Monday, September 9th, 2013 – daily report

Introduction to soil zoology – apl. Prof. Dr. M. Wanner

Based on the script provided by M. Wanner

Definition of soil

The soil is a natural body consisting of layers that are composed of minerals mixed with organic matter. It forms a structure filled with pore spaces, which could be changed by physical, chemical and biological processes. The soil is an abiotic and biotic habitat for a lot of organisms, as bacteria, fungi, protists, animals, and plants (Fig. 1).

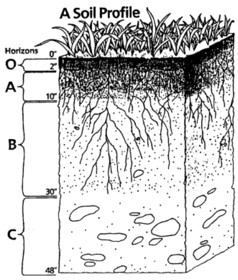

Figure 1: soil profile with the different layers. o-horizion=organic matter, a= top layer; humus b=subsoil, mineral layer, c=parent rock

Functions of soil

The basic functions of soil are regulating the water and the nutrient cycle. The soil is used as source of raw materials, like mineral resources. It is the livelihood for plants and animals.

The organisms of soil

In the soil are living a lot of different organisms. From microorganisms to vertebrates, a huge range can be found in a little area in the soil. The organisms are classified in microflora, microfauna, macrofauna, megafauna. (Fig. 2)

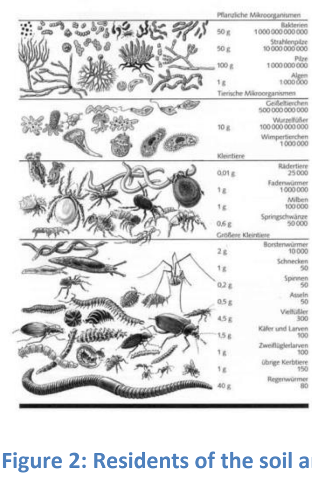

Figure 2: Residents of the soil and the abundance of species

Soil organisms reveal the highest abundance in the upper soil layers, as e.g. bacteria and fungi (microflora), protozoa and nematodes (microfauna, and larger soil animals (meso- and megafauna) (Fig. 2).

Classification of soil organisms

The part of the microflora includes bacteria, fungi and algae. Furthermore the classification of the microfauna (protists and animals) includes protists, rotifers and tartigrades. The animal kingdom involves e.g. the earthworms, snails, arthropods and vertebrates. Including this classification is also the size of the animals. The microfauna are with its protozoa the smallest unit in the animal classification. Thereupon in the mesofauna can be found bigger animals like springtails or mites. In the macrofauna there are earthworms and ground beetles and the largest size classification is called the megafauna, including big snails and earthworms.

Soil animal location

The animals are mostly restricted in the upper layer of the soil. The location can be classified in different areas:

- Edaphon: organisms living in the soil without the roots
- Edaphic: animals living on the soil surface
- Euedaphic: animals living inside the soil
- Hemiedaphic/anecic: animals living in the “transition zone”

Habitat

There are different types of habitats, where also different organisms live in. First there is the aquatic habitat, mostly for the microfauna. In the terrestrical habitat are macro-, meso- and megafauna.

Diet

There are different types of feed in the habitat of soil. Saphrophagus feed on dead organic matter, Microphytophagus feed on bacteria and fungi, the Zoophagus feed on living animals and Phytophagus feed on plants.

Why are soil organisms so important?

Soil organisms have a positive impact on the structure of soil, but also they are very important for the soil fertility. Those organisms are often bio-indicators for a success control of the soil and in which state the soil moves. Additionally they are used as management measures. The protection of soil is more and more debated, and in that case the soil organisms serves for better understanding, if a specific area in a landscape have to be protected or not. Hence with the existing of macro- and microfauna politicians get a better understanding for protection and the biodiversity of the soil, because there is no effective soil-management without knowledge of the soil animals.

Ecosystem services

Ecosystem services are one of the most important functions of soil organisms because they have such a huge impact on e.g. the soil formation. Additionally is the decomposition an example for the importance for soil fertility. Furthermore there are the bioturbation, organic matter or primary source of carbohydrates and nutrients for soil life. Of course there are more functions of the ecosystem services which are needed for the balance of life in the soil.

