July 2018

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A German-Chilean Research Initiative
www.earthshape.net

What is *EarthShape*?

The general overarching research question of EarthShape is:

How do microorganisms, animals and plants influence the form and development of the Earth’s surface over time, considering present and back to early geologic times?

This project lasts 6 years. It started 2016 and is financiated by the German Research Foundation (DFG-SPP 1803).

This initiative involves reserachers of diferent universities and research centers in Chile. It is also supported by the National Forest Corporation (CONAF).

During phase 1 (2016-2018) EarthShape included:

13 interdisciplinary projects,

17 doctoral students,

33 german researchers and

19 chilean researchers.

Centro de Estudios Avanzados en Zonas Áridas (CEAZA)

Pontificia Universidad Católica de Chile (PUC)

Universidad Austral de Chile (UACh)

Universidad Católica del Norte (UCN)

Universidad de Chile (UChile)

Universidad de Concepción (UdeC)

Universidad de La Frontera (UFro)

Universidad de La Serena (ULS)

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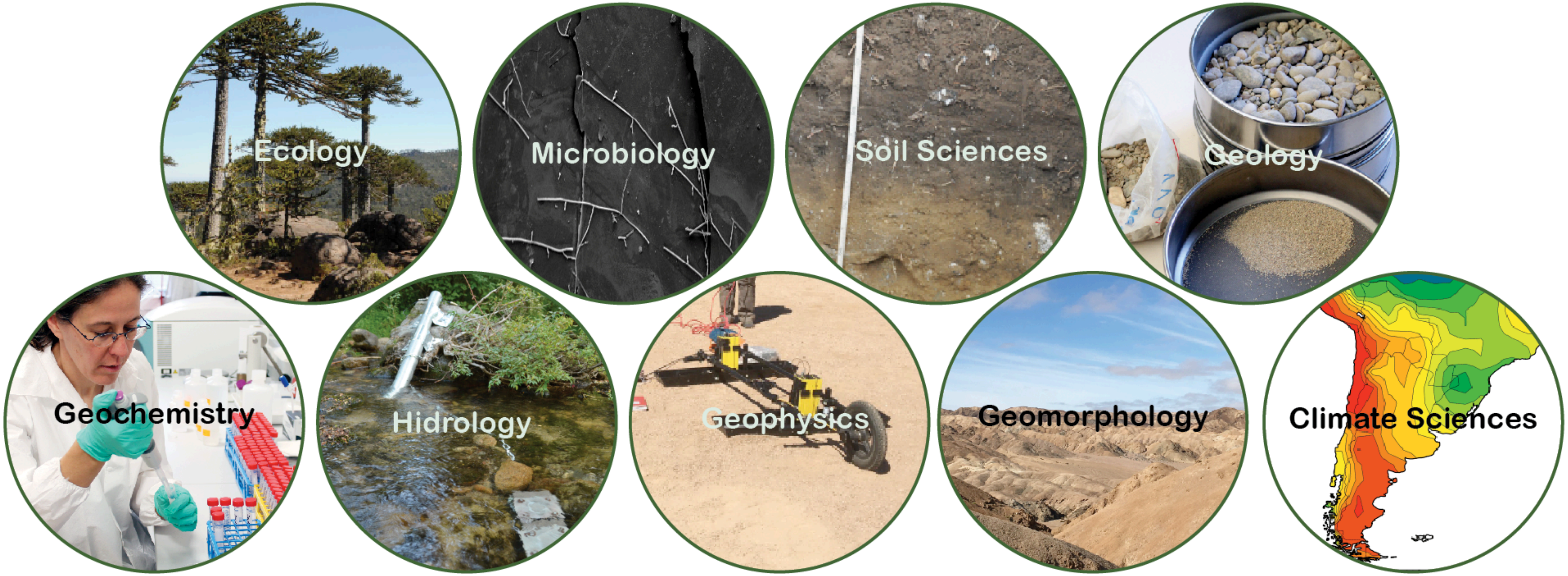
EarthShape bridges between several scientific disciplines, including geologists and biologists, to study this complex question from several points of view.

The scientists are based at the following disciplines:



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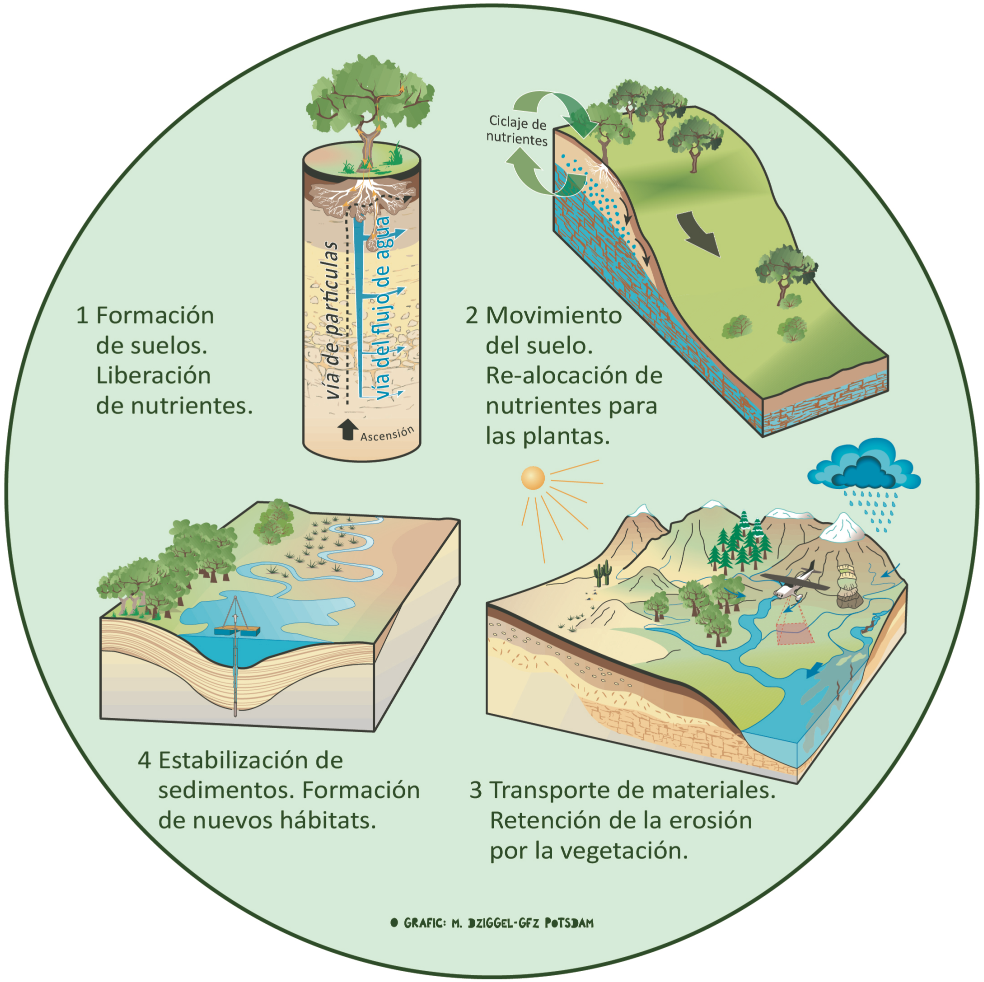
The general research question is too complex to be answered in a single way.

