaving soil with pF value of more than 4.2. However, this ratio increased again at the beginning of each irrigation and Kirinsou plant recovered to the normal growth. 2) Cumulative evapotranspiration ratios with square root of elapsed time are forming a good fit of quadratic curve with correlation coefficient of more than 0.99. 3) Evapotranspiration was affected negatively with soil pF value in which this relationship was passing through three different phases. In first phase, the evapotranspiration was influenced by LAI. In second phase, the evapotranspiration decreased shapely. Whereas, in the third phase, the evapotranspiration was decreasing gradually and gave values of less than 0.1. 4) The stress periods, when soil pF values were over than starting point of the third phase, were correlated negatively with dry shoot weight and LAI of Kirinsou. It is concluded that the point of depletion for moisture content of normal growth in Kidinsou is pF4.2.

The pot experiment under the saline irrigation was concluded as below. 1) Leaf water potential under the 18.0(ds m^{-1}) was mostly over than -2.5(MPa) which didn't show much difference with under the lower salinity irrigation. 2) LAI and biomass were highest under the well-watered by tap water while decreasing gradually according to more salinity of irrigation water. Whereas, those didn't show the reduction of LAI and biomass in all blot under the water-stressed condition. 3) It was suggested that Evergreen Kirinsou had some tolerance of salinity since leaf water could be retained under the irrigation of saline of 18.0(ds m^{-1}), although decreasing the yield due to salt stress.

The monitoring of water erosion by photogrammetry was effective for soil conservation. Moreover, it is found that an artificial soil which has effective to resistance of water erosion and irrigation scheduling, and drought-resistance of Sedum plant could be contributed to establish the sustainable soil bed of green roof.

Al-Busaidi, A.

Effect of seawater irrigation management on physicochemical properties of soil-water-plant system

Increasing food production to meet the needs of the increasing population on a sustainable basis remains the primary goal in the developing world. Many countries are looking to the irrigated agriculture as the reliable source to achieve this increased production. The utilization of the groundwater with the poor recharging system is an emerging threat to the arid and semiarid areas of the world. Due to several environmental reasons the groundwater is being degraded and negatively impacting food production. Therefore, the researchers have to look at ways to use effectively marginal-quality waters as an alternative source for irrigation. The problems associated with the use of low quality waters for agriculture need to be searched and addressed in such a way that it could produce technically sound, economically viable and environmentally safe system. Therefore our research studies were mainly focused on the utilization of saline-waters for crop production. Several experiments were conducted at the Subdivision of Land Conservation of the Arid Land Research Center, Tottori University, Japan during 2004 - 06.

The 1st experiment was conducted to determine the efficiency of seawater to leach salt from a simulated profile of a coastal sandy soil. Soil salinity level was highly dependent on soil depth and virtually reduced by the range of 17.8 to 90.4 % through a leaching process with seawater. A lower level of salinity occurred in the surface soil as compared to the underlying soil layers. An efficient leaching happened when the application of seawater became equal to the depth of soil to be leached. The leaching trial undertaken in the field confirmed the findings of the laboratory study.

The 2nd experiment was carried out to evaluate the effects of different meteorological conditions on growth of barley and salt accumulations in sand dune soil irrigated with diluted seawater under three experimental environments– glasshouse during winter 2005, controlled growth-chamber conditions (20 ^{o}C, 60 % RH) and greenhouse during summer 2005. Plants were irrigated with diluted seawater adjusted to the electrical conductivity levels of 3, 8 and 13 dS m^{-1}. The results showed that saline waters and experimental conditions remarkably affected the evapo-transpiration rate, soil moisture, salts accumulation and plant biomass production. Low temperature conditions exhibited highest plant growth and soil moisture, and lowest salt deposition. Plants showed no symptoms of salt stress in the glasshouse. Growth-chamber and greenhouse conditions profoundly reduced plant biomass and accumulated higher salts in the soil. Higher stress of salinity was noticed in plants irrigated with high saline water. The increasing level of salinity in irrigation water impaired the dry shoot yield by an average of 60 %. The higher temperature conditions of greenhouse and growth-chamber caused substantial water loss and induced water deficit in plants.