Decomposition of organic matter – litter breakdown enhanced by soil fauna

Biotic decomposition is a process where living organisms support the disaggregation of organic material with its dispersions and decomposition products. There is a directly decomposition by fragmentation of organic matter and the indirectly composition by feeding on microbes. Decomposition is one of the most important functions of organisms in the soil and receives the life cycle in the soil and the food web.

Problems with studying soil organisms

Studying soil organisms is not that easy as some people imagine. Including this studies there are a lot of problems. First of all soil is not homogenous, it is a variable, heterogeneous medium which changes a lot of times and it is a mixture of solid, liquid and gaseous environments. You never find a soil which is only one type of bedrock. The population of soil organisms can be extremely high and is quite diverse. Additionally the processes between the organisms and their environment are much important for the ecosystem. Therefore different methods are needs to investigate the soil.

Prokaryotes in Their Environments

Prokaryotes are very important in element cycling and the decomposition, because these organisms are able to fix nitrogen and because of this, they prevent the accumulation of toxic levels of nitrogen in lakes and oceans. Including this organisms, one of the oldest are *Cyanobacteria.* They can change earth by generating atmospheric O_2.

Protozoa

Protozoa are microscopic unicellular eukaryotic organisms and they are find in almost every possible habitat. Protozoa are very old animals, in fact they can be found in fossils in sedimentary rocks of pre-cambium era. Also they have a polyphyletic and paraphyletic origin.

Soil protozoa

Those protozoa feed mainly bacteria, but also fungi, algae and organic matter and because of that they have an important function to the decomposition in the soil and for the food and energy turnover. The length is 5 to 500 µm and they live actively in water-filled soil pores. They are responsible for 40 % of the Nitrogen mineralization and contribute 30 % to faunal biomass and 70 % to respiration.

Habitat of earthworms

There are three groups of species, the epigeic species are living nearly under the surface and they are high pigmented, because they are more often exposed to the sunlight. On the other hand there are the anecic species, which living deeper in the soil and they are able to construct burrows that are stable.

Soil arthropods

Another important class of animals in the soil are the arthropods. Here you can find species of Aranae, Pseudoscorpions, and Diplopoda.

Soil degradation, disturbance and organismic succession – apl. Prof. Dr. M. Wanner
Based on the script from M. Wanner

Definition of Soil degradation

Soil or land degradation is the decline of ecosystem services of the soil up to the point of the loss of these services. The main processes of degradation are water and wind erosion, the excess of salts and chemical degradation. Furthermore there are the physical degradation e.g. structure loss, sealing or crusting and biological degradation like biodiversity loss.

Disturbance or catastrophe

A catastrophe is an extreme tragedy with terrible consequences, in the ecology also called XXL-disturbance. A catastrophe includes e.g. an earthquake or a hurricane and after such events the ecosystem is much damaged and many organisms lost their habitat, the complete balance of the ecosystems is destroyed. Such an event is limited and it is not a regular component of the ecosystem. On the other hand a disturbance is an alteration of a regular process. As a consequence of a disturbance, there are often created niches and this event increase the biodiversity.
There are two mechanisms to increase biodiversity. The first one is the landscape diversity, which is linked to biodiversity. A change in the landscape generates a change in biodiversity. The second one is the decrease in local competition results and as a result of this there is an increase of the local biodiversity. This is called the intermediate disturbance hypothesis. On the other hand there is the metapopulation theory, which means, that a metapopulation considered consisting of several distinct populations together with areas of suitable habitat. The population is often stable because immigrants can re-colonize the habitat.

The characteristics of today‘s landscapes in Europe
There are different kind of factors which forms the landscapes. Most of them are effected by human like fragmentation in form of traffic and highways. Additionally there are the sealing, the intensive agricultural and forestal exploitation. Those changes include consequences for biodiversity. Genetic isolation is a result for fragmentation and soil degradation a result for sealing. With every change in landscape follows a change in biodiversity.

What is “natural”?

To call something natural you have to know what implies natural. The forests in Germany were cleared in the 18th century and now more than 98 % of the German forests are of “artificial” origin. 2000y ago Germany was covered with oak and beech forests. The lakes are strongly influenced by human, the rivers in Germany are to 98 % regulated and meadows resulted from agricultural use. As a result of this, all our landscapes are created by human and cannot be called as “natural” anymore.

