The effect of dryland farming management system on infiltration patterns, surface runoff and soil erosion in Haean-Catchment

TERRECO-10 and TERRECO-12

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

1 Soil Physics Department, University of Bayreuth, Germany
2 Department of Biological Environment, Kangwon National University, South Korea

- Tracer experiments
- Stereophotography
- Erosion plots
- Treatment plots
- Modeling

Research goals

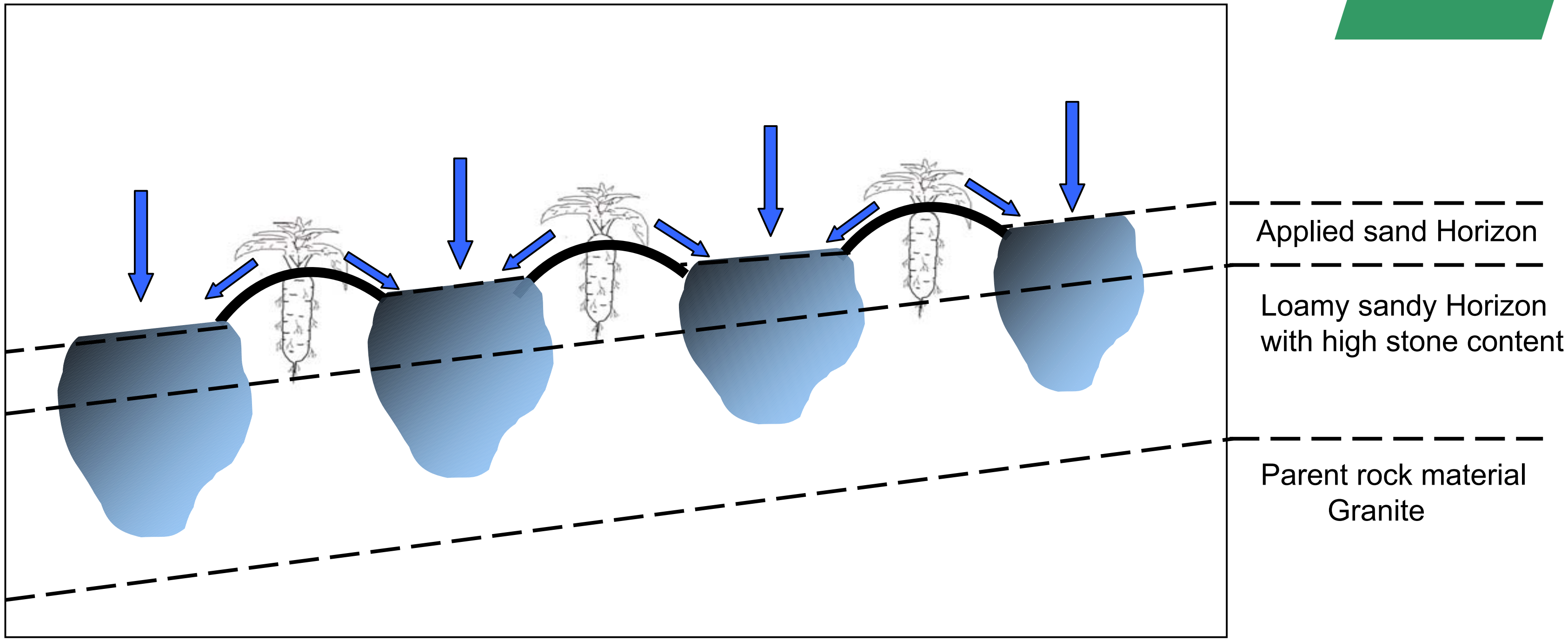
Dry farmland is a potential a source of surface and groundwater pollution by leaching and soil erosion

Climate change: probability of extreme rainstorm events will increase


Dryland fields in Haean catchment, plastic covered plant rows (distance 70 cm) are a typical agricultural management strategy

- ➡ **Quantification of water dynamics and soil loss during rainstorm events**
- ➡ **Understanding processes of water flow and erosion**
- ➡ **Developing measures for sustainable agriculture and erosion control (enhance water and nutrient availability, decreasing soil loss as well as sediment and nutrient transport)**

Processes



(1) Row planting system → Artificial infiltration in furrows

(2) Slope → Effects on lateral flow

(3) Crops → Effects of root systems

(4) Polymers → Effects on infiltration depth

Combination of Methods

Dye tracer studies → a)–d) below (left), and → **Experimental Design**

Stereophotography → a)–d) below (right), and → **Experimental Design**

Dye tracer studies

a) Tracer application

b) Calibration & Photography

c) Image processing

d) Analysis (Dye coverage function, Risk index)

Stereophotography

a) Calibration & Photography

b) Digital Elevation Model

c) Geostatistical analysis

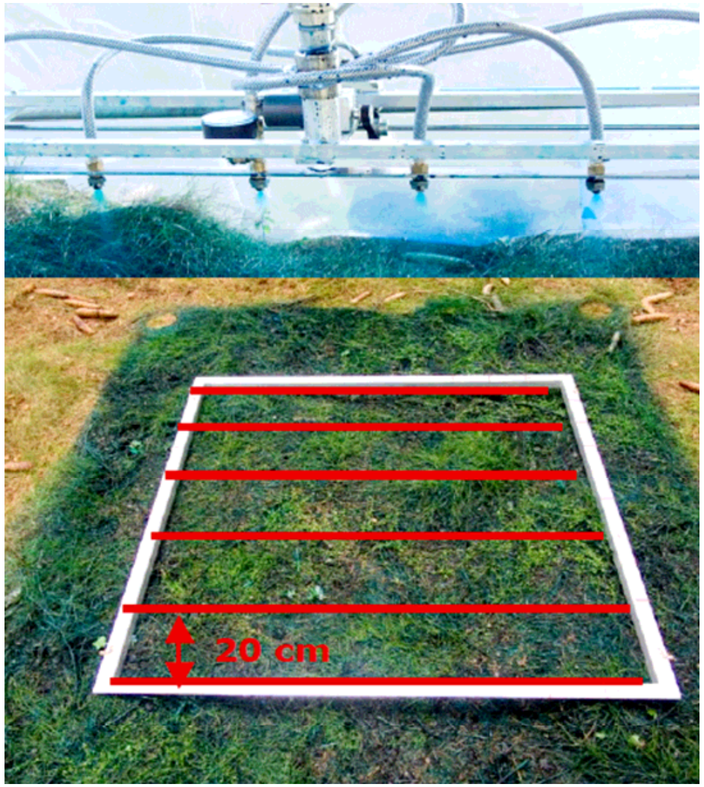
d) 3D process modeling

Tracer experiments

Tracer application

Tracer:

- ***Brilliant Blue FCF***
- ***Potassium Iodide***

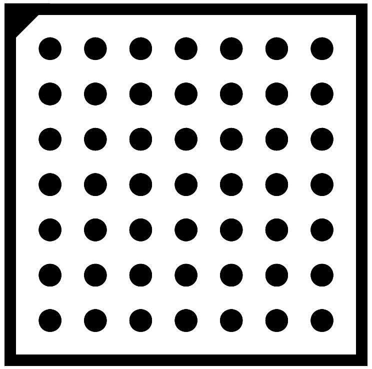


→ ***additional application of soluble starch and Iron(III)Nitrate for visualization of Potassium iodide***

