DFG/KOSEF International Research Training Group Workshop

Complex Terrain and Ecological Heterogeneity (TERRECO): Evaluating ecosystem services in production versus water yield and water quality in mountainous landscapes

Bayreuth Center of Ecology and Environmental Research (BayCEER)

Faculty of Environmental Sciences
Kangwon National University (KNU), Chuncheon, South Korea

cooperatively with the Korea Forest Research Institute (KFRI), Seoul, Korea

Seoul National University, Seoul, Korea

Yonsei University, Seoul, Korea

Research Institute of Gangwon (RIG), Chuncheon, Korea

Bayreuth, April 11 – 14, 2010
Dr. Hans-Frisch Strasse 1

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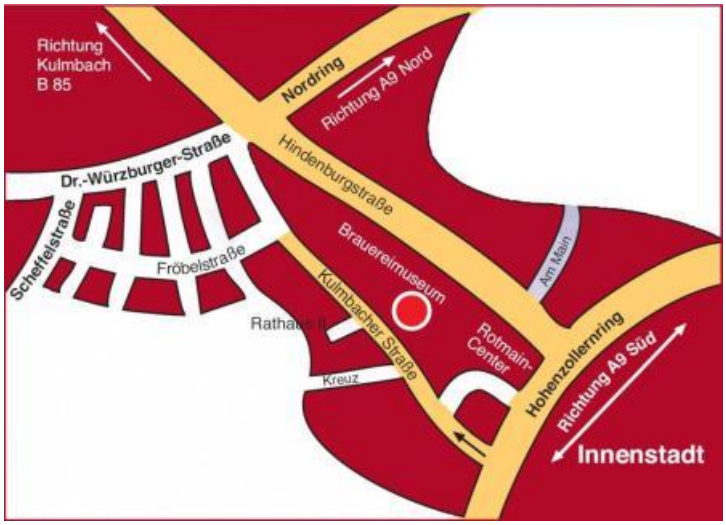
Time Schedule

April 10 **Arrival of foreign participants to Hotel Bayerischer Hof**

April 11

14:00 **Meet for coffee in center of Bayreuth**
(Cafe San Remo, Maximilianstrasse 26)

15:30 **Walk to Brauerei- and Büttnerei-Museum**
(Beer and Barrel Making Museum)



16:00 **Museum tour in English finishing with a free beer**

18:00 **Dinner à la carte at Gasthof Goldener Löwe**
Kulmbacher Strasse at corner with Kreuz Strasse

April 12

7:40 Pick-up of foreign guests from Hotel Bayerischer Hof

8:00 Chairman: John Tenhunen
Opening remarks followed by presentations of 2010 research plans of German participants

8:15 Assessment of fertilizer levels on ecosystem processes
J. Kettering, S. Berger, B. Lee, S. Lindner, E. Martin

Fertilization levels, 15N labeling and N flow separation
J. Kettering, S. Berger, B. Huwe, Y. Kuzyakov, B. Lee, S. Lindner, M. Ruidisch, J. Tenhunen

Nitrous oxide and methane fluxes and underlying biogenic processes as affected by land use systems and climate
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Herbivore limitation and natural enemy interactions: responses to landscape, management, and impacts on ecosystem functioning
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9:00 Estimation of stand level gas exchange fluxes
E. Jung and P. Zhao

Water use by forests in Haean Catchment
Eun-Young Jung and Dennis Otieno

Spatial assessment of atmosphere-ecosystem exchanges via micrometeorological measurements and footprint modeling
Peng Zhao, Johannes Lüers, Thomas Foken and John Tenhunen

9:30 Hydrological properties, water flow and transport on slopes
B. Huwe

Water movement and erosion on dry farmland in the Haean catchment
Sebastian Arnhold, Marianne Ruidisch, Bernd Huwe, Bruno Glaser, and Yong Sik Ok

Tracer experiments using brilliant blue and stereo-photographiy: The effect of dryland farming management systems on infiltration patterns, surface runoff and soil erosion
Marianne Ruidisch, Sebastian Arnhold, Bruno Glaser, Yong Sik Ok, and Bernd Huwe[1]

10:00 Coffee Break

10:40 Nitrate, phosphorous and DOC export from a catchment under monsoonal climate conditions – the case of the Haean Catchment, South Korea
Svenja Bartsch, Ji-Hyung Park, Bomchul Kim, Jaesung Eum, Stefan Peiffer, Christopher L. Shope, Jan H. Fleckenstein

11:10 Fluxes of dissolvied and fine particulate organic matter from terrestrial to aquatic systems in dependence on temperature and precipitation regime
Stefan Strohmeier, Jan H. Fleckenstein, Stefan Peiffer, Ji-Hyung Park, Egbert Matzner

11:20 **The political ecology of "Climate Change" in South Korea**
Susann Trabert and Detlef Müller-Mahn

11:40 **The impact of socio-economic land-use decisions on ecosystem services in small catchments**
Patrick Poppenborg and Thomas Koellner

12:00 **Lunch**

13:30 **Chairman: Sinkyu Kang**
Presentation of research interests by Korean participants

13:40 **Effects of PAM and biopolymer on Chinese cabbage growth and soil properties**
Yong Sik Ok, Yasser M. Awad, Sang Soo Lee, Yakov Kuzyakov and J. Tenhunen

14:00 **Comparison of the effects of biopolymer and PAM for controlling soil erosion**
Yong Sik Ok, Yasser M. Awad, Sang Soo Lee, Yakov Kuzyakov and J. Tenhunen

14:20 **PAM efficacy for reducing soil erosion and runoff as influenced by slope**
Sang Soo Lee, Clark J. Gantzer, Allen L. Thompson and Stephen H. Anderson

14:40 **Absence of correspondence between denitrification rates and denitrifier abundance determined by molecular approaches.**
Hojeong Kang, Seunhoon Lee, and Keunyea Song

15:00 **Decline of evergreen coniferous forests due to global warming in Korea**
Jong-Hwan Lim, Joon-Hwan Shin and Suk-Kwon Kim

15:20 **Coffee Break**

16:00 **The characteristics of the breeding bird community in the Haean Catchment**
Chan-Ryul Park, Hee Moon Yang, Dowon Lee and Kwang Ok Byeon

16:20 **Measurement of forest value in Korea**
Joon Soon Kim

16:40 **Perspectives of water acquisition and management in Pungsu practices of traditional cultural landscapes: the Choson Dynasty Era**
Dowon Lee

17:00 **The spatial distribution of land use potentials and its implication for land use changes and landuse policies in Korea**
Soo Jin Park

18:00 **Dinner**

19:30 **Economic valuation of conserving Soyang Lake and its catchment**
Andy Choi and Man-Sig Jun, Research Institute of Gangwon

April 13

8:00 Pick-up of foreign guests from Hotel Bayerischer Hof

8:15 TERRECO summer 2010 and beyond – where should we go?
One half hour on each topic:
Haean Catchment experiments 2010
Potentials for individual cooperation in 2011 and beyond
TERRECO project goals 2011 to 2013

Groups and leaders:
Surface Exchange and Plant Production: Sinkyu Kang and Yakov Kuzyakov
Soil Erosion and Transport: Bernd Huwe and Yong Sik Ok
Hydrology and Biogeochemistry: Stefan Peiffer and Kyonga Kim
Biodiversity: Jong-Hwan Lim and Gian-Reto Walther
Socio-economic Linkages: Soo Jin Park and Thomas Köllner

10:15 Summary of discussions by group leaders (15 minutes each group)

12:00 Lunch

13:30 Chairman Sinkyu Kang
Presentation of TERRECO modelling concepts

13:40 A case study of social-ecologically-based management of ecosystem services: Global change impacts on agricultural production versus water quality in mountain landscapes
John Tenhunen and Members of the TERRECO Project

14:00 Landscape level carbon and water balances and agricultural production in mountainous terrain of the Haean Basin, South Korea
Bora Lee, John Tenhunen, Ralf Geyer, Bumsuk Seo, Yuelin Li and Sinkyu Kang

14:20 Assessment of regional forest disasters in Soyang Basin using RHESSys
Jonghan Ko, Jungryel Choi, and Sinkyu Kang

14:40 Hydrograph separation using geochemical tracer by three-component mixing model for the coniferous forested catchment in Gwangneung Gyeonggido
Kyongha Kim and Jae-Yun Yoo

15:00 Modelling the hydrologic impact on surface-water concentrations throughout the Haean Catchment and Soyang Lake Watershed
Christopher L. Shope, Svenja Bartsch, Jan Fleckenstein, Stefan Peiffer

15:20 Coffee Break

16:00 Modelling soil greenhouse gas exchange of terrestrial ecosystems and up-scaling procedures
Ralf Kiese, Christian Werner, Edwin Haas, Klaus Butterbach-Bahl

16:20 Modeling the tradeoffs between agricultural production and environmental protection in Soyang Watershed of South Korea
Nguyen Trung Thanh

16:40 **Quantifying and evaluating trade-offs between multiple ecosystem services in Haean Catchment**
Thomas Koellner, Patrick Poppenborg, Bora Lee, Emily Martin, Stefan Strohmeier, Steve Lindner, Svenja Bartsch, Yohannes Ayanu

17:30 **Dinner – Buffet of Bavarian Specialties including Beer**

19:00 **Feedback on TERRECO in the Context of Global Change Studies from Reviewers** (A. Becker and J. Reynolds)

19:30 **Long-term ecological studies at Dinghushan Forest Natural Reserve**
Prof. Guoyi Zhou, Chinese Academy of Science

20:30 **"Flauerbauer" (musical entertainment) and "gemütliches Beisammensein"**

April 14

9:00 **Pick-up of foreign guests from Hotel Bayerischer Hof**

9:30 **Information on June workshop in Yanggu**
General discussion and wrap up

11:55 **Official closing of workshop**

12:00 **Lunch**

14:00 **June workshop committee meeting**

Abstracts

Fertilization levels, ^{15}N labeling and N flow separation

J. Kettering[1], S. Berger[3], B. Huwe[2], Y. Kuzyakov[1], B. Lee[4], S. Lindner[4], M. Ruidisch[2], J. Tenhunen[4]

[1] Department of Agroecosystem Research, Univ. Bayreuth
[2] Department of Soil Physics, University of Bayreuth
[3] Laboratory for Isotope Biogeochemistry, Univ. Bayreuth
[4] Department of Plant Ecology, University of Bayreuth

Nitrogen is one of the most important nutrients for plant growth and the application of fertilizer nitrogen is playing an important role in agricultural production. Yet, the efficiency of fertilizer nitrogen is low and losses are large. We hypothesize that nitrate leaching is the main N loss pathway in Haean catchment due to excessive rainfalls during monsoon season, poor water and nutrient storage characteristics of the top soil as well as high fertilization rates, and low N uptake efficiency by plants.

In this experiment, nitrogen dynamics and budgets in a typical agricultural soil of Haean basin are investigated in a summer radish cropping system comparing the effects of four different fertilizer N rates (50, 150, 250 and 350 kg N ha^{-1}). The fertilizer will be applied before planting and then a second time during the growing season. Crop management including inputs of pesticides and herbicides is conducted according to local conventional agricultural practices. The main focus of this approach is to investigate (1) the biomass response to different N application rates; (2) the retention of inorganic N in the soil profile; (3) the specific N use efficiency of plants for the various treatments; (4) and the N loss pathways as related to the different fertilizer rates. Therefore, we use ^{15}N labelled potassium nitrate ($K^{15}NO_3$) to follow the fate of fertilizer in the ecosystem and to document its major loss pathways. Observed pools in 2010 will be soil, plants, seepage and the atmosphere. Rates will be determined as following:

- Recovery rate (percentage of applied 15N fertilizer taken up by aboveground plants)
- Retention rate (percentage of applied 15N fertilizer recovered in the top 100 cm of the soil profile)
- Loss rate (subtracting the recovery rate and retention rate from 100)

Furthermore, we coupled the ^{15}N dilution method with exchange resins to identify the atmospheric N deposition into the system. Atmospheric N deposition is a key parameter in the N cycle of ecosystems and should therefore be taken into account for N fertilizer recommendations. Measurements of the total atmospheric N deposition will be conducted from Mai to August 2010 at three representative locations in Haean basin.

Nitrous oxide and methane fluxes and underlying biogenic processes as affected by land use systems and climate

Sina Berger and Gerhard Gebauer
Laboratory of Isotope Biogeochemistry, BayCEER,
University of Bayreuth

Nitrous oxide (N_2O) and methane (CH_4) are both greenhouse gases of the atmosphere with a considerably higher global warming potential per molecule than CO_2. The gas exchange between soil surfaces and atmosphere contributes considerably to the ongoing increase of N_2O and CH_4 concentrations in the atmosphere. However, the underlying processes in soils are rather diverse and complex. N_2O as well as CH_4 are both produced and consumed in soils by a suite of microbially mediated processes. N_2O and CH_4 production and consumption are, furthermore, affected by the type of soil, climate, moisture regime and land use.
In this project temporal dynamics of N_2O and CH_4 exchange between soils and atmosphere and underlying biogenic processes are investigated in dependence on climate and management in three types of land use systems in the Haean Basin, South Korea:

- Radish field
- Rice paddy
- Mixed broadleaf forest

N_2O and CH_4 fluxes will be measured during the growing season in 2010 in daily to weekly intervals using closed chambers and photoacoustic detection in the field or gas chromatography at KNU, respectively. Processes of N_2O and CH_4 production and consumption along soil profiles will be identified by concentration and stable isotope abundance analysis of soil air collected along depth profiles using PreCon-GC-C-IRMS at UBT.

Fertilization affects on PIXGRO model parameters – allocation and CO_2 uptake capacity

Bora Lee, Steve Lindner, John Tenhunen
Department of Plant Ecology, University of Bayreuth

The influence of land use on water and carbon cycles in terrestrial ecosystem are strongly linked with each other; simultaneous evaluation can give us more insight into characteristics of and interactions between the cycles. The process-based spatial simulation model PIXGRO is being developed to estimate gross primary production, ecosystem respiration, net ecosystem CO_2 exchange and water use by forest and crop fields of Haean Basin, South Korea. Topography, climate and management strongly influence ecophysiological processes and land surface fluxes. PIXGRO captures this effect, it is designed as a tool for bridging between measured gas exchange fluxes, derived parameters for carboxylation capacity, seasonal changes in biomass and structure in the case of herbaceous and crop plants, and biomass yields, taking into account specific ecophysiological behaviour of individual species. PIXGRO focuses on this bridging, describing gas exchange on an hourly time step, and plant growth and phenology on a daily basis, via simple classical growth and carbon allocation routines as derived in agronomic studies. In addition, direct comparisons between model simulated response and ecophysiological field studies are being conducted. Further validation is being carried out with respect to seasonal development in biomass observed in sequential harvests as well as estimated via remote sensing. Our initial effort for regional mountainous watershed application of PIXGRO and up-scaling of field measurements showed promising results for broad-scale model application in Soyang watershed.

Influence of weeds on CO_2 exchange and bioproductivity of agroecosystems in the Haean-myun basin, South Korea

Steve Lindner, Gian-Reto Walther
Department of Plant Ecology, University of Bayreuth

Studies demonstrate significant limiting effect of weeds on crop production. The underlying physiological mechanisms are, however, not clear. Intensive measurements were carried out on different crop fields in Haean-myun basin (South Korea) in 2009 to gain in-depth knowledge on weed-crop interaction and its implication on CO_2 exchange and productivity in agroecosystems. Ecosystem CO_2 chambers were used to measure CO_2 fluxes in paddies, potato, radish, cabbage and bean fields. Furthermore, we examined above- and belowground biomass, soil/plant

nutrient content alongside continuous records of microclimate and soil moisture. Maximum Net Ecosystem Exchange (NEE) in the middle of July was around -12.72 ± 0.66 µmol m^{-2} s^{-1}, for rice, ~ -19.17 ± 5.49 µmol m^{-2} s^{-1} for radish and -17.04 ± 4.84 µmol m^{-2} s^{-1} for bean. More rapid growth was realised in cabbage and potato with maximum NEE of -38.21 ± 7.02 and -48.19 ± 15.69 µmol m^{-2} s^{-1} occurring in June. The ecosystem respiration (Reco) was 2.64 ± 0.44, 50.07±30.01 and 11.38±5.28 µmol m^{-2} s^{-1} in July for rice, cabbage and potato fields respectively. The maximum Reco in radish and bean fields were 28.89 ± 6.55 and 35.70 ± 17.69 µmol m^{-2} s^{-1} and occurred in September. In order to draw accurate conclusions from these results, more measurements are planned for 2010, where we will compare in more detail the fluxes in areas dominated by weeds or crops, and identify their interactions. In addition, we plan to estimate relative weed species abundance and cover. These findings will be integrated into the larger TERRECO project models in order to understand whole ecosystem interactions in the catchment.

Herbivore limitation and natural enemy interactions: responses to landscape, management, and impacts on ecosystem functioning

Emily A. Martin[1], Chan-Ryul Park[2], Dowon Lee[3], Ingolf Steffan-Dewenter[1]

[1] Department of Animal Ecology, University of Bayreuth
[2] Korea Forest Research Institute, Seoul
[3] Graduate School of Environmental Studies, Seoul National University

The mechanisms of biological pest control involve complex interactions between plants, insect herbivores and their natural enemies. For instance, birds may act as natural enemies of some pests, while also consuming other natural enemies – such as carabid beetles or parasitoid wasps. The impact of such complex trophic cascades on crop productivity is not well known, and highly context-dependent. Moreover, spatiotemporal heterogeneity has rarely been integrated in studies of top-down control on production, despite its strong impact on species distributions.

In order to gain understanding of these mechanisms and contribute to ecosystem service management in Haean, South Korea, we plan to investigate: i) the effect of natural enemy interactions on herbivore limitation, crop productivity and nutrient cycling; ii) the relative contribution of natural enemy guilds vs. abiotic constraints (fertilizer level, herbicides) to herbivore pressure; iii) the response of natural enemy efficiency and interactions to landscape complexity. Within an integrated field experiment accounting for different management treatments, we plan to measure herbivore abundance, herbivory and crop biomass under 4 enclosure treatments, comparing the importance of birds, flying predators, ground predators and their interactions for herbivore control and productivity. In addition, 7 enclosure treatments shall be replicated across the landscape in 20 cabbage fields, in order to understand the effect of spatial heterogeneity and landscape complexity on natural enemy interactions, pest control efficiency and crop productivity.

(for integrated description of above research see section with Experiment Descriptions)

Water use by forests in Haean Catchment

Eun-Young Jung and Dennis Otieno
Department of Plant Ecology, University of Bayreuth

50% of Haean catchment is occupied by mixed deciduous forests aged about 40 years and mostly dominated by *Quercus* species. To estimate forest water use in the catchment, we identified three study sites differing in altitude, slope and aspect as representative of forest structure and microclimate in the catchment. Site A and B were at same altitude of about 700 m, but differed in aspect. Site C was located in the bottom of the catchment at an elevation of 450 m and south aspect. Two different sapflow methods were used to estimate tree transpiration. One was Thermal Dissipate Probes (TDP) designed for overstory trees, which have more than 10cm diameter and the other was Stem Heat Balance (SHB) for 1 to 1.5 cm stem diameter trees, usually considered as understory. 15 TDPs plus 10 SHBs at site A, 10 TDPs plus 5 SHBs at site B and 10 TDPs at site C were installed in early spring, 2009. Sapwood area (SA) and leaf area index (LAI) were used for scaling up sap flux density to stand transpiration. SA of overstory per study area (m^2 ha^{-1}) was 10.5 for site A, 9.1 for site B and 6.7 for site C. LAI of understory (m^2 m^{-2}) was 0.37 ± 0.26 for site A and 0.77 ± 0.20 for site B, respectively. Site C had very little understory enough to be ignored. Maximum sap flux density of the canopy trees were 31.4 ± 3.3 g m^{-2} s^{-1}, 26.8 ± 2.5 g m^{-2} s^{-1} and 28.3 ± 2.3 g m^{-2} s^{-1} for sites A, B and C respectively. Mean daily transpiration from the canopy trees was 0.69 ± 0.28, 0.63 ± 0.19 and 0.61 ± 0.15 mm d^{-1} for sites A, B and C, while daily mean transpiration from the understory was 0.53 ± 0.27 and 2.08 ± 1.34 mm d^{-1} for sites A and B, respectively. Differences in transpiration among the sites were attributed to LAI differences. Stand transpiration within the catchment was determined by LAI.