In the 3rd experiment, the investigation was aimed to evaluate the effects of saline irrigation on barley and salts accumulation in a greenhouse under different leaching fractions. The saline water significantly interfered with the growth of barley. Both the quantity and quality of water regulated salts distribution within the soil. Higher leaching fraction lowered soil salinity and increased soil water content. The salts were found higher near or immediately below the soil surface. An enhanced leaching fraction carried more salts down the soil horizon. Higher saline irrigation retarded evaporation. Infiltration rate and hydraulic conductivity of soil remained similar across the treatments. Conjunctive use of marginal water at relative leaching fraction could effectively enhance the yield of crop in water scarce areas.

In the 4th experiment, calcium-type artificial zeolite was used as an amendment to mitigate the plant grown under saline irrigation. The study primarily investigated the joint influence of zeolite (1 & 5 %) and diluted seawater (3 &16 dS m^{-1}) on the composition of soil and performance of barley. Saline irrigation significantly suppressed plant growth in terms of plant height, leaf area, dry weight and grain yield. Plant biomass yield was improved in salt stressed barley due to zeolite amendment. The application of zeolite apparently enhanced water and salt holding capacity of soil as compared to control soil. The soil analysis exhibited high concentrations of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} under saline water especially in upper soil surface and deceased with soil depth. The salts were directly related to the intensive applications of saline water. A low composition of salts in soil amended with zeolite was noticed. The cations concentrations in plants also varied due to saline water and zeolite applications. Higher zeolite dose increased Ca^{2+} concentration of plants under high saline treatment. Application of zeolite in the soil may adsorb heavy metals and produce a favorable environment for plants. The study indicates that zeolite amendment could effectively ameliorate crop stress and improve the physicochemical properties of sandy soil.

Ould Ahmed, B

Sustainable drip irrigation scheduling using poor quality water under arid environment

Globally, the area under irrigation is five times larger today than what it was a hundred years ago. Without irrigation, increases in agriculture to feed the world's growing population would not have been possible. In addition, as competition for fresh water increases, water of better quality would primarily be used for domestic purposes whereas, water of lower quality would be use for irrigation. Therefore, the challenge for agriculture in the future will be to maintain or even increase crop production with water of lesser quality and increase water use efficiency.

Drip irrigation system has the advantage of maintaining high water content near the plant root and thus enhancing water use efficiency. However, its performance depends on water quality as poor quality water may induce emitter clogging. Use of saline water with appropriate irrigation management techniques might help in achieving long-term sustainability in agricultural in dry areas where availability of good quality water is limited. A study on drip irrigation with low quality water for sustainable production under simulated arid environment was carried out at the Arid Land Research Center, Tottori University, and in the Tohaku National Irrigation Project area, Tottori, Japan (35°32´N and 134°13´) during 2004 and 2006. The study included the following four parts:

The first part of the study was to assess the effect of two levels of irrigation input, each at two frequencies, on sorghum (*Sorghum bicolor* (L) Moench) grain yield as impacted by available soil water after irrigation and the electrical conductivity of soil water (EC_{sw}) in a dune sand, in a greenhouse experiment. Saline water (7.32 dS m^{-1}) at input amounts equivalent to 50% or 100% of pan evaporation was applied daily or every second day. Using the Time Domain Reflectometry technique (TDR), soil water content and EC_{sw} were monitored simultaneously just before and 1-2 hr after irrigation. The cumulative recharge by irrigation in the top 25 cm of the profile ranged from 309 to 662 mm and it depended on irrigation input amounts, which ranged from 382 to 765 mm, and the frequency of irrigation. The potential cumulative evapotranspiration (ET_c) was 578 mm. The daily recharge matched against the corresponding ET_c indicated that grain yield might have been impacted by water stress in the 50% irrigation input, regardless of the frequency, but not in the 100% input treatment. The daily EC_{sw} in the root-zone matched against the FAO threshold (13.6 dS m^{-1}) indicated the possibility of salinity stress during the late maturity stage in the 50% input treatment, regardless of the irrigation frequency, but no stress in the 100% input treatment. Though there was no water or salinity stress in the every second day irrigated 100% input treatment, the significant relative yield reduction, compared with the daily 100% input, is attributed to inherent limited available soil water capacity and rapid percolation losses between irrigations in this sand. The results indicate that daily irrigation at 100% input is the most appropriate saline water irrigation management option for this dune sand.