Thus, the porject is organized into four clusters of questions. Every sub-project focuses on one of these clusters.

List of projects on the EarthShape webpage:

https://esdynamics.geo.uni-tuebingen.de/earthshape/index.php?id=129



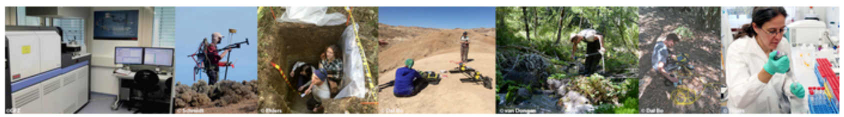
Projects
P1: Plant Traits and Decomposition
P2: Coupled Modelling
P3: Biofilms & Weathering
P4: Sediment Storage & Connectivity
P5: Crustweathering
P6: Root Carbon
P7: Paleoclimate
P8: Imaging of Weathering front
P9: Sediment Transport
P10: Phosphorus solubilization
P11: Green & Grey world
P12: Biogenic Weathering
P13: Microbiological Stabilization
A3: Carbon & Nutrient Fluxes

EarthShape Projects Active in Phase I (2016-2019)

The EarthShape projects started on january 1, 2016 and have a duration of three years.

By clicking on the project number and short title on the left you find the summary of each project.

Several projects have subprojects and we also have an associate project listed. The Associate project is not directly funded through the program, but working in EarthShape study areas.



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The research sites are located in the Chilean Coastal Cordillera:

They range from the Atacama desert in the north, to the Araucaria forests 1.300 km further south.
Along the selected sites there is a long ecological and climatic gradient, ranging from a very arid ambient, to humid conditions.

This selection excludes other factors that could interfere with the conducted studies, such as diferences in rock type and impact of glaciers and volcanoes.

We have a database of the four sites that consist of:

- **Soil pits** with analysis of the different soil layers
- Monitoring of climate with **meteorological stations** with data visible in the internet and renewed once a day:

https://esdynamics.geo.uni-tuebingen.de/earthshape/index.php?id=68

At the sites with running superficial water, we have installed **hidrologic stations**, generating data about the water current.

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What is the use of fallen leaves?
Is their effect different in different climates along Chile?
What does their decomposition depend on?

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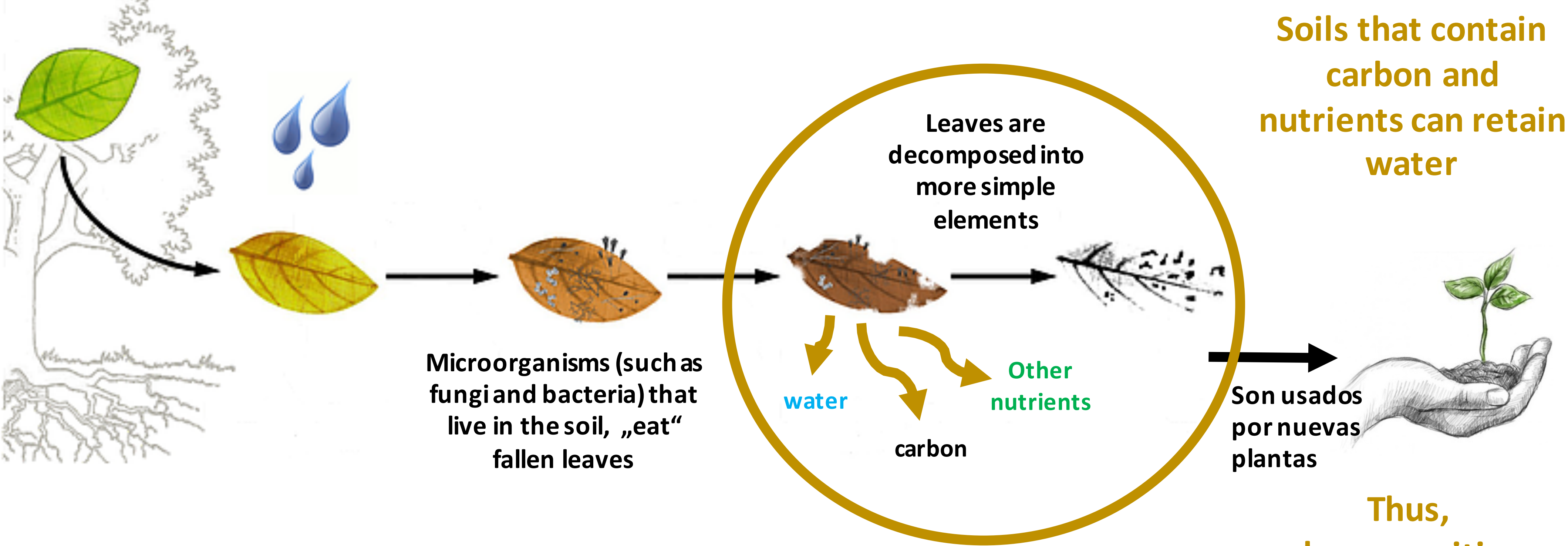
Soils that contain carbon and nutrients can retain water



Thus, decomposition leads to nutrient rich and high quality soils.