Secondary habitats for endangered species: Post-mining landscapes & military training areas?

These areas are large, unfragmented, the soil is not sealed and there is no agricultural use. The soil is nutrient poor and there are highly dynamic conditions. Such habitats could be important for endangered species. For an example there is the Open-cast-Mining Site Berzdorf Rutschung. Here can be found very good conditions for early plant successional stages and it is a shelter from strong winds. The most important fact of this area is, that there is no public access and the ecosystem can develop as natural as possible. This area is quite important for dragonflies, amphibians, birds and vascular plants. The military areas are also small hotspots for amoebae, because these landscapes are not used anymore and the organisms could expand without human influences.

Soils under drought - Dr. Virginie Baldy

Soil can be considered as a medium for plant growth, as a recycling system, as a water supply and purification, as a habitat, as an engineering medium, etc.

Among the different horizons present within the soil profile, organic horizons occupy the upper layers of it. These organic horizons constitute the humus layers. Therefore from top to bottom it is possible to find different organic soil horizons: non-fragmented leaves (OL), organic layer including faunal faeces (OH), organo-mineral layer (E or A). These superficial horizons are the most active in a food web and flow of energy perspective. Soil quality and fertility depend from the decomposition process. This leaf litter decomposition is a key process for ecosystem functioning, and it’s mainly a biological process.

There is a lack of data about the C sequestration in humus.

Fragmentations and mixing of the horizons create physical and chemical modifications. As a result, humification and mineralization processes occur.

This decomposition process is carried out by different groups including fungi, bacteria, insects, arthropods, etc. According to their respective size, it is possible to distinguish among: microfauna (<0.2 mm, nematodes and protozoa), mesofauna (0.2-4 mm, microarthropods and others), macrofauna (> 4mm).

Leaf litter decomposition is controlled by:

a) Leaf litter chemistry (structure and defense compounds, nutrients)

b) Environmental conditions (i.e. water content)

For studying litter decomposition, litter bags in situ approach method is used. With mesh size depending on the fauna we wanted to study. We put a certain amount of litter in net bags. Some of the litter bags were retrieved from the field at regular intervals. We determine leaf mass loss during decomposition, and decomposers associated to decomposed leaves, by means of biomass and diversity measurements.

Methods for studying the mesofauna:

• Berlese funnel mesofauna extraction. Based on the principle that mesofauna escapes from dry litter and falls down to an alcohol solution. After extraction, organisms are counted and identified.

• Ergosterol is a fungal biomass indicator: extraction, purification and quantification by HPLC

• Microbial catabolic profiles associated to decomposed leaves (based in color changed related to degradation capacity) are also used due to optical density is proportional to degradation capacity of the organism.

• Litter secondary metabolites dynamics: terpenoids and phenolics extraction (chromatography and spectrometry).

Do stress and disturbance affect leaf litter decomposition?

Mediterranean terrestrial ecosystem is characterized by a climate with a hot and dry summer, low annual rainfall, violent rainy and windy events, recurrent fires, sols often shallow, and an old anthropogenic pressure. These ecosystems are colonized by plants adapted to these stressed conditions, with special morphology (as scleprophyllous plants are dominant) and special physiology as these plants are producing large amount and diversity of secondary compounds.

Water stress affects litter decomposition: during dry periods fungal biomass development is almost stopped and therefore decomposition is almost stopped. There is a positive linear relation between litter humidity and litter fungal biomass, and this is also visible in the number of individuals of mesofauna which is increased in humid seasons. Mesofauna colonization occurs later than fungi colonization since mesofauna needs fungi to start the process. In the temperate forest, we observed a continuous dynamics for leaf mass loss and decomposers. On the opposite, in the shrubland, we observed a discontinuous dynamics, depending on drought periods.

Compost amendment on Mediterranean soils is a suitable technique for accelerating the natural recovery process of soils degraded by recurrent fires, by increasing soil fertility. Although, sludge compost contains high quantity of P which can represent an environmental problem. Compost amendment increases leaf nutrients content but does not affect litter decomposition, fungal biomass and abundance of microarthropods associated with litter. It helps the plants to survive during dry period because it contains more water than soil.

