Characterization of the Wiler field site

June 14/15 2007

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Summary

In this report, preliminary results from the excursion to the Wiler field site are presented and discussed. During two days, measurements were carried out in the field to determine geophysical properties of the subsoil, field water content, infiltration capacity and root distribution. Samples from the meadow and the forest were analyzed with respect to chemical properties. As a main conclusion we found that the soil thickness is for sure more than two meters and geophysical measurements did not show any indication for massive bedrock within the first 15 meters. Further on, the water distribution was more heterogeneous in the forest than in the meadow probably due to the effect of stem flow and roots (soil pipes). Also the chemical analysis indicates a difference between the forest and the meadow with more organic material, lower pH and higher cation exchange capacity in the forest. In additional laboratory experiments, mechanical and hydraulic properties will be analyzed.


PART A: PRELIMINARY RESULTS

A.1. General Characterization

During an excursion (April 29) in the Valais the Wiler field site was accepted as site with the highest potential with respect to support of the local authorities, access, steepness, presence of meadow and forest and availability of water. After a first contact with the local authorities, it became obvious that it was impossible to release a landslide at the initially chosen site due to the complexity with respect to ownership (the meadow below belongs to more than 40 owners). Together with the forester, Massimiliano Schwarz and Daniel Locher found another field site in the vicinity with similar (even better!) properties that does not belong to several private owners.
The field site consists of a forest area and a meadow. Before the year 2000, the meadow-area was forest as well and roots of dead trees remain and may affect the hydraulic and mechanical properties of the meadow. The mean slope is in the range of 35°. In the upper part of the meadow, snow avalanche preventions are installed. In the east, a steep ravine with a creek ('Wilerbach') is a natural boundary of the field site. A previous landslide in the southern part indicates that the region is active with respect to landslides.

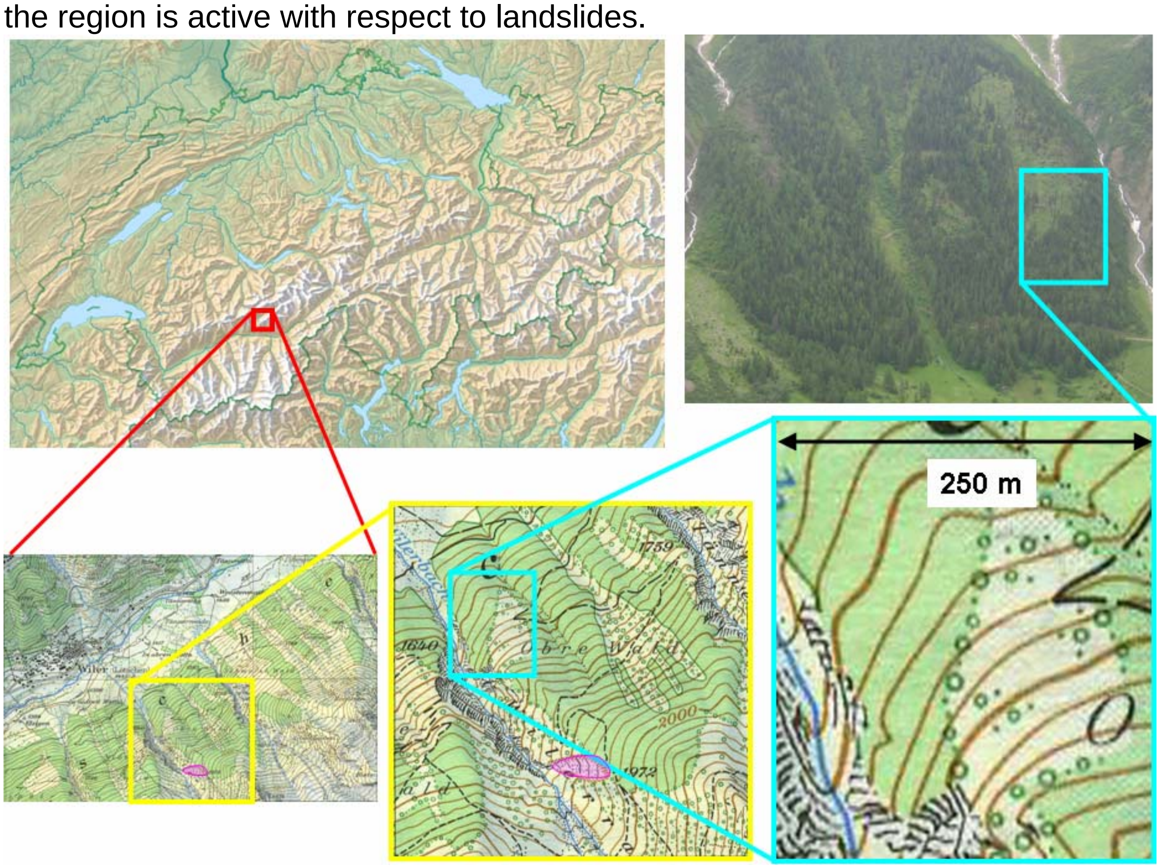


Figure 1: Localization of the new field site. The blue rectangle indicates the region that will contain the areas that will be instrumented and affected to release a landslide. In pink, the position of a former landslide is shown.

A. 2 Geology

A. 2.1. Geological overview

The Lötschental is mainly situated in the Aar massive which is consisting of crystalline rocks (Fig. 2). In the North, the sedimentary Doldenhorn nappe (light green; Jurassic) is followed by the Gastern granite (red; Hercynian) which belongs already to the Aar-massif. In the center, forming the valley, are old crystalline rocks (brown; pre-Hercynian) bounding on the central Aar granite in the South (red; Hercynian). Some amphibolitic bands (dark green) interlayer the old crystalline rocks. Glaciers are figured in blue and cover a large surface, and the alluviums on the valley floors are marked in white.