Spatial assessment of atmosphere-ecosystem exchanges via micrometeorological measurements and footprint modeling

Peng Zhao[1], Johannes Lüers[1], Thomas Foken[1], John Tenhunen[2]

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[2] Department of Plant Ecology, University of Bayreuth

This study is concentrated in Haean-myun Catchment, an intensively used landscape within the Soyang Lake watershed including Soyang Lake Reservoir, and a sub-catchment of the Han River system which drains 26% of the land surface of South Korea. The aim of this study is to better understand the energy and matter exchange above farmlands (rice fields and dry crops) during the whole growing period including monsoon seasons in such a complex terrain as Haean Basin in Korea.

To determine reliable evaporation and net ecosystem exchange (NEE) of Carbon, and to determine reliable information about near surface atmospheric stratification conditions, including convective events in Haean Basin, a mobile eddy covariance complex (USA-1, LI-7500) will be installed in Haean Basin to collect the 3D wind vector, water vapor and carbon dioxide concentration at a sampling frequency of 20 Hz continuously. It will be moved from a typical rice field to a typical dry crop field about every half a month, and vice versa, from late April to October in 2010, to obtain data of both wet and dry surfaces. Biomass will be sampled manually and a net radiometer will measure the net radiation simultaneously. A post-processing software packages called TK2 will be used to obtain reliable sensible and latent heat and carbon dioxide fluxes with a high standard in data quality. Ongoing Footprint analysis will give an opportunity to track the spatial contribution of the surrounding land uses to the

observed heat and CO_2 fluxes helping to interpret the data. Useful data will be picked out to determine the variability of the stratification of the near surface boundary atmospheric layer to better understand the process of evaporation and the NEE above farmlands in a monsoon driven climate. This information could be used to compare different approaches of surface exchange studies (e.g. chamber measurements), and will be integrated into the relating models.

Water movement and erosion on dry farmland in the Haean catchment

Sebastian Arnhold [1], Marianne Ruidisch [1], Bernd Huwe [1], Bruno Glaser [1], Yong Sik Ok[2]

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[2] Department of Biological Environment, Kangwon National University

(for complete text see section with Experiment Descriptions)

Tracer experiments using brilliant blue and stereo-photography: The effect of dryland farming management systems on infiltration patterns, surface runoff and soil erosion

Marianne Ruidisch[1], Sebastian Arnhold[1], Bruno Glaser[1], Yong Sik Ok[2], Bernd Huwe[1]

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[2] Department of Biological Environment, Kangwon National University

(for complete text see section with Experiment Descriptions)

Nitrate, phosphorous and DOC export from a catchment under monsoonal climate conditions – the case of the Haean catchment, South Korea

S. Bartsch[1], J.-H. Park[2], B. Kim[3], J. Eum[3], S. Peiffer[1], C. L. Shope[1] , J. H. Fleckenstein[1]

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[2] College of Forest & Environmental Sciences, Kangwon National University
[3] Department of Environmental Science, Kangwon National University

The hydrogeochemical dynamics in mountainous areas of the Korean Peninsula are mainly driven by a monsoon-type climate. To examine the interplay between hydrological processes and the mobilization and subsequent transport and export of nitrate and DOC from catchments, a field study was initiated in the Haean catchment in north-eastern South Korea under highly variable hydrologic conditions. In order to identify nitrate and DOC source areas, a subcatchment (blue dragon river) within the Haean basin, which includes different types of landuses (forest, dry land farming, and rice paddies), was selected.

In 2009, high frequency surface water samples were collected at several locations during summer storm events. A similar but more comprehensive sampling routine will be completed in 2010. In order to investigate the groundwater level fluctuations relative to the hydraulic potentials, a piezometer transect was installed across a second order stream of the subcatchment. The results so far suggest deep groundwater seepage to the aquifer with practically no base flow contributions to the stream in the mid-elevation range of the catchment. It is hypothesized however, that subsurface flow might play an important role in near stream biogeochemical processes in the forested upland areas. Therefore, base flow fractions and the origin of stream water in the upper forested area of the subcatchment will be characterized via ^{16}O and ^{18}O stable isotope analysis. In 2009 the focus of research was within the subcatchment, in 2010 additionally a second piezometer transect will be installed at a third order stream in the lower part of the catchment (main stem of the Mandae River) where more dynamic groundwater/surface water interactions are assumed due to expected higher groundwater levels in this part of the basin.

In order to investigate these interactions piezometers equipped with temperature sensors and pressure transducers will be installed directly into the river bed. Based on the observed temperature time series and the hydraulic potentials the water fluxes between the groundwater and the river can be calculated using the finite-difference numerical code, VS2DH. VS2DH solves Richard's equation for variably-saturated water flow, and the advection-conduction equation for energy transport.

The export of nitrate and DOC were found to be variable in time and strongly correlated to the hydrologic dynamics, i.e. the monsoon and pre- and post-monsoon hydrological conditions. In the river, nitrate concentrations rapidly decreased during summer storm events due to dilution and the DOC concentrations increased up to six times higher than background concentrations. Contrary, to the river water, nitrate concentrations in the groundwater increased during storm events whereas DOC concentrations increased during dry conditions. The results also suggested that the highest nitrate concentrations in the groundwater (39.8 mg/L) were found in dry-land farming areas. In contrast, rice paddies seem to attenuate the nitrate export into the groundwater in spite of high fertilizer application rates.

(for longer description see also section with Experiment Descriptions)

Fluxes of dissolved and fine particulate organic matter from terrestrial to aquatic systems in dependence on temperature and precipitation regime

Stefan Strohmeier[1], Jan H. Fleckenstein[2], Stefan Peiffer[2], Ji-Hyung Park[3], Egbert Matzner[1]

[1] Department of Soil Ecology, University of Bayreuth
[2] Department of Hydrology, University of Bayreuth
[3] College of Forest & Environmental Sciences, Kangwon National University

Besides the riverine transport of organic matter to the sea, the fate of organic matter within the terrestrial system is of great importance. Here, the organic matter can be transformed, stored or decomposed and lost in gaseous form to the atmosphere. Dissolved and particulate organic matter (DOC/POC) are two carbon forms of practical relevance for drinking water purification and for the mobility and trans- port behavior of toxic compounds. From a scientific point of view their roles in the carbon cycle are relevant in terms of quantity and as a source of energy and carbon for microorganisms. However, not much is known about the importance of DOC in comparison to POC regarding quantitative transport and qualitative changes in dependence on precipitation, runoff and temperature.

This study aims to address the following research questions: 1) What is the role of DOM compared to POM for the transport of Carbon from terrestrial to aquatic ecosystems? Which are the sources and do they differ? 2) Do DOM and POM differ as a source for microorganisms? 3) Which are the major drivers for the transport of DOM

(POM)? These defined research questions will be approached by the following means:

(1) DOM and POM fluxes will be measured in forest percolates and in runoff at two different sites. The sources will be identified by quality parameters (spectroscopy, isotope analysis). (2) Incubation experiments will be conducted with different DOM and POM. (3.1) A statistical analysis of a long term data set (1988–2008) obtained by the Bavarian Environment Agency which contains precipitation, runoff, DOC and variables such as sulfate, nitrate, iron, etc. (3.2) High frequency measurements of DOC by means of a newly obtained spectrometric device which allows on-site and real-time measurements. The results of this thesis will contribute to a better understanding of the DOC and POC dynamics in watersheds in terms of quantity and quality. It will help to predict the carbon export from the Fichtelgebirge and the Haean catchment in the future.

The political ecology of "Climate Change" in South Korea

Susann Trabert and Detlef Müller-Mahn
Department of Social and Population Geography,
University of Bayreuth

In recent decades the global climate has undergone severe changes that result in weather events having an impact on the regional and local scale. These observations summarized as "climate change" have become a prominent topic in the scientific community especially in natural sciences as well as among political actors like governments, parties and NGOs. Due to the scientific findings of an up warming atmosphere and the possible (negative) consequences, national governments take Climate Change on the agendas of environmental, agricultural, social and economic policy.

In 2008 on the 60th anniversary of the founding of the Republic of Korea the South Korean president Lee Myung-Bak announced "Low Carbon, Green Growth" as the new national vision for the next 60 years. The core idea is to adopt a growth strategy that addresses both environmental and economic concerns by reducing greenhouse gases and by improving energy efficiency. Thus, the key question of this study focuses on the political discourse of Climate Change and its materialized outcomes by analyzing this political rhetoric from a critical standpoint. The mode of implementation of Climate Change related policies will be examined on the regional level (Kangwon Province) and locally among farmers in Inje County. In order to show the down scaling of political decision making from the national to the local level, Climate Change will be considered as a social concept that is perceived by different actors in a different way. Linking adaptation and mitigation programs as well as their implementation on the interface of political discourse, sources of power and the media to the social realities of farmers is a key aspect to understand how political and individual decision making come together. The interface of the political discourse and the media on Climate Change will also be partly considered on different scales because the exploration of new alliances between discursive practices and politics appears today as a major topic to be addressed in order to understand the construction of social reality at a time of crisis (climate change) and uncertainty.

A second additional step of analysis will aim to evaluate and categorize Climate Change related policies in terms of ecosystem services and their trade-offs in order to display future possibilities to protect environmental services in South Korea.

While the analysis consists partly text examinations, interpretation and expert interviews, there will be a survey conducted in different villages in Inje County – the case study area – to receive an understanding of the general conception of climatic changes and what solutions the farmers see in the challenge of dealing with climate changes and other changing conditions (market, demographic aspects, etc.) in the regional context. The knowledge about the structure of political instruments, their way of implementation and the response of the addressed farmers will help to define diligently parameters of development scenarios of Kangwon Province.

The impact of socio-economic land-use decisions on ecosystem services in small catchments

Patrick Poppenborg and Thomas Koellner
Professorship for Ecological Services, Univ. of Bayreuth

The project's main goal is to model the spatially-explicit impact of agricultural land-use decisions on ecosystem services. It takes place in Haean basin in the northeastern part of South Korea, where agricultural land-use practices come along with heavy erosion, which can amount up to 100 cm soil loss during strong rain events. Furthermore, farmers' problems with unseasonably low temperatures have increased in recent years, which perils the cultivation of their traditional crops. As land-use decision-making is part of a multilayered human-environment system, the model will incorporate social, economic and ecological considerations of local actors. In order to cope with these different dimensions, the model will use influence diagrams based on Bayesian statistics, also referred to as Bayesian Belief Networks. Being embedded in the International Research Training Group TERRECO, the model will be implemented at the interface between the involved disciplines of socio-economic and ecological sciences. The model's results about land-use decision-making will be displayed in a spatially-explicit manner with the help of Arc GIS maps. In this way, it will be possible to show the spatial changes in land use under different management options, and how these changes impact the provision of ecosystem services.

Effects of PAM and biopolymer on Chinese cabbage growth and soil properties

Yong Sik Ok[1], Yasser M. Awad[1], Sang Soo Lee[1], Yakov Kuzyakov[2], John Tenhunen[3]

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Soil erosion in highland agricultural systems reduces crop productivity and triggers eutrophication of surrounding watersheds due to the loss of nutrients such as phosphorous. This study was conducted to assess the effects of polymers (polyacrylamide [PAM] and biopolymer) that have been applied to prevent soil erosion on soil properties and on the growth of Chinese cabbage. Two types of commercial PAM (Soilfix G1 and Magnafloc 336) and one type of synthesized biopolymer (a copolymer of lignin, starch, acrylamide, and acrylic acid [LSAA]) were evaluated through a seed germination bioassay of Chinese cabbage (*Brassica campestris* L.) and pot experiments. The seed germination rates of the Chinese cabbage were 95-98% in the 0.5% and 1% polymer treated groups, which were similar to the control group (98%). Both groups of PAM and biopolymer promoted the growth of the Chinese cabbage (leaf length and width) when compared to the control group, and the fresh weight of Chinese cabbage was increased by 42-70% when compared to the control group. While 53% of the control group consisted of soil aggregates, the groups of Soilfix G1, Magnafloc 336, and

biopolymer comprised 71, 73 and 66%, respectively. In addition, the lowest soil water retention was observed in the control group (45%), while this value was higher than other values from Soilfix G1, Magnafloc 336, and biopolymer treated groups (70, 65 and 67%, respectively). Both applications of PAM and biopolymer prevented soil erosion through improvement of the physiochemical soil properties and promoted the growth of Chinese cabbage as indicated by a pronounced increase yield.

Acknowledgement: This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ0074092010)" Rural Development Administration, Republic of Korea.

Comparison of the effects of biopolymer and PAM for controlling soil erosion

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Soil erosion and infiltration rate are major factors to crop productivity and upstream water quality. This study was conducted to determine if a copolymer of lignin, starch, acrylamide, and acrylic acid (LSAA) shows a significant reduction in soil loss from the laboratory experiments and to compare the effectiveness of LSAA and anionic polyacrylamide (PAM). To accomplish this, the ester group and carboxy group of the biopolymer were confirmed using FT-IR analysis because these groups are known to prevent soil loss with the interaction of soil particles. The applications of biopolymer and PAM at a rate of 200 kg ha^{-1} decreased soil loss by 98% and 96%, respectively, when compared to the untreated control.
Treatments of biopolymer and PAM induced no change in the pH from the runoff when compared to the untreated control, and these pH values did not exceed the criteria for water quality. Furthermore, the electrical conductivity (EC) of runoff was increased for all treated areas compared to the untreated control; however, these increases were not significant at 0.05 level. Total nitrogen (T-N) and total phosphorus (T-P) contents among biopolymer treatment groups were similar to these values from the untreated control. Conversely, the contents of T-N (3.29 mg L^{-1}) and T-P (0.14 mg L^{-1}) for PAM-treated area were greater than these contents for the biopolymer-treated area (T-N content of 2.74 mg L^{-1} and T-P content of 0.09 mg L^{-1}). Our results suggest that biopolymers are an emerging alternative to PAM for reducing soil loss and contents of T-N and T-P in runoff.

Acknowledgement: This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ0074092010)" Rural Development Administration, Republic of Korea.

Polyacrylamide efficacy for reducing soil erosion and runoff as influenced by slope

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Anionic polyacrylamide (PAM) can reduce soil erosion. Slope is an important factor determining erosion rate; however, PAM guidelines have not been well developed for different slopes. The objective of this study was to evaluate the extent which 20-kg ha^{-1} (18-lb ac^{-1}) PAM (20P) and 40-kg ha^{-1} (36-lb ac^{-1}) PAM (40P) increase the time to initial runoff (TRO), decrease cumulative runoff (RO), and decrease cumulative sediment loss (SL) on a Mexico silt loam soil adjusted to slopes of 10%, 20%, and 40%. Soils were packed to a bulk density of 1.3 Mg m^{-3} (81 lb ft^{-3}) in test beds 0.3 m x 0.3 m x 0.15 m (12 in x 12 in x 6 in) and were subjected to a 61-mm h^{-1} (2.4-in hr^{-1}) simulated rainfall with a kinetic energy (KE) of 1.5 kJ m^{-2} h^{-1} (103 ft lb ft^{-2} hr^{-1}) for 1 h. Differences in TRO and SL for all slopes and PAM rates were all highly significant, as were all two-way interactions ($p < 0.01$). Applications of 20P and 40P increased TRO at slopes of 20% and 40% compared to the untreated control (0P); however, no difference in TRO was found for soils having 20P and 40P. Values of TRO with 20P and 40P were not increased at a 10% slope compared to 0P. Slope was not a factor in reducing RO. Applications of 40P for all tested slopes had greater RO than 20P. Polyacrylamide reduced SL for all tested slopes. A higher rate of PAM (40P) had less SL than a lower rate of PAM (20P) at slopes of 20% and 40%. With 40P, the reduction in SL was 72% greater than 0P at 40% slope. Therefore, slope is a critical factor in determining a proper PAM rate for reducing soil erosion. Future work on PAM applications for differing rainfall intensities and plot length would be beneficial in developing improved guidelines for PAM use.

Absence of correspondence between denitrification rates and denitrifier abundance determined by molecular approaches

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Denitrification process is of great importance in various environmental issues, because it is a key removal process of nitrogen from water body as well as its byproduct, N_2O, is a radiatively active gas. Denitrification is mostly mediated by facultative anaerobic bacteria under anaerobic conditions. Previous studies have reported key controlling variables for denitrification such as red-ox potential, carbon availability and nitrate supply. Recently, various molecular approaches have applied to understand abundance and composition of bacteria involved in the process, but not many studies have connected such information to process rates.

In this study, we have measured denitrification rates employing an acetylene blocking method along with bacterial analysis for their abundance (real time Q-PCR) and composition (T-RFLP) in various ecosystems. The target genes were *nirS* and *nosZ* genes, and ecosystems assessed include constructed wetlands, riparian wetlands, stream sediments and floodplain soils. Denitrifiation rates appeared to be strongly influenced by environmental conditions such as temperature, organic matter content and pH. In contrast, microbial abundance measured by real time Q-PCR did not exhibit substantial variations over seasons. Poor correlations between process rates and microbial abundance suggest that both approaches should be employed complementary to better understand denitrification process.

Decline of evergreen coniferous forests due to global warming in Korea

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Recently, evergreen coniferous forests in Korea are declining, especially after the warm and dry winter season. Following the mass mortality of pines in 1998, 2002 and 2007, more than 1 million trees were dead in 2009 due to the drought and warm temperature in winter promoted the pathogenicity of *Cenangium ferruginosum*, especially on southern area of the distribution range. Mortality of Korean fir in Mt. Halla increased linearly with increasing previous winter temperature. Physiological measurement showed that higher temperature in spring season is stressful to them. These two cases support the hypothesis that heat accelerates drought stress which is one of the major mechanisms of dieback of the populations on southern part of distribution range by global warming. Korean climate has distinct four seasons with hot/humid summer and cold/dry winter and IPCC-SRES models projected seasonally different patterns. Air temperature increase rate will be more rapid in winter than summer while precipitation is more variable and uncertain. Thus evergreen coniferous forests in Korea will be more vulnerable to future climate due to the increase of winter temperature. Early actions to adapt to the future climate for maintaining forest health, productivity and biodiversity such as thinning and diversifying forest type and age class are strongly recommended.

The characteristics of breeding bird community in the Haean Catchment

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We surveyed breeding bird community and patch use of birds to understand the species composition of agricultural landscape by 10-minutes point count methods at twenty-five survey points including five-organic and 20-conventional points in Haean catchment of Yanggu. Among forty-eight birds observed, species richness of nesting guild was high in order of canopy-, ground-, hole- and bush nesters, and that of foraging guild was terrestrial insectivores, aquatic foragers, granivores, ground foragers and omnivores, respectively. Birds frequently utilized patches of MAEUL (village) and riparian forests, number of species was significantly high at organic farming points. Foraging guilds except ground foragers showed aggregate patterns by cluster analysis of survey points. Ground foragers aggregate near the points of organic farms. Due to limited access to the forest area, forest birds such as tits and woodpeckers did not dominate, however canopy nesters dominate study areas. Also, MAEUL (village) and riparian forests can provide good habitat including nest and foraging areas for birds at agricultural landscapes. This result indicates that organic farms can influence the species composition of birds and they can be important foraging areas for ground foragers. In this year, we will focus on the breeding factors for bio-indicators of focal birds like bull-headed shrikes (small predators) and stonechats (ground nesters especially at banks in paddy) with different cultivation regimes.