Results:

Descomposition depends on:

- Leaves quality (meaning characteristics of diferent plants)
- Clima (environmental temperature and moisture)

→ Our objective is to study the long-term decomposition of different Chilean plant species, and in different climates, to understand <u>how</u> and <u>depending on what</u> it works now, and also <u>how</u> it will develop with a change of climate in the future.

Biological Soil Crusts of the Atacama Desert

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1. What is a Biological soil crust?

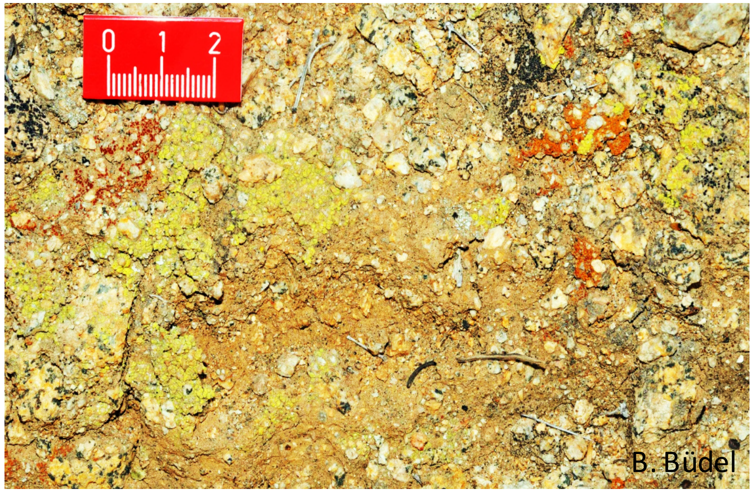
- It is a mixture of organisms at the soils surface composed of: **bacteria, fungi, bryophytes, lichens, cyanobacteria, algae** and their byproducts
- On a global scale, they form the most productive microbial biomass in arid regions
- Crustose lichens are the dominant component in theNP Pan de Azúcar, visible as coloured or blackish spots on the ground
- They are alive, but only active when they receive water, usually via fog

2. What is the function of a Biological Soil Crust?

- Biological soil crusts stabilize the top soil layer against getting blown away by wind
- While breathing (photosynthesis) they fix CO_2 of the atmosphere => they reduce a climate change effect
- They can make nitrogen and phosphorus accessible for other plants as important nutrients

3. What is the aim of our research?

- We want to identify the organisms that contribute to the biological soil crusts
- We use meteorological stations to understand which type of climate they need to be able to grow
- Laboratory tests tell us which nutrients are made available for other plants
- Overall, we want to understand, which role the biological soil crusts play in the landscape of the NP Pan de Azúcar



Biological Soil Crust (Lichens) in Pan de Azúcar (orange and green spots)

Meteorological station in NP Pan de Azúcar

Example from Parque Nacional Nahuelbuta, Chile

New method: "Remote Sensing" Which advantages does it provide?

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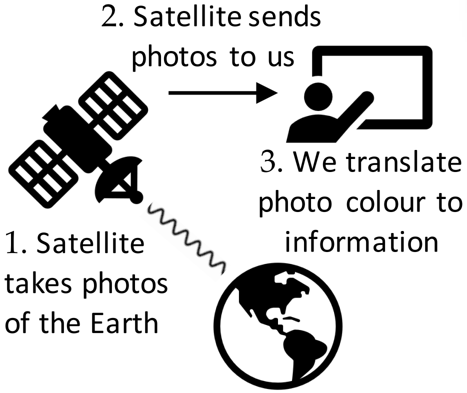
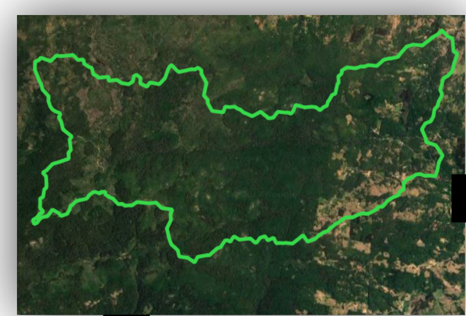
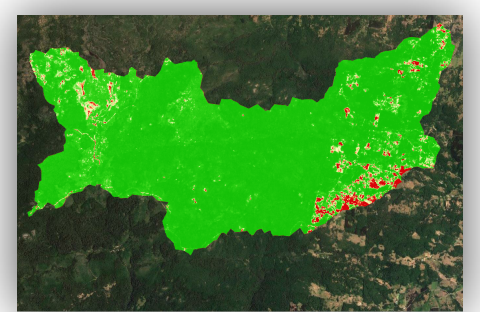
Base of knowledge:
What is "remote sensing"?





Question example 1: Where are the living plants in the National Park?

Digital Analysis



Living plants in green and rocks and soil in brown to red

Digital Analysis

Aerial photo provided by *GoogleEarth* with a small catchment in the park highlighted

Question example 2: Where are the Araucaries?

Endangered Monkey Puzzle trees (*Araucaria araucana*) in the park

> "A picture is worth a thousand words. A satellite image is worth a million dollars."
> - *Sarah Parcak (American archeologist)*

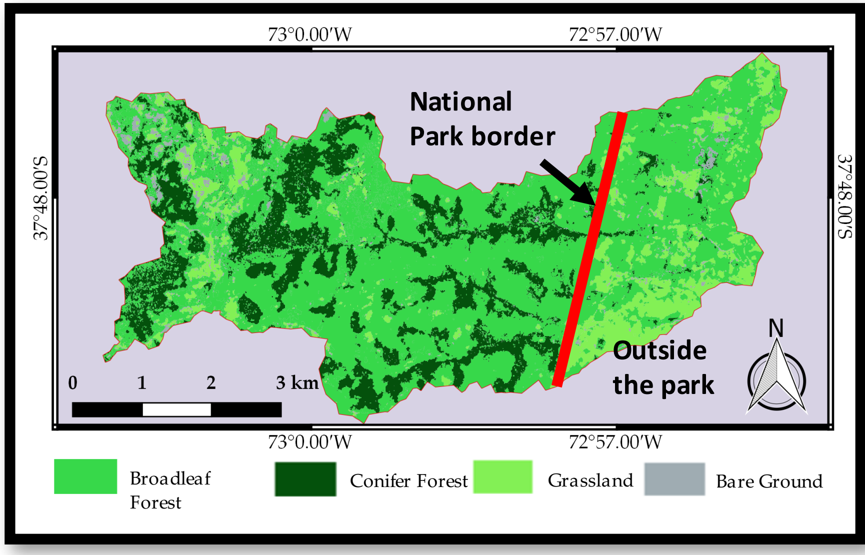
Advantages?