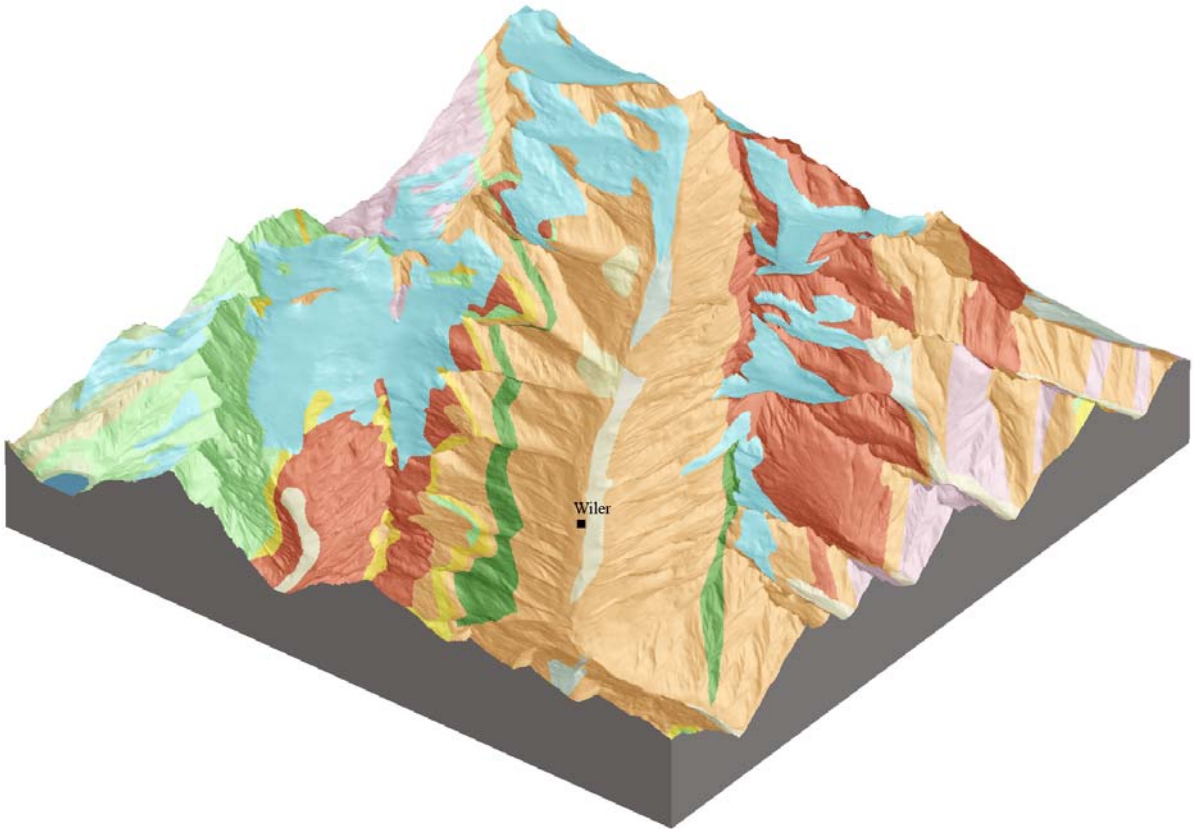


Fig. 2: Geological bloc-overview of the Lötschental. View from S-W.

A.2.2. Site geology

The hard rock basement of the experiment site consists only of old Aar crystalline. The largest fraction represents the polymetamorphic metasediments, which were retrogradely overprinted in a green-schist facies during the alpine orogeny. Today these rocks crop out as gneisses, schists or even phyllites, depending on the deformation. They contain plagioclase, feldspar, biotite and white mica plus the alteration products chlorite and sericite. In addition amphibolites can often be found as long bands interlayering the gneisses. They contain mainly hornblende and plagioclase and are of eruptive or magmatic origin. The experimental site is based upon chlorite-gneisses near the limit to biotite-sericite-gneisses (Fig. 3). This can be seen in the topography by a steepening of the slope. As it's the case for the whole northern slope the gneisses are dipping 60° to 80° in direction of 130° (see photos below).

<u>Quaternary</u>

During the last glaciation the valley was reshaped by the glacier, leading to a typical "U"shaped profile. At a regional scale, the rock surface is quite regular and depressions are often filled with morainic material. More important glacial deposits are found on the southern slope.

At the experiment site scale (northern slope), Quaternary deposits look like a sedimentation in water, locally showing a stratification of thin debris with a low clay fraction. The current interpretation of such a deposit, at least not purely morainic, is that the site was located at the intersection of a lateral glacier with the main one. In such conditions, small lakes often occur on the border of the glacier. Boreholes will help to confirm this fluvio-glaciar interpretation of the site. The first assessment of the material suggests that it is prone to debris flow. Above the site (ca. 1800 m.a.s.l) a 200 m long landslide occurred recently; the material is there moraine.

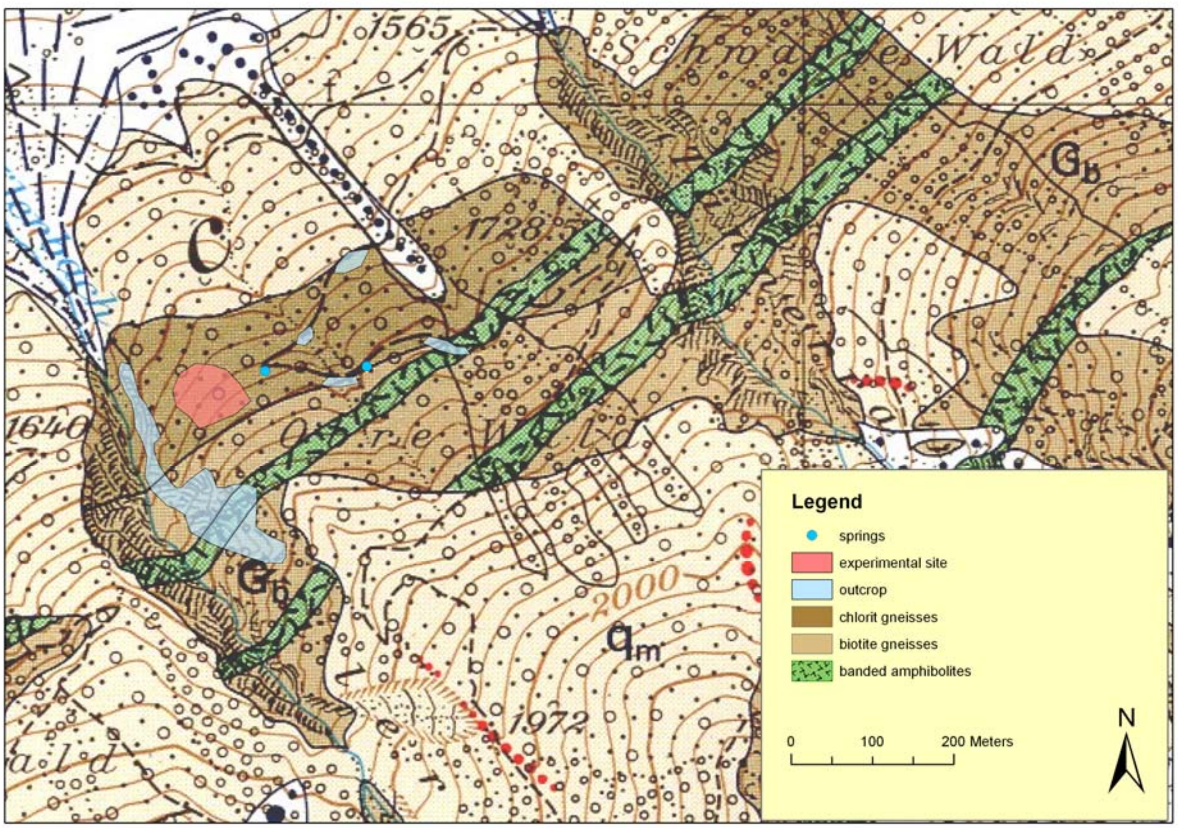


Fig. 3: Geology of the experimental site

A.2.3. Hydrogeology

In general the northern slope of the Lötschental is quite dry. Most of the water is drained superficially by the rivers and their large catchment areas. At the site scale, the only feeding is probably the direct infiltration. Deeper feeding of the slope by the gneisses is not expected. Only two very small sources were found close to the experimental site (Fig. 3) indicating a small subsurface flow. Both springs (ca. 1 l/min) are within the Quaternary deposits.