The second part of the study was to investigate the clogging problem induced by low quality water in Tohaku National Irrigation Project. Seven emitters of different types were assessed for the variation in their discharge flow rate without filter during two irrigation seasons. The statistical analysis of mean discharge ratio (*Dra*), uniformity coefficient (*Uc*), and the coefficient of performance variation of emitters along a lateral line in the field (*Vf*) indicated that the mist spraying type emitter had the best performance for irrigation in Tohaku area, particularly when the emitter was new or only one-year old. The results suggest that the emitter line used for two irrigation season should either be replaced or washed carefully if reused for the third season.

In the third part of this study the impact of two input amounts (one half and full of open pan

evaporation), two frequencies (daily and every second day), and three salinity levels of irrigation water (7.32, 9.40, and 12.50 dS m^{-1}) on the temporal dynamics of the stress indicators; water (K_w) and salinity (K_s) stress coefficients, and leaf water potential (*LWP*) in sorghum were investigated. The K_w for an input amount equivalent to one-half of open-pan on daily basis (EP0.50-1) ranged from 0.32 to 0.51 and K_s from 0.50 to 0.98 K_w compared with 0.51 to 0.98 for the 100% of open-pan input on daily basis (EP1.00-1) and 0.80 to 0.98 for K_s. The K_w for the 3 increasing salinity levels (S-1 to -3) ranged from 0.68 to 0.96 for S-1, 0.58 to 0.90 for S-2, and 0.43 to 0.89 for S-3, and from 0.85 to 1.00 for the control. The corresponding K_s range was 0.89 to 0.98, 0.70 to 0.96, 0.49 to 0.70, and 1.00, respectively. The *LWP* range for the 3 salinity levels were -1.70 to -0.70 MPa for S-1, -2.50 to -1.20 MPa for S-2, and -2.90 to -1.60 MPa for S-3 and -0.70 to -0.20 for the control. The time series statistical parameters; mean, median, *CV*, and the 20^{th} percentile values (*PC20*), assessed to discriminate the temporal sensitivity of the stress indicator coefficients showed that *CV* and *PC20* are equally better than median which in turn is better than mean. Sorghum grain yield depended on irrigation input amount and frequency, *LWP*, and the interaction involving K_w and K_s (R^2_{adj} 0.71 to 0.85). The temporal dynamics of the stress indicators (K_w, K_s and LWP) indicated that irrigation input EP1.00-1 provided the least risk with regard to water and salinity stress in relation to sorghum grain yield.

In the fourth part of the study the possibility of use of saline water for leaching salt was evaluated. In a greenhouse study, sorghum was grown on dune sand with drip irrigation using water with four different levels of salinity (5.40, 7.32, 9.40, and 12.50 dS m^{-1}) and normal water as a control in the first season. The crop was again grown in the second season but at the start of the second season the soil was leached using either 25 mm of normal water or 25 and 50 mm of saline water four times in two weeks. Using the Time Domain Reflectometry (TDR) technique, soil water electrical conductivity (EC_{sw}) in the root zone was monitored during both the seasons. The daily EC_{sw}, compared against the FAO threshold (13.6 dS m^{-1}), indicated the possibility that the crop would have been exposed to salinity stress under irrigation with different levels of salinity. The salinity stress was higher in the second season as compared to the first season. While the soil salinity was reduced by leaching with normal water, there was no difference ($P < 0.005$) in the salinity when two levels of saline water were used for leaching. Though there was no water stress, the significant reduction in the yield with the use of saline water for irrigation, as compared with the control, could be attributed to salt input. The results indicate that leaching with saline water just before the start of the second season could reduce the salinity of sandy soil. However, the reduction in salinity was better when leaching was done with normal water. As the amount of normal water required for leaching is rather small (less than 25 mm), this amount can easily be collected by water harvesting from rainfall in the semiarid region. With this procedure sustainability of sorghum production using saline water for irrigation in water-scarce dry area can be achieved.

Ravolonantenaina, A. H.