We can create maps of

- Vegetation
- Soil
- Risk of natural hazards
- etc.

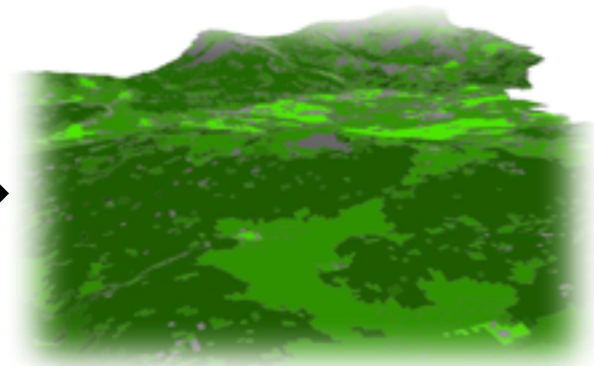
⇒ Information for government and private authorities

\+ Satellite images are often free (=> low cost)
\+ Satellite images do not destruct
\+ Time consuming field work is reduced



Finally: all needle trees and Araucaries (image colour: darker green), relative to other plants with leaves (image colour: ligher green)

Also in 3D!



Rain and Drought: An important balance!
What happens when extreme events occur?

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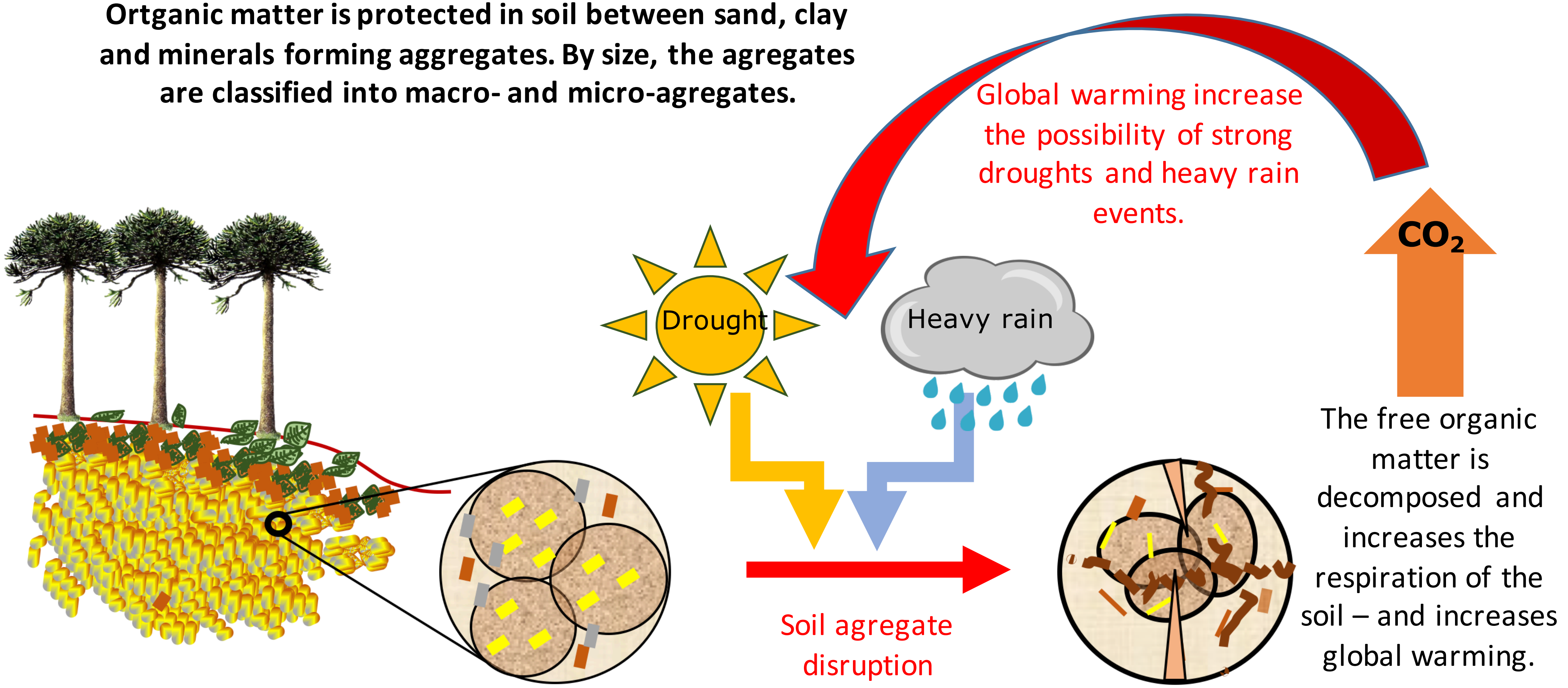
Ortganic matter is protected in soil between sand, clay and minerals forming aggregates. By size, the agregates are classified into macro- and micro-agregates.



The macro-agregates cannot protect the micro-aggregates: **They break apart.**

Free organic matter

Aggregate protected organic matter

Mineral bounded organic matter

Geophysics

?

Soil and water are fundamental resources for the humanity:

- Every day we drink about 1.5 L or water
- All the food that we eat is produced directly (plants/fruit) or indirectly (animals) from the soil

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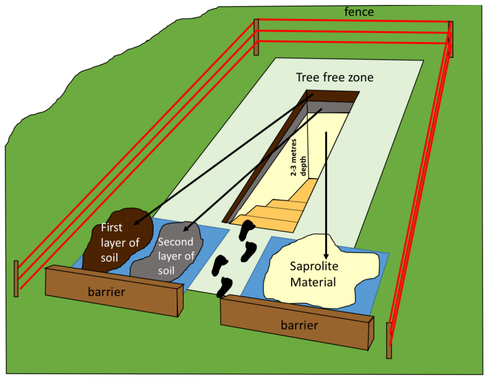
How do we discover the soil characteristic and the water distribution in the subsurface?