Photos: outcropping gneiss

soil with fluvio-glacial and moraine

small landslide

A.3. Geophysical Properties

Dani Or bought an instrument (IRIS) to measure the electrical resistivity in the field. In a transect along the slope 48 electrodes were installed with a spacing of 2 m. The transect was completely within the meadow (in a later test, the spacing was increased to 5 m and the transect was within the forest as well).
Low values were indicators for high water and/or clay content. The device is brand new and the analysis and presentation is preliminary. Fortunately, we could profit from the help of the group of Klaus Holliger (UNIL) that enables us to obtain information from the underground.

Figure 4: Preparation of the transect in the meadow to analyze the subsoil. The four collaborators (red circles) install the electrodes to measure electrical resistivity.

Below the results are shown for three transects with a distance of 5 m. The patterns remain similar in all transects. The first 5 m in soil depth are more heterogeneous than the subsoil below.

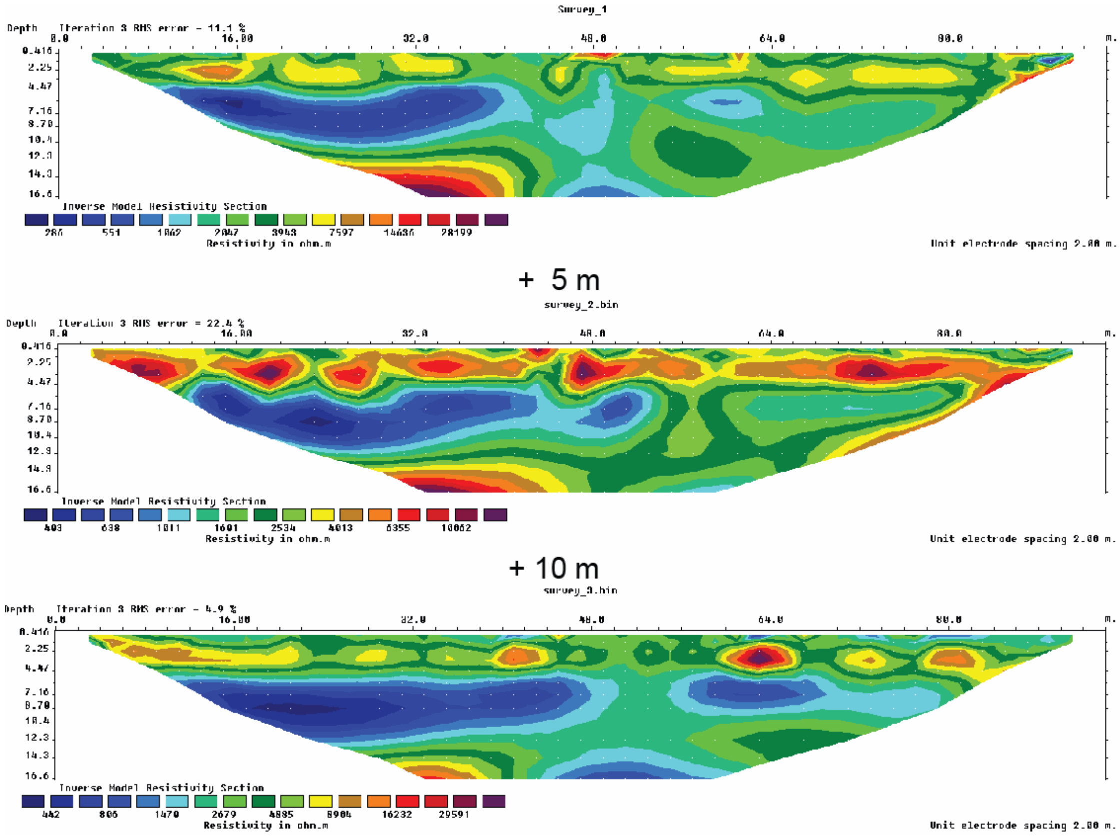


Figure 5: Electrical resistivity measured in three transect in the meadow with 2 m spacing of the electrodes. Low (blue) values indicate high water (or clay) content. The height of the surface decreases from the left to the right. Please note that the scale of the resistivity changes from image to image (we just started to use the instrument and the software!). The profile consists of a heterogeneous first layer (0 to 4 m) with a more homogeneous wet region between 5 and 12 m.

A fourth transect was analyzed with 2 m and 5 m spacing of the electrodes. The patterns measured with different resolutions were similar and even for a maximum depth of 40 m no indication of massive bedrock was found. This hypothesis must be confirmed in additional analysis of the data and borehole measurements.

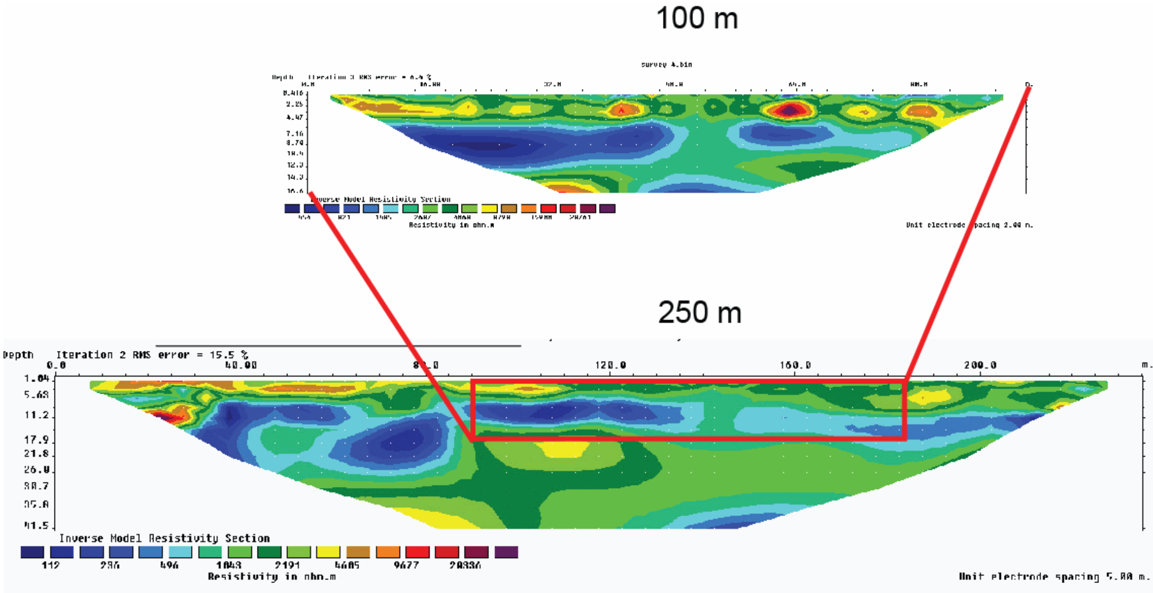


Figure 6: Transects of different lengths (top 100 m, bottom 250 m) and spacing of electrodes (top 2m, bottom 5 m). In the figure at the bottom, the right boundary is in the forest while the first image is completely within the meadow.