Measurement of forest value in Korea

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The total value of natural resources is a sum of use value, option value and existence value. The use value can be identified as a utility value of individuals. The use value consists of direct and indirect use values. Depending on a perspective, natural resources could be evaluated in aspect of costs or benefits. The option value means future use value. The existence value is non-use value. Natural resources play a role as a supplier and human beings play a role as a consumer. The public functions of Korean forest have been evaluated since 1987. It is mostly used the replacement cost method for the evaluation. The time dependent change in these values are presented and discussed for the period 1990 to the present.

The total value of natural resources in 2005 was over 425 million Euros. Among those 425 million Euros is divided to seven different functions: water storage for 112 million Euros (27%), clean air for 86 million Euros (20%), sediment yield control for 79 million Euros (19%), recreation for 74 million Euros (18%), water purification for 38 million Euros (9%), soil slip erosion control for 26 million Euros (6%), and wildlife conservation for 4.9 million Euros (1%).

Perspectives of water acquisition and management in Pungsu practices of traditional cultural landscapes: the Choson Dynasty Era

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This talk is to help foreign audience understand how the typical configuration of traditional Korean agricultural landscapes had been preferentially made in terms of topography. Some of Korean pungsu practices, which had significantly acted to shape Korea's cultural landscapes, are addressed from a perspective of modern ecology. Discussion is restricted to the Choson Dynasty era considering availability of relevant materials, such as written documents, oral information, and remaining landscapes. Firstly, we investigate the limited availability of water resources supposing that extensive application of pungsu principles were related to the water as a limiting factor in the Choson Dynasty era. Then, five subjects of pungsu practices were illustrated: (1) preference of meandering water flows, (2) watershed-based land uses and village of rear-mountain-and-front-water, (3) mountain of fire anima or vitality and soil moisture, (4) village ponds, and (5) management of village boundary.

Preference of meandering streams that originated from Chinese fengshui was naturally maintained as Korean people hope that water would hold in needed spaces long under circumstance of poor availability. Principle of village of rear-mountain-and-front-water that was also rooted in Chinese fengshui, seems to be maintained and improved in Korea as a landform and life of rice paddy that required a lot of water supply. Particularly in villages which had the legend - surrounding mountains cherish vitality of fire, soil and air, showed dedicated practices concerning moisture of soil and air for their residential area and nearby croplands. For instance, making ponds inside their village and enforcing village boundary by nurturing a grove or forest on flat area or a little low part were to keep the water and moisture acquired with much effort within the village.

The pungsu practices that Korean people had developed to enhance water use efficiency in the Choson Dynasty era (1392-1910) can be classified into acquisition, collection and retention, and discharge of water. The land-use practices of rear-mountain-and-front-water preferentially set by people were to acquire clean waters from upland forests (acquisition of water). Villagers used to irrigate water into the village from an adjacent stream and prolong time of stagnation by making ponds, which might contribute to enhancing soil moisture and recharging groundwater. In addition, they lessened evaporation loss

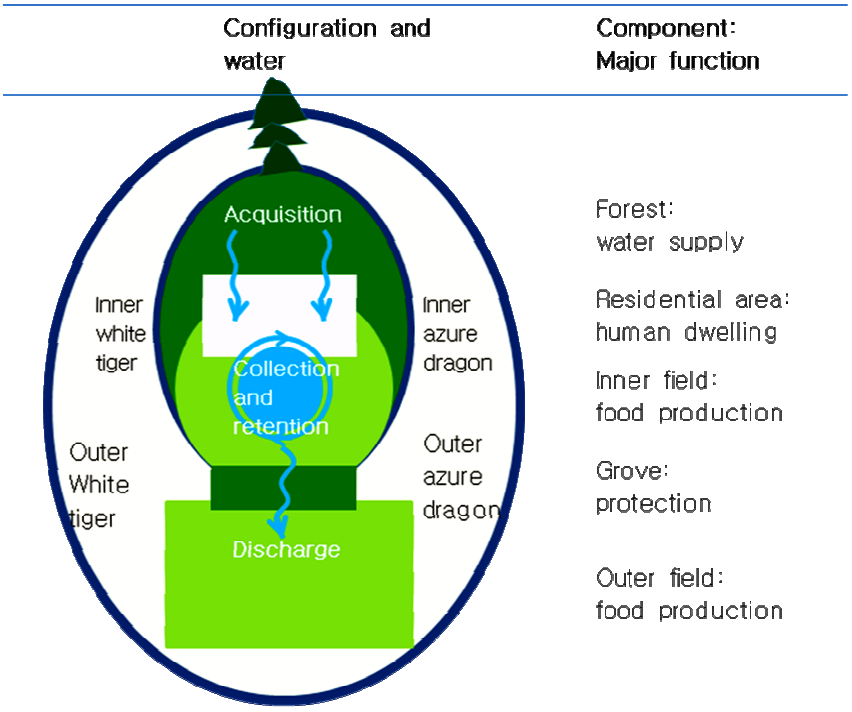

Figure 1. A typical configuration and spatial components of traditional Korean village as related to acquisition, collection and retention, and discharge of water. Line of oval tracts denotes boundary of village, including watershed divides and a village grove or symbolic features. The circle and circled arrow denote collection and retention by reuse of water, respectively.

from water in residential area and inner rice paddy and kept air moist by enforcing surrounding boundary of the village with groves and forests. Where water retention capacity of soil is especially poor, people stressed practice of water collection and retention as they talked that they had a rear mountain with fire anima (collection and retention of water). Preference of meandering water flows may be related to retardation of water discharge from the village and agricultural areas (discharge of water). These endeavors might have shaped Korea's traditional cultural landscapes where pungsu principles were employed to interpret the landform for land-use planning and design. Based on the above discussion and other documents (see references and discussion in Lee and Park 2010), a typical configuration of traditional village that traditional Korean people did especially preferred is shown in Figure 1.

Pungsu includes principles to calm or control winds and acquire waters as the word indicates. Starting from the recognition that a lack of water resource was at least one of major factors that made Korean people cling to pungsu, this study tracks documents and remaining landscapes. I discussed relevant practices to acquire and manage water resources by using pungsu principles in the Choson Dynasty era, where people suffered from drought and shortage of water supply. I could identify traditional culture and certain wisdom in the practices that people introduced pungsu from China and interpreted it according to our landscapes to exploit scarce resources wisely in traditional Korean communities although some irrational contents are also included.

Acknowledgement:
I would like to express my grateful appreciation to Professor Yoon, Hong-key at University of Auckland and Mr. Ryu Youngryel at University of California, Berkeley for introducing some useful references and giving constructive comments on an early draft of this paper. While I was improving the ideas in this paper, this research was supported by the National Research Foundation of Korea (project number 2009-007602).

Reference:
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The spatial distribution of land use potentials and its implication for land use changes and landuse policies in Korea

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Due to the high population density and mountainous terrain, demands for land resources are extremely high in Korea. Rapid economic development and urbanization processes during the past few decades have brought in many aversive impacts on land quality and its ecological functions. This study developed an algorithm to characterize land use potential at the national level, and compare the results with land use change patterns and current land use policies in Korea. The algorithm developed is based on the premise that there are distinctive landscape units over the landscape in which unique hydrological, geomorphological, and ecological processes occur. A semivariogram analysis was first used to characterize the spatial dependency of environmental factors, which resulted in a clear hierarchical structure of the following order; climate > vegetation > physiography > geology > landforms. A multi-scale hierarchical delineation procedure identified 42 different landscape units, and a numerical ranking method was applied to derive a land use potential index from the landscape units delineated. The comparison between the land use potential and land use changes during last thirty five years shows significant spatial and temporal trends; the high correlation coefficient with the proportion of agricultural lands is decreasing rapidly at the si-gun administrative level, while the correlation coefficient with the proportion of urban area is increasing. High land use potential areas are clustered at few locations with poor spatial connectivity among them. These results suggest that the spatial differentiation of land use policy with the increase of spatial connectivity is the

best strategy to meet both the high demand on land resource and ecological sustainability in Korea. The implication of the findings for land use patterns in the Yangu study site will also be discussed during the presentation.

Modelling Session Abstracts

A case study of social-ecologically-based management of ecosystem services: Global change impacts on agricultural production versus water quality in mountain landscapes

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As a case study where management based on social-ecological principles should lead to sustainable supply of ecosystem services, the international project TERRECO (Complex Terrain and Ecological Heterogeneity) applies a transdisciplinary modelling approach to examine current and potential future natural resource use within the largest reservoir system of South Korea, Soyang Lake Watershed. Due to intensive fertilization, small catchments within the watershed export some of the world's highest levels for N and P, while steep terrain and monsoon rains result in extremely high material transport. To consider future management with climate change at regional scale, new integrated modelling approaches are being developed for land surface processes and production, for hydrology and transport, for economic evaluation of ecosystem services, and for associated management and decision-making. The models are supported by ground-based studies of ecosystem physiology and agricultural yield, of soil properties and erosion, of stream flows and transport, of groundwater exchange, of farm economic balances, of statistical data bases, and of individuals preferences in decision-making within particular regulatory and economic frameworks. Scenario evaluations are planned in partnership with provincial and national agencies that currently carry out land use planning and advise on policy making. A common interest among project participants and agency planners focuses on scenarios examining sustainability of ecosystem services. The required transdisciplinary integration for assess-ments of alternative futures, drives the development of modelling systems that apply at landscape to regional scales, couple to specific conceptual goals, and should provide for communication on uncertainties with managers and stakeholders.

Landscape level carbon and water balances and agricultural production in mountainous terrain of the Haean Basin, South Korea

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The process-based spatial simulation model PIXGRO is being developed to estimate gross primary production, ecosystem respiration, net ecosystem CO_2 exchange and water use by forest and crop fields of Haean Basin, South Korea at landscape scale. Simulations are run for individual years from early spring to late fall, providing estimates for dryland crops and rice paddies with respect to carbon gain, biomass and leaf area development, allocation of photoproducts to the belowground ecosystem compartment, and harvest yields. In the case of deciduous oak forests, gas exchange is estimated, but spatial simulation of growth over the single annual cycles is not included. Spatial parameterization of the model is derived for forest LAI based on remote sensing, for forest and cropland fluxes via eddy covariance and chamber studies, for soil characteristics by generalization from spatial surveys, for climate drivers by generalizing observations at ca. 20 monitoring stations distributed throughout the basin and along the elevation gradient from 500 to 1000 m, and for incident radiation via modelling of radiation components in complex terrain. Validation of the model is being carried out at point scale based on comparison of model output at selected locations with observations of LAI, biomass, fluxes and crop yield, as well as with known trends in ecosystem response documented in the literature and regional statistical data. The resulting modelling tool is useful for estimation of ecosystem services at landscape scale, first expressed as kg ha^{-1} crop yield, but via future cooperative studies also in terms of monetary gain to individual farms and farming cooperatives applying particular management strategies.

Assessment of regional forest disasters in Soyang Basin using RHESSys

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Regional Hydro-Ecological Simulation System (RHESSys) is a useful hydro-ecological model to simulate carbon, water, and nutrient fluxes. This research aims to develop a forest environmental information simulation system (FEISS) for Inbuk sub-basin in Soyang basin, Kangwon, ROK, which helps forecast and reduce forest disasters such as landslide and fire under a changing climate. Input data sets are created using GIS to simulate the Inbuk forest ecosystems. These include chronological climate information as well as GIS-based map projection data such as DEM, land use, soil type, vegetation, and biomass. Spin-up runs are performed to produce reasonable parameters for the current forest environments which are prescribed into the further simulations. Parameterization and/or calibration are executed using 3 yr (2001-2003) data and the validation is followed using 5 yr (2004-2008) data. Simulations by the parameterized model show a reasonable agreement with the measurements of streamflow and biomass. Results from the validation show a potential to reproduce the variables at a sub-basin scale. Other issues including map projections of this on-going research for the disaster-related variables will be discussed.

Hydrograph separation using geochemical tracer by three-component mixing model for the coniferous forested catchment in Gwangneung Gyeonggido, Republic of Korea

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This study was conducted to clarify runoff production processes in forested catchment through hydrograph separation using three-component mixing model based on the End Member Mixing Analysis (EMMA) model. The study area is located in the coniferous-forested experimental catchment, Gwangneung Gyeonggido near Seoul, Korea (N 37 45', E 127 09'). This catchment is covered by *Pinus koraiensis* and *Abies holophylla* planted at stocking rate of 3,000 trees ha^{-1} in 1976.

Thinning and pruning were carried out two times in the spring of 1996 and 2004 respectively. We monitored eight successive events during the periods from June 15 to September 15, 2005. Throughfall, soil water and groundwater were sampled by the bulk sampler after each event. Stream water was sampled every 2-hour through ISCO automatic sampler for 48 hours. The geochemical tracers were determined in the result of principal components analysis. The concentrations of $SO4^{2-}$ and Na^{+} for stream water almost were distributed within the triangle diagram of the end members; throughfall, soil water and ground water. Average contributions of throughfall, soil water and groundwater on producing stream flow for 6 events were 17%, 25% and 58% respectively. The antecedent precipitation index (API) plays an important role in determining which end member prevails during events. It was found that the low API event produced more ground water compared with the high API event. On the other hand, rain water showed opposite result. It may be caused by saturation overland flow producing in areas where soil water content is near saturation. API controls runoff producing mechanism whether surface or subsurface flow prevails.

(for complete text see section with Experiment Descriptions)

Modelling the hydrologic impact on surface-water concentrations throughout the Haean Catchment and Soyang Lake Watershed

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Understanding the influence of complex biogeochemical interactions within a watershed and characterizing the spatial and temporal influence of these interactions on the surface water outlet loading remains elusive. This is particularly important in ungauged catchments with limited field data. A variety of conceptual, topographic, and process-based models have been used to estimate the hydrologic response to the driving meteorological factors.
HBV is a semi-distributed, conceptual model that was utilized in the upland forest portion of the watershed to simulate the observed surface water discharge by varying several conceptual parameters. The primary influence was found to be within parameters associated with the soil moisture and storage response functions. These results are important to future investigations throughout the Haean since limited field data requires interpolating sparse data and quantifying the processes that are most influential. Additionally, the topography-based model TOPMODEL will be used in order to simulate hydrologic water fluxes through the same forest catchment. TOPMODEL is a physically based, distributed watershed model and is used to predict saturation excess and the potential for saturation overland flow and subsurface stormflow. A third model to be applied is the semi-distributed SWAT model used to predict the impact of land management practices on water, sediment, and nutrient yield. By analyzing temporal and spatial soil, land use, and management scenarios long-term impacts can be quantified.

The conceptual and topographic models can be used to predict the hydrologic response in the upper forested reach during periods without discharge records. These results can be coupled to historical biochemical data to estimate nutrient loading from this important source location. The SWAT model incorporates the hydrologic response data from the previous models as well as a wide variety of readily available field data to investigate future water management scenarios and climate change impacts. Future work includes estimating physically-based statistical distributions of the hydrologic parameters within a variety of subcatchments throughout the Soyang Lake watershed and up-scaling the results to the entire watershed.

Modelling soil greenhouse gas exchange of terrestrial ecosystems and up-scaling procedures

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Quantifying sources and sinks of greenhouse gases like CO_2, N_2O and CH_4 for natural, agricultural and forest ecosystems is crucial to our understanding of land-use/ management change effects on global climate change including feedback mechanisms. GHG exchange from soils is driven by microbial nutrient turnover. Thereby, GHG emissions are the result of the complex interaction of the processes involved in production, consumption (i.e. mineralization, nitrification, denitrification, methanogenesis and methane oxidation) and transport and their controlling environmental conditions such as nutrient availability, aeration, soil moisture and soil temperature, highly varying in space and time. Process oriented biogeochemical models provide a useful instrument for integrating our knowledge of the key processes and driving variables to estimate C- and N trace gas emissions from soils. As field measurements will always be limited in space and time, such models are also a promising tool for scenario analysis and for up-scaling of GHG emissions on different scales. Within recent years at IMK-IFU we have further developed and integrated the biogeochemical DNDC model into a Modular Biosphere Simulation Environment (MoBiLE) for simulation of soil GHG exchange of forest and agricultural ecosystems. The presentation aims on (i) introducing the structural design of the model framework, including model principals and processes, (ii) model application on site scale and (iv) up-scaling on landscape, regional and global scales.

Modelling the tradeoffs between agricultural production and environmental protection in Soyang Watershed of South Korea

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The most common environmental problems due to agricultural production are sediment runoffs and production chemicals from the application of chemical fertilizers, pesticides, and herbicides. These are non-point pollutants which are characterized by a very high cost of monitoring and control in addition to enforcement difficulties. This has raised one of the most popular issues in environmental and resources economics, internalization of externalities.
Modelling agricultural systems that recognize the environmental dimensions has evolved during the last decades. Multi-objective mathematical models encompassed the diversity of objectives inherent in agricultural activities as a result of externalities. Mathematical programming in its various forms is the privileged technique among researchers to analyze the sector-wide effects of agricultural policies. In the structure of mathematical programming, the decision problems at the sector level can be viewed as a two level process. At the macro level, the policy maker is trying to find how best to allocate limited budgetary resource to achieve multiple objectives in an environment where it is uncertain how farmers will respond to a change in policies. At the micro level, producers are trying to maximize their own objectives e.g. farm income maximization, given the new policy environmental and their resource constraints.

Located in Gangwon province of South Korea, Soyang Watershed is a typical example for the examination of nature - human interactions. The watershed holds an essential role in providing water quantity and quality for part of Korean population in addition to a number of other

ecosystem services but is strongly influenced by human activities including intensive agricultural production. Thus, the focus of the research is on building an economic simulation model for agriculture at the watershed level. Thus, the watershed is considered as a bridge between micro level analysis of individual farmers and a regional or sectoral approach with the specific considerations on existing environmental problems regarding watershed management. The model will be an economic analytical framework applicable not only for Soyang in Korea but also for other watersheds elsewhere.

The study is to examine the changes in agricultural production level and thus the welfare of producers and consumers of agricultural products within a multiple objective framework and under different relevant scenarios. The total regional welfare is maximized, given the quantity of eroded soil and leached chemicals are minimized. The study is supposed to provide some light on the tradeoffs in monetary terms between agricultural production and environmental protection in such a country that both food self-sufficiency and environmental protection are prioritized in its political agenda.

Quantifying and evaluating trade-offs between multiple ecosystem services in Haean Catchment

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Ecosystems offer a large portfolio of services beneficial to mankind, ranging from provisioning services, regulating and supporting services, to cultural services. Decisions about their management, however, are often based on an incomplete understanding of the underlying driving forces and mostly neglect their high degree of interconnectedness. As a result, ecosystem services are typically undervalued and undergo unsustainable depletion, with nearly two thirds of the world's ecosystems declining in productivity.

A step towards improving this situation is to enable better consideration of ecosystem services in decision-making. One effort is the InVEST tool of the Natural Capital Project (http://www.naturalcapitalproject.org/InVEST.html), which is a practical set of models for quantifying and mapping the values of multiple ecosystem services across landscapes. The goal is to use following InVEST models for Haean catchment: biodiversity, carbon storage and sequestration, avoided reservoir sedimentation, crop pollination, and reservoir hydropower.

The results can support natural resource management in finding land use patterns that provide an optimal mix of benefits from ecosystem services, given competing interests by different stakeholders. InVEST lends itself for transdisciplinary work, since it is capable of embracing results of multiple scientific disciplines on the one hand, but on the other hand it is intelligible enough to involve all kinds of stakeholders and efficiently communicate results.