Direct methods

We can observe the soil distribution and the presence of water digging a hole:

- Much work / time consuming
- Expensive

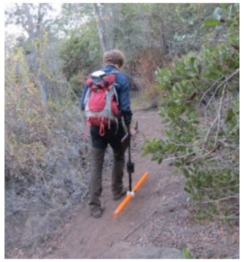


Example of excavated hole (pedon) in the frame of the EarthShape project

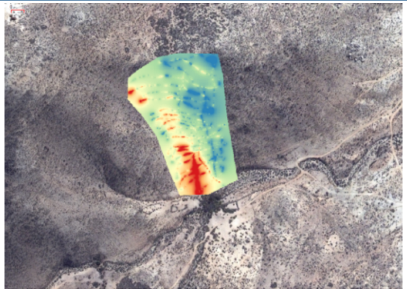
Indirect methods

We can perform indirect geophysical measurements that use electromagnetic principles, detecting changes in the registered signal that can be linked with the presence of water and the clay content in the soil:

- Fast
- Non invasive
- Not expensive

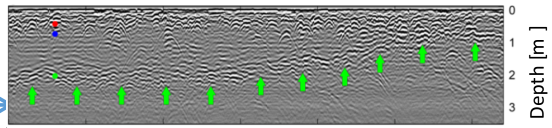


Geophysical measurements



Observations and analysis of the **soil electrical conductivity**

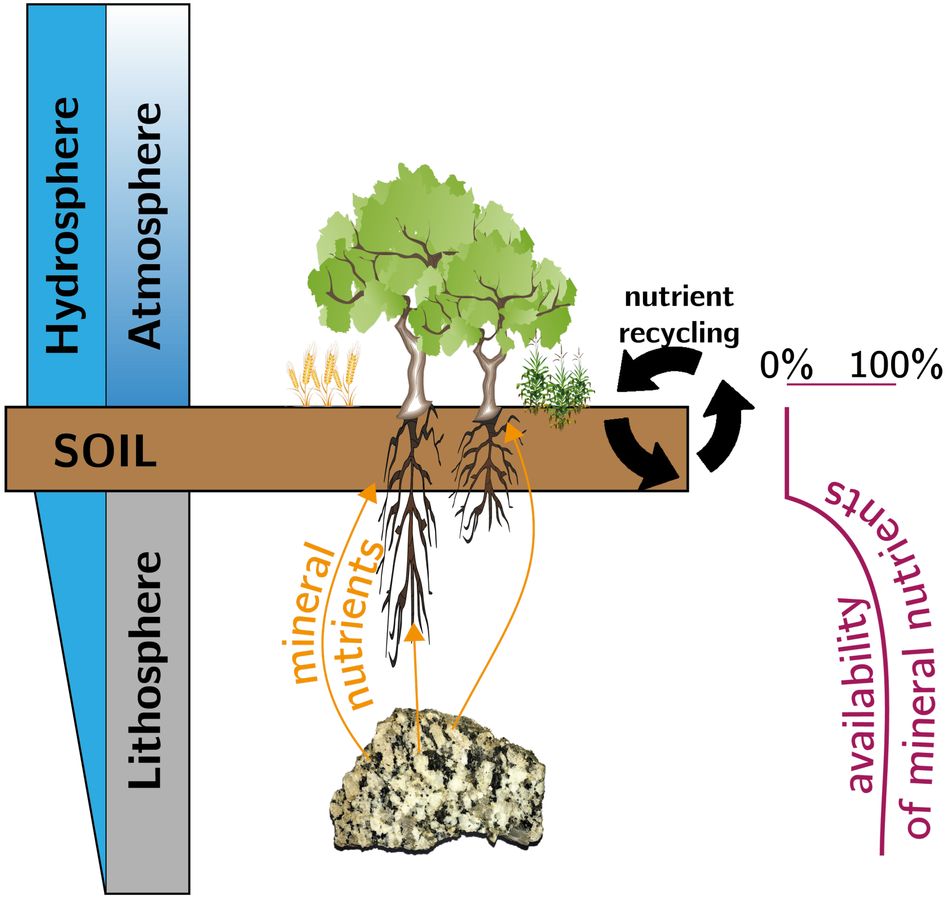
Electrical conductivity can be linked with the presence/absence of water, salinity, and clay in the soil
Example: red = water



Imaging the distribution an dthe lateral variation of the **soil layers**

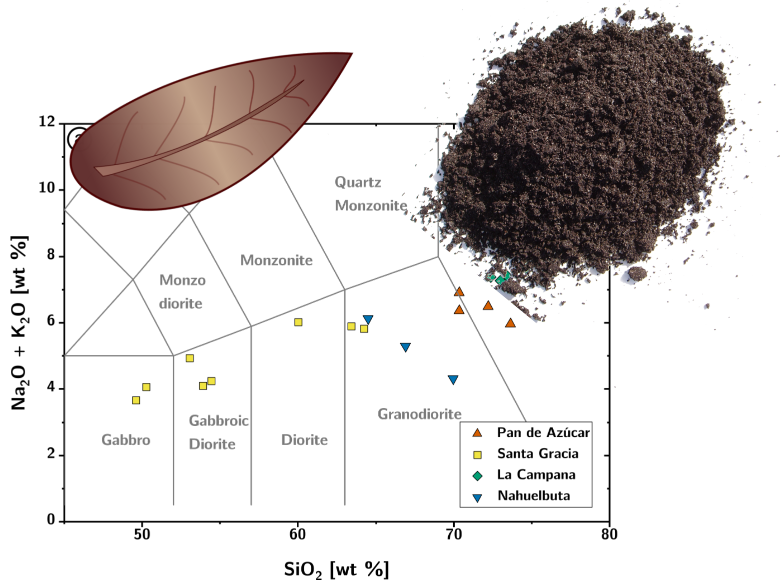
Observation of the lateral soil layers variability without digging

Soil chemistry:
How do we know when agricultural land is fertile?