Interpretation:

There is no clear indication of massive bedrock. Additional analysis with boreholes has to confirm this and to validate the ERT measurements. For sure, the hypothesis that the soil is very shallow (less than 1m) was disapproved also with small boreholes made with an auger that proofed the existence of soil in the first 2 m. However, the relevance of the underground with respect to hydrology is not clear and may not relevant in case of water flow dominated by water flow in the topsoil along plant roots.

A.4. Water content distribution

The volumetric water content was measured at 19 locations using a TDR probe with 3 rods of 15 cm length. For each location, five values within a circle of 5 m in diameter were monitored and averaged. The water content was measured at the surface (denoted as 'topsoil', soil depth 0-15 cm) and in the depth ranging from 30 to 45 cm ('subsoil'). The mean water content in the meadow was 0.31±0.05 $m^3 m^{-3}$ at the surface and 0.20±0.03 $m^3 m^{-3}$ in the subsoil. For the forest the values were smaller at the surface (0.18±0.05 $m^3 m^{-3}$) and in the subsoil (0.14±0.03 $m^3 m^{-3}$).

water content	meadow	forest
Topsoil (0-15 cm)	0.31 $m^3 m^{-3}$	0.18 $m^3 m^{-3}$
Subsoil (30-45 cm)	0.20 $m^3 m^{-3}$	0.14 $m^3 m^{-3}$

The average values for the 19 positions are presented below (Figure 7).

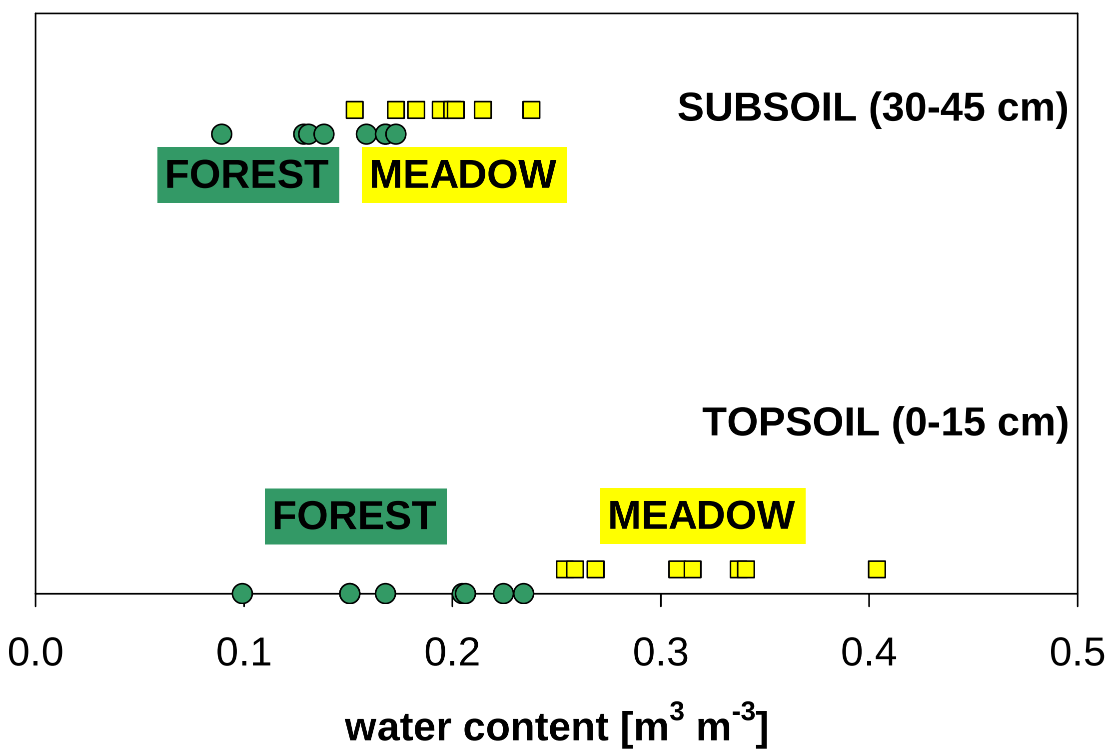


Figure 7: The variability of water content in the meadow and in the forest. Water content at 19 locations were measured using a TDR-rode with 15 cm in length. The water content was higher in the meadow and at the surface.

The water content is higher at the surface than in the subsoil and the meadow is wetter than the forest. Below, all single measurements are shown (5 values for each of the 19 locations). One 'outlier' with water content of 0.43 m^3 m^{-3} for the forest was confirmed by an additional measurement with another TDR probe.

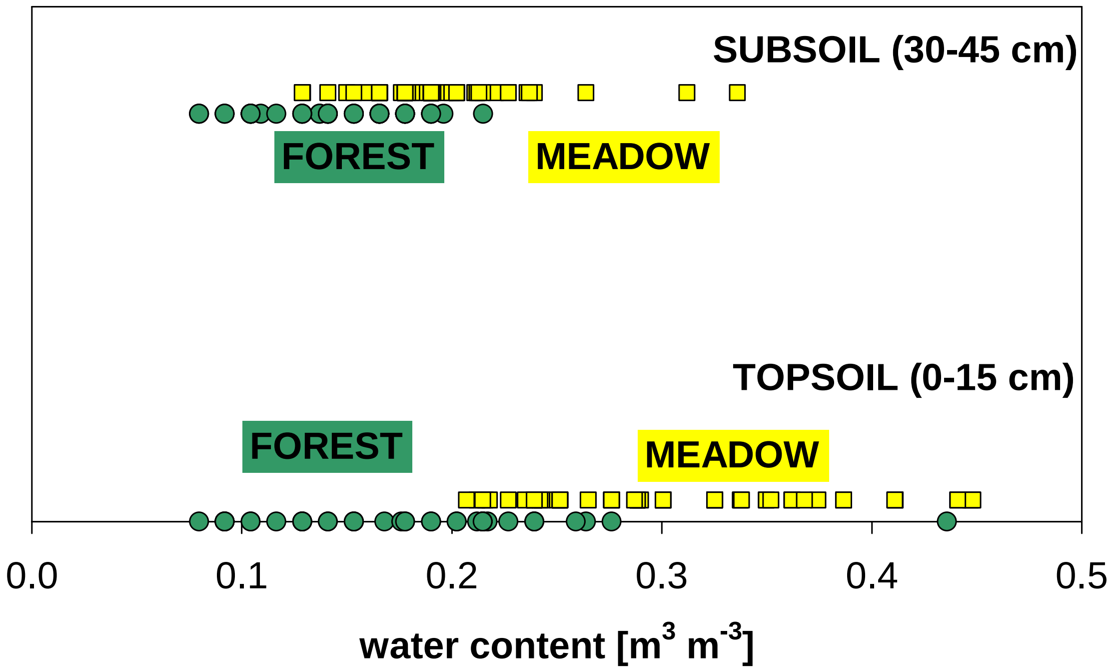


Figure 8: All water content values measured at 5 positions for the 19 locations. At one spot in the forest, an extra-ordinary high value was measured.