Acid soil erosion and its improvement

Acid soils occupy approximately 30 % of the total ice-free land area of the world. Soil acidity can increasingly pose severe problems in agricultural systems in many parts of the world. Poor plant growth in acid soils can be correlated directly with aluminum saturation. In addition, increasing soil acidification can cause a considerable breakdown of the clay minerals and can also cause adverse

effects on soil hydraulic properties, which in turn led to soil erosion. In fact, the adverse effect of acidity on plant growth and the weakness of soil physical structure itself make the acid soil to be susceptible to erosion by water during rainy season. As a consequence, vast areas of acid soils in the tropical zone, where the largest pool of potential arable acid soil exists, are at risk of degradation and environmental impoverishment. Soil acidification occurs naturally as a result of intensive weathering, or acid sulfate soils, or from parent materials poor in basic cations. However, soil acidification can be either accelerated by the activity of plants, animals, and humans or slowed down by careful management practices. The implementation of liming practice has been found effective in alleviating the soil acidity and in reducing acid soil erosion. However, the large amounts required and the absence of lime pits positioned close to paddocks where lime is needed make soil liming an expensive option in many situation. In addition, soil liming effectiveness is believed only lasted for short-term, it required repeated application at least annually, and may be economically unprofitable in many soils. Therefore, other management options need to be employed either in isolation or together with liming to allow continuity of food and fiber production on land with a high acidification potential and on the other hand to lessen the off-site impacts of acid soil erosion on environmental ecosystem.

One of the biggest problems in acid soil erosion research is the variability of soil physicochemical properties in the nature. There is a limitation for basic research to be conducted on a natural soil due to inherent variability of the soil properties in the field. As a result, it is hard to determine which factor is more important and to predict where and when soil erosion events are going to take place. These problems have generated the need for controllable and reliable simulated soil, such as simulated acid soil. And also, the increase of human-induced soil acidity as results of excess use of fertilizer and the developing the industrialization makes more realistic in using artificial acid soil for a basic study. On the other hand, the availability of some approaches such as modeling on soil erosion under simulated rainfall may also help at least to understand these processes. A study on the characteristics of acid soil erosion under simulated rainfall of 30 and 60 mm h^{-1} rainfall intensity was carried out at Arid Land Research center, Tottori University, Japan. This study includes the following three parts:

In the first part, the effects of amendments and vegetation cover on natural acid soil erosion were studied. A natural acid sulfate soil taken from Yamaguchi prefecture situated in the western edge of the Japanese island of Honshu was used in this study. The soil was amended with 10 and 15 % for Ca type artificial zeolite and 0.5 and 5 % for hydrated lime. *Sedum sediforme* (*Rupestria* group) was used as live surface. The plants on the three aforementioned vegetation covers were spread on the soil surface during root initiation, and allowed to grow on the untreated and treated acid soils for five months under irrigation at two-day intervals and at an air temperature of 25 □C before rainfall simulation experiment. The rainfall simulation results showed that the incorporation of artificial zeolite and hydrated lime decreased surface runoff (*SR*) and sediment concentration (*SC*) in *SR* and the magnitude of reduction become higher as the rate of amendment increased. From our results we conclude that the reductions in *SR* and *SC* is associated with increase in aggregate stability, particularly the fractions > 500 μm and < 2000 μm. The incorporation of artificial zeolite and hydrated lime decreased also *SR* and soil losses in *SR* by the rain splashing and the magnitude of reduction become higher when another pre-treatment with irrigation for five months was applied before subjecting the samples to simulated rainfall. However, it was found that application of amendments induced also the aggregate size ≤ 106 μm that are mostly responsible for crusting. As a result, the amendment induced reduction in *SR* was confined to the first two phases which lasted for

approximately the first 45 minutes. It was found that artificial zeolite is more effective and its longevity was more persistent than hydrated lime in improving the ability of this acid soil to resist water erosion and also in improving sedum plant growth. Sedum plant cover increased significantly surface runoff; however, it decreased significantly the *SC*, soil loss and total soil loss by rain splash. The particle size distribution of the soil sediment, and soil splash was changed significantly, which led to decrease in the proportion of silt and clay which is mostly responsible for crusting the soil surface. The improvement of mean weight diameter of sediment carried through runoff with vegetative cover subjected to two rainfall intensities could be expressed by a mathematical relation with high degree of reliability. Hereby, implementation of acid soil-conservation measures against water erosion may be improved by knowledge about surface runoff and soil loss patterns, which are related to the characteristics of soil erosion involved.