→ ***Irrigation rate: 64 mm / hour / m²***

→ ***Excavation of soil profiles 24 hours after irrigation***

Calibration, Photography & Sampling



Step 1

Calibration of Camera with Calibration plate

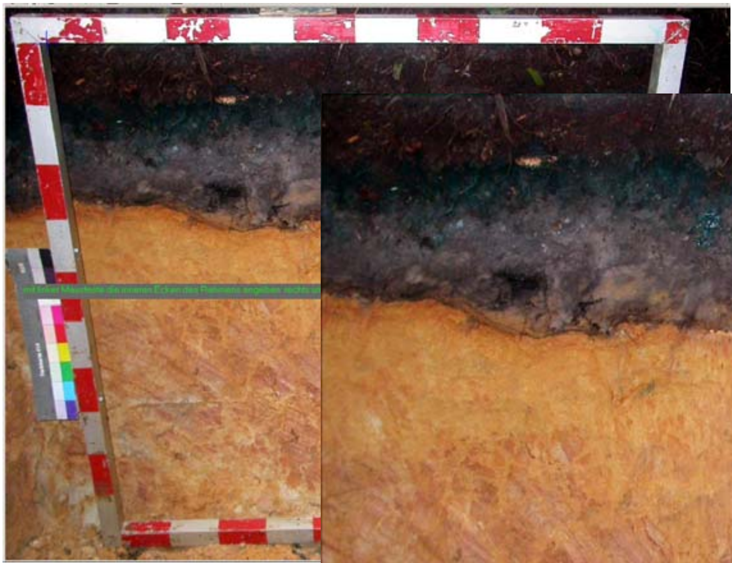
Step 2

Photography in RAW and JPEG format with frame and colour scale

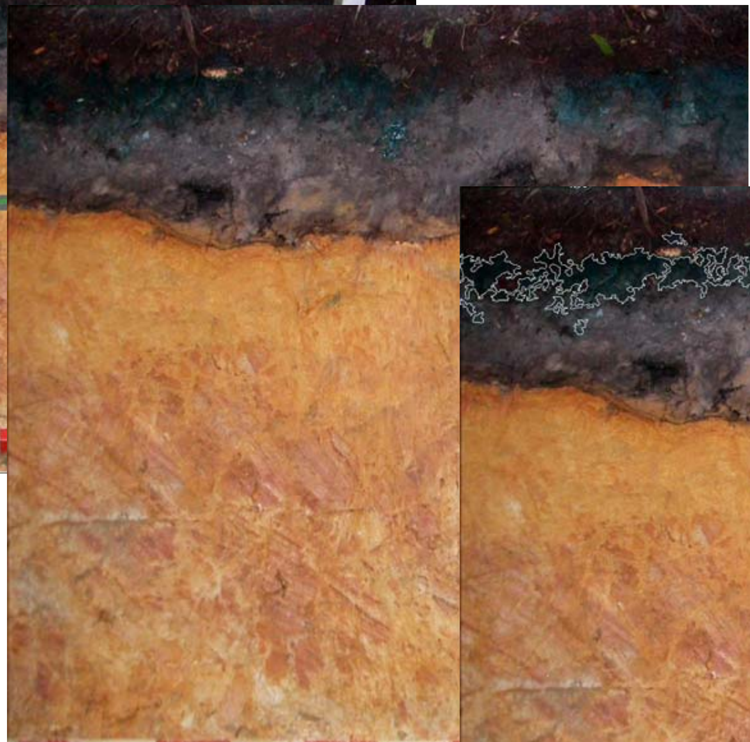
Step 3 Soil sampling

- **Brilliant Blue stained and non stained parts**
- **Bulk density**
- **Root density**
- **mixed samples for grain size analysis, anions & cations, C/N**

Image processing



1. Soil profile
photographed

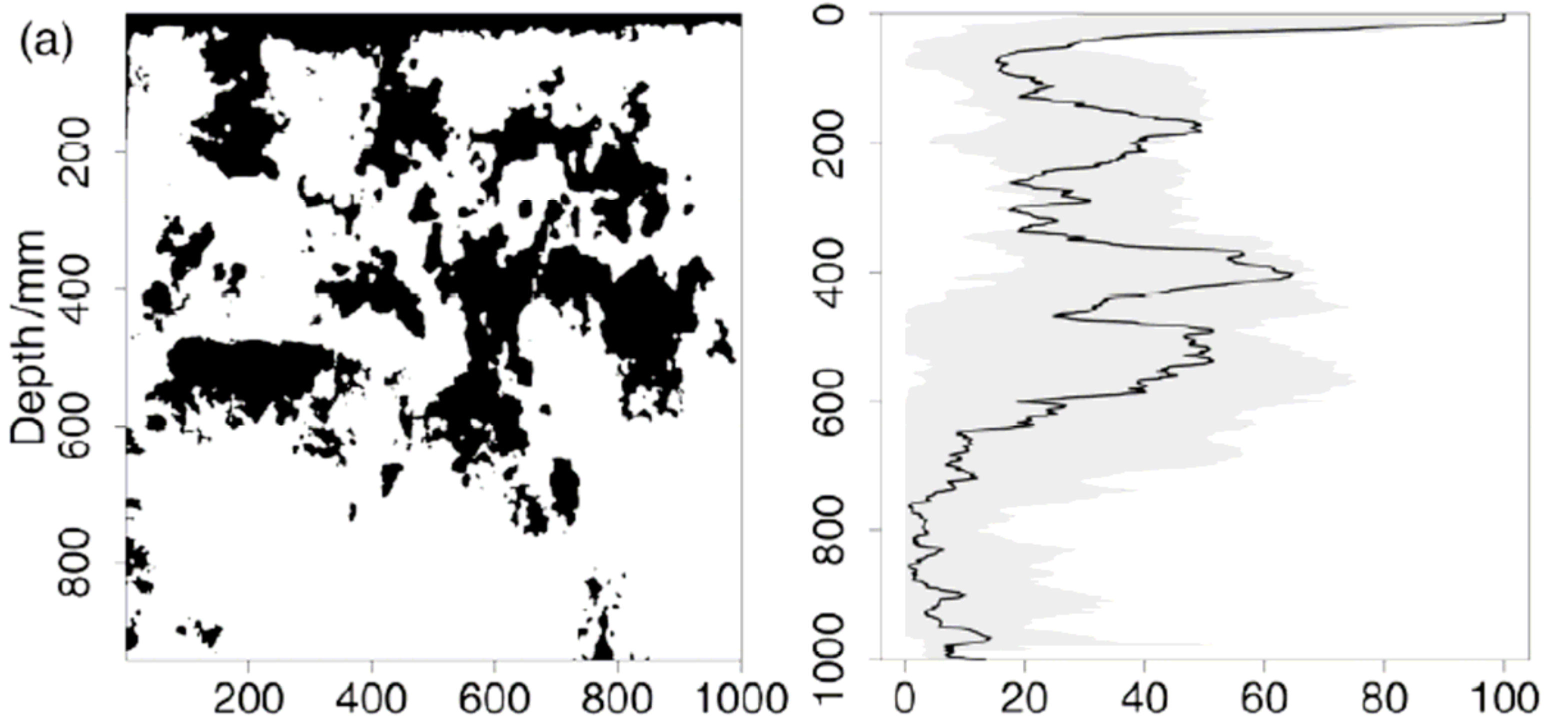


2. Photo after correc
of the perpective
with Halcon Software

3. Selection of B
stained parts in

4. Conversion to binary image
0 = white and 1 = black pixels

Dye coverage function



(a) Binary Image
0 = non-stained pixel
1 = Brilliant Blue stained pixel

→

(b) Percentage of dye coverage per depth

Risk index for vulnerability of groundwater to pollutants

$$H(d, \xi_r, s) = 1 - \left(1 + \frac{\xi_r\, d}{s}\right)^{-1/\xi_r}$$

1) $\xi_r < 0$: Dye tracer does not exceed a certain depth

2) $\xi_r > 0$: Dye tracer reaches water table

3) $\xi_r = 0$: water table will be reached, but transported mass might be negligible

Stereophotography

Stereo photography

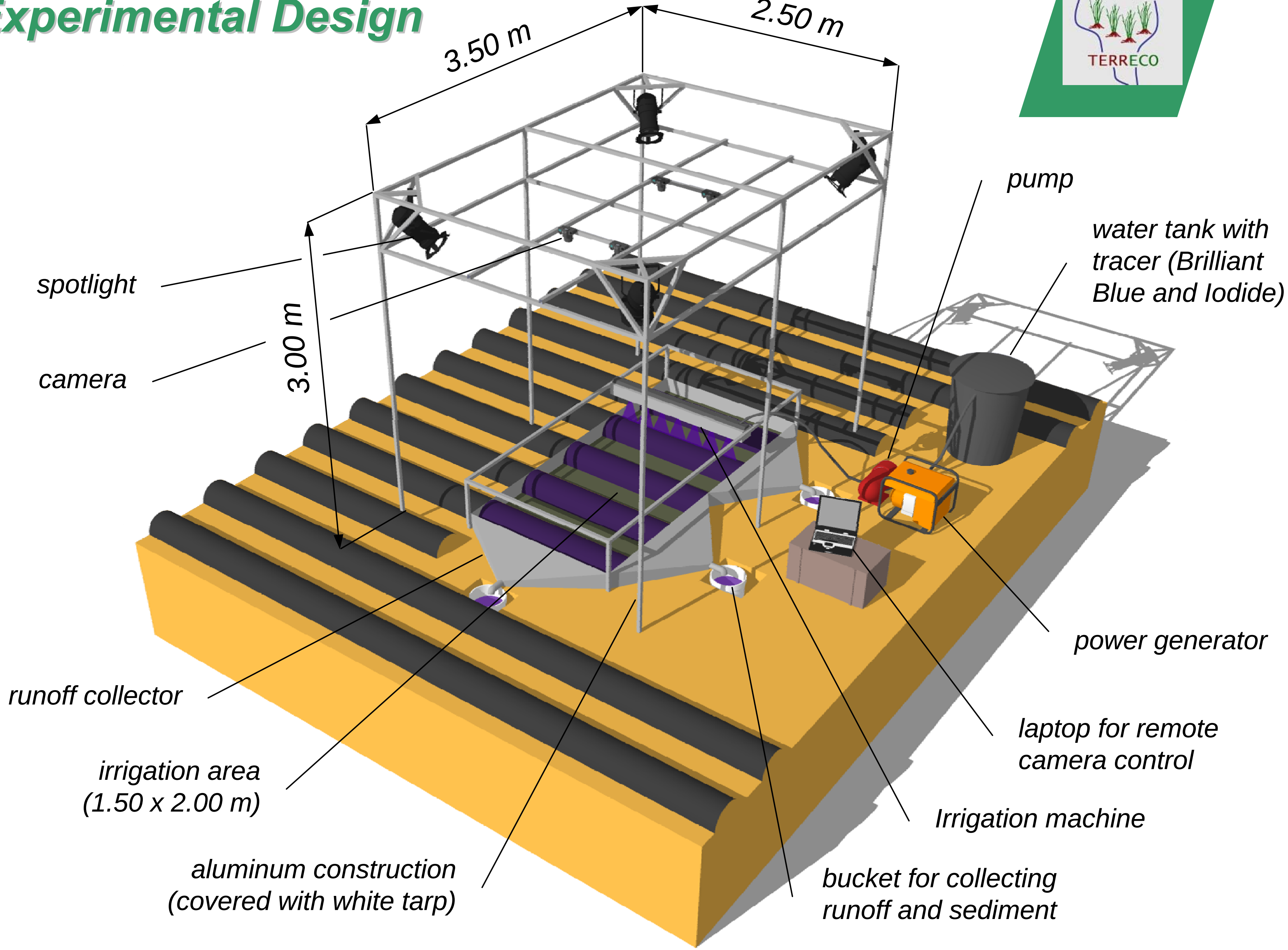
Processes on soil surface during irrigation:

- Infiltration process
- Changes in soil surface roughness
- Soil loss

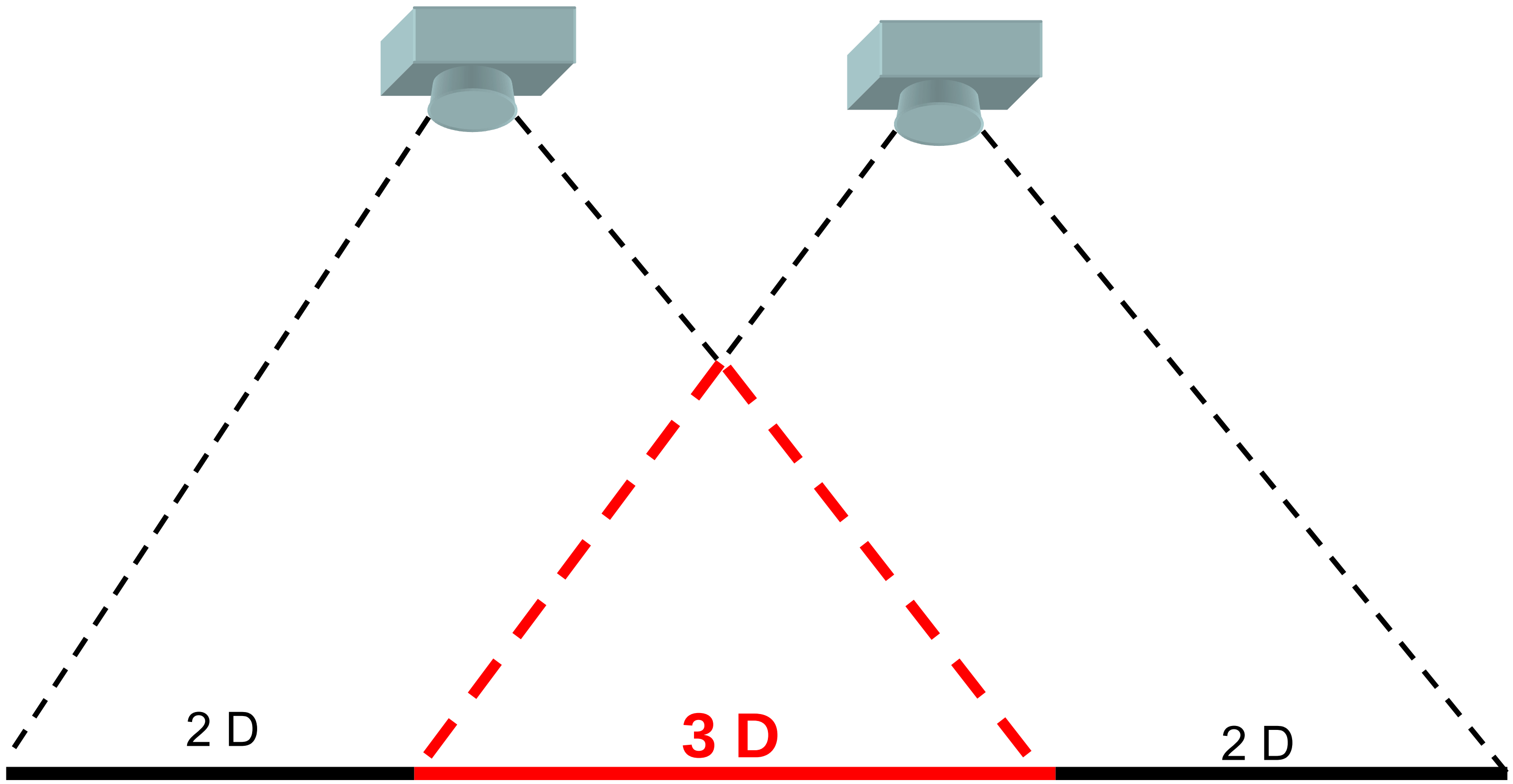
→ High temporal and spatial resolution

→ Pictures in RAW and JPEG format

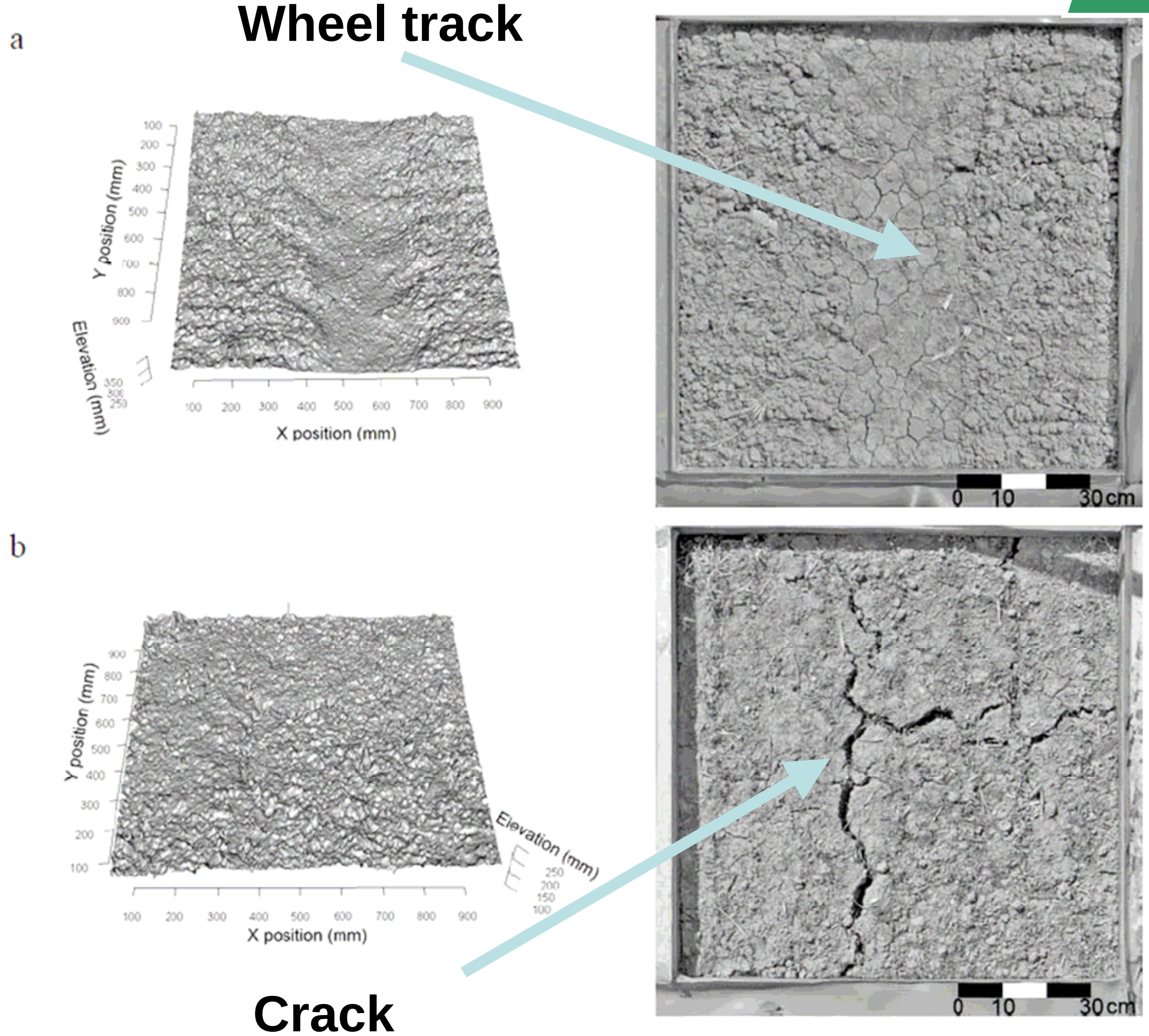
Experimental Design



Principle of Stereo photography



Digital Elevation Map



INRA
Avignon
France

Source: Bogner, Christina, Dissertation: Analysis of flow patterns and flow mechanisms in soil

Analysis

- Water storage in puddles, infiltration, surface runoff
- Amount of eroded soil material
- Changes in soil surface roughness during irrigation: nugget, range, sill, fractal dimension, Hurst coefficient