Interpretation:
The decreased water content in the subsoil may be an indicator for a fast transversal transport in the topsoil along the plant roots and less vertical infiltration. The reduced water content in the forest may be caused by interception of the trees and a highly heterogeneous pattern of water flow from the stems of the trees and along large roots in the soil resulting in a pattern of a few wet pathways within a generally dry soil.

5. Infiltration capacity

The infiltration rate and the hydraulic conductivity can be determined using infiltrometers (a water-filled transparent tube in contact with the soil surface). A time series with the decrease of the water level in the infiltrometer gives the cumulative infiltration rate.

Figure 9: Experiments with infiltrometers to determine the infiltration rate. In the left picture, the water filled infiltrometer is connected to the soil (forest). At the right, the decrease of the water table in the infiltrometer is monitored (meadow).

Conceptually, the infiltration process can be subdivided in a first period that is controlled by capillary forces (sorptivity) and a second stage that is dominated by gravity flow and the (saturated) hydraulic conductivity. The second period is a steady-state with constant infiltration rate and a linear increase of the cumulative infiltration rate with time. In the experiments conducted in the meadow and the forest of the field site, the second stage could not be detected (see Figure 10).

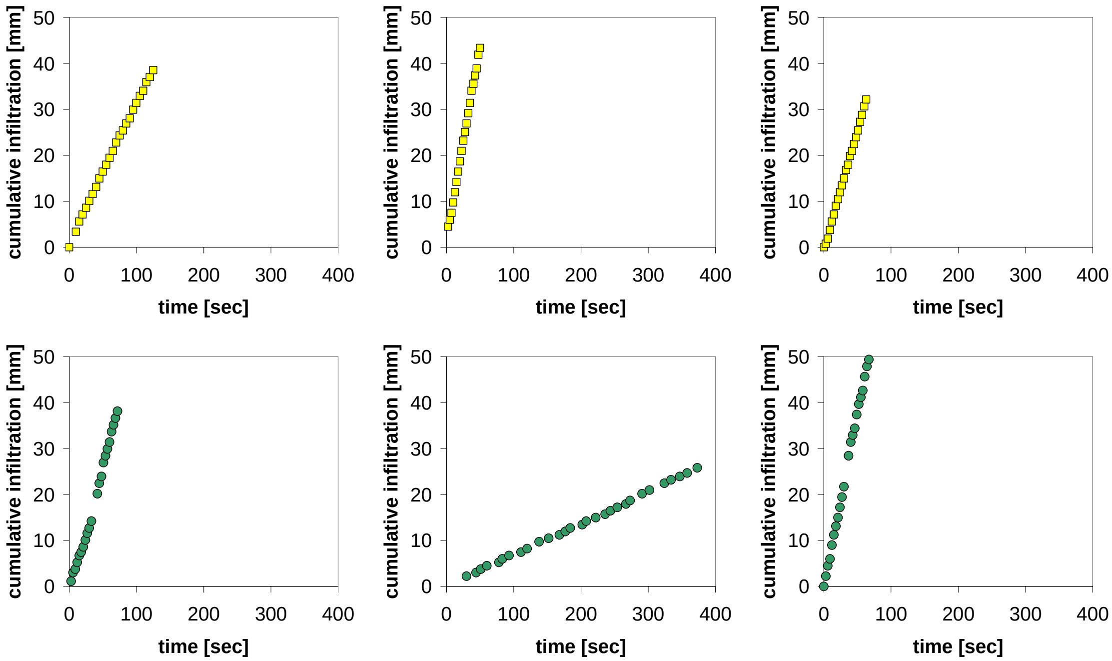


Figure 10: Infiltration rates measured in the meadow (top row; yellow symbols) and in the forest (bottom; green symbols). The system reached very quickly a steady state with a constant infiltration rate (corresponding to a linear increase of cumulative infiltration with time) and no period controlled by capillary forces could be detected.

The infiltration rate in the steady state is compared in the figure below for the meadow and the forest. While the infiltration values were always higher than 25 m per day in the meadow, a small value was measured at one position in the forest (6 m day^{-1}). To test the existence of a water repellent organic surface in the latter case, the organic horizon was removed and the infiltration experiment was repeated. Without organic horizon, the infiltration rate decreased to 1.6 m day^{-1}. This decrease cannot be explained with the small initial water content (0.08 m^3 m^{-3}) because another infiltration experiment in 5 m distance in the forest with the same initial water content resulted in an infiltration rate of 60 m day^{-1}. Probably, less flow paths along plant roots existed at this position.

The initial water contents were higher in the meadow than in the forest. For the meadow, the values were always higher than 20 m^3 m^{-3} but always smaller in the forest. This could be expected based on the analysis of the water content presented in section A4.

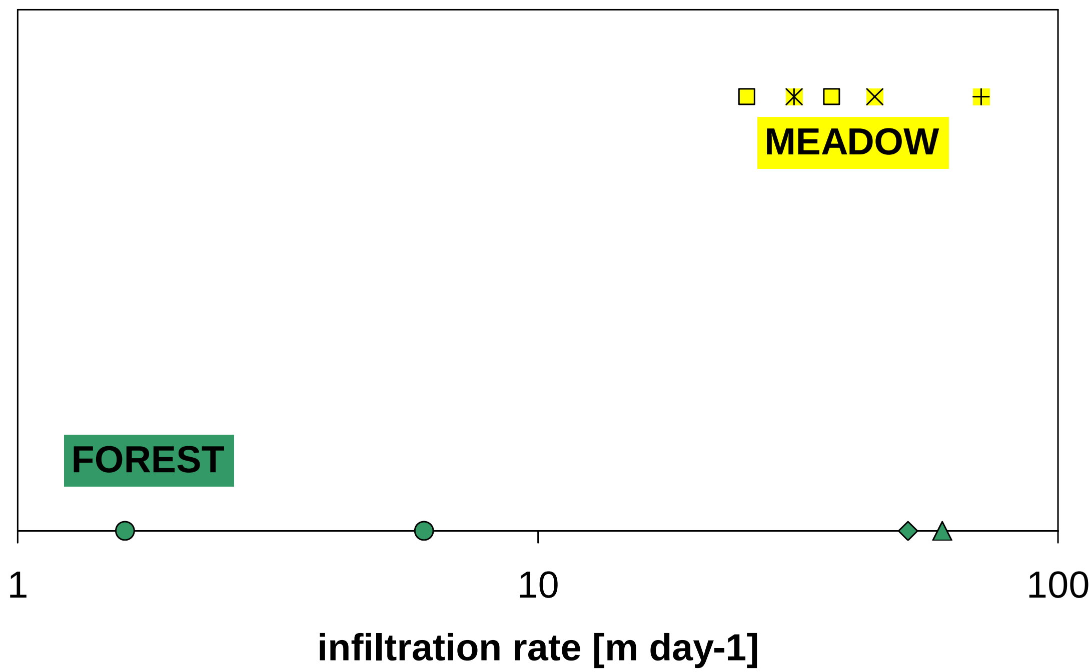


Figure 11: Measured infiltration rates in the steady state at the end of the infiltration experiments. In the meadow, the infiltration rate was measured at four positions (one with a repetition indicated by the empty squares) and the values were always higher than 10 m day-1. In the forest, the infiltration was measured at three positions (the circles indicate measurements at the surface and in 10 cm depth at the same position).