Long-term ecological studies at Dinghushan Forest Natural Reserve

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Introduction

Research at Dinghushan Forest Ecosystem Research Station (hereafter referred to as DHS) is based on the study of successional processes, patterns and functions in subtropical forest ecosystems, with the goals of understanding the associated biodiversity, mechanisms of origin, along with potentials for maintenance and future development. Thus, our studies are designed to guide the management of this natural reserve. We are working to advance basic understanding of the successional processes and dynamics in typical forests of the chinese subtropical region; to detect relationships between forest succession dynamics and environmental change; to provide scientific information for evaluation and sustainable management of subtropical forests; to accumulate basic information on subtropical forest ecosystems for the national Chinese Ecological Research Network (CERN); and to enhance understanding of the ecological functions of subtropical forest ecosystems for policy makers.

Figure 1. View of the evergreen broadleaf mature forest at Dinghushan Reserve.

DHS is located in Dinghushan Natural Reserve (112°30'39''-112°33'41'' E, 23°09'21''-23°11'30''N), with an area of 1,133 ha and an elevation ranging from 10 to 1,000 m above sea level. The region is characterized by a typical southern subtropical monsoon climate, with annual average precipitation of 1,950 mm, of which nearly 70% falls from April to September and 30% from October to March. The annual mean temperature is 20.8°C, and relative humidity is 80%. The predominant soil types are lateritic red-earth at lower elevation and yellow earth in the higher altitude region. Favored by the subtropical monsoon climate and long history of protection, DHS is covered by monsoon evergreen broadleaf forest together with successional forest stages. Therefore, DHS is an ideal place to examine successional processes and patterns occurring within subtropical forest ecosystems, as well as to consider ways to restore or rehabilitate degraded forest sites in subtropical China.

Research program and progress

Ecological studies have been carried out in DHS since the 1950s. During the last three decades, research in DHS has progressed in 4 stages with respect to local focus and the development of goals as described below:

I. Background investigations

Background information related to topography, geology, soils, mammals, birds, vegetation, flora, fungi, and soil microbes were gathered from 1978 to 1985. Investigations were conducted by the South China Institute of Botany (renamed as South China Botanical Garden in 2002), Zhongshan University, South China Normal University, Guangdong Institute of Soil Sciences, Guangdong Entomological Institute, and Guangdong Institute of Geography. Permanent forest observation plots along with forest hydrological and meteorological observations were set up. Topographic, soils, and vegetation maps were obtained based on these field investigations. The first volume of "*Tropical and Subtropical Forest Ecosystem Researc*h" was published during this period. Nine volumes on this topic have been published to date.

II. Vegetation structure, dynamics, biomass distribution and productivity research

Research from the late 1980s to 1990 were focused on vegetation structure, dynamics, light use efficiency, biomass distribution and productivity. Such research filled an important gap in knowledge about productivity in subtropical forest ecosystems in South China. Long-term litter monitoring was carried out in the monsoon evergreen broadleaf forest and successional forests in this phase of research development as well.

III. Ecosystem patterns and ecosystem function research

DHS became a member of CERN in 1991. Automatic observation systems with advanced capabilities were installed to replace manual observations with the aid of CERN. In addition to regular periodic observational studies required by CERN, research projects on forest ecosystem patterns and functions were carried out at DHS. Research projects and foci initiated during this stage include the following:

- Nutrient cycles in monsoon evergreen broadleaf forest ecosystems;
- Hydrological cycle mode in monsoon evergreen broadleaf forest ecosystems;
- Mechanisms of ecosystem structural development and productivity in monsoon evergreen broadleaf forest ecosystems;
- Energy flows in the Soil-Plant-Atmosphere system in monsoon evergreen broadleaf forest ecosystems;
- Human impacts on patterns and functions of *Pinus massoninan* forest in Dinghushan (International cooperation project);
- Mechanisms of ecosystem biodiversity protection and maintenance in Dinghushan (International cooperation project);
- Greenhouse gas flux (CO_2、CH_4、O_3、N_2O、CFC_5) monitoring in Dinghushan (International cooperation project).

These research projects improved the research capacities of DHS significantly. They also provided a broad research platform for understanding C、N、H_2O、 and P dynamics and budgets, their interactions and their response to global environmental change in forest ecosystems of South China.

IV. Ecosystem processes, interactions, and response to global change

Since 2000, research goals at DHS have been oriented to advancing our understanding of C, N, and H_2O cycles in forest ecosystems, their interactions, and the responses and adaptions to global change; to elaborating carbon source-sink functions of subtropical forests; to illustrating the contributions of subtropical forests to alleviation of global environmental

change; and to providing a scientific reference base for international environmental negotiations by policy makers. Major research projects during this period include the following foci:

- Ecosystem patterns and functions as influenced by topography, elevation and oceanic-terrestrial patterns;
- Carbon fluxes in monsoon evergreen broadleaf forest ecosystem in South China;
- Carbon cycles in typical subtropical forests in South China;
- Soil-atmospheric CO_2, N_2O, and CH_4 fluxes in subtropical forest ecosystems;
- Effects of nitrogen deposition on soil nitrogen processes in subtropical forests in South China;
- C, N, H_2O cycles and their interactions in subtropical forest ecosystems.
- Human activities and global change impacts on ecological processes;

This research has been funded by CERN, by national programs, by NSFC projects, knowledge innovations projects in CAS, and the Natural Science Foundation of Guangdong Province. Research capability in DHS improved to a new level with long-term observations and successful implementation of these projects. Research results were published in highly ranked ecology journals such as *Science, Ecology, and Global Change Biology.* These recent scientific contributions made by DHS can be summarized according to the following three topics:

(1) **Old-growth forest can accumulate organic carbon in soils**. Based on analyses of soil data gathered over 25 years, soil organic carbon has been increasing in old-growth forest (reference 13 below). The results provide convincing evidence contrary to the perception that old forests are not a significant carbon sink. It is eroding an old doctrine in ecosystem ecology established several decades ago, which regards the forest carbon pool as achieving a balance as forests mature. It also may fundamentally change our thinking about ecosystem processes and call for establishing a new, non-equilibrium conceptual framework to quantify carbon sequestration capacity. The results provide a scientific reference upon which to debate the contribution of tropical and subtropical forests in alleviating atmospheric CO_2 accumulation. The findings may contribute to resolving a current enigma confronting global scientists with respect to quantifying global carbon balance.

(2) **Forest succession has notable influences on hydrological processes through canopy structure dynamics.** The mid-successional subtropical forest (coniferous and broadleaf mixed forests) in South China has proven more advantageous in reducing surface runoff and increasing water holding by forests, than forests at early- and advanced-successional stages. These results provide a scientific reference for managing forests with respect to the hydrological cycle, and are significant as well with respect to restoring and rehabilitating degraded forest ecosystems in the subtropics of China.

(3) **Systemic research on C, N, and H_2O cycles and their interactions in forested regions**. A value of 25 is the suggested critical C/N ratio for soil nitrification in subtropical forests in South China. It stresses the importance of interaction between C and N cycles in forest ecosystems, especially regarding nitrogen deposition which has become a global environmental issue. This finding indicates that increasing nitrogen deposition results in accelerated soil acidification, triggering nutrient loss, changing nutrient balances, and finally leading to forest degradation. Results of our studies have shown that runoff and soil erosion are major hydrological pathways of carbon loss from forest ecosystems. Carbon lost via hydrological pathways varies with forest succession processes. Mature forest has a relatively high carbon loss via hydrological pathways as compared to immature forests. This result illustrates that mature forests are still a strong carbon sink, even if net primary productivity is close to zero.

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Experiment Descriptions

Flux Control, N Balances and Production in Agroecosystems of Haean Catchment

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Background

Development of modelling tools to estimate the contribution of agricultural fields to the export of nutrients via stream systems to the Soyang Lake reservoir requires that information be obtained on plant uptake of nutrients, release of nutrients in seepage water, and long-term retention of nutrients in soils. Additionally, in order to determine optimal gains in ecosystem services, namely production of agricultural products versus limited export impacts on water quality, nutrient balances and production must be examined within a range of fertilization levels.

Such studies have been carried out in Chinese agroecosystems for rice, maize and wheat (Fig. 1; Ju et al. 2009), varying N addition rate from 50 to 400 kg ha^{-1}. Fertilizer addition within this range is also commonly employed in the Haean Catchment. While the information from Ju et al. (2009) are extremely useful for modeling of the agricultural systems of the Soyang Lake watershed, a similar experiment is planned for the summer of 2010 in the Haean Catchment. New elements of this experiment are 1) it will be conducted with a dicotyledenous root crop species, 2) the common farming methods will be employed, 3) parameters important to growth, yield and production models will be simultaneously assessed, 4) N_2O release will be measured, and 5) insect populations will be monitored.

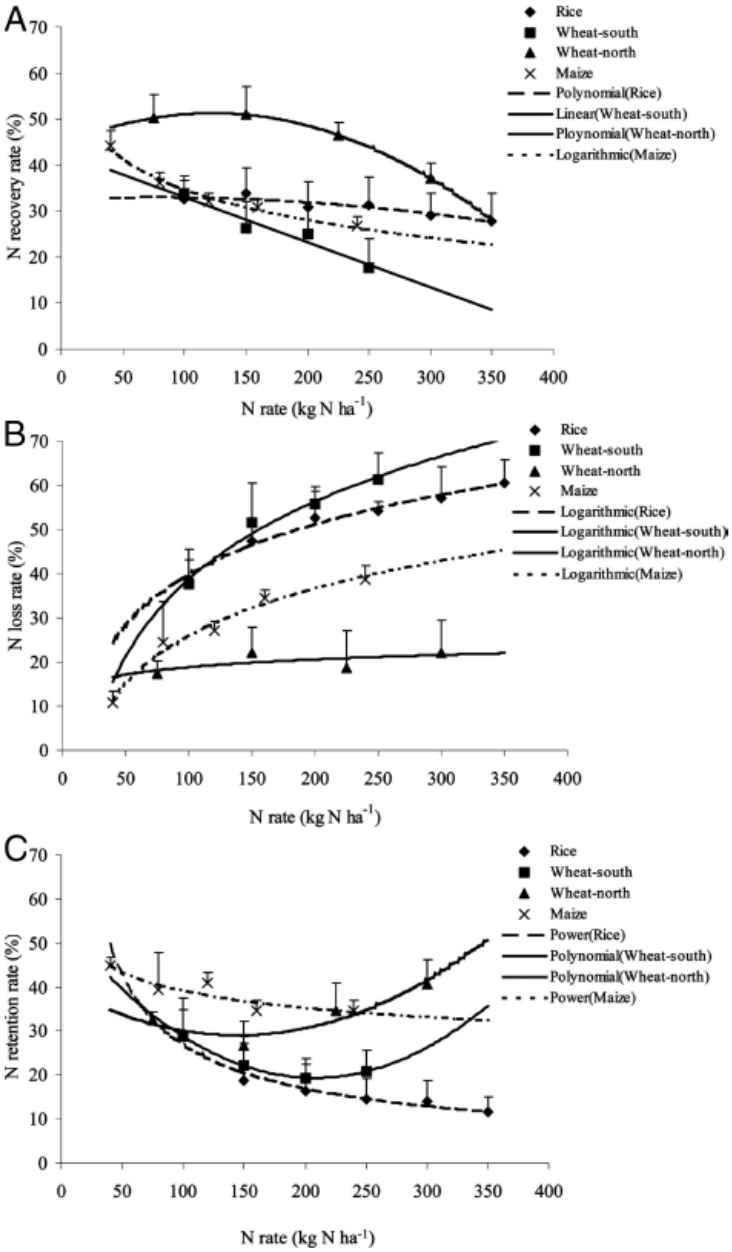


Figure 1. Relationships of N recovery rate (A), loss rate (B), and retention rate (C) with N application rate in 4 crops. Vertical bars denote standard deviation of the mean (average of 6 ^{15}N field experiments). Reproduced for educational purposes from Ju et al. (2009).

Figure 2. Field selected for fertilization experiment near Haean-myun center. The plots are located at the far side. On the middle left one can see an embankment where the bordering road descends.

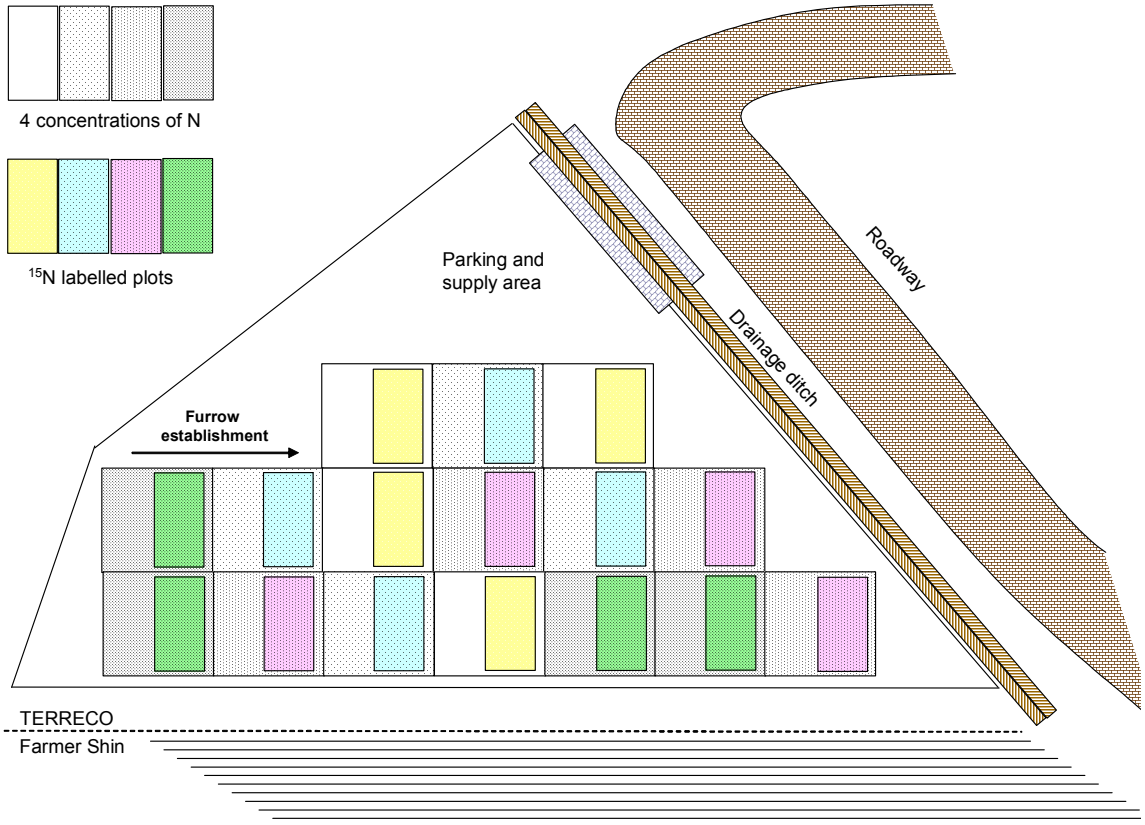


Figure 3. Diagram showing location of the experimental plots in the rented part of the field shown in Fig. 2. Four concentrations of N (50, 150, 250 and 350 kg N ha^{-1} randomly located) in commonly used N, P, K fertilizer will be applied. Colors indicate the 15 N labeled area (actually smaller as explained below). Large 8 x 8 meter plots are provided with different levels of N by manual spraying. After spraying, ridges and furrows are established with tractor, moving only in the direction from left to right as shown. The large buffer areas prevent any movement of previous fertilizer level into the main experimental plot areas (in color). They also provide opportunity for additional experimentation.

Recommendations by the Rural Development Administration in Korea for growth of radish range from 200 to 350 kg N ha^{-1}, depending on soil fertility. Application rates indicated by farmers of the Haean Catchment range between 150 and 400 kg N ha^{-1}. Thus, fertilization will be carried out with commonly used N, P, K fertilizer, applying 50, 150, 150 and 350 kg N ha^{-1} in the treatment plots illustrated in Fig. 3.

The planned plot studies allow us to investigate (1) carbon uptake capacity, nutrient uptake, carbon and nutrient allocation, and biomass increase in response to different N application rates; (2) retention of inorganic N in the soil profile; (3) the specific N use efficiency of plants for the various treatments; (4) and agroecosystem N loss pathways as related to different fertilization levels. We apply $K^{15}NO_3$ to follow the fate of applied fertilizer and to document its progressive distribution and potential loss. In addition, atmospheric N deposition will be estimated. The ^{15}N study is carried out in plots with dimensions of 1.5 m by 1.5 m (Fig. 4). Each plot will contain 8 radish plants. Crop management includes normal inputs of pesticides and herbicides according to local conventional agricultural practices. Carbon allocation and biomass increase is monitored via the sequential harvests indicated in Fig 4.

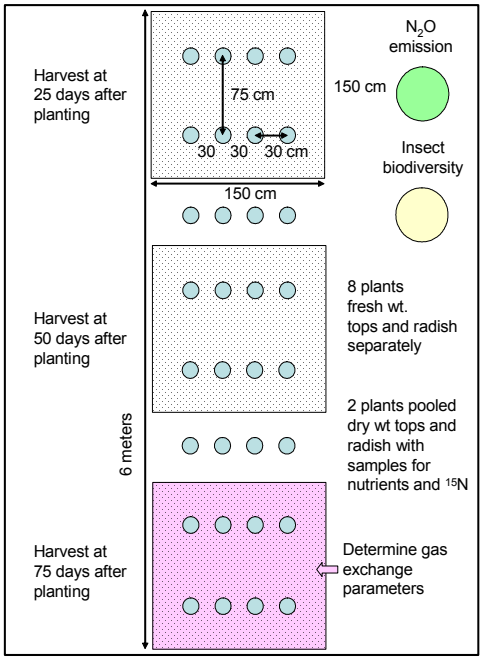


Figure 4. Illustration of components of the experimental plots: areas for sequential harvests, size of harvest and ^{15}N plots, indication that additional installations will be made for N_20 emissions and study of the insect communities.

To a certain extent, coordinated observation of seasonal changes in agroecosystem water use and water use efficiency can also be determined for the treatment plots. We rely in this case on observations of leaf level gas exchange measured with cuvette systems. Additionally, the changes in soil moisture are followed via instrumentation at different depths in the soil.

Differences in carbon uptake capacity, in net ecosystem CO_2 exchange and ecosystem respiration are measured using chambers between first of May to middle of August. Nevertheless, an emphasis on comparison across the treatments will be focused on the mature stage of the crop 75 days after planting. Chamber studies in the treatment plots are further coordinated with observations carried out with eddy covariance methodology in both dry land fields and rice paddies (Fig 5.). On the one hand, the eddy studies cannot be applied along with fertilizer level variation, but the data provide a continuous picture of crop development; linking surface exchange to crop CO_2 uptake capacity, to allocation, and to growth and yield. The chamber studies provide during 2010 for one crop information on the influences of fertilizer level, but only as “snapshots” with respect to carbon flows at several times during the season. Carrying out the experimentation and eddy covariance studies together with development of the PIXGRO model, provides an opportunity to maximize the usefulness of these observations, combining the observed responses in the context of PIXGRO model parameterization and validation. Additional dimensions in validation are planned for 2011.

Field installations and instrumentation

All fertilization plot measurements will be conducted from beginning of May to beginning of August. Eddy covariance and CO_2 chamber gas exchange measurements begin in late April and continue to mid-October. To follow the fate of the tracer, $K^{15}NO_3$ is applied

Figure 5. Sites selected for monitoring of agroecosystem CO_2 and H_2O exchange via eddy covariance methodology in the Haean Catchment. Left panel illustrates the dry land field location which most likely will be planted with potato above the eddy installation site (50 m to the right of the brick utility shed) and with cabbage below. Right panel illustrates the rice paddy eddy covariance site.

homogeneously in the plots together with the synthetic fertilizer before planting the radish seeds on May 20 and before covering with black plastic.