Soil erosion:
Field size slope experiments

Experimental design for water flow and erosion measurement

Field 1

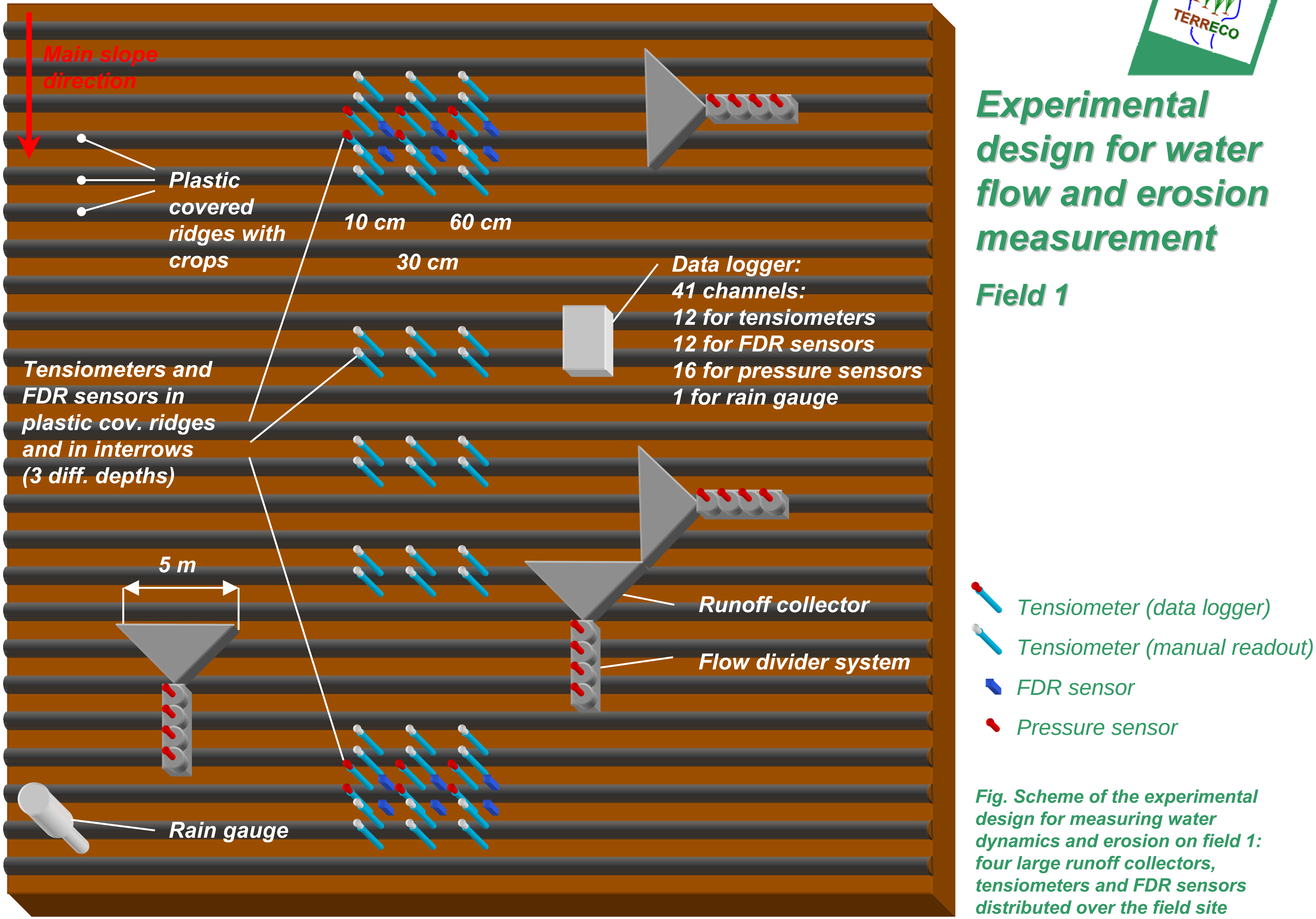


Fig. Scheme of the experimental design for measuring water dynamics and erosion on field 1: four large runoff collectors, tensiometers and FDR sensors distributed over the field site

Experimental design for water flow and erosion measurement

Field 2

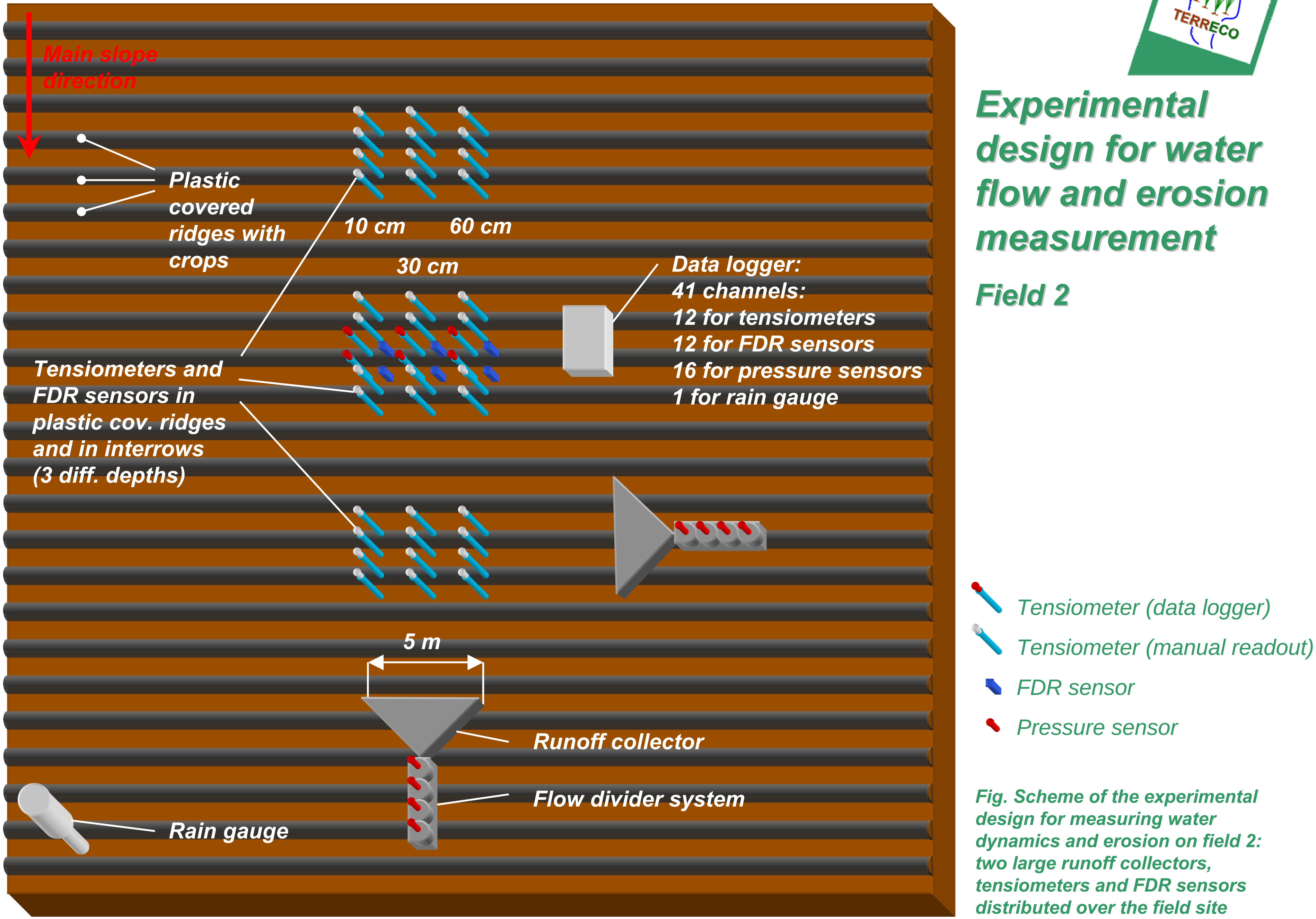


Fig. Scheme of the experimental design for measuring water dynamics and erosion on field 2: two large runoff collectors, tensiometers and FDR sensors distributed over the field site

The runoff collector

Designed for collecting surface runoff and transported soil particles from large runoff plots or field sites

Runoff with sediment is routed by a 15 cm diamter pipe to the multislot divider system (for sampling and quantification of runoff, sediment and transported chemicals)