Interpretation:
The measurements indicate that values are generally high in the meadow but depend on the water redistribution between the stem and the roots in the forest. The effect of the plant roots was visualized in an experiment with a small profile prepared in downslope direction. Immediately after the onset of infiltration, water dropped from roots into the profile (see the wet material from the profile in the hand of the collaborator). When this fast mechanism along the roots does not work, the infiltration rate is limited by the properties of the soil matrix. From that we may conclude that the preferential flow along roots is the dominant water flow mechanism for the forest and the properties of the matrix are less relevant.

A. 6 Root distribution

In three forest profiles differing in distance from the trunk of the tree, the aerial fraction of roots larger than 2-3 mm was estimated. The fraction of roots in the profiles was mapped on a foil and quantified later on using image analysis. The root density decreases with depth and the distance form the stem.

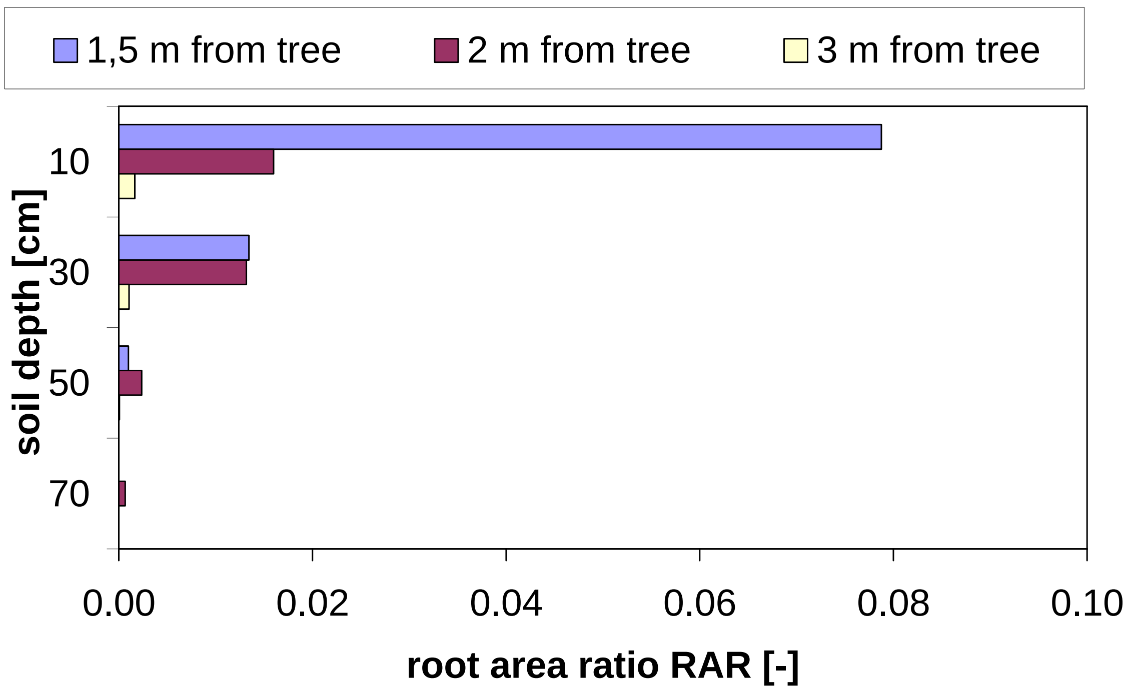


Figure 12: Root distribution as a function of soil depth and distance form the trunk of the tree.

Figure 13: Profiles to reveal the structure of large roots.

The root distribution will be completed with an analysis of images of fine plants. For that purpose samples of 5 cm in diameter were collected in the field and will be washed and prepared to reveal the structure and length of the roots.

A. 7. Chemical analysis

Based on 11 disturbed samples, the soil has a texture with 52% sand, 39% silt and 9% clay for the forest and 53% sand, 40%silt and 7% clay for the meadow. The samples were analyzed with respect to cation exchange capacity, acidity (pH) and content of organic matter as well. The results are presented below.