To measure soil water content, to model seepage over the course of the season, and to estimate N loss in seepage water, we install suction lysimeters, tensiometers and FRD sensors/Echo-logger (see Fig. 6). Three suction lysimeters will be set into each of the plots that will be harvested at day 75 after planting. The placement of these suction lysimeters differs in depth as well as location. Two of them will be placed underneath the plastic cover on planting rows; one at 30 cm depth and one at 60 cm depth. The third lysimeter will be located between rows at 30 cm depth. The placement of the 3 tensiometers in the plot only differs in terms of depths: 10 cm, 30 cm, and 60 cm. All of them are placed in rows and beneath plastic. In only one plot, we will additionally install 3 to 6 FDR sensors or Echo logger, respectively, to record soil moisture.

To determine the atmospheric N input, we use a modified device which is based on the isotope dilution method as well as on the exchange resin method (see Fig. 7). Four replicates of the device will be placed on this field site. To gain information about the C allocation in soil and plant parts, we will carry out a small experiment with $^{13}CO_2$ on the three ^{15}N plots of one treatment (recommended level of fertilization by RDA). On these plots, we will conduct a one-time pulse labeling of shoots with a transparent Plexiglas chamber in which we create a $^{13}CO_2$ atmosphere.

N loss in seepage water

Collection of seepage will be conducted at four different dates, including a day before planting, and days 25, 50, and 75 after planting. Additionally, we will collect seepage samples after heavy rain events during the monsoon season. The samples need to be filtered, acidified and stored cool and dark until analysis (N_{tot}, ^{15}N). Tensiometer and FRD sensors must be read out manually two times a week. A limited number of recording devices will be used to obtain representative continuous records of soil moisture. Data from all soil moisture measurements will be used during winter 2010 to model seepage fluxes (cooperation with research group of B. Huwe).

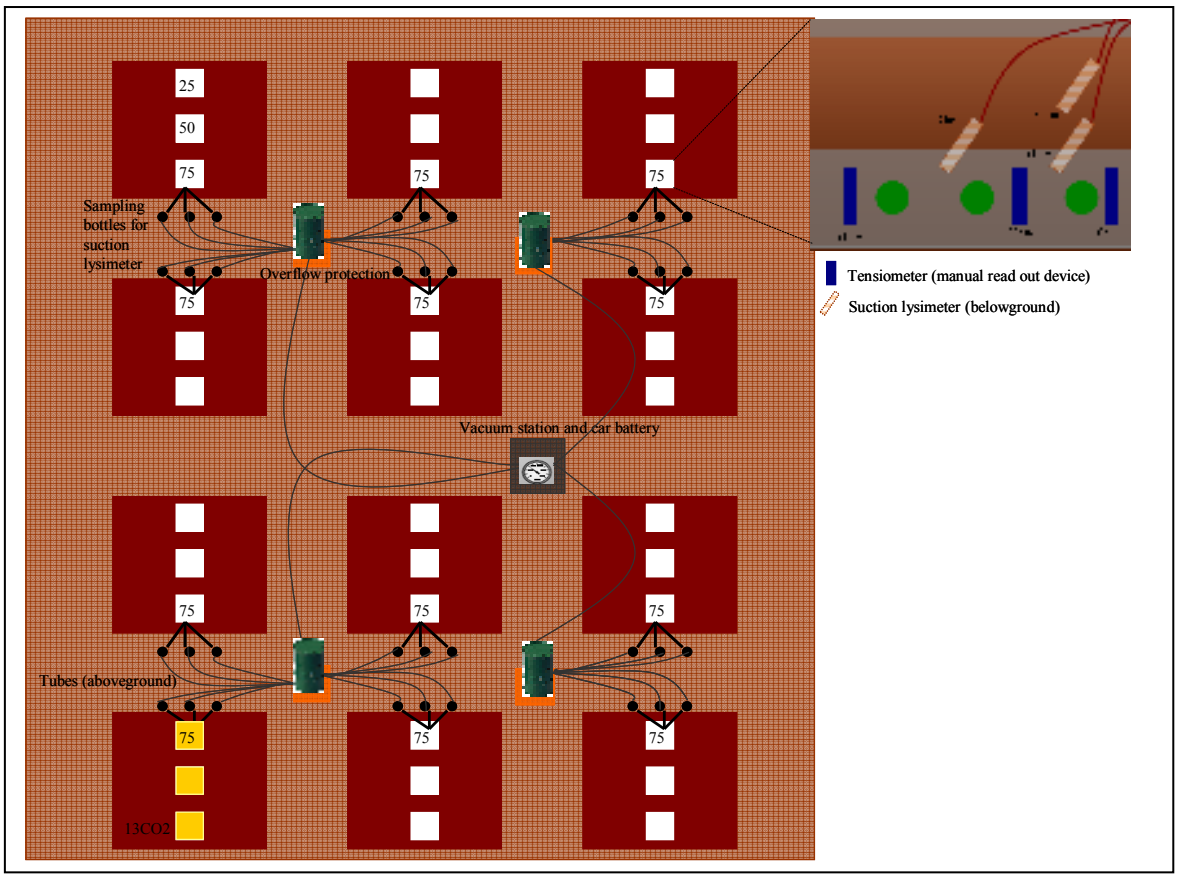


Figure 6. Lysimeter and tensiometer installations

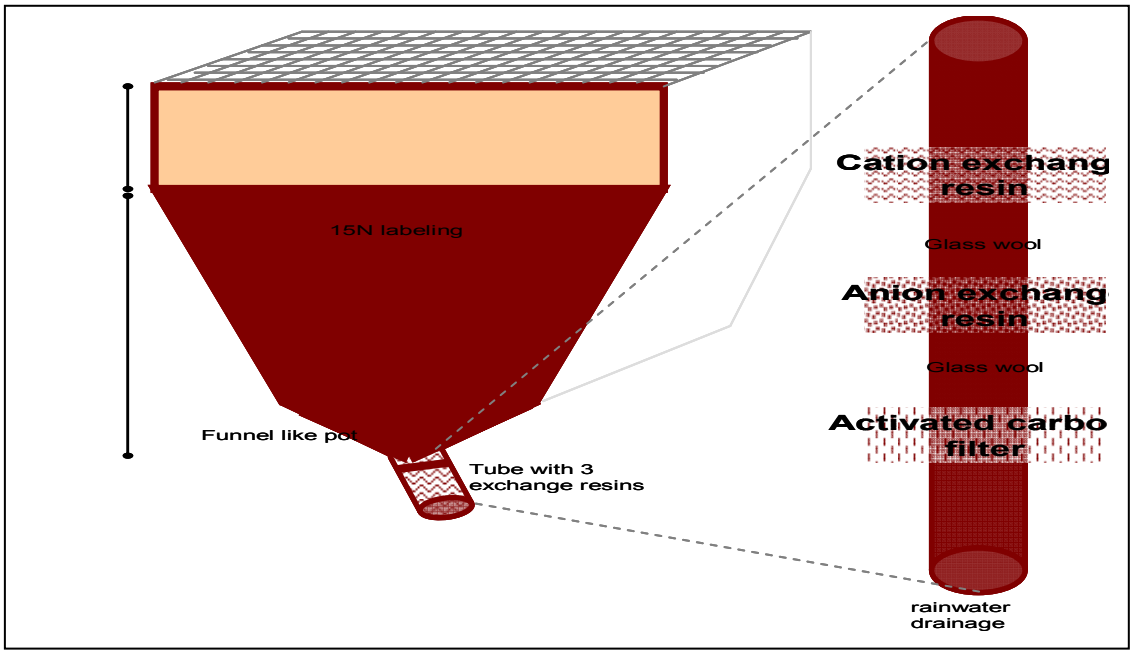


Figure 7. Device to measure atmospheric deposition

Plant harvests for growth, C allocation, and N uptake

The plots will be harvested at three different times: days 25, 50, and 75 after planting. At least 6 plants will be harvested manually and weighed for their fresh weight immediately at the field site. Four of these plants will be subsequently separated into root/radish and leaves/stems, shredded and dried at 65°C for three days. Afterwards, dry weight will be determined and the samples will be stored dry until analysis (N_{tot}, ^{15}N, ^{13}C, C_{tot}). Information is also obtained on changing root to shoot ratio with growth at differing fertilizer levels.

Soil nutrient status

Soil samples will be taken at 6 different times in the plots: before fertilizer application (soil N_{min}), before planting (initial conditions), day 25, day 50, and day 75 (^{15}N, N_{tot}) after planting as well as in spring 2011 (soil N_{min}, ^{15}N). These samples will be taken separately in rows and interrows. Additionally, they will be taken at 3 different depths: 0-15 cm, 15-30 cm, and 30-60 cm. Soil is sampled with a steel soil corer, 4 cm i.d.; samples are dried for 2 days and stored dry until analysis (C_{tot}, ^{13}C).

Atmospheric deposition

Measurements of the total accumulative atmospheric N deposition are conducted from Mai to August 2010 at three locations in the Haean catchment with 4 replicates at each location. Having the focus on the accumulative deposition over the period, we only need to sample the exchange resins as well as the quartz sand at the end of the growing season. Both will be stored dry until analysis (^{15}N, NO_3^-, NH_4^+, DON).

Emissions of N_2O

N_2O flux will be measured with closed chambers with a photoacoustic trace gas analyzer. The sampling times and details are under discussion.

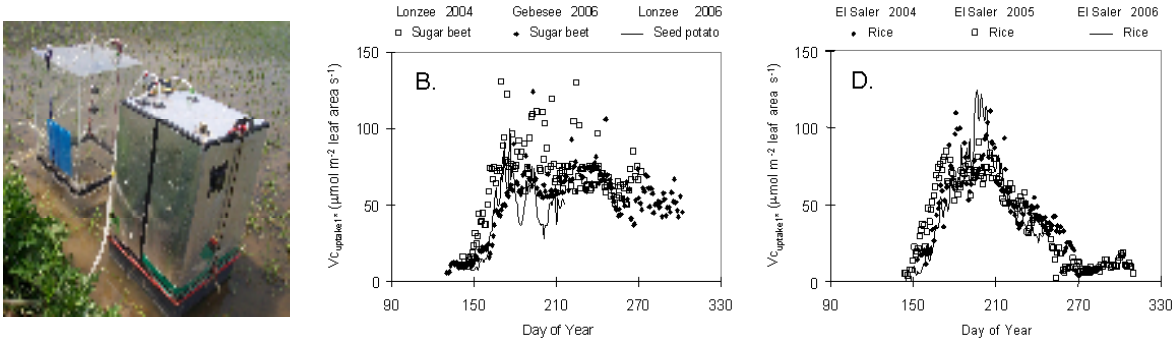
Chamber measurements of gas exchange

Closed gas exchange chambers (38 cm * 38 cm * 54 cm) are employed to measure CO_2 exchange of agroecosystem monoliths in both light and dark conditions (Fig. 8A; Li et al. 2008). Light chambers are constructed of transparent Plexiglas; dark chambers are constructed of opaque PVC and covered with an opaque insulation layer and reflective aluminum foil. The six sets of chamber measurements are planned in radish plots. The observations are centered on 20-25 days, 45-50 days and 70-75 days after planting. The measurements are conducted over the course of the day in order to obtain information on light response of the crop. From the light response, it is possible to estimate the physiological capacity for CO2 uptake as illustrated in Fig. 8B (Li et al. 2010).

Leaf gas exchange will be monitored essentially on a daily basis with an automated cuvette system recording leaf net CO_2 exchange, transpiration rate and stomatal conductance. The gas exchange system tracks ambient conditions, recording information both on environmental conditions and gas exchange response each minute. The apparatus will be used both to examine differences among treatment plots and response of the plants studied via eddy covariance.

Eddy covariance measurements of gas exchange

A mobile eddy covariance measurement system will be used on permanently installed masts at the two locations indicated in Fig. 5. The instrumentation will be moved between these locations on a 7 to 10 day basis, depending on weather conditions during the period. Thus, a comparative picture for NEE, GPP, Reco, ET and environmental characteristics will be



A. B.

Figure 8. A. Illustration of the closed system gas exchange chambers. B. Illustration of the different seasonal patterns obtained for physiological capacity for CO2 uptake for root crops and for rice as evaluated at European crop sites within the project Carbo Europe (Li et al. 2010).

obtained for the two main agroecosystem types found in Haean Catchment. We hope to carry out 6 to 7 observations of ecosystem gas exchange at each location during the course of the season. During each measurement period at each location, plants will be harvested from within the footprint area of the tower (8 locations) and separated into roots, stems, leaves and reproductive parts for biomass and nutrient analysis.

Insect populations and herbivory in dependence on fertilization level

Observations will be carried out examing the influence of fertilization levels on insect populations and herbivory. The experiments are still in the planning stage.

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Water movement and soil erosion on dry farmland in the Haean catchment (South Korea)

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Dry farmland areas especially on steep slopes can become an important source for surface and groundwater pollution when they are exposed to high precipitation events. Especially during monsoonal rainstorm events affecting the Korean peninsula, large amounts of fertilizer and agrochemicals can be leached and move to the groundwater. High soil erosion rates lead to the loss of fertile topsoil and to decreasing water quality of the adjacent streams and reservoirs by sediment and transported nutrients. In the course of climate change the probability of intense rainstorm events will increase. Thus, effective measures for improving soil water balances and erosion control are crucial to maintain agricultural productivity and conserve water bodies.

The primary research goal of our project is the quantification of water dynamics and soil loss as well as understanding the factors influencing the processes of water flow and erosion on dry farmland in Haean catchment during intense monsoonal rainstorms. Based on the outcome of these experiments measures shall be developed for a sustainable and environmentally sound agriculture.

Large runoff collectors (Fig. 1A) are installed on two dryland field sites in Haean catchment in north-west of South Korea in order to collect surface runoff and eroded soil material from the contributing area above. Detailed topographical survey using a tachymeter will be conducted in order to develop a high resolution digital elevation model for determining contributing areas and find optimal collector positions on the field sites. The collectors will be placed parallel and perpendicular to the plastic covered plant rows to investigate its effects on surface water flow and sediment transport. Runoff and sediment is routed from the collector to the multislot divider system (Fig. 1B) (Pinson et al. 2004), which is designed for providing a storm-integrated and discharge-weighted sample of runoff and sediment yield (Bonilla et al. 2006). Sampling runoff and sediment after each single rain event will give information about erosion rates as well as nutrient amounts transported by runoff and eroded soil.

A monitoring network of tensiometers and FDR sensors is installed on both field sites where the runoff collectors are located. Daily-readout tensiometers are distributed along the slope gradient in order to investigate the downslope oriented water dynamics over the field site. At each measuring location tensiometers are installed in three different depths (10, 30 and 60 cm) for quantifying vertical water dynamics. On two slope positions FDR sensors and recording tensiometers connected to a data logger are installed within the plant rows as well as within the interrows close together with varying depths. Recording pressure head and moisture content every 30 minutes provides a high resolution data base of the water flow characteristics below and between the plastic covered furrows.

Monitoring soil water movement and erosion rates during the monsoon period provides the information for understanding the hydrological processes in farmland soils in Haean. Further these measuring results give the framework and data base for process-based models like EROSION 3D, HYDRUS 2D/3D and SWAT 2005. These models are used first for catchment scale simulation of water dynamics and erosion rates (upscaling) (Fig. 2) and second for developing scenarios considering conservation measures as well as future changes in climate, landscape or agricultural politics.

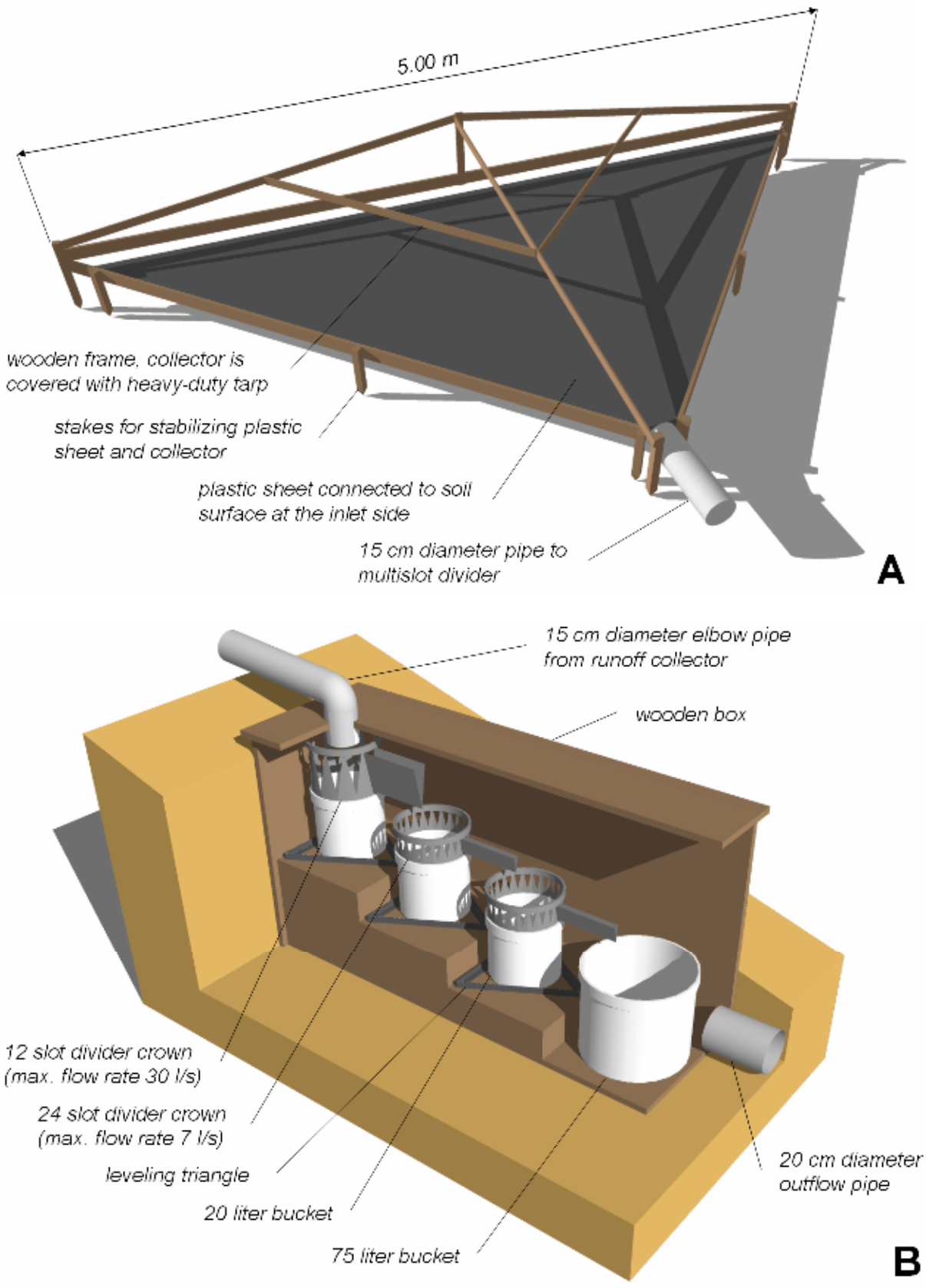

Fig. 1: Runoff collector (A) for collecting and routing runoff and sediment to the multislot divider system (B), which is designed for quantification and sampling runoff, sediment material and chemical losses from field sites even during large runoff amounts by intense rainstorm events or large contributing areas (designed after Pinson et al. 2004 and Bonilla et al. 2006)