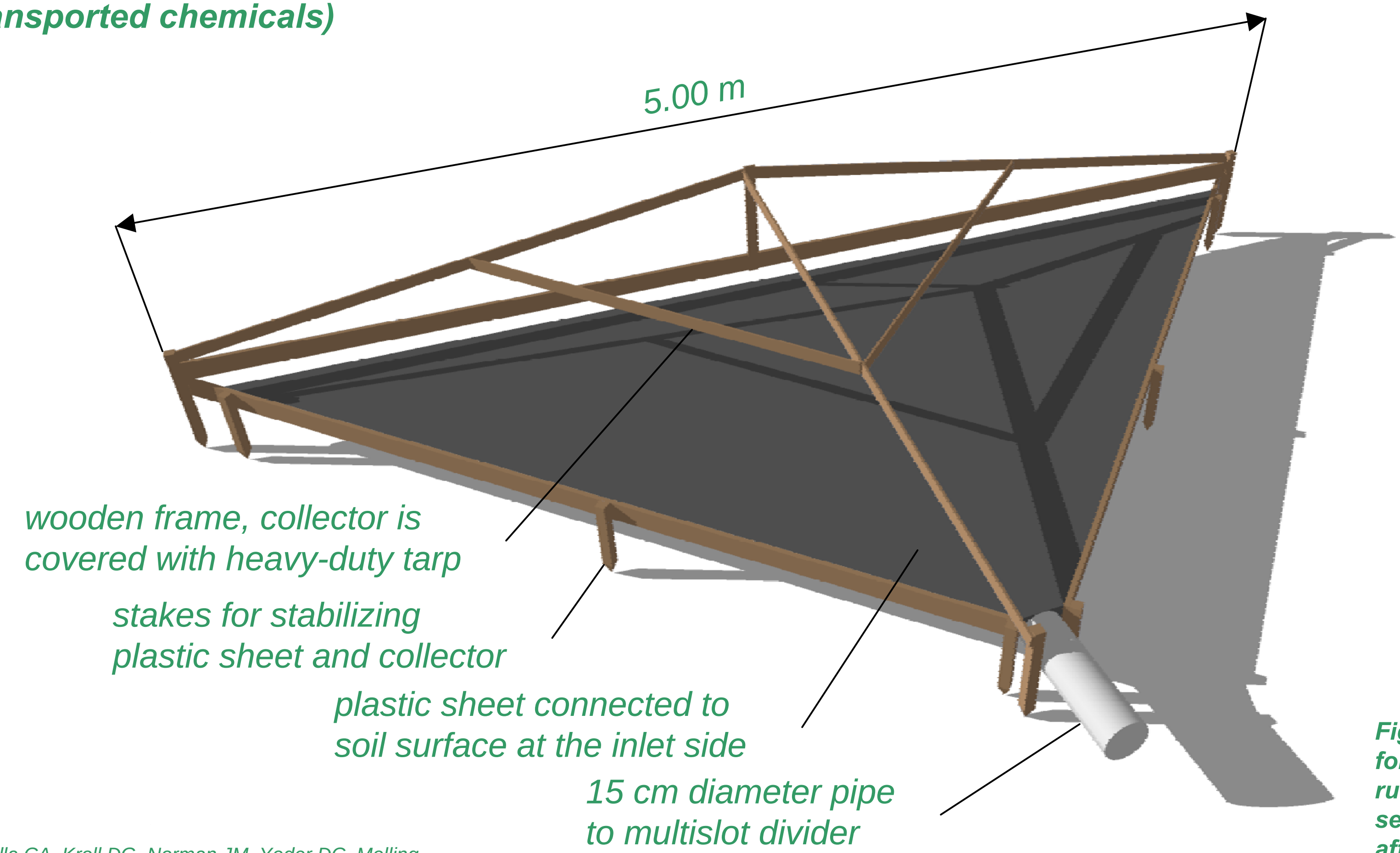


Fig. Runoff collector for collecting surface runoff and eroded sediment (designed after Bonilla et al. 2006)

Bonilla CA, Kroll DG, Norman JM, Yoder DC, Molling CC, Miller PS, Panuska JC, Topel JB, Wakeman PL, Karthikeyan KG (2006): Instrumentation for measuring runoff, sediment, and chemical losses from agricultural fields, Journal of Environmental Quality 35: 216–223

The multislot flow divider system

Designed for sampling surface runoff and sediment during extreme precipitation events and large contributing areas

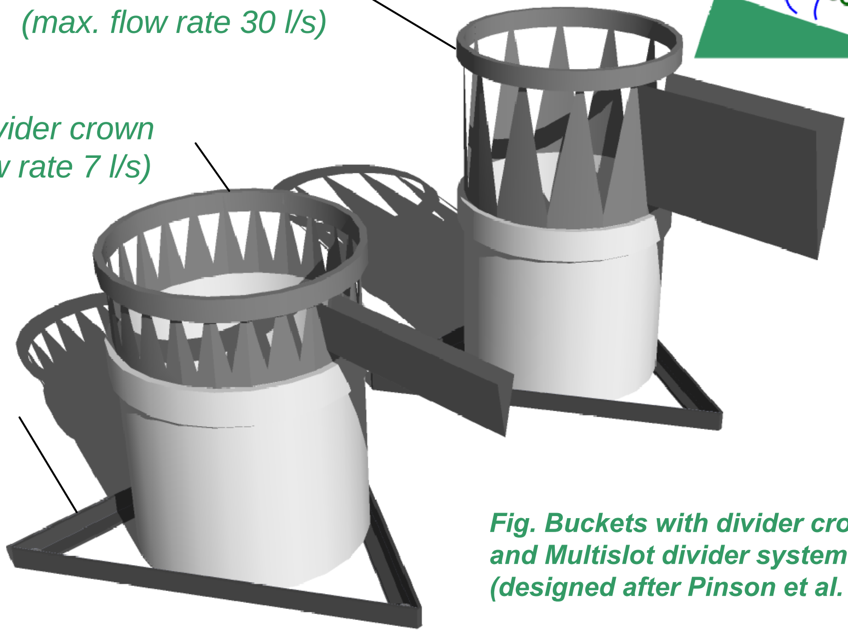
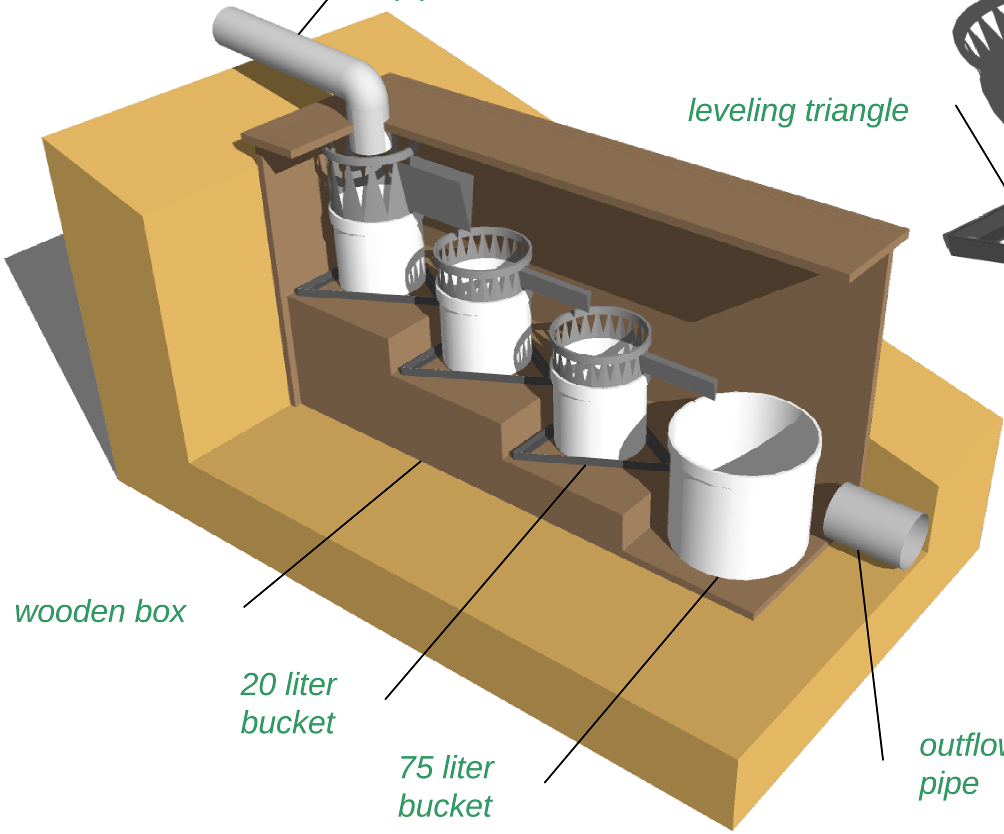
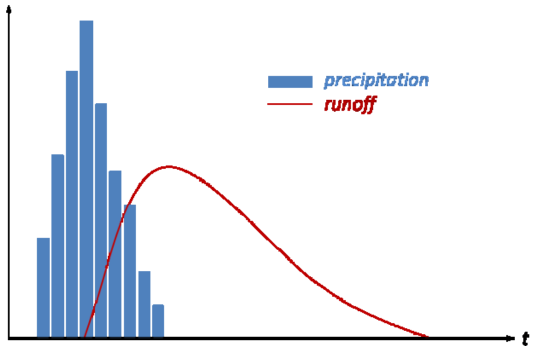


Fig. Buckets with divider crown and Multislot divider system (left) (designed after Pinson et al. 2004)



This combination of three 20 liter buckets and one 75 bucket has a runoff capacity of 524 m³

In each of the buckets a pressure sensor is installed (connected to a data logger) - runoff rate over time can be estimated



Recording the water level in the buckets during the rain events - runoff generation can be calculated

Pinson WT, Yoder DC, Buchanan JR, Wright WC, Wilkerson JB (2004): Design and evaluation of an improved flow divider for sampling runoff plots, Applied Engineering in Agriculture 20(4): 433-437

Topographical survey

A tachymeter is used for developing detailed digital elevation models of the experimental field sites:

Fig. Tachymeter for exact measurement of elevation between different points (source: Bavarian Environmental Agency)

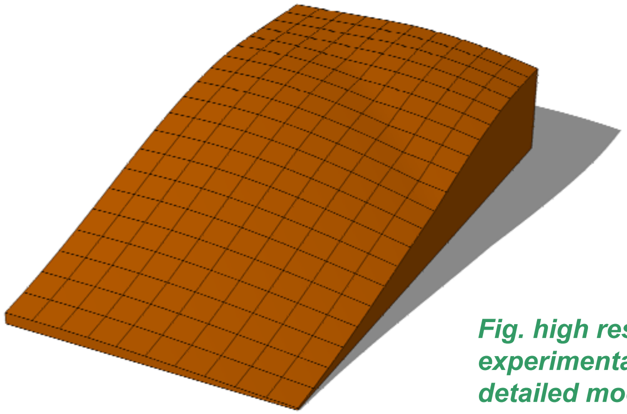


Fig. high resolution DEMs of the experimental field sites are necessary for detailed modeling water flow and erosion with physically based models

Using surface analysis functions of GIS:

- *the optimal positions of the runoff collectors on the field sites can be estimated (field-representive measurement and sampling)*
- *contributing areas of runoff collectors can be calculated (erosion rates per area (in kg/ha) can be quantified)*
- *high resolution DEM is important for field size scale modeling (EROSION 3D, HYDRUS 2D/3D)*