In the French Mediterranean region you can see a land use change after an abandonment of agriculture. This abandoned land is colonized by Aleppo pine (*Pinus halepensis* Mill.) which is an expansionist species. In 1980, 180 000 ha were colonized by this species, compared to 36000 ha at the end of the XIXth century. *Pinus halepensis* is a plant species which produces a high amount of Plant Secondary Metabolites (PSM). There are three ways of release of PSMs: i) volatilization and this way of release is involved in biosphere-atmosphere relationship; ii) leachates and roots exudates and then participate to biotic interactions; iii) leaf litter decomposition and then participate to biogeochemical cycles. We compared the dynamics of PSM amount and diversity during needle decomposition in three successional stages of *P. halepensis*: colonization stage (~10 years old), stabilization stage (~30 years old) and mature stage (>60 years old, mixed forest).

The chemical diversity of *P. halepensis* varied according to organs like roots or needles and successional stage, especially between colonization and mature stages. We performed a leaf litter decomposition experiment during 30 months in the three pine forests, and we determined leaf litter mass loss, phenolics and terpenoids litter contents, microbial and micrarthropods dynamics. We sampled litter bags every 6 months after rain.

We observed a quick leaching or/and decomposition of phenolics during decomposition but for the colonization stage phenolics remained stable longer compared to stabilization and mature stages. We observed a slower decomposition of litter terpenoids compared to the phenolics, and a lower amount of terpenoids in litter from colonization stage forest compared to the two others stages. Dynamics of decomposers: We observed an increase of abundance of microarthropods during the process whatever the stage, and fewer organisms associated to decomposed leaves for colonization stage. We observed a negative correlation between fungal biomass and phenolic index during decomposition. The more phenols, the fewer fungi associated to leaves. Leaf mass loss was less important for colonization stage. In conclusion we observed more phenolics, less terpenoids, less decomposers and a lower decomposition rate for the colonization stage, due to phenolics.

Secondary Metabolism of Plants – Importance and functions – Prof. Dr. Catherine Fernandez

Based on the script of Prof. Dr. Catherine Fernandez

Primary metabolites are essential for growth and development and have genes with high stringency controlling essential functions. The secondary metabolism is essential for the survival of the individual and those genes are with a high plasticity controlling functions that are under selection pressure of a continuously changing environment. They are unique, diverse and adaptive. The primary and secondary metabolites serve the producing organisms by improving their survival fitness. A further attribute is the high diversity of these metabolites. The most important blocks employed in the biosynthesis of secondary metabolites are derived e.g. from Acetyl-CoA.

There are different types of secondary metabolites, e.g. Phenolic compounds, terpenoids and alkaloids. Terpenoids are formed by the polymerization of units of 5 carbons and are generally lipophilic and because of that they can be found in essential oils. Another example are the alkaloids and they are a group that contain mostly basic nitrogen atoms. They have a great biological activity and pharmacological effect and are often used as medications. Phenols or phenolics are a class of chemical compounds consisting of a hydroxyl bonded directly to an aromatic hydrocarbon group. The hydrophilic compounds are biosynthetized is in the cytosol, alkaloids and terpenoids are synthesized in the plastides, but also some alkaloids are produced in the mitochondria. The lipophilic compounds are produced in the endoplasmic reticulum. Furthermore the production of the secondary metabolites varies according to several parameters e.g. physiological like age, season and organs. Some varies in the genetic factors also influence the production of these metabolites. Biotic interactions (e.g. herbivory) and environmental parameters and have also impact on secondary metabolite production. For example, the effects of water have an impact of the production, because drought increases PSM production. In plants there can be found a different location of metabolites like in leafs, rod or fruits.

Secondary metabolites are also necessary for surviving of the organisms, because of that there are some theories on defense production and resources. For example the Carbon nutrient balance hypothesis (CNBH). This hypothesis proposes that the degree of resource availability in the habitat determines plant carbohydrate status which determines the nature of chemical defenses. Another hypothesis is the so called Growth-Differentiation Balance Hypothesis. It relies on an assumed negative correlation between defense and growth. Growth is here dominant under favorable conditions and differentiation dominates when conditions are suboptimal for growth. The role of plant secondary metabolites concerns defense against abiotic factors (e.g. drought, high temperature, ozone), biotic factors (e.g. herbivory, pathogens or plants via allelopathy).