Results:
By knowing the missing nutrients, farmers can fertilize their farmland specifically.
=> Less quantity of fertilyzer needed

Geoquemical Analysis :
¿Which substances are in the soil?



Nutrients derived from rocks and minerals are essential for plants, but are generally depleted in arable top soil.

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How does vegetation respond to climate change? Can they survive at the same places?

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Many plants cannot survive at any place, the ydepent a lot on the climate and the soil. They are adapted to the climate and the soil of their origin.






The experiments:

- Rainout shelters simulate a drought mechanically
- Transplants of soil with seeds to another climate helpfs to understand its influence on the germination and growth of plants
- Exchange of dried leaves to another climate helps understanding its influence on the decomposition of the leaves

We study under artificially modified climatic conditions:

- germination
- growth
- decomposition
- Nutrient cycle between plants and soil

This is how we can understand how ecosystems will change in the future and we can try to protect them as much as posible!

What does climate change mean for agricultural practice?

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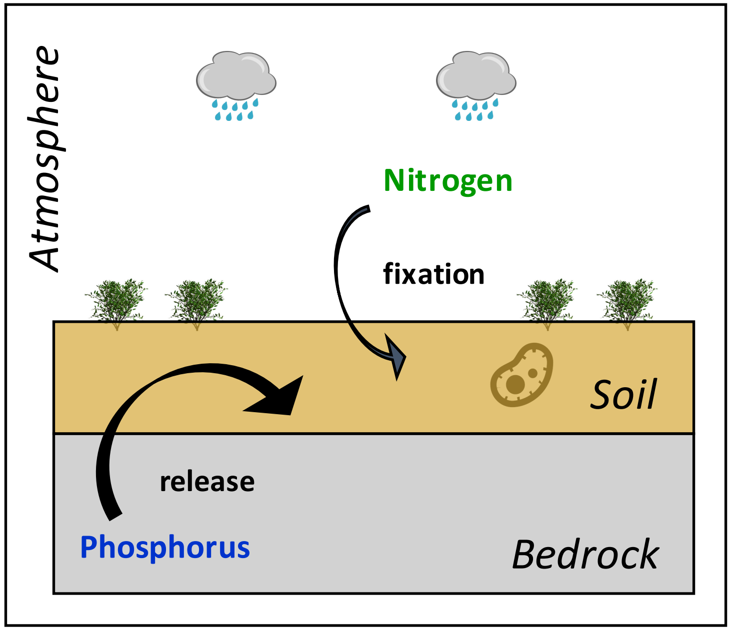
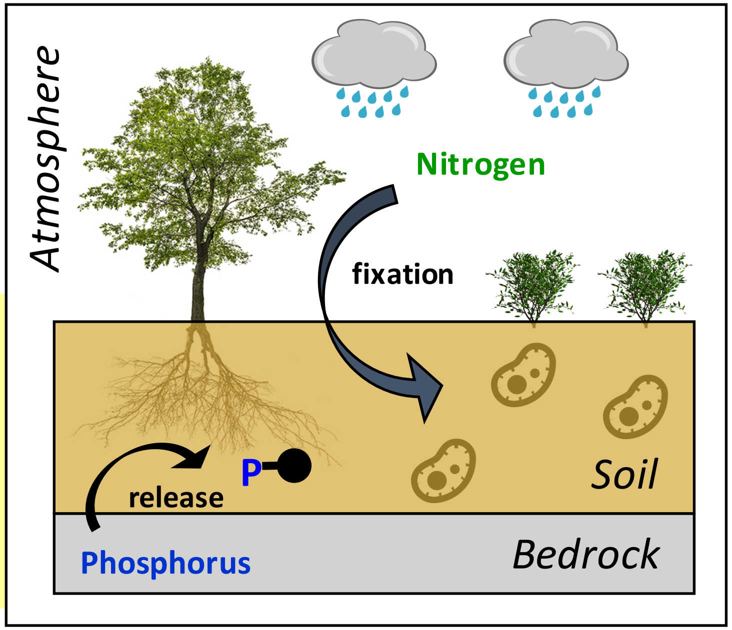
Young soil



Soil development (natural process)

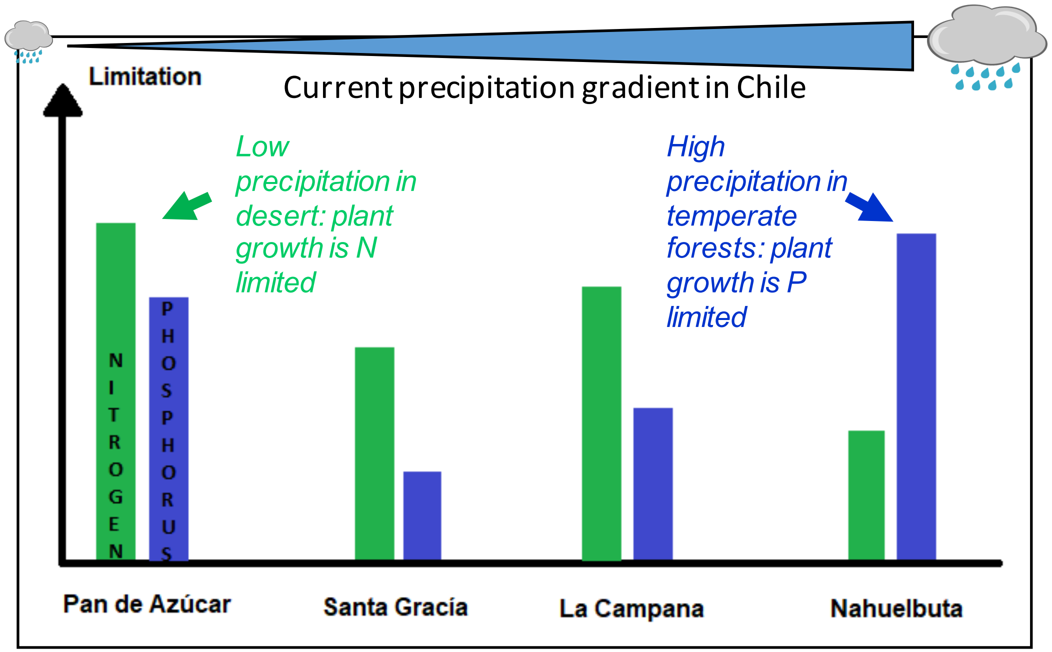
- more N fixed by microorganisms
- bedrock weathers: more P chemically adsorbed by iron and aluminium mineral ions!