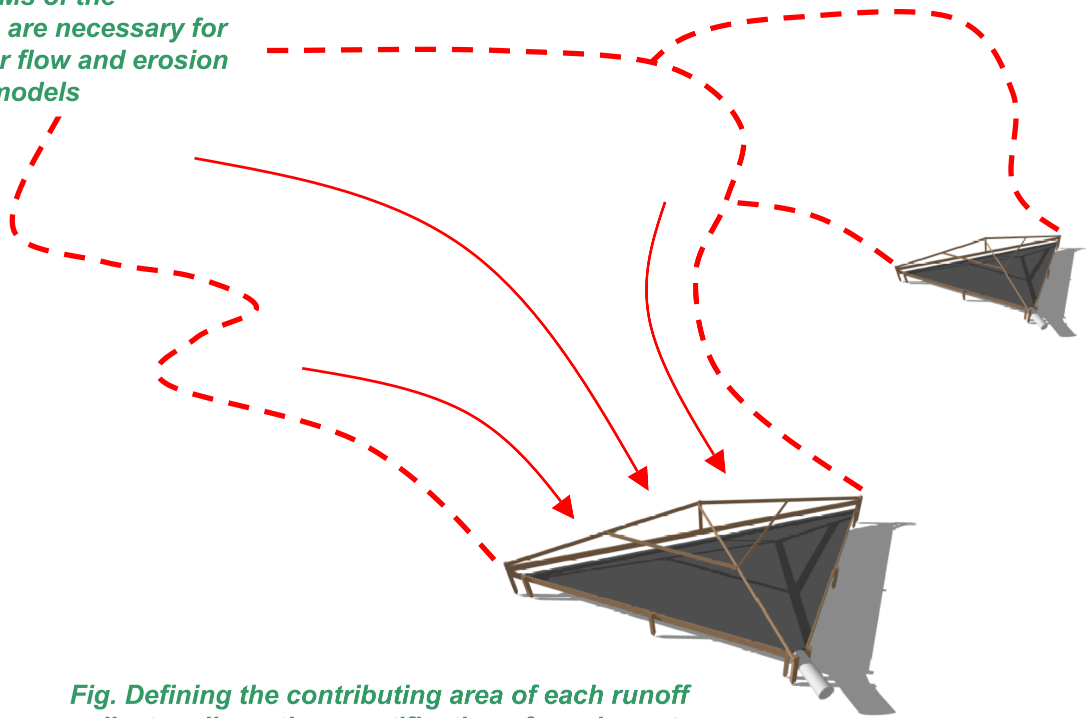
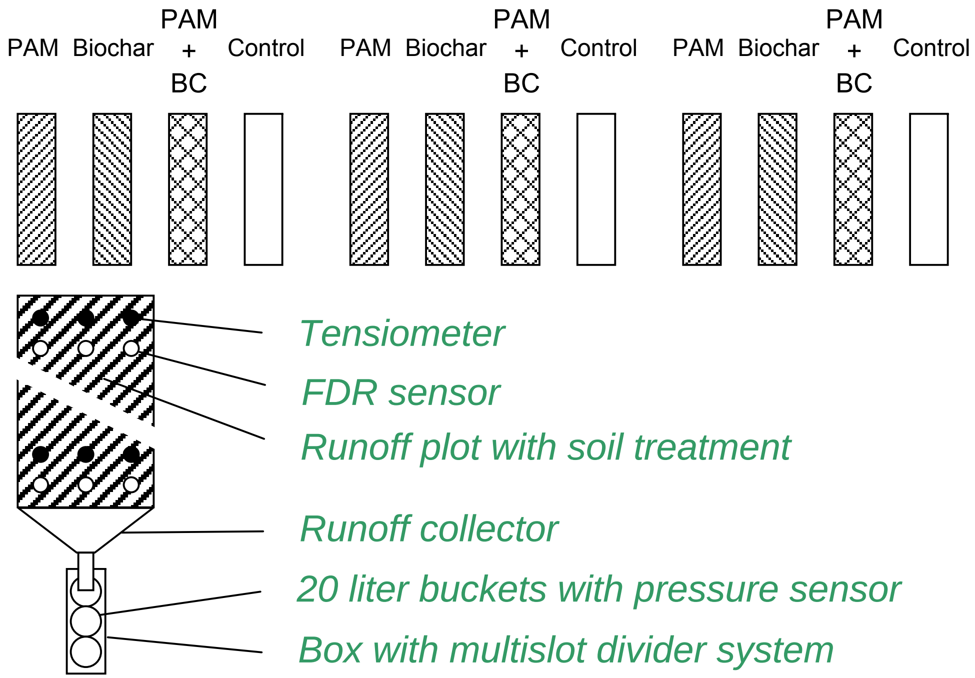


Fig. Defining the contributing area of each runoff collector allows the quantification of erosion rates

Treatment plot experiments

Measuring the effect of PAM and Biochar on soil erosion

Application of Polyacrylamide (Magnafloc 336) and Biochar on the top soil of agricultural fields in Haean catchment



Runoff plots on Haean dry farmland sites

Tensiometer and FDR sensors

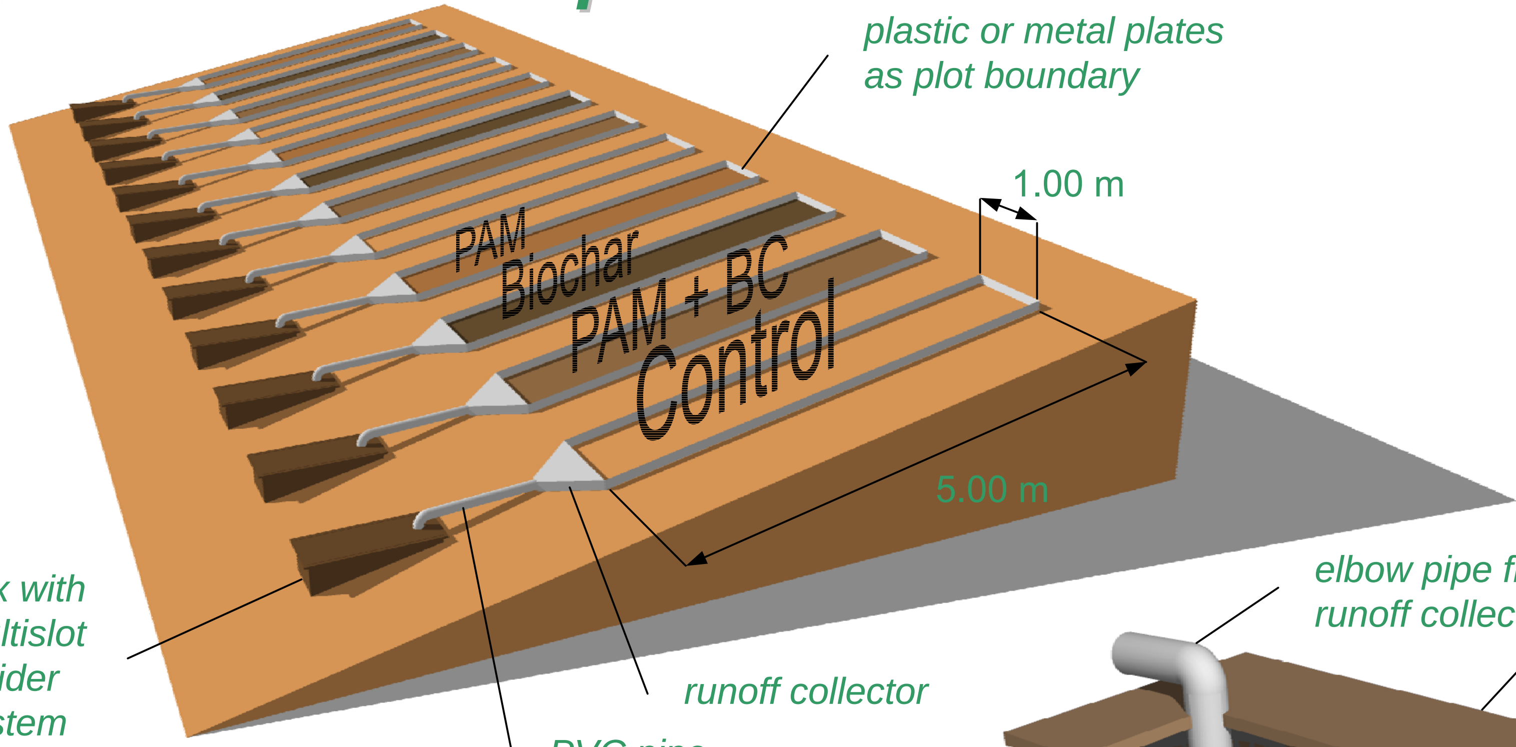
Erosion measurement with runoff collectors and multislot dividers