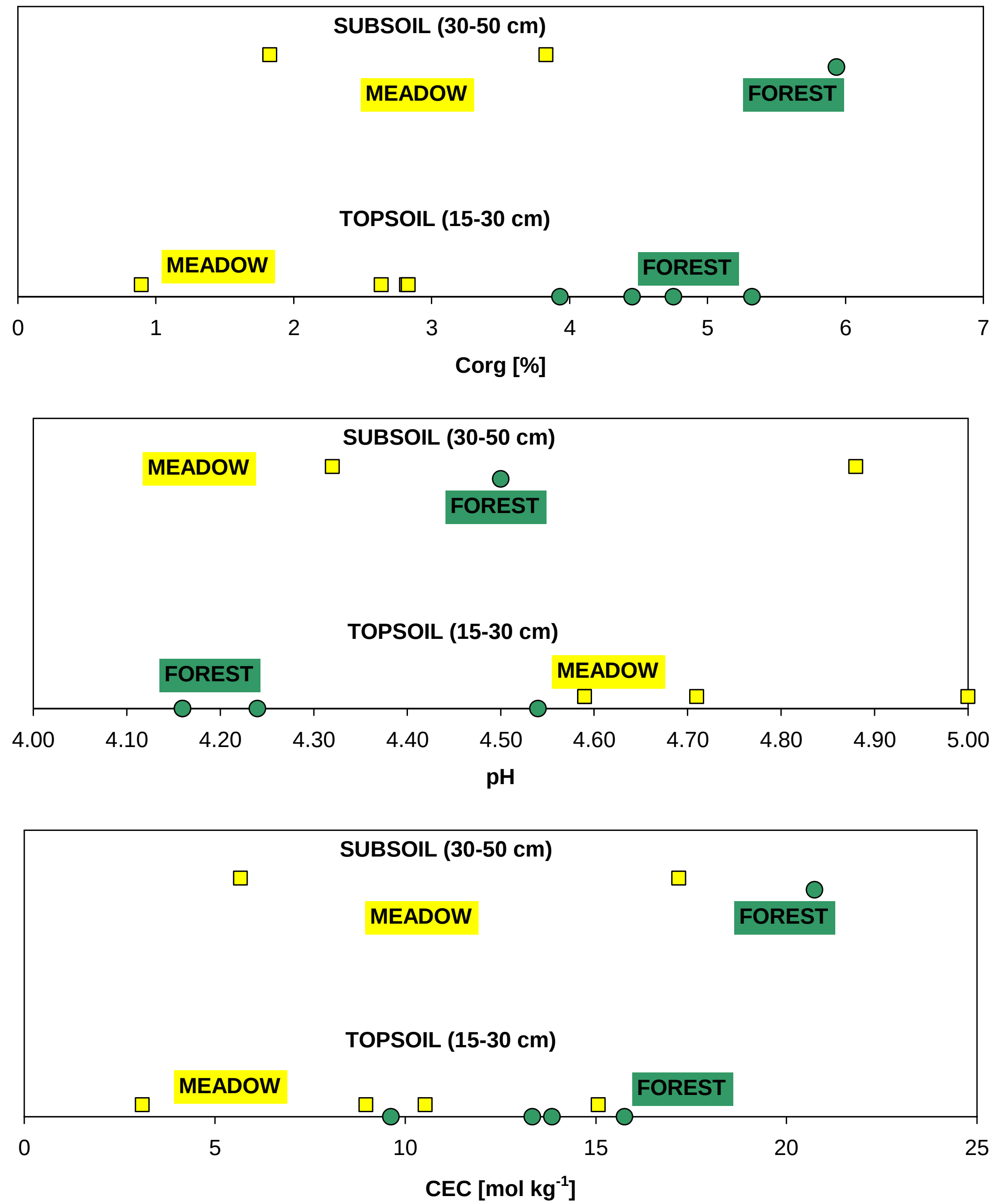


Figure 14: Chemical properties of the soils in the meadow and the forest. The largest difference between forest and meadow was found with respect to organic content.

Part B: Schedule for instrumentation

Based on the characterization presented in Part A we are confident that this field site is interesting and appropriate to study the triggering of landslides. We propose to trigger two landslides one located in the meadow and one in the forest (see Figure below).

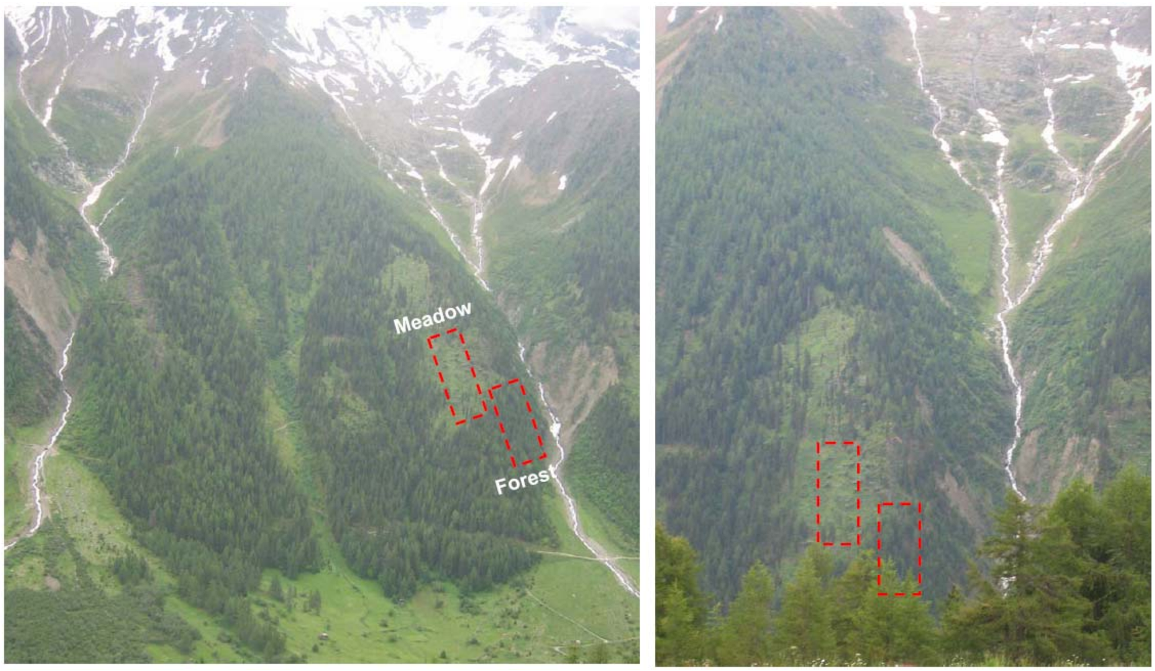


Figure 1: Location of field sites to release landslides in the forest and in the meadow.

To reach the goal of the TRAMM project, i.e. the prediction of an artificially released landslide, we must accomplish the two tasks before winter:

- a test experiment with respect to landslide release
- instrumentation to monitor the hydrology (and mechanical properties)

B. 1 Test experiment to release a small area

A few m^3 will be released to test the feasibility of an artificial landslide for this type of soil and slope. For that purpose, the position of the release must be specified. The most critical part of this experiment is the water transport to the field because a large volume of water is probably needed to release the mass.

Task	**Reasonable**	**Time**
Discussion with the forester with respect to water supply and choice of the site	Manfred / Massimiliano	1st half July
To inform Geobrugg with respect to protection devices	Manfred	1st half July
System of water channels from the creek to the field site	Manfred	July
Trench to enhance water infiltration	Manfred	August
Instrumentation of test-site (acoustics, capacitors)	Paolo	1st half July
Additional instrumentation for test release	Lyesse/Sarah	1st half July

Important: The LASEP will instrument the site to measure the water content and with acoustic sensors to have a first impression about the signals in the field. Other instrumentation, especially with respect to the mechanical properties, must be specified as soon as possible. The installation procedure should be discussed with Paolo Cremonino (paolo.cremonio@lasep.ch, the responsible for the LASEP instrumentation).

B. 2 Instrumentation of the field site

The main field site described in Part A will be instrumented in summer 2007. As described in the Requip proposal, we will install several banks of instruments that are concentrated on the most important structures. The data are sent (wireless) to a central station at the boundary of the field site.