The second part was to investigate the physical mechanism involved in surface runoff (*SR*) and sediment (*SD*) generation processes in a simulated acid sulfate soil. Acid sulfate soil is actually occurred in nature as a result of oxidization of pyrite. Three different types of soil pH were prepared by mixing the soil material ≤ 2 mm with 1 *M* pure H_2SO_4, 0.5 *M* H_2SO_4, and 0 *M* H_2SO_4 using tap water of 70 liters. The results showed that time incremented *SR* and *SD* generation from a simulated acid soil are characterized by three phases indicating different soil factors or mechanism controlling the different phases. We show these three phase processes can be mathematically described by a time dependent elongated S-shape curve, highlighting the factors or mechanism controlling the different phases varied with time. Soil acidity and rain intensity modified the parameters of functional relationships of the curves indicating the factors/mechanism controlling SR and SD generation processes. The infiltration limited SR or SD phase is represented by the lower horizontal segment of the curve (Phase I). The infiltration and unsaturated hydraulic conductivity (*Kus*) limited *SR* or *SD* phase by the rapidly increasing linear segment (phase II) and the saturated hydraulic conductivity (K_W) limited phase (phase III) by the upper horizontal segment. Larger the proportion of the smaller size particles in aggregate size distribution smaller was infiltration, *Kus*, and K_W that affected *SR* and *SD*. The smaller size particles are associated to surface seal, pore-clogging, pore size reductions. The generation of larger proportion of smaller size particles is controlled by the soil use management variable such as soil organic carbon (SOC). Thus we conclude greater emphasis should be placed in the maintenance of SOC in acid soils to reduce acidity induced increases in *SR* and *SD*, and consequently for long term sustainable use of the soil resource.

In the third part, soil erosion from soil acidified with HNO_3, H_2SO_4, and mixture of these two acids was studied under simulated rainfall. Three different types of acid soils were prepared by mixing the soil material ≤ 2 mm with 1 *M* pure H_2SO_4, 2 *M* pure HNO_3, and a mixture of 1 *M* pure H_2SO_4 and 2 *M* pure HNO_3, using tap water of 70 liters. The rainfall simulation results showed that the incremented sediment concentration (*SC*) with rain depth indicates a qualitatively different pattern as a result of the type of soil acidification. It could be the result of difference in the mechanisms of soil aggregate break down as determined by the electric repulsive force among soil particles, which in turn is a function of an absolute value of the surface potential of the clay or of ion concentrations or valency of the counterion. The results showed that the soil aggregate stability was affected by the ratio of water soluble Al^{3+} to its exchangeable form, which in turn had negative impact on the aggregate size of the soil erosion. There seems to be a negative interaction between the infiltration and/or water transport processes and soil erosion in soil acidification as influenced by the soil aggregate stability.

(2) Master's Theses

Division of Climatology and Water Resources

Kobashi, A.

Meteorological and land-surface conditions related to dust emission in the Loess Plateau of China

Division of Afforestation and Land Conservation

Irie, G.

Effect of absorbent polymer (fiber floc) amendment on soil water retention

Ozaki, M.

Use of animal manures sodic soil amendment

Tanaka, S.

Evaluation of total available of bed soil with vegetated plant for sloped green roof

Division of Biological Production

Takeda, I.

Effect of defoliation on water use and grain yield in sorghum under drought stress

Demachi, Y.

Identification of indicator plants to evaluate sand dune shufting in the Mu Us Sandland, China, and relationships between germination, emergence characteristics of the plants and its growing environments

Masuda, K.

Growth responses of sesame to drought stress and its differences among cultivars

Matsunaga, Y.

Effects of water and nutrient on seedling growth in *Jatropha curcas* L.

(3) Graduation Theses by Undergraduate Students

Division of Afforestation and Land Conservation

Asada, M

Spatial distribution and seasonal change of nitrogen in Tottori sand dunes