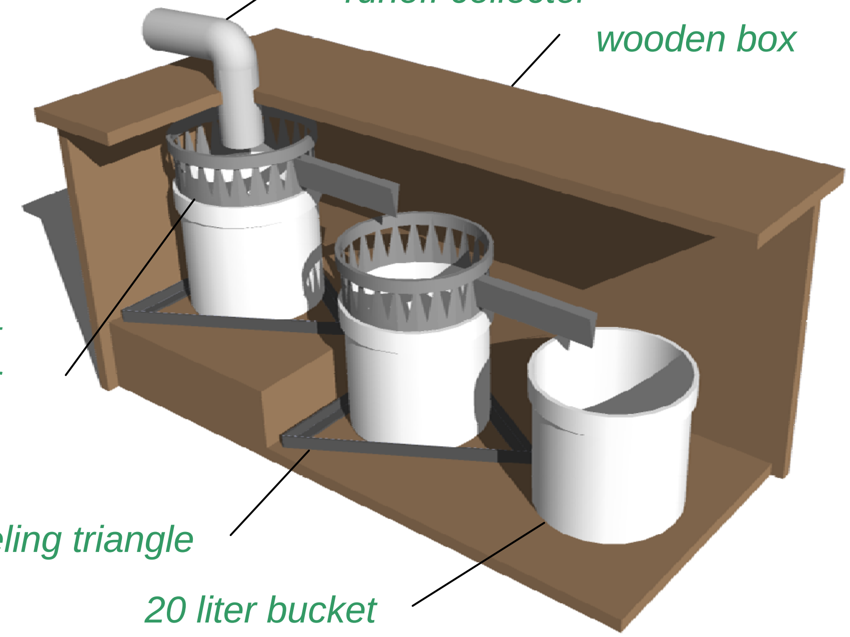
Stereo-photography for surface analysis

Pressure sensors in the buckets record water level continuously

Rain gauge on the field site

Preview of runoff plots





12 runoff plots with three treatment plots and one control plot (three replicates)

Arranged in randomized design on the same contour line on the field

Multislot divider system can handle large runoff amounts by extreme rain events (capacity 12 m³)

Tensiometer, FDR sensors and pressure sensors in the buckets only for one replicate

Preview of stereo-photography for surface analysis

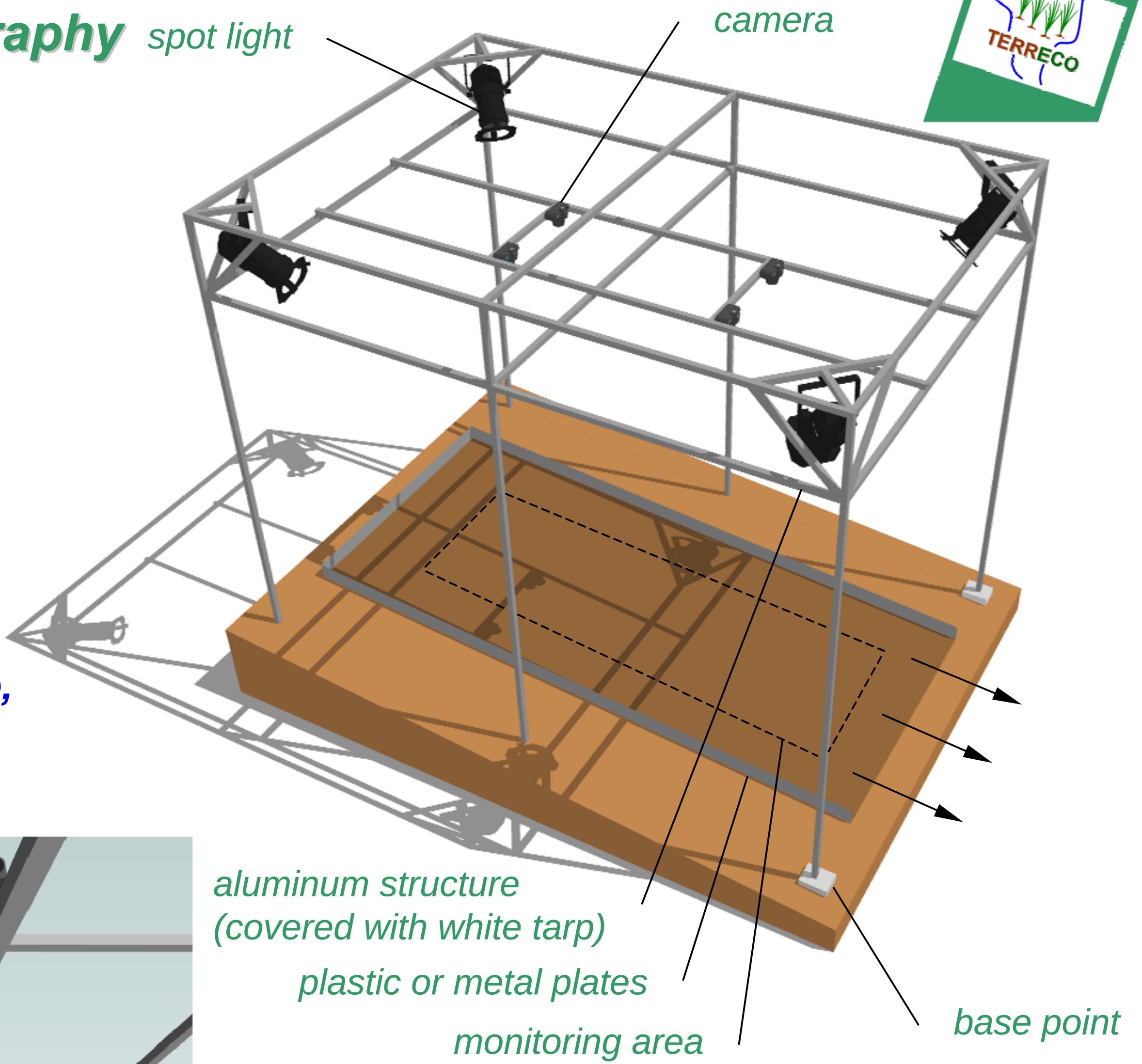
4 Cameras (Canon EOS 1000D)

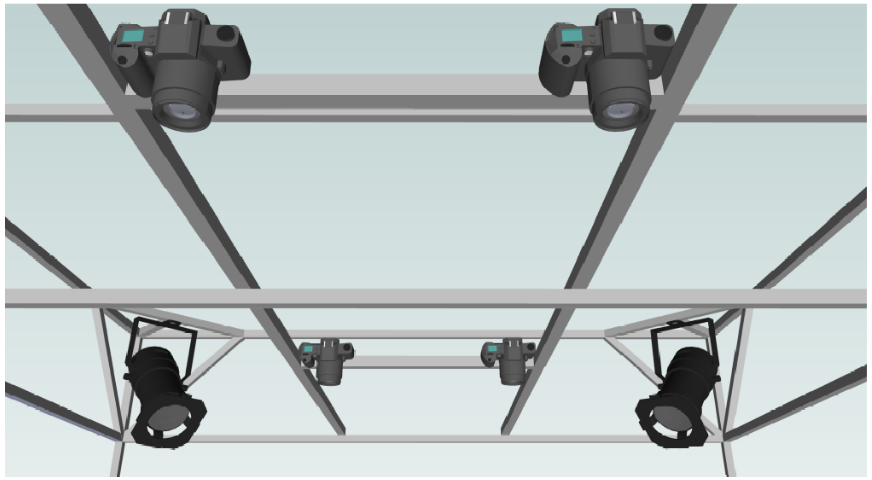
Photos before and after each rainstorm event

High resolution DEM from the soil surface

Amount of soil loss by calculating the elevation differences

Information on surface structure, flow patterns and erosion processes





Modeling approaches

Modeling soil water flow and solute transport:

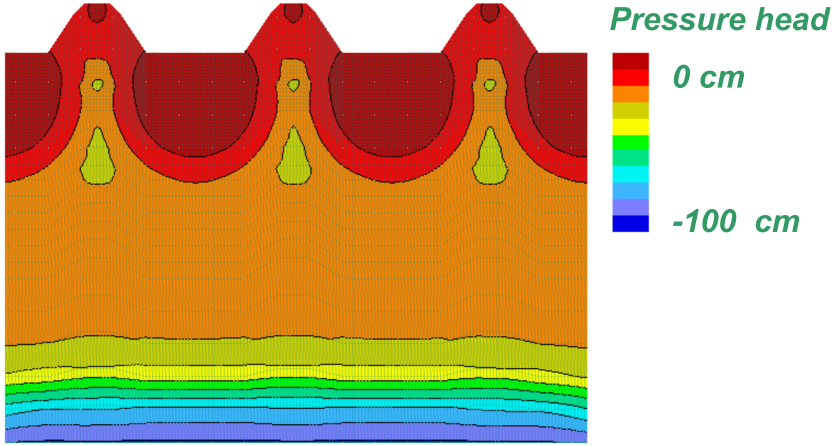
HYDRUS 2D/3D *- physically based model to simulate water fluxes and solute transport in porous media - unsaturated zone (Haean agricultural soils)*

Small scale water dynamics

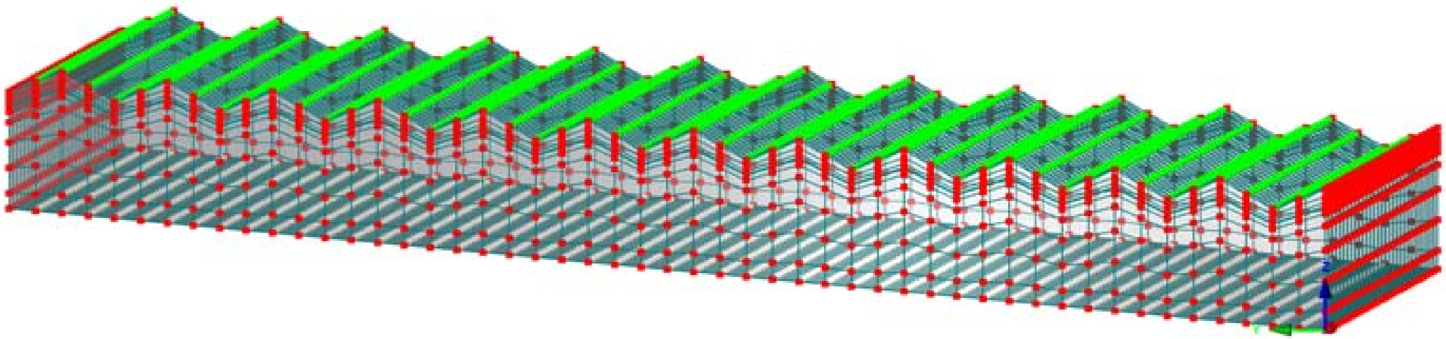
Water movement and flow patterns along a slope