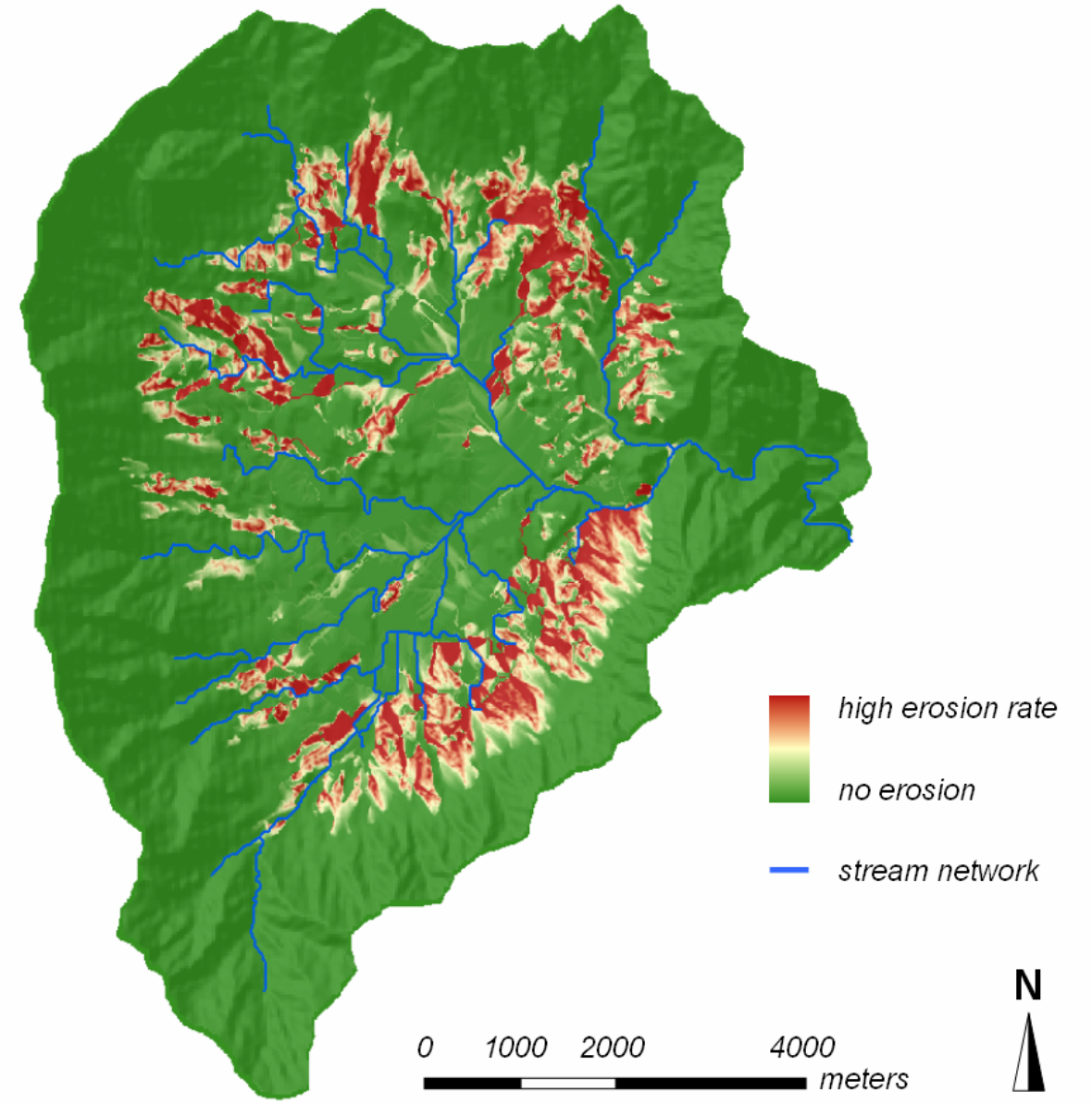

Fig. 2: Soil erosion map of Haean catchment, which shows high erosion rates (yellow to red) on the dry farmland belt between areas of no or very low erosion (green) at the forested hills at the edge and the flat areas and rice paddies in the center of the catchment (developed with the EROSION 3D model)

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Tracer experiments using brilliant blue and stereo-photography: The effect of dryland farming management systems on infiltration patterns, surface runoff and soil erosion

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The intense use of fertilizer and pesticides and its leaching during monsoon season has an increasing impact on the drinking water reservoir of Soyang River in South Korean project region. However, the effects of microtopography (rows covered by foil and surface roughness) on dryland farming field sites on infiltration, preferential flow and surface runoff is poorly understood.

We will conduct 9 irrigation experiments with dye tracer Brilliant Blue FCF and Potassium iodide at four agricultural fields with different crop types and different slopes. Irrigation rate will be 64 mm/hour. One day after irrigation soil profile will be excavated and photographed. Image analysis will be carried out by converting pictures into binary images and the dye coverage function will be calculated. A risk index for vulnerability of groundwater to pollutants will be derived by fitting the generalized Pareto distribution to the dye coverage function (Schlather & Huwe, 2005).

During infiltration experiments, infiltration rates and surface runoff will be recorded by stereophotography system. This system consists of four digital cameras (Canon D1000 SLR), which will be installed in 3 m height (Bogner, Mirzaei, & Huwe, in preparation). DSLR Remote Pro Multi Camera software enables to take pictures synchronously by remote control during the entire irrigation period. From this data a digital elevation model of soil surface in high resolution (2 mm) will be calculated. Surface runoff and sediment transport will be collected by sediments collectors. The sediment collectors and a metal frame will delineate the irrigated area.

We will analyse the influence of (1) row planting system covered by foil vs. bare soil, (2) rooting systems of radish, cabbage and potato, (3) soil additives such as Polyacrylamides (PAM), Biochar and a mix of both as well as (4) different slopes on infiltration patterns, changes in surface roughness during simulated rainfall and sediment transport.

Quantification of infiltration rates and surface runoff will be possible due to delineation of irrigated area and stereophotography system. Tracer experiments allow qualifying the main factors, which are responsible for matrix flow and preferential flow paths. Results will constitute the database for hydrological and erosion modelling with physically based models such as HYDRUS 3D, Hydrogeosphere and Erosion 3D.

Overall, we expect that the combination of both methods will lead to a deeper understanding of soil erosion and soil water drainage processes on dryland farming field sites with typical row planting system in hillslope areas. The land management system will be evaluated from a soil physical perspective.

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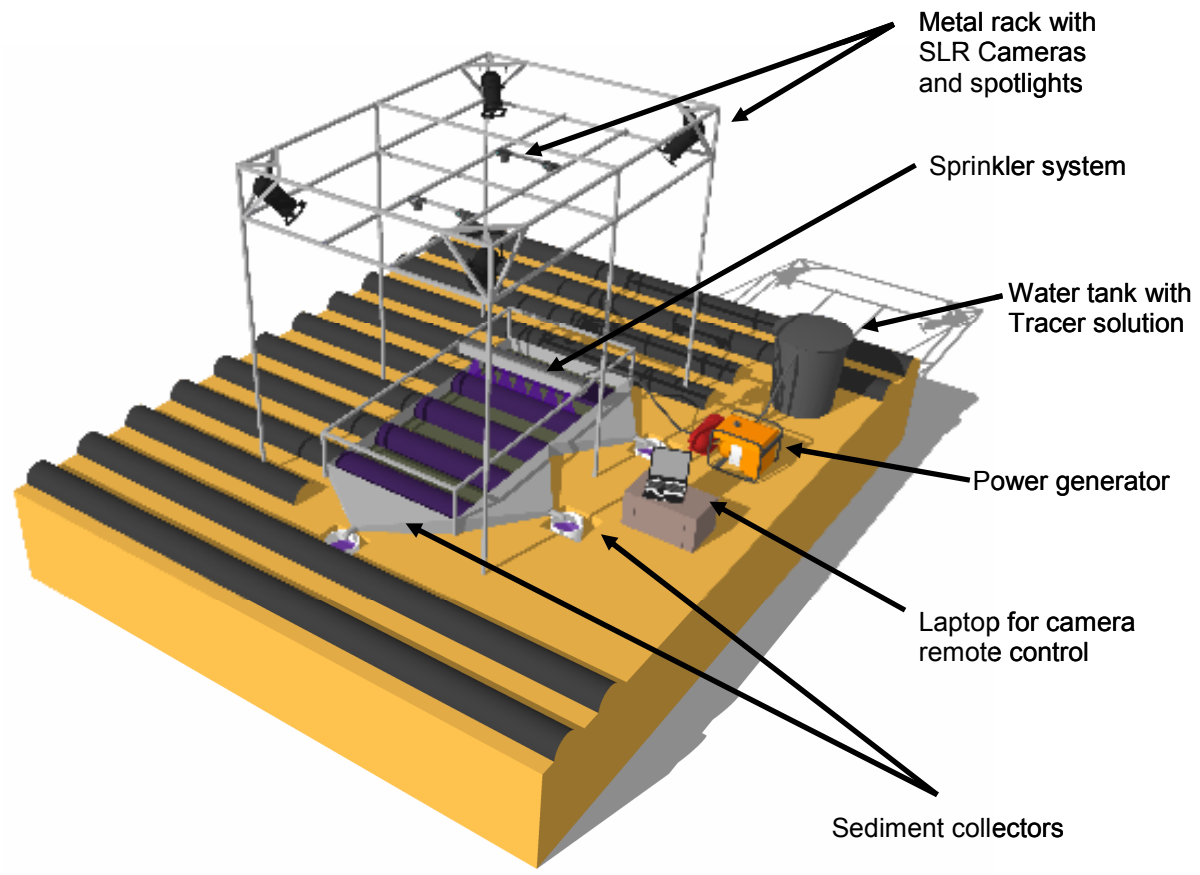

Figure 1. Design of irrigation experiment combined with stereophotography.

Nitrate, phosphorous and DOC export from a catchment under monsoonal climate conditions the case of the Haean catchment, South Korea

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1. Abstract

The hydrogeochemical dynamics in mountainous areas of the Korean Peninsula are mainly driven by a monsoon-type climate. To examine the interplay between hydrological processes and the mobilization and subsequent transport and export of nitrate and DOC from catchments, a field study was initiated in the Haean catchment in north-eastern South Korea under highly variable hydrologic conditions. In order to identify nitrate and DOC source areas, a subcatchment (blue dragon river) within the Haean basin, which includes different types of landuses (forest, dry land farming, and rice paddies), was selected.
In 2009, high frequency surface water samples were collected at several locations during summer storm events. A similar but more comprehensive sampling routine will be completed in 2010. In order to investigate the groundwater level fluctuations relative to the hydraulic potentials, a piezometer transect was installed across a second order stream of the subcatchment. The results so far suggest deep groundwater seepage to the aquifer with practically no base flow contributions to the stream in the mid-elevation range of the

catchment. It is hypothesized however, that subsurface flow might play an important role in near stream biogeochemical processes in the forested upland areas. Therefore, base flow fractions and the origin of stream water in the upper forested area of the subcatchment will be characterized via ^{16}O and ^{18}O stable isotope analysis. In 2009 the focus of research was within the subcatchment, in 2010 additionally a second piezometer transect will be installed at a third order stream in the lower part of the catchment (main stem of the Mandae River) where more dynamic groundwater/surface water interactions are assumed due to expected higher groundwater levels in this part of the basin.
In order to investigate these interactions piezometers equipped with temperature sensors and pressure transducers will be installed directly into the river bed. Based on the observed temperature time series and the hydraulic potentials the water fluxes between the groundwater and the river can be calculated using the finite-difference numerical code, VS2DH. VS2DH solves Richard's equation for variably-saturated water flow, and the advection-conduction equation for energy transport.
The export of nitrate and DOC were found to be variable in time and strongly correlated to the hydrologic dynamics, i.e. the monsoon and pre- and post-monsoon hydrological conditions. In the river, nitrate concentrations rapidly decreased during summer storm events due to dilution and the DOC concentrations increased up to six times higher than background concentrations. Contrary, to the river water, nitrate concentrations in the groundwater increased during storm events whereas DOC concentrations increased during dry conditions. The results also suggested that the highest nitrate concentrations in the groundwater (39.8 mg/L) were found in dry-land farming areas. In contrast, rice paddies seem to attenuate the nitrate export into the groundwater in spite of high fertilizer application rates.

2. Description of the methodology to be applied

2.1. Identification of sink and source areas of nitrate and DOC

2.1.1. Surface water sampling:

In 2009 surface water sampling was conducted at sites which reflect the different land uses within the subcatchment (see Map 1). During dry conditions river water was sampled once a week and during storm events every two hours at each site, respectively. Samples were analyzed for nitrate and DOC concentrations. The analyses were conducted by Bomchul Kim's laboratory (Department of Environmental Science, Kangwon National University). Additionally in-situ the following parameters were measured: Temperature, O_2 saturation, electric conductivity and the pH-value. In 2010 the water samples additionally will be analyzed for the following parameters: TDN, NH_4, and turbidity, phosphate, SSC, total phosphorous, dissolved phosphorous. Knowledge about TDN and the ammonium concentrations in the water is necessary to describe possible nitrogen transformations. SSC, turbidity, phosphate, total phosphorous and dissolved phosphorous are important parameters for the erosion modeling group. Furthermore, phosphorous input from terrestrial nonpoint sources such as fertilizer runoff is often the main cause of eutrophication.

2.1.2. Groundwater sampling:

In 2009 the groundwater sampling was conducted out of the wells of the piezometer transect using a suction pump and a self made flow through vessel. Groundwater was sampled once a week and before and after storm events. The samples were analyzed for nitrate and DOC (Bomchul Kim's Laboratory, Kangwon National University). In-situ the following parameters were measured: Temperature, O_2 saturation, electric conductivity and the pH-values. In 2009 groundwater was only sampled out of the four wells of the piezometer transect. In 2010 another piezometer transect (4 wells) will be built in the lower part of the catchment, which provides information about the groundwater conditions of this area as well. For the representation and the modeling of the whole catchment

information about already existing and usable wells distributed in the catchment is needed.

2.2. Characterization of the discharges within the catchment

2.2.1. Weir:

In order to identify the discharge ranges within the catchment a sharp crested v-notch weir was built at the forest site S1. Upstream the weir a pressure transducer was installed which logs the water level every five minutes. Due to the known shape of the weir plate and the logged water levels continuous discharge data can be calculated. In March 2010 a rectangular weir will be built at a new site S4a (see Map 1). The weir will be installed on an already existing bridge which is located directly after the two tributaries of the subcatchment are joining (see Map 1). Since, the discharge of one of these tributaries is already measurable with the measured discharges of the second weir the discharges of the second tributary can be calculated as well.

2.2.2. Stage-discharge relationship:

In 2009 pipes equipped with pressure transducers which continuous measured the water levels were installed on pillars. Discharges at different water levels were measured using an electromagnetic current meter. With the measured water levels and the current meter measurements at different water levels rating curves were created. By the means of the rating curve continuous discharge data at site S3 and S5 were calculated. In 2009 at Site S3 the pipe was not properly fixed. As a result, the measured water levels are showing unrealistic fluctuations which leads to problems in creating a reliable rating curve. Furthermore, changes of the riverbed during storm events may lead to these problems. In order to ovoid unrealistic fluctuations at site S3 in 2010 the pressure transducer will be placed in a hole drilled into the basement of the bridge. The location of the hole will be in the middle of the bridge basement. The diameter of the hole will be 8 cm and the depth 30 cm. Since, there will be sediment accumulation in the hole; a removable collecting vessel will be installed into an outer pipe. The outer pipe will be fixed by using concrete and closed by a slotted cap.

2.2.3. Float method and current meter measurements:

The float method will be used during storm events at the third-order stream where the second piezometer transect will be built. Thereby, the length of the stream reach will be measured and the start and finish point will be marked. In order to obtain accurate measurements the longest length without changing stream conditions is desired. A floating body (orange) will be placed at the start point in the middle of the stream. The time until the floating body reaches the finish point will be measured via stopwatch. The mean stream flow velocity is approximately 0.8 of the measured velocity for rough bottom conditions and 0.9 of the measured velocity for smooth bottom conditions. During dry conditions river cross section profiles will be taken and flow measurements will be performed using the current meter. In order to create a rating curve of every measurement the water level at the same point will always be noted. This combination of methods will provide a rough estimate of the discharges within the third order streams.

2.3. Characterization of river-/aquifer interactions and the riparian zone

2.3.1. Temperature as natural tracer:

Since, heat is transferred continuously between surface water, underlying sediments and adjacent groundwater heat can be used as a natural tracer for the determination of river-/aquifer interactions. In this study the characterization of interactions between the river and the groundwater plays an important role in order to determine possible nonpoint sources of nutrients like nitrate. Therefore, the main method to analyze groundwater-/surface water interactions will be to use heat as tracer. In order to obtain the temperatures for investigating river-/groundwater exchange fluxes a 60 to 100 m long

reach of the third-order stream will be equipped with one three small and large piezometers, instrumented with temperature sensors. In Figure 1 the positioning of one small and one large piezometer at the cross section site within the stream reach are given as well as the position in the Haean Catchment. If possible all these piezometers will be installed by hand in the riverbed. The small piezometers will be installed around 1 m under the riverbed and the large ones if possible in 2 m to 3 m depths under the riverbed. The distribution of the temperature sensors in the large piezometer are given in Figure 1. A higher density of temperature sensors will be installed in the area around the interface of the streambed and the sediments below, since there the highest temperature gradients are expected. The vertical hydraulic gradient will be observed by measuring the heads in the large piezometers and in the river itself via pressure transducers. The pressure transducer will be fixed into the river bed by using a fencepost. The pressure transducer will also measure the temperature of the stream water. The vertical hydraulic gradient in the riparian zone will be investigated by the wells of the piezometer transect as shown in Fig. 1.

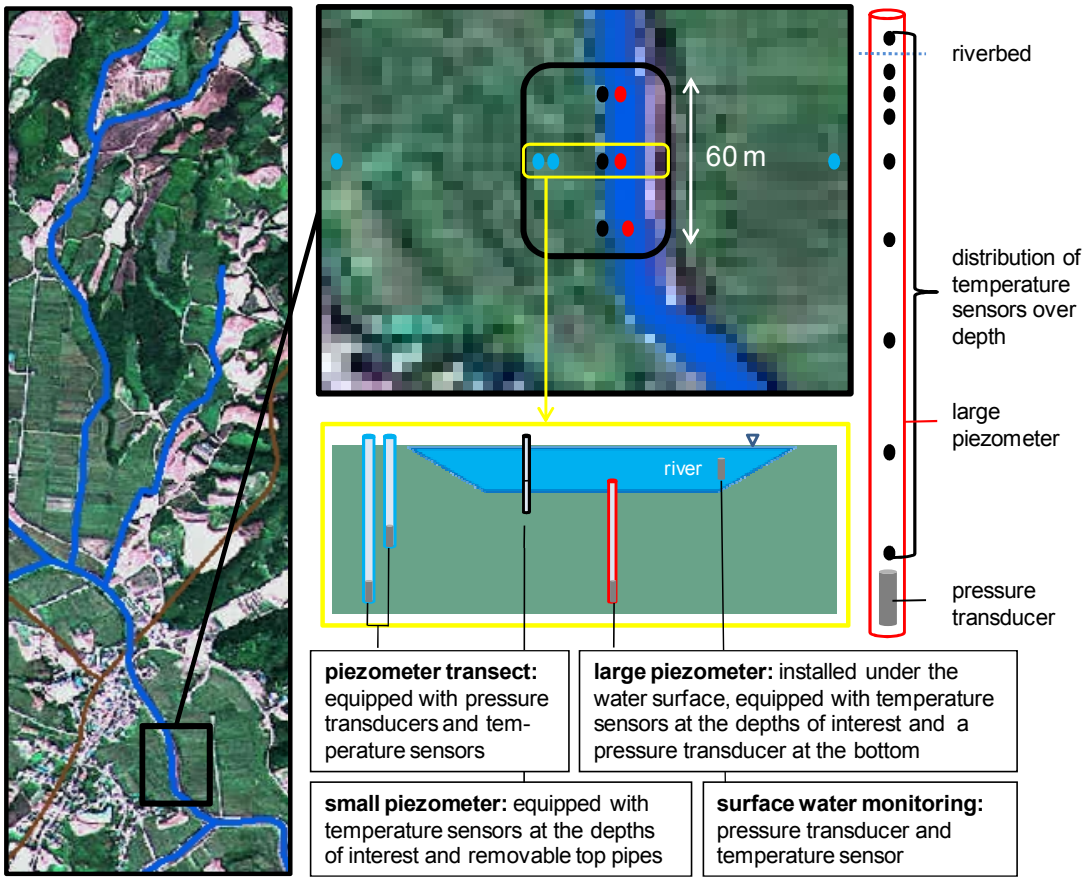


Figure 1. Temperature installations at the third-order river site.