Old soil



Climate change means e.g. increasing precipitation. This leads to faster soil weathering. The released phosphorus is chemically bound and not bioavailable.

Result:
Global warming may cause the need for fertilization with phosphorus!



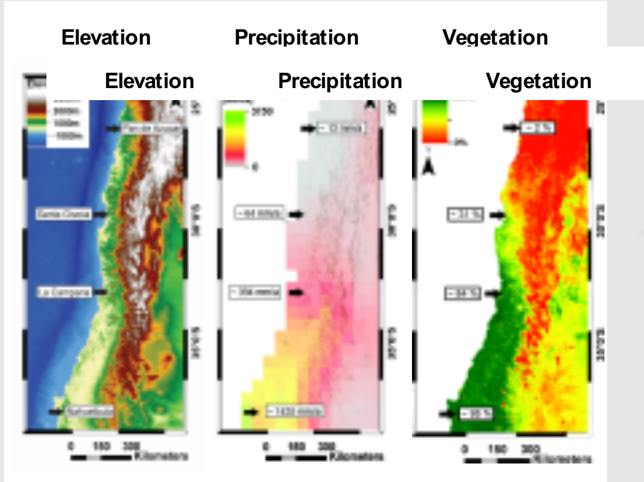
How does our land look like in the future? – possible scenarios based on available knowledge

Background I:

Rain (precipitation) erodes land. This results in reduced reliefs and slopes.

Vegetation protects land from erosion. The roots stabilize the ground.

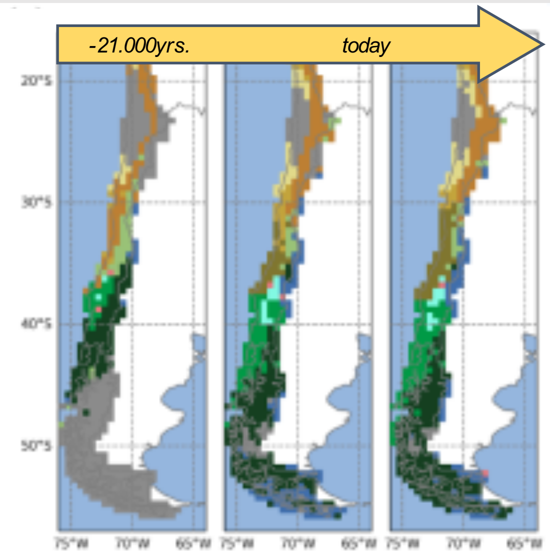
Background II: Information from satellite images



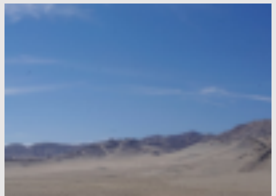
We can extract detailed knowledge from satellite images.

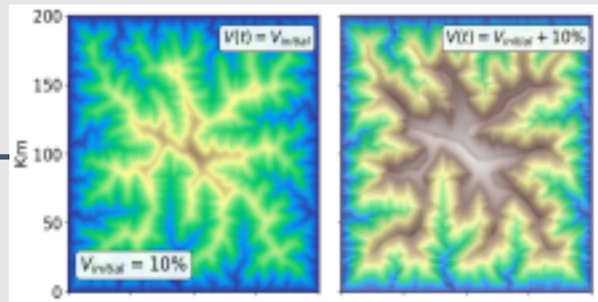
What happens when vegetation becomes more or less (due to e.g. climate change, deforestation, etc.) ?
What happens when it rains more or less?
What happens when both vary at the same time?

Background III:
vegetation computer models



We can extract detailed knowledge from vegetation models based on polen records and other data that show how vegetation developed over the last 20.000 years





Combining information from satellite images & computer models allows us to calculate how landscapes will develop if precipitation and / or vegetation change.

How can we get information about climatic changes in the past?

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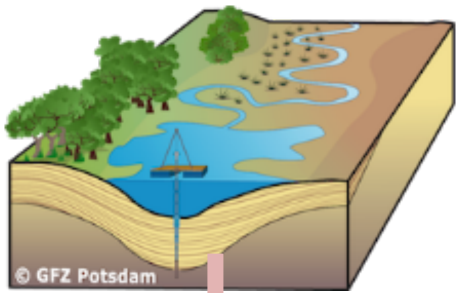
Paleoclimate: reconstruction of past climate changes

Step 1: Collect material containing paleoclimate information (soils, lakes, peatlands or ice deposits)

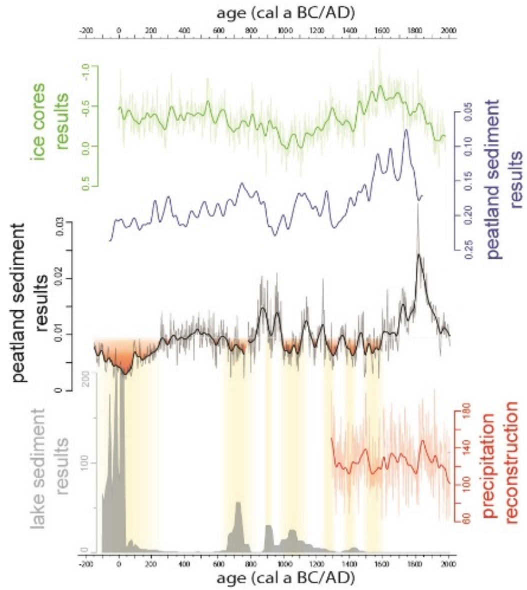


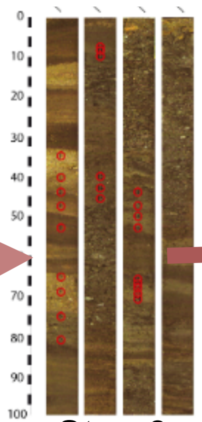
Step 2: Sampling of climate archives by corring, e.g. lakes (sedimentation took place for a long time)