Transport of agrochemicals

Model calibration and validation with measured data



Water dynamics within row and interrows on Haean dry farmland (developed with HYDRUS 2D model)



Three-dimensional model of a farmland slope in Haean catchment with plastic covered furrows (developed with HYDRUS 3D model)

Modeling soil erosion and sediment transport: Upscaling and developing future scenarios

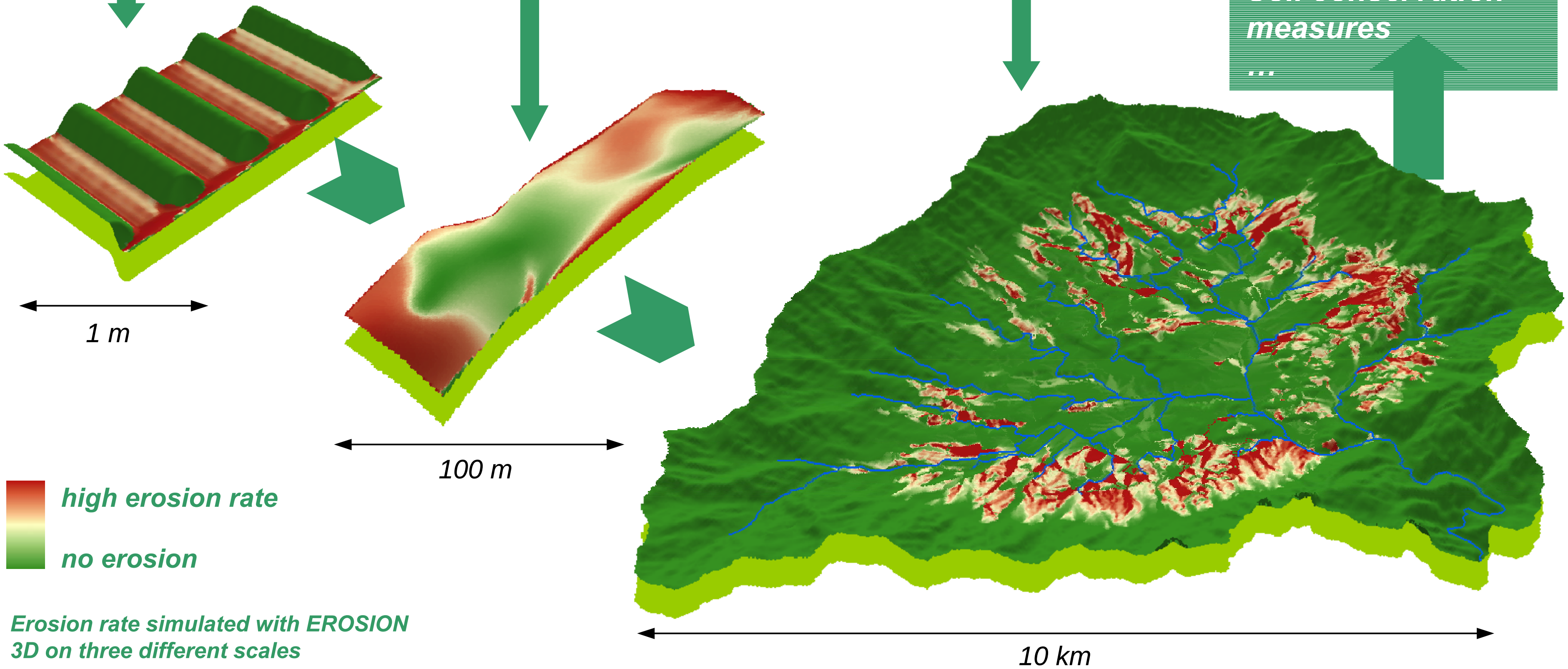
EROSION 3D - *physically based model to simulate surface runoff, soil erosion and particle transport by rainstorm events*

Plot scale	Field size scale	Catchment scale
Irrigation experiments	Runoff collectors	Stream measurement (TERRECO-13)

Validating model results and calibration

Scenarios:

Climate change
Land use change
Soil conservation measures
…



Erosion rate simulated with EROSION 3D on three different scales

SWAT (Soil and Water Assessment Tool)

Prediction of the impact of land management practices on water, sediment and agricultural chemical yields in large watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al. 2005)

- *Physically based hydrological model, including soil erosion, water quality, and nutrient and pesticide transports*
- *Data and results from different TERRECO projects can be included*
- *Long term scenarios for predicting water dynamics, transport of soil and chemicals and water quality:*

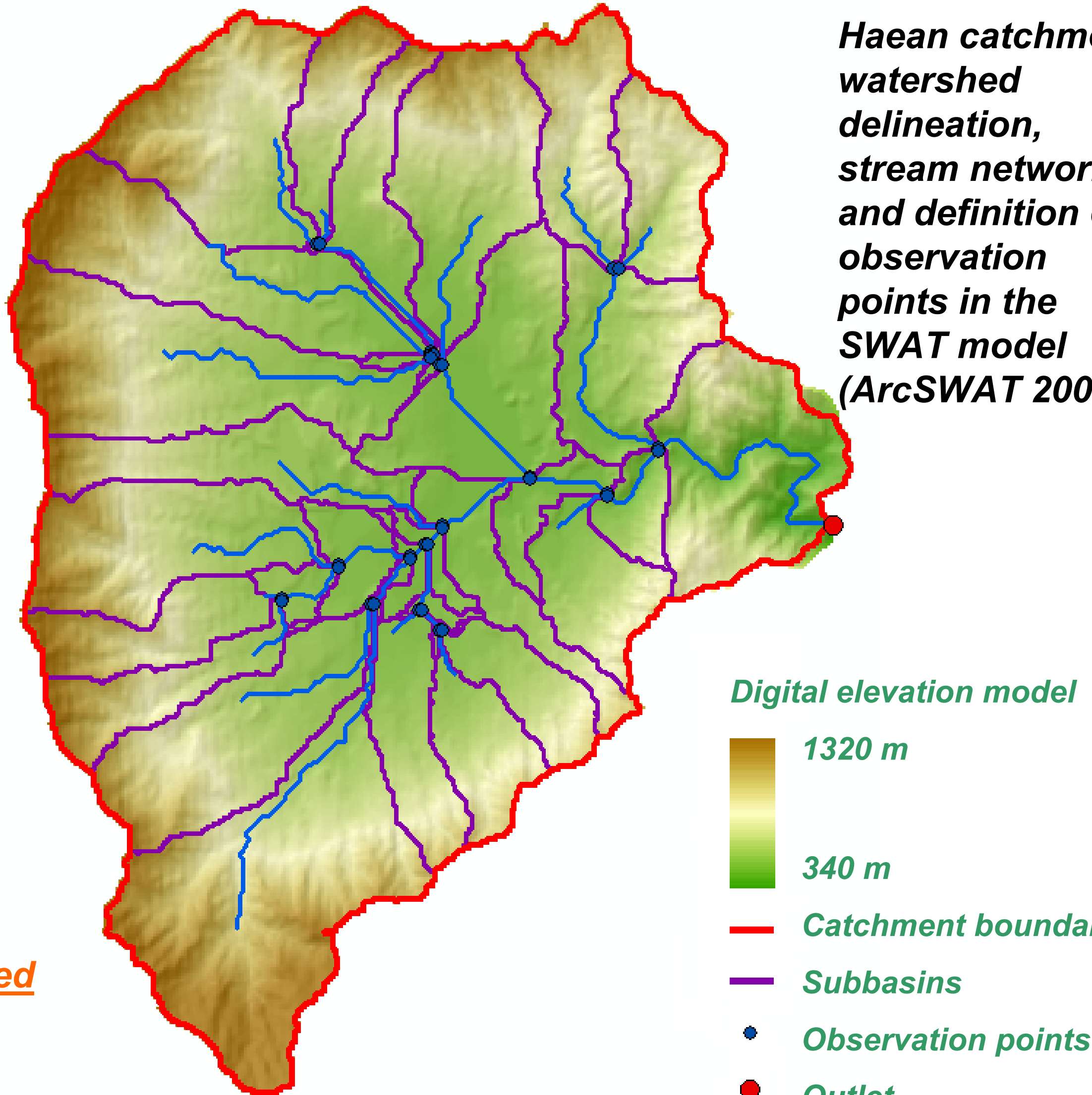
  Climate change

  Land use change

  Agricultural policies

…

➡ *Upscaling to Soyang Lake watershed*



Haean catchment watershed delineation, stream network and definition of observation points in the SWAT model (ArcSWAT 2009)

Neitsch SL, Arnold JG, Kiniry JR, Williams JR (2005): Soil and Water Assessment Tool - Theoretical Documentation, Version 2005


Thank you