In order to estimate the water exchange fluxes based on the observed temperatures VS2DH, a partially coupled model of fluid and heat flow model, will be used for flow and heat transport modeling. The finite-difference numerical code VS2DH solves the Richard's equation for the variably saturated water flow, and the advection-conduction equation for energy transport.

2.3.2. Piezometer transects:

A standard method for the characterization of river-aquifer interactions is based on hydraulic gradient monitoring via piezometer transects and nested piezometers. In 2009, the first piezometer transect was built. It is located perpendicular to the river and close to site S4 (see: Map 1C). It consists of 4 wells. Two nested wells are close to the river 0.5 m

from each other and in order to determine the vertical hydraulic gradient with different depths (7.81 m; 2.64 m). The screens are at the bottom of the wells with a length of 0.5 m. Two deep wells (W1: 9 m; W4: 16.10 m) were built with a distance to the river of 60 m and 80 m, respectively. Every well is equipped with a pressure transducer in order to continuously investigate the water level fluctuations and the hydraulic potentials. In the Haean Catchment most of the second-order streams in the lower part of the catchment are at least partially channeled. The piezometer transect built in 2009 is located at such a channeled river. Hence, the connection of the river to the groundwater is limited. In March 2010 a second piezometer transect will be built in the lower part of the catchment (see: Map 1C) across a third-order stream where both conditions, a gaining as well as a losing stream due to the monsoonal climate conditions are assumed. The depths of the wells are depending on the groundwater levels. The piezometer transect will consist of 4 wells. As done in 2009, two will be installed close to the river and close to each other in different depths. Two, more deep wells will be built up in a distance of around 60 m – 100 m to river. All these wells will be equipped with pressure transducers.

2.3.3. Sample well:

In order to gain more information about how the groundwater level fluctuations are related to the nitrate and DOC concentrations a 5th well will be installed. This well will be located around 3 m away from the lowest observation well of the piezometer transect and will have the exactly same measurements and distance to the river as the observation well. The sample well will be equipped with an ISCO Autosampler (as done i.e. by Inamdar et al., 2008) which can automatically collect groundwater samples in a preprogrammed interval. The distance (3 m) of the sampling well to the observation well is recommended in order to avoid groundwater fluctuations due to groundwater sampling. By the mean of this sampling method groundwater samples can be obtained during storm events and the measured concentrations can be related to the measured groundwater levels.

2.3.4. Slug tests:

Saturated hydraulic conductivity will be measured via slug tests performed in the piezometer wells. Therefore, water will be filled into the piezometer wells. The installed pressure transducers will log in an interval of 10 second the falling water column. Due to the known geometry of the wells the average saturated hydraulic conductivities for the formation in which the screens are installed can be calculated using different analytical methods for example the Hvorslev method (Fetter, 2001). The best method to apply depends on the aquifer type. The Slug tests will be performed 3-6 times for every well to monitor repeatability.

2.3.5. Stable isotopes ^{16}O, ^{18}O:

Stable isotopes like ^{16}O and ^{18}O can be used for identifying the origin of water. In this study this method will be used to characterize the base flow in the upper forested area (Site S1: see Map 1A) of the Haean Catchment. Therefore, water is put in a clean dry bottle, which is filled completely to the top, and capped tightly. The main objective is to protect the sample from evaporation and exchange with atmospheric water vapor. Samples should not be filtered. The samples will be analyzed in Germany (Prof. Gebauer).

2.4. Investigate how rice paddies affect the nitrate export from the Haean Catchment

2.4.1. Transport pathways and transformations of nitrate in rice paddies:

In the Haean Catchment, rice paddies play an important role since a high percentage of the cultivated area is covered by rice fields. Furthermore, rice paddies provide potential benefits for water quality improvement. On the one hand paddy fields retain runoff water which reduces soil erosion and alleviate downstream flooding. On the other hand, since the water movement in rice paddy soils is very slow due to its low hydraulic conductivities, rice paddies have the potential to remove nitrogen through plant uptake and

biogeochemical reactions (Kang et al., 2005). Hence, in order to monitor hydrology and water quality of the Haean Catchment, knowledge about the system “rice paddy” is an important prerequisite for TERRECO modeling. In this study the infiltration rate of paddy water to the groundwater as well as the water retention of rice paddy soils are the parameters of major interest. In order to investigate the water fluxes in and under the paddy soils heat as a natural tracer will be used. Therefore, temperature probes will be installed into a rice paddy. The temperature probe will consist of steel tubes with attached temperature data loggers at different depths. The length of steel tubes as well as the position of temperature loggers depends on the thickness of the saturated and unsaturated zone. The major flux of interest is the one from the saturated into the unsaturated zone since therewith nutrients like nitrate may be transported to the groundwater. Hence, the temperature probes will be installed through the saturated as well as through the unsaturated zone as given in Figure 2. By the means of the measured temperatures in different depths the water flux can be determined via modeling for example with the model VS2DHI (see: ix. temperature as natural tracer). The water column in the paddy itself will be continuously measured by installing a pipe equipped with a pressure transducer directly into the field. For measuring the temperature of the paddy water a three single temperature logger will be placed into the water. Since, knowledge about groundwater fluctuations under the rice paddy are needed the installation of an observation well equipped with a pressure transducer is necessary. A second well with the same measurements as the observation well will be built for groundwater sampling. This sampling well will be equipped with an ISCO Autosampler in order to gain information about the changes in nitrate and ammonium concentrations related to the groundwater fluctuations during storm events. TDN, NH_4, phosphate, total phosphorous and dissolved phosphorous concentrations in the paddy water will be obtained by taking (once a week during dry conditions and every two hours during storm events) surface water samples. In-situ temperature, O_2 saturation, electric conductivity and the pH-value will be measured. The analyses of the samples will be conducted again by Bomchul Kim’s laboratory. The drainage outlet heights will be manually read out from a scale fixed at the rice paddy outlet. In order to gain information about the nitrate concentrations at different depths in the saturated rice paddy soil three dialyze chambers will be installed into the soil.

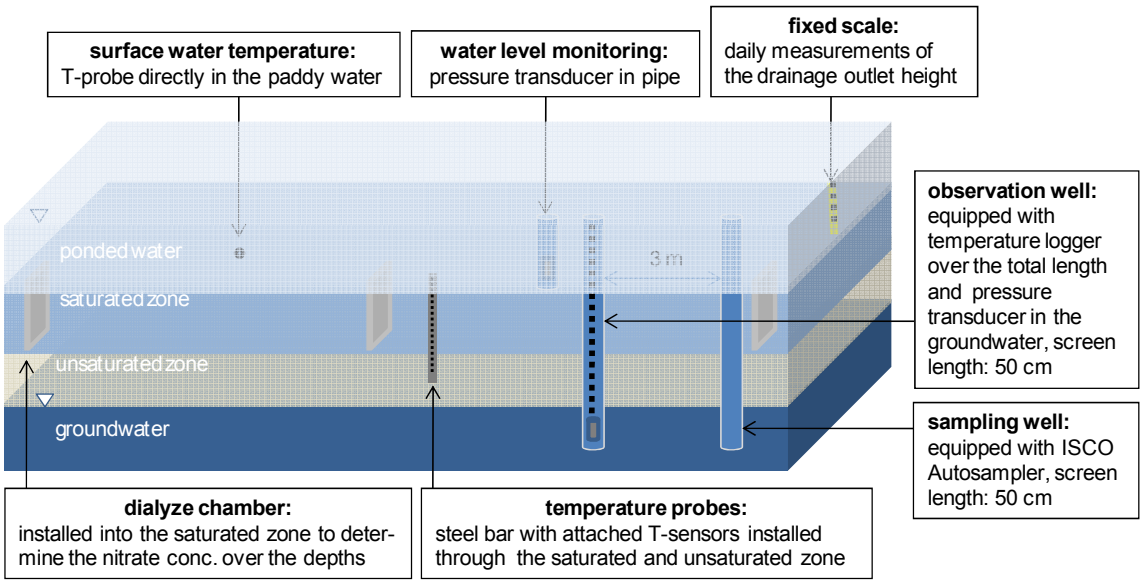
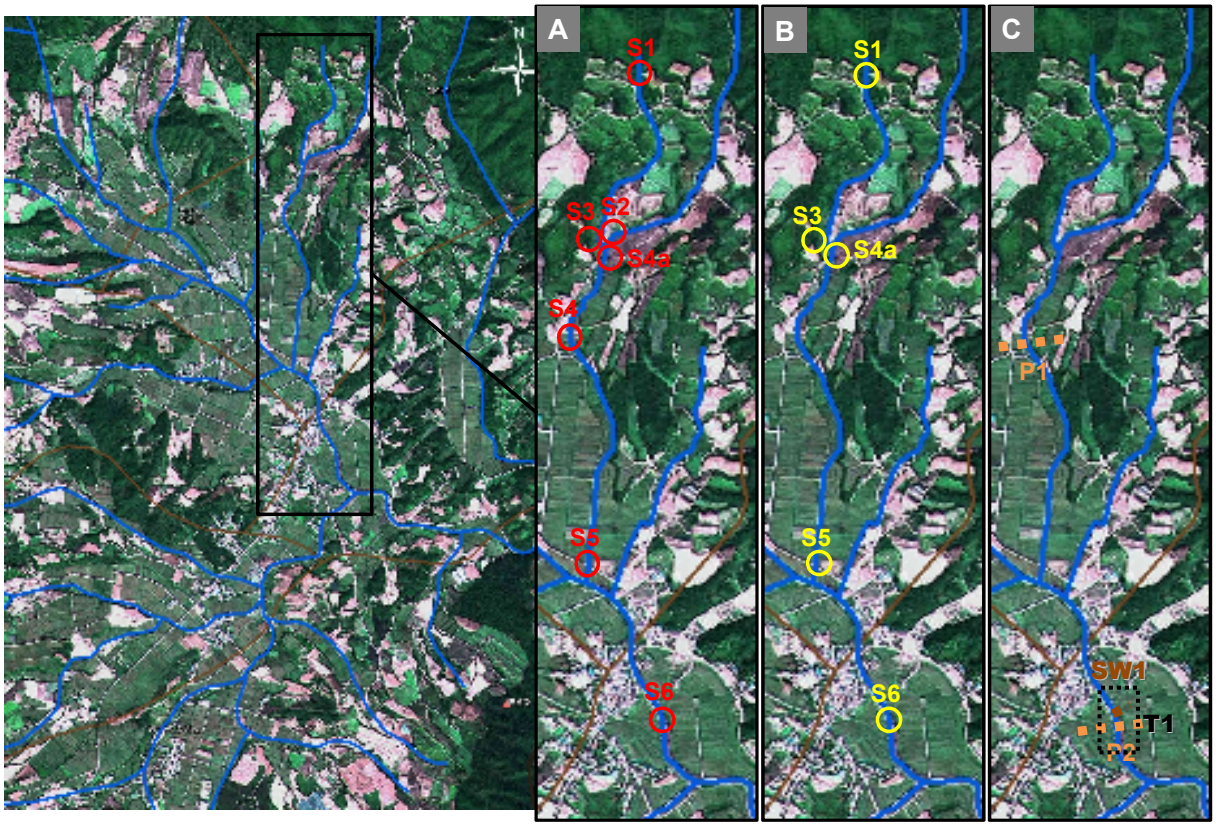


Figure 2. Installations for measuring water fluxes in rice paddy soils and for sampling the soil and groundwater.

3. Field experimental sites



Map 1. Haean Catchment; zoom in: study area.

A. **Surface water sampling sites**: S1: naturally vegetated forest area, S2 and S3: affected by dry land farming (radish, potato, cabbage), S4: affected by dry land farming and rice paddies, S5: (subcatchment outlet): mainly affected by rice paddies, S6: third-order stream.
B. **Discharge measurement sites**: S1 and S4a: weirs, S3 and S5: Stage-discharge relationship method, S6: Float method and current meter measurements.
C. **Piezometer transects, sample well, temperature measurements:** P1: Piezometer transect (2009), P2: Piezometer transect (2010), SW1: Sample well, T1: Stream reach for temperature measurements.
Rice paddy: The exact location for rice paddy measurements is not chosen yet but the rice paddy will be located in the subcatchment.

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Hydrograph separation using geochemical tracer by three-component mixing model for the coniferous forested catchment in Gwangneung Gyeonggido, Republic of Korea

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ABSTRACT

This study was conducted to clarify runoff production processes in forested catchment through hydrograph separation using three-component mixing model based on the End Member Mixing Analysis (EMMA) model. The study area is located in the coniferous-forested experimental catchment, Gwangneung Gyeonggido near Seoul, Korea (N 37 45', E 127 09'). This catchment is covered by *Pinus koraiensis* and *Abies holophylla* planted at stocking rate of 3,000 trees ha^{-1} in 1976. Thinning and pruning were carried out two times in the spring of 1996 and 2004 respectively. We monitored eight successive events during the periods from June 15 to September 15, 2005. Throughfall, soil water and groundwater were sampled by the bulk sampler after each event. Stream water was sampled every 2-hour through ISCO automatic sampler for 48 hours. The geochemical tracers were determined in the result of principal components analysis. The concentrations of $SO4^{2-}$ and Na^{+} for stream water almost were distributed within the triangle diagram of the end members; throughfall, soil water and ground water. Average contributions of throughfall, soil water and groundwater on producing stream flow for 6 events were 17%, 25% and 58% respectively. The antecedent precipitation index (API) plays an important role in determining which end member prevails during events. It was found that the low API event produced more ground water compared with the high API event. On the other hand, rain water showed opposite result. It may be caused by saturation overland flow producing in areas where soil water content is near saturation. API controls runoff producing mechanism whether surface or subsurface flow prevails.

Key Words: Hydrograph separation, EMMA model, geochemical tracer, coniferous forest catchment, antecedent precipitation index

1. INTRODUCTION

Forest hydrology deals with flow paths and runoff components in a forested catchment. Understanding on flow paths and runoff components plays an important role in predicting water quantities and qualities of stream flow water in mountainous landscape (Christophersen *et al*., 1990; Hooper, 2001; Kim *et al*., 2006). Studies on the runoff component by hydrograph separation have dealt with several kinds of tracers such as a stable isotope (i.e. ^{18}O and ^{2}H) and a radioactive isotope (i.e. ^{3}H) and a geochemical element (i.e. Na^{+}, SO_4^{2-}, Mg^{2+}, Ca^{2+}, Cl^{-} and Br^{-}) (Hooper *et al*., 1990; Bazemore *et al*., 1994; Buttle, 1994).

The analysis of storm flow chemical patterns has become a tool to infer flow path contributions of pre-event and event water components. As a result, the research on tracers to identify pathways of water in the catchment has been conducted. Pinder and Jones (1969) introduced the basic hydrograph separation technique based on a mass balance approach. This two-component model has been applied widely and it can be expanded to three-component model in cases where either the discharge of one of the components was known or two tracers were used simultaneously (Genereux *et al*. 1993).

Christophersen *et al*. (1990) and Hooper *et al*. (1990) introduced a new technique to predict proportions of contributing sources; it assumes that stream flow water quality is determined by a mixture of subsurface sources (e.g. ground water and soil water) from various depths. These sources are called end-members because their chemical compositions constitute the

extremes of possible stream water observations (Christophersen and Hooper, 1992). Therefore End Member Mixing Analysis (EMMA) model has been used to estimate contribution of each component (end-members).

The identification of flow sources and pathways using tracers in forest lands of Korea has been started only a few years ago. In their pioneering work, Kim and Jeong (2002) investigated the contribution of new and old water in the stream depending on forest types including the natural-mature deciduous and two planted-young coniferous forests through the two-component mixing model using electrical conductivity (EC) as a natural chemical tracer. They concluded that the hydrograph separation technique using two-component mixing model is useful for searching a fingerprint of hydrological component, and EC served as a good tracer. Kim *et al*., (2006) also tested the EMMA model in the coniferous forest catchment, and showed that three components including groundwater, soil water and throughfall contribute to the formation of streamflow. They also suggested that chloride-nitrate ion may serve the most suitable tracer for the three-component mixing analysis using the EMMA model in the coniferous forest catchment.

Two-component mixing model is powerful tools for the study of hydrological processes at the catchment scale. Nevertheless the validation of the assumptions of the two-component model has been often questioned because conditions required for the application of these models are not satisfied essentially. More precisely, the pre-event water presents a large spatial variability. The limitations of two-component mixing models have resulted in attempts to extend geochemical hydrograph separation to three components using multiple environmental tracers (Joerin *et al.*, 2002).

These studies have been continued now, and the results clearly suggest that natural geochemical tracers such as Na^+, $SO4^{2-,}$ Ca^{2+} and Acid Neutralizing Capacity (ANC) were useful to the three-component mixing analysis, and Na^+ concentration was especially meaningful in the all sampled events (Yoo *et al*., 2006). In many preliminary studies, Na^+ concentration already acted as a good tracer for a two-component hydrograph separation to identify the stream flow runoff components in mountainous or alpine areas. Iorgulescu (1997) developed a three-component mixing model based on SiO_2 and Ca^{2+} concentrations.

Therefore, as a follow-up study of hydrograph separation using the EMMA model for the coniferous forest catchment in Korea, we have tested the effectiveness and consistency of using $SO4^{2-}$ and Na^+ concentration as a geochemical tracer on the three-component mixing analysis to identify flow paths and separate hydrographs in this study, and evaluate factors effecting significantly in variations of the contributions of runoff components.

2. MATERIAL AND METHODS

2.1. Site description

This study was performed in the coniferous experimental catchment (13.6ha; Fig. 1), located on Gwangneung experiment forest (N 37° 45′, E 127° 09′), Gyeonggi-do near Seoul metropolitan, Korea. This coniferous forest of *Pinus koraiensis* and *Abies holophylla* was planted at stocking rate of 3,000 stems ha^{-1} in 1976. Thinning and pruning were carried out two times in the spring of 1996 and 2004. The altitude of the experimental catchment ranges from 160 m to 290 m. The slope shows from 13° to 35°. The underlying bedrock consists of gneiss and the soil texture is classified as sandy loam.

2.2. Methods of sampling and Chemical Analysis

Stream flow level was measured every 10 minutes using the float-encoder water level gauge (OTT Thalimedes) at the catchment outlet with a 120° V-notch sharp crest weir. Rainfall was recorded at 10 minutes interval in the weighing rain gauge with a data logger. Stream water samples starting at rainfall intensity more than 3 mm per 15 minutes were collected automatically at 2 hours interval during the event (ISCO 6712FR). Groundwater was sampled directly from screen well with 10 cm diameter periodically. Groundwater level was measured at every 10 minutes by the pressure sensor typed water level gauge (Van Essen DI-241). Soil water was collected by zero tension lysimeter in the soil depth 10~15 cm on hillslope. The samples of throughfall water take from automatic wet-deposit sampler (Sin-il SL12001).