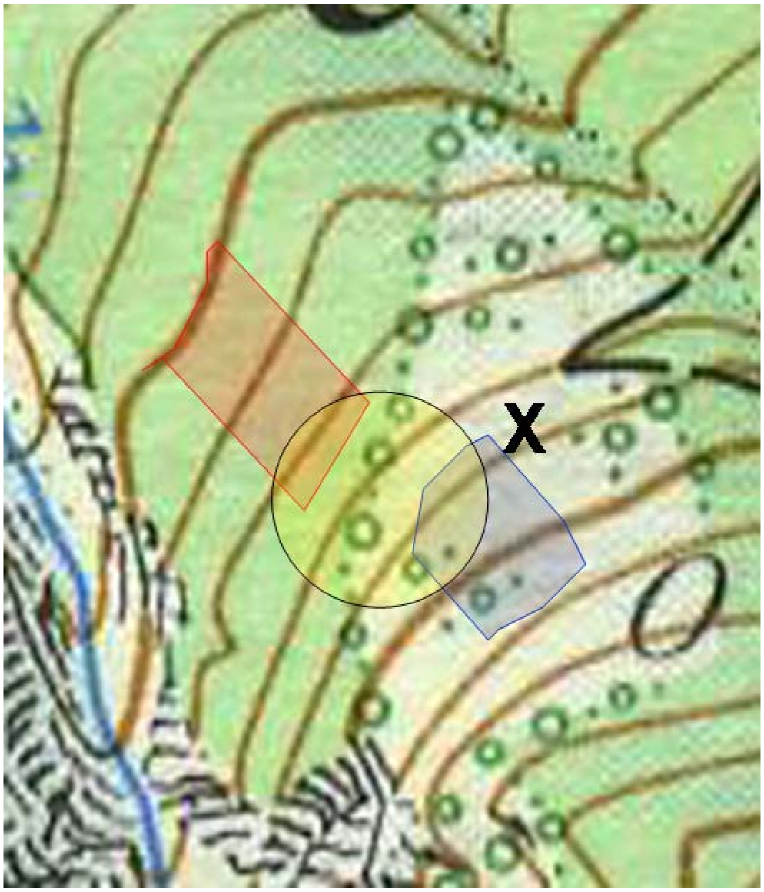
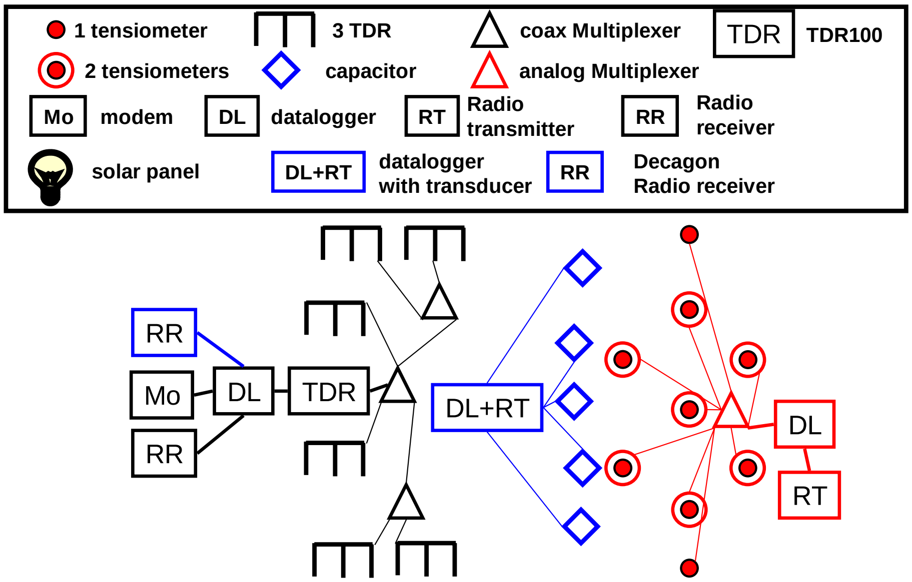


Figure 2: Bank of instruments will be installed in the forest (red), the meadow (blue) and the two zones are interlinked by the IRIS system (yellow) to monitor the three-dimensional water distribution based on Electrical Resistivity. The black X indicates the position of the weather station and central data-logger.

Below, the contents of the experimental banks are listed:

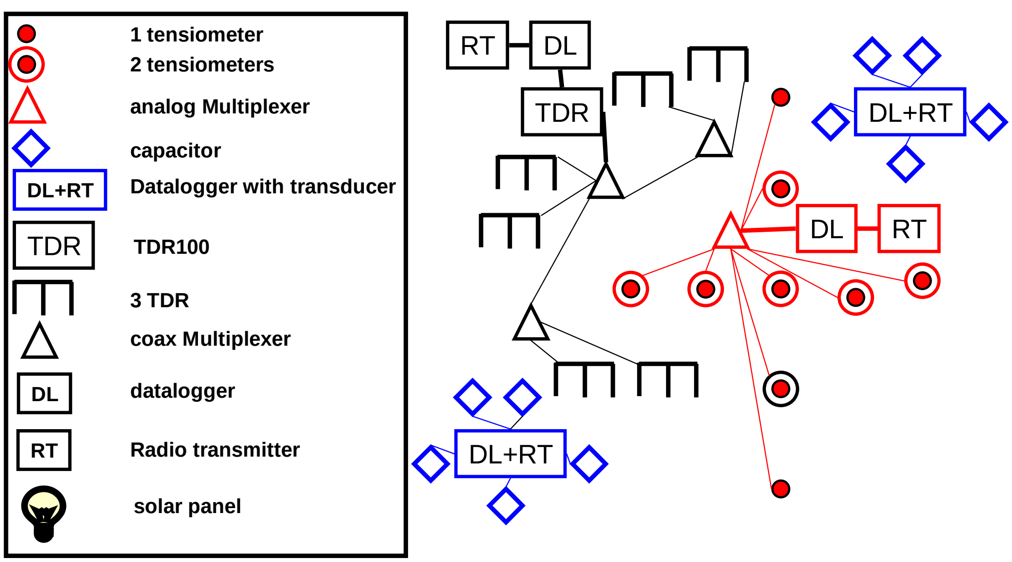
Material for the instrumentation in the meadow

18 TDR-rpobes (6 x 3)	1 TDR100	3 coax multiplexer	1 datalogger(CENTRAL STATION)
16 tensiometers	1 analog multiplexer	1 datalogger	
1 Decagon datalogger/transmitter	1 Decagon receiver	5 Decagon capacitors	
1 receiver	1 modem	1 solar panel	



Material for the instrumentation in the forest

18 TDR-rpobes (6 x 3)	1 TDR100	3 coax multiplexer	1 datalogger
16 tensiometers	1 analog multiplexer	1 datalogger	
2 Decagon datalogger/transmitter	10 Decagon capacitors		1 solar panel



In addition, a solar panel is used for the IRIS - system. The measurement of the temperature must be specified.

The list below should help to plan the instrumentation:

Task	**responsible**	**Time**
Testing the communication between TDR and datalogger and modem	Paolo	End of June
Data communication between IRIS and central station	Paolo	End of June
Preparation of tensiometers	Rodrigue	End of June
Clearing the forest (with forester)	Massimiliano	July
Specified plan/quote for the boreholes	Laurent	July
Concept for the measurements of temperature	Manfred/Dani	July
Additional Instrumentation	Sarah, Lyesse	1st half July
Test instrumentation at EPFL	Dani	1st half July
Instrumentation in the field	Dani	July/August
Instrumentation of the boreholes	Laurent	August