Information about the paleoclimate is important to
- understand the frequency and causes for climate changes
- study the resistance of ecosystems
- provide information for the modelling of future climate changes

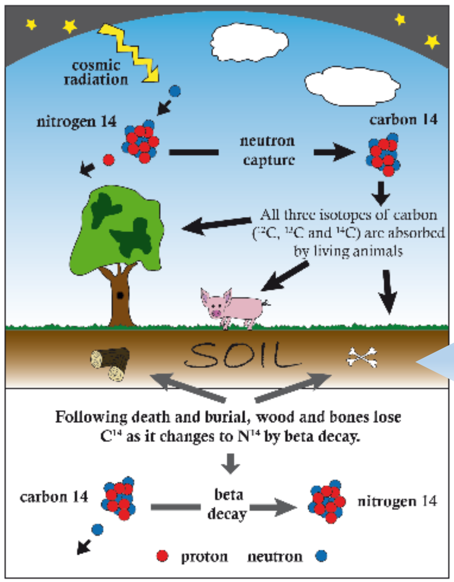
Step 3: dating of organic material – identification of the respective ages; radiocarbon method (C^{14})

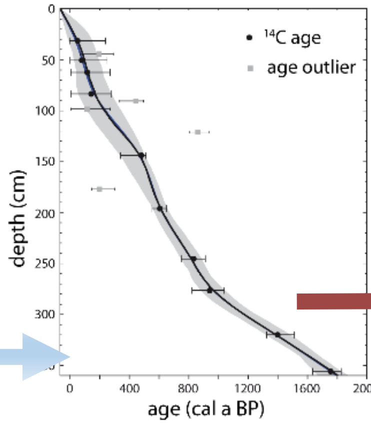
Step 6: Integration of results in regional context – local or regional paleoclimate signal?





Step 3: Processing of the vertical profiles





Dating results of the organic material within the vertical profile

Step 5: geochemical analyses: detailed detection of element composition of the samples

How are soils generated? – By weathering!
And how can we find out about the velocity of soil being formed?
- Based on cosmogenic nuclides!

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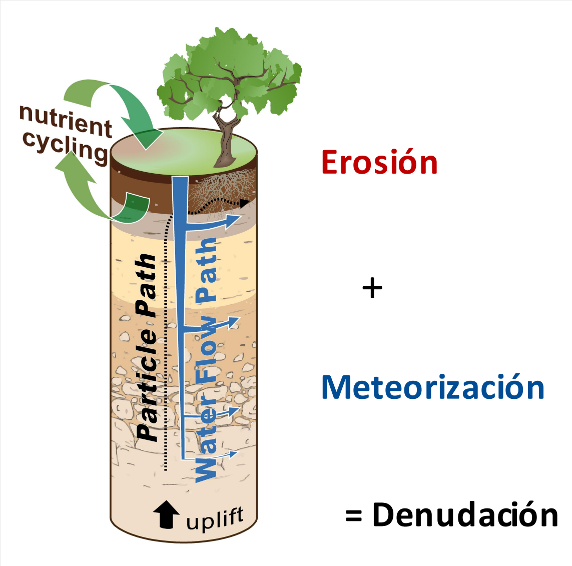
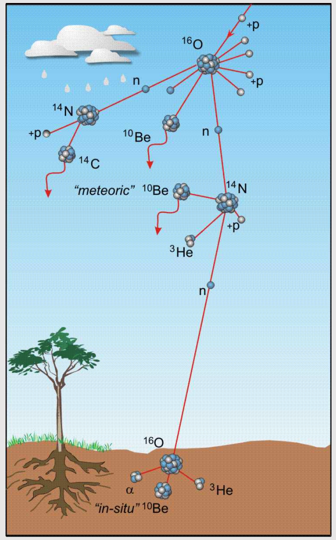


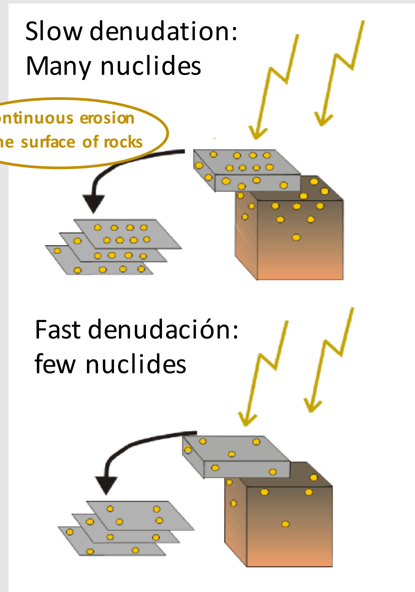
The Earth's surface is always under changing conditions. At the surface there is erosion, in peeder layers there is weathering, degrading rock very slowly. Both processes together are named denudation.

Cosmogenic atoms of ^{10}Be are produced by cosmic radiation at the first meter of the earth's surface. Only in this depth the "clock" works, and it starts working when the material comes up to the first layer (via erosion).

The "clock" is located in the quartz: ^{10}Be cosmogenic nuclides acumulate in there. The half lifetime of such atoms is 1,4 million years.



The method is aplicable on soils and also for river sediments.



If we observe indetail the quantity of cosmogenic nuclides of ^{10}Be atoms in the soil layers, we can detect if the soil erodes fast or slowly.

This type of quartz analysis allows us to get information over the last 10.000 years.

Rain moves soil downhill on hillslopes – what are the consequences?

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Soil is the basis for all food production. Rainfall moves soil and may disturb plant growing.
This soil movement is a type of erosion, composed of factors as temperature, amount of rain, slope of the surface, soil texture and nutrient content.
Experiments with controlled rainfall simulations allow to understand this process.

The experiment:

Step 1: controlled amount of waterflow falls on teh ground

Step 2: Collection of runoff and sediment

Step 3: Separation of sediment and runoff in the laboratory

Step 4: Analysis of nutrients and soil texture

Results of the experiment:

Movement of soil and nutrients per time and surface area

Results will be used for the protection of soils

July 2018

What is *EarthShape*?

Impressum

Financiated by:
Priority programme EARTHSHAPE
Deutsche Forschungsgemeinschaft (DFG)

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