All water samples obtained from the stream, screen wells, lysimeters and wet-deposit sampler were analyzed in the laboratory immediately. Concentrations of cations and anions were determined with ion chromatography (Anion, Sykam, DE/S-135; Cation, Dionex, DX-320 IC System).

2.3. Three-component mixing model

Three-component mixing models are used to separate runoff components in stream flow water. In this study, $SO4^{2-}$ and Na^{+} concentration data of throughfall, soil water, ground water and stream flow were applied to three-component mixing model through mass balance equation 1, 2 and 3.

$$f_a + f_b + f_c = 1 \quad (1)$$
$$C1_a f_a + C1_b f_b + C1_c f_c = C_{st} \quad (2)$$
$$C2_a f_a + C2_b f_b + C2_c f_c = C_{st} \quad (3)$$

where, the subscript *a, b* and *c* refer to the runoff components, *f* is the contribution of each runoff component, *C1 and C2* are the tracer concentrations and the subscript *st* refers to the streamflow.

Several conditions must be met for this three-component model: (1) Tracer concentrations of each component must be significantly different, (2) there are only three components contributing to streamflow, and (3) the tracer compositions of each component are constant for the duration of the event, or variation is known from measurements (Buttle, 1994; Lie *et al*., 2004).

3. RESULTS AND DISCUSSION

3.1. Hydrological responses

8 rainfall events were sampled to apply the mixing model from June 15 to September 15, 2005. Table 1 shows the hydrological characteristics of the sampled events. The amounts of rainfall for each event ranged from 7.2 mm for the event 3 to 147.2 mm for the event 2. Runoff rates were calculated from 10.1 % as minimum value to 51.0 % as maximum one. Intuitively antecedent precipitation index (API) affects the runoff rate. For instance the event 2, which had the amount of rainfall of 147.2 mm and API_{10} of 1.3 mm, was less one fifth times in the runoff rate than the event 4, which had the amount of rainfall of 105.6 mm and API_{10} of 169.1 mm. Peak flow showed the same tendency to the runoff rate as the peak flows of the event 2 and 4 were 0.16 and 1.28 mm for 10 minutes. It seems to be caused that there is big difference of soil water storage between two events. High soil water content may be easy to produce saturated overland flow in the catchment.

3.2. Temporal variations of water quantity and quality

Figure 2 represents the temporal changes of rainfall, runoff, ground water level and tracer concentration for each event. The ground water level generally responded to runoff concurrently in all events. Especially groundwater level in the event 4 arrived to land surface at the peak flow period. It affords an illustration of a great contribution of saturated overland flow on stream flow during the event 4.

The concentration of Na^{+} decreased suddenly in a rising limb and resumed slowly in a recession limb of the hydrographs. It indicates that Na^{+} controlled geologically shows a very good dilution response with increasing runoff. Na^{+} enriches to pre-event concentration as groundwater flow was prevailing after peak flow (Caissie *et al*., 1996). However, the concentration of SO_4^{2-} showed little changes in comparisons of Na^{+} because it usually was released from a soil column.

3.3. Hydrograph separation using three-component mixing model

Figure 3 shows the bivariate plot for SO_4^{2-} and Na^{+} for stream water and the end members during the events. The concentrations of those for stream water almost distributed within the triangle diagram of the end members including throughfall, soil water and groundwater

except the event 1 and 2. SO_4^{2-} and Na^+ were suitable as the natural tracer as shown in the figure. Average contributions of throughfall, soil water and groundwater on producing stream flow were 17%, 25% and 58% respectively. The antecedent precipitation index (API) plays an important role in determining which end member prevails during events. There was a big difference of API between the event 2 and 4 in table 1. It found that the event 2 lower API produced more ground water compared with the event 4 higher one. On the other hand, throughfall in the event 4 contributed on producing runoff much more than that in the event 2. That may be caused by saturation overland flow producing in areas where soil water content is near saturation. The event 2 much rainfall infiltrated and stored in soil resulted in runoff ratio less than 10%, while on the other the event 4 showed higher runoff ratio in 48%.

4. CONCLUSION

Hydrological processes on producing mechanism of storm runoff in a forested catchment have been studied since 1960s. Hydrograph separation techniques are useful tools for information on producing mechanism of storm runoff. We separated hydrographs using SO_4^{2-} and Na^+ as a geochemical tracer and end-member mixing model. Hydrograph separation can supply valuable information on runoff processes in a forested catchment. 8 sample events during the 4 months from June 15 to September 15, 2005 showed very different situations of partitioning end members; throughfall, soil water and ground water. It may suggest that all events of this study experienced different hydrological situations. In particular, antecedent precipitation index (API) plays an important role in partitioning of end members; throughfall, soil water and ground water. In general, high antecedent precipitation index may cause high contribution of rain water. It may be due to saturated overland flow where soil moisture content or ground water level was high. High proportion of rain water may cause to land surface erosion and high turbidity of stream flow.

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TABLE AND FIGURES

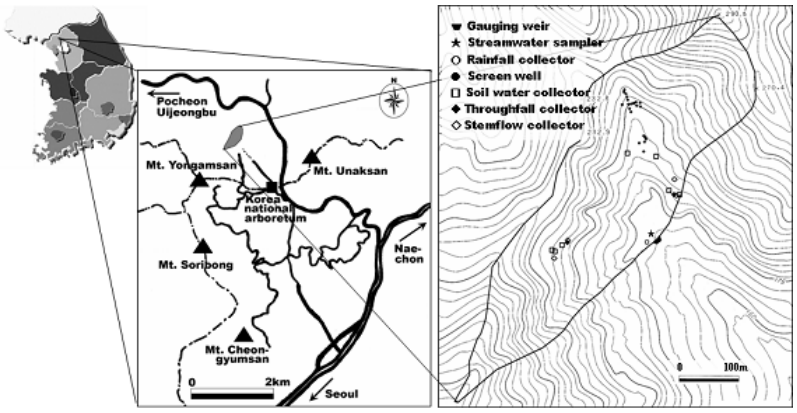


Figure 1. Location and topography of the experimental catchment in Gwangneung, Gyeonggi-do.

Table 1. Hydrological characteristics of the 8 sample events.

	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
Observed period	15~17, Jun.	26~28, Jun.	29~30, Jun.	1~2, Jul.	3~5, Jul.	9~10, Jul.	24~26, Aug.	13~15, Sep.
Precipitation (mm)	11.7	147.2	7.2	105.6	33.6	40.6	83.5	85.5
Maximum rainfall intensity (mm/10min)	5.6	11.1	2.1	17.7	2.4	2.5	4.5	7.5
Antecedent Precipitation Index for 5 days, API_5 (mm)	0.2	0.0	154.7	161.9	120.3	1.3	1.5	7.0
Antecedent Precipitation Index for 10 days, API_{10} (mm)	12.4	1.3	154.7	161.9	267.5	154.3	19.5	7.0
Total runoff (mm)	1.4	14.9	3.0	51.0	17.1	9.1	16.8	14.1
Peak flow (mm/10min)	0.01	0.16	0.02	1.28	0.09	0.05	0.10	0.11
Runoff rate (%)	11.9	10.1	41.1	48.3	51.0	22.3	20.1	16.5

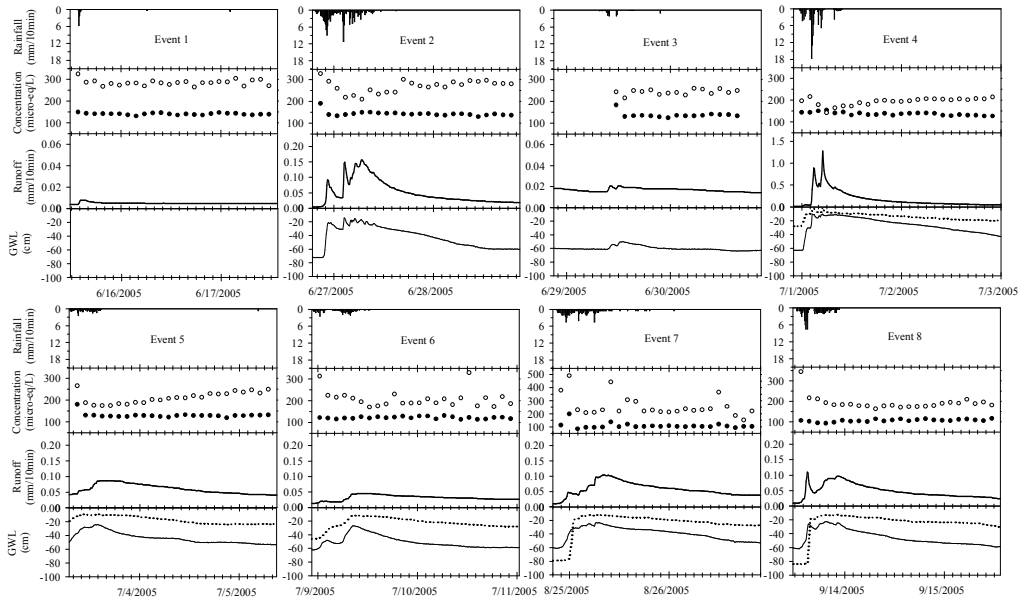


Figure 2. The temporal changes of ion concentrations, rainfall, stream discharge and groundwater level (GWL) for a period of stormflow. closed circles (•) : SO_4^{2-} conc, open circles (◦) : Na^+ conc solid line (—) : well No. 7, doted line (…) : well No. 22.

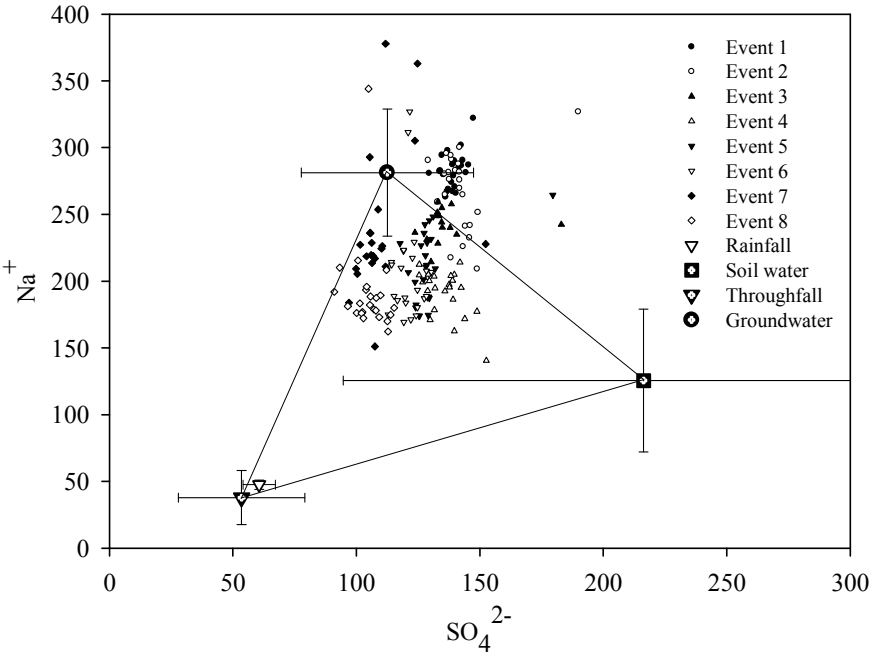


Figure 3. Bivariate plot for Na^+ and SO_4^{2-} for rainfall, throughfall, soil water, ground water and stream water. The bars represent standard deviation.

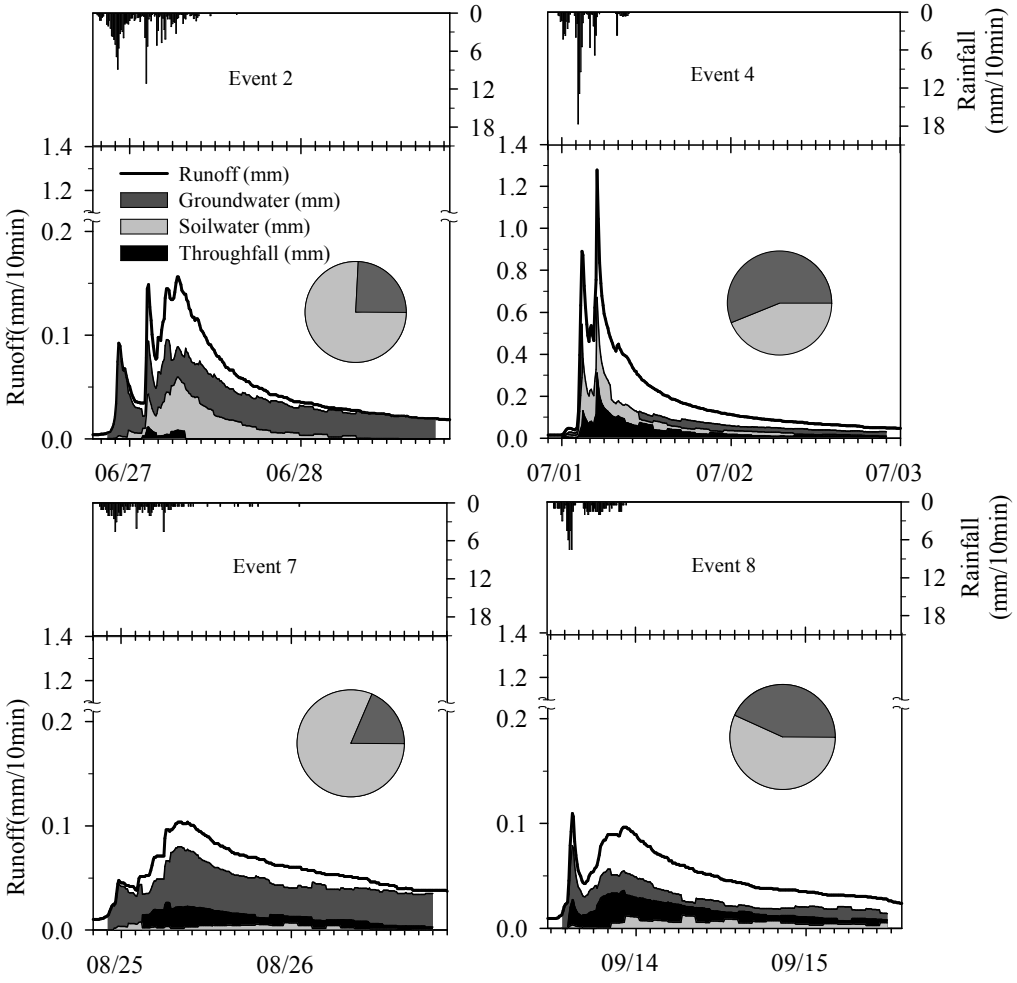


Figure 4. Three-component hydrograph separation of catchment runoff for event 2, 4, 7 and 8. Pie charts represent the relative proportions of throughfall, soil water and ground water in the stream waters.

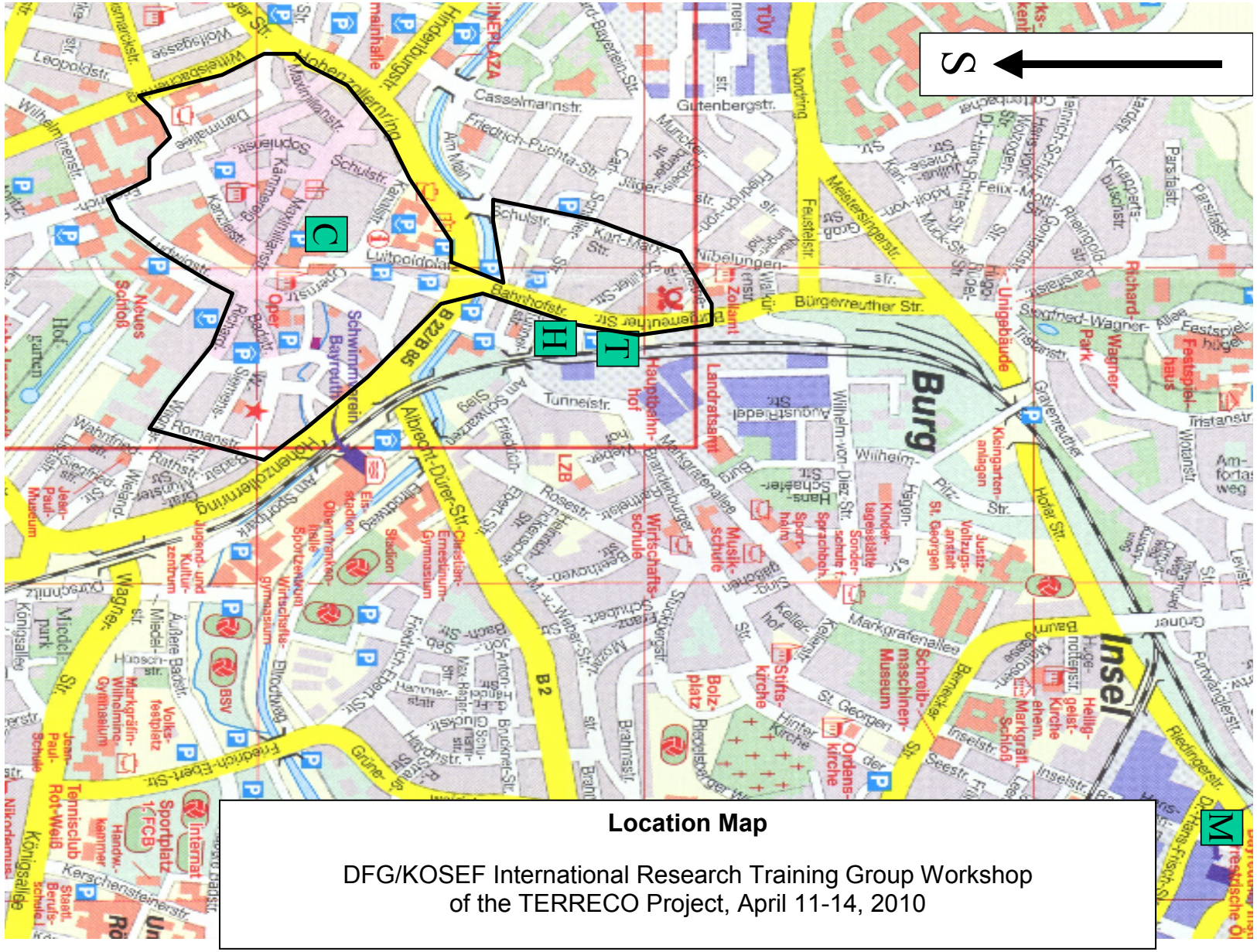
Logistics Information

Accomodations: A block of rooms has been reserved for foreign participants at the Hotel Bayerischer Hof, which is conveniently located at the Bayreuth railway station (out the front door, turn left and cross the parking lot). The train station is indicated in square T on the Location Map, the hotel as square H. Information about the hotel may be viewed at www.bayerischer-hof.de (telephone: 0049 921 78600, email: (hotel@bayerischer-hof.de), fax: 0049 921 7860560.

From the hotel it is very easy to walk to the center of the commercial district of Bayreuth (delimited by a black line and square C on the map). An interesting information booklet on the history and sites in Bayreuth may be obtained in English from the book shop within the train station.

Meeting Location: The workshop will be held at the Bayreuth Center for Ecology and Environmental Research, University of Bayreuth (BayCEER), Bayreuth, Germany. The Center is located in Hans-Frisch-Str. 1-3 (marked with square M on the north part of the Location Map). It can be reached, if necessary, by taxi in less than 5 minutes and with costs less than 5 Euro. Taxis are always found in front of the train station and hotel. But we will also offer a shuttle service each day to the meeting in the morning, and after the meeting in the evening.

Help: Please feel free to ask any questions that you may have. Contact the Coordination Secretary of the TERRECO project, Department of Plant Ecology, Ms. Baerbel Heindl-Tenhunen by email (baerbel.heindl-tenhunen@uni-bayreuth.de).



Location Map

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