Secondary metabolites are released in the environment by four pathways: volatilization leaves leachates, roots exudates, decomposition of leaf litter. The compounds could act in allelopathy processes. Allelopathy is defined by Rice (1984) as “Any direct or indirect effect by one plant, including micro-organisms, on another through the production of chemical compounds that escape into the environment and subsequently influence the growth and development of neighboring plants includes both inhibitory and stimulative reciprocal biochemical interactions” and by Inderjit (2011) as « Suppression of the growth and/or establishment of neighboring plants by chemicals released from a plant or plant parts ». Allelochemicals: the secretions of plants are the chemical substances which can affect the growth, behavior and population biology of other live beings. Currently, allelopathy research focusses on the interaction between:

- Plants – plants,
- Plants – microorganisms,
- Microorganisms – microorganisms.
- Allelopathy include also autotoxicity

In allelopathy there is donor plant and target plant or microorganism. Allelopathy plays a role in plant succession as in the secondary succession in Mediterranean region (with *Pinus halepensis* as donor plant). This process is also important in the context of plant invasion, with the Novel Weapons hypothesis (Callaway & Aschehoug, 2000). Microbes are important in allelopathy as targets and as mediators of allelopathy in plants. They can enhance plant allelopathy effect (degradation of toxic compounds could create more toxic products; Mycorrhizal networks could facilitate the transfer of allelochemicals from donor to target plant). However, microbes also can detoxify allelochemicals through degradation and limit allelochemical impact.

Seminar by Lukas Griesinger und Jakob Gerber

Protozoa as bioindicators in agroecosystems, with emphasis on farming practices, biocides, and biodiversity (W. Foissner, Agriculture Ecosystems & Environment, 1997 Universität Salzburg)

Introduction: Soil Protozoology

- Unicellular animal-like eukaryots
- Mostly asexual reproduction (fission)
- Sometimes sexual

- Important part in the soil food web (feeding on bacteria)
- Moist conditions required
- Can form cysts
- Most frequent in the upper 15 cm of soil

Protozoa classification

- Testacea (pseudopods and a shell)
- Naked amoebae (pseudopods and no shell cover)
- Flagellates (whip-like flagella)
- Ciliates (hair-like cilia)

Groups of protozoa

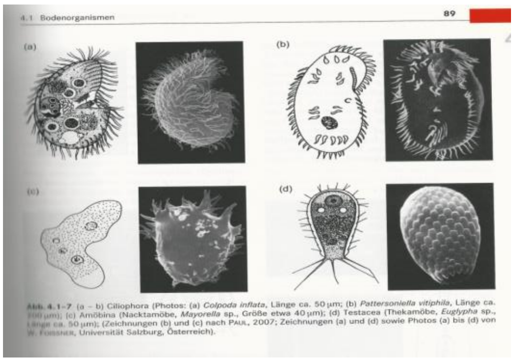

Figure 3: Picture of each group (Lehrbuch der Bodenkunde, Scheffer/Schachtschabel)

Importance of protozoans in the food web

- Enhancing the growth of others due to excretion of 60% of ingested nutrients (Bardgett and Griffiths 1997)
- They make nitrogen (also phosphorus) available by feeding on bacteria and release it for others like plants
- They regulate and stimulate bacterial communities by grazing on them
- Eventually there is an increase of the decomposition rate and soil fertility
- In general the presence of protozoans is valuable and necessary for a good soil quality

Conventional Farming and ecofarming effects on soil fauna

Ecofarming method: main aim is to protect and stimulate soil life, as well as maintain soil fertility and resource regeneration if it is possible

Conventional farming method: main concern is more an economic profitable approach in order to farm just efficient

- Significant differences between the two farming types considering a wheat field and a vineyard

→ there is more biomass on the ecofarming site

- Soil zoological factors of ecofarmed and conventionally farmed grasslands and meadows are not really different

Results:

1. Many zoological parameters are statistically not different between the two farming plots
2. No distinct differences in composition of ciliates and testate amoebae between ecofarmed and conventionally farmed fields
3. Nevertheless there is a higher biological activity in ecofarmed sites also accompanied by higher humus content and less soil compaction
4. In semiarid regions conventional farming does more damage to soil fauna than in Atlantic regions
5. Agricultural ecosystems are more sensitive to conventional farming than ecofarming
6. Soil life is distinctly richer in ecofarmed variants (Pfiffner et al. 1990), depending on investigation methods
7. Potential of nitrogen mineralization and also microbial and parasitoid abundance and diversity is higher in organic farms
8. Still there are sometimes no significantly differences for any of the investigated parameters

→ to sum up it is best according to present knowledge to prefer farming methods which conserve soil life and biodiversity of communities! (But also further research has to be done)

Effects of biocides on soil protozoa

Well-designed field studies are rare.

For the most commonly biocides there are studies.

BUT the testate amoebas have been mostly ignored.

Even though pesticides and their metabolites are bound in humus
=> a main source of food for amoeba

5 Conclusions

1. Reaction of soil protozoa to biocide stress is the same as of other organism
2. Protozoans are just as sensitive to pesticides as other test organisms
3. Insecticides are more toxic than herbicides
4. Insecticides disturb soil protozoa critically
5. Fungicides very likely do not disturb soil protozoa critically

Comments on the paper

- It is more of a review and summary
- Many cites
- Criticism and hints that literature and efforts in this field of biology have to be improved

Seminar by Anne Lotter and Gloria Gessinger

<u>Dynamics of initial ecosystem Development at the artificial catchment Chicken Creek, Lusatia, Germany (Michael Elmer • Werner Gerwin • Wolfgang Schaaf • Markus K. Zaplata • Karin Hohberg • Rossen Nenov • Oliver Bens • Reinhard F. Hüttl)</u>

Aim of the environmental monitoring program

- ecosystem development:
  - increase of complexity of structures and their interactions
- determine evolving properties and functions
- ➢ fundamental approach and essential requirement to untangle the complex web of processes
- ➢ better understanding of both ecosystem functioning as well as ecosystem reactions to alterations of structural properties.
- During ecosystem development both the complexity of structures and their interactions increases as additional patterns (e.g., surface and subsurface flow paths, humus layers and soil horizons, rooting channels and worm burrows) and processes (e.g., erosion and sedimentation, C-accumulation and pedogenesis, effects of biota) appear.
- These initial processes determine and control evolving properties and functions of the system
- Thus, the analysis of young ecosystems in their initial stage of development seems to be a fundamental approach and essential requirement to disentangle the complex

web of processes, and help in better understanding both ecosystem functioning as well as ecosystem reactions to alterations of structural properties.

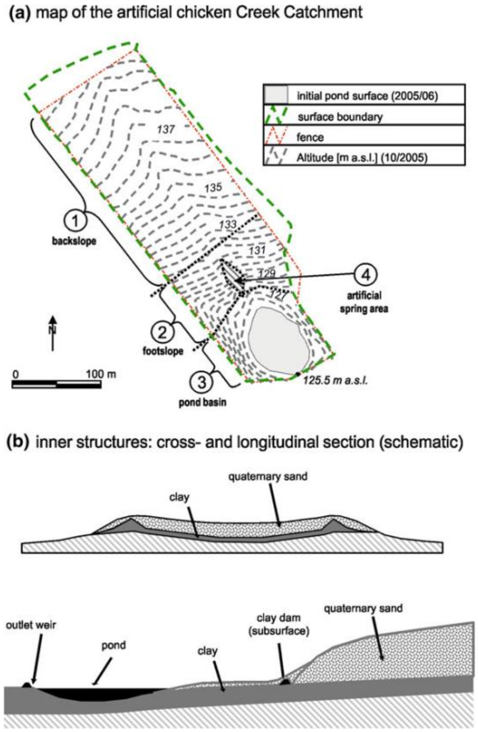

Figure 4: Map of the artificial catchment (a) and schematic profiles showing inner structures of the site (b)

- two-layer system
  - clay layer
  - overlying sandy layer
- watershed covered sand area of 6 ha
- unrestricted and unmanaged succession
- the site can be divided into three major sections:
  - backslope area
  - footslope
  - pond basin
- subsurface clay dam

  - barrier for groundwater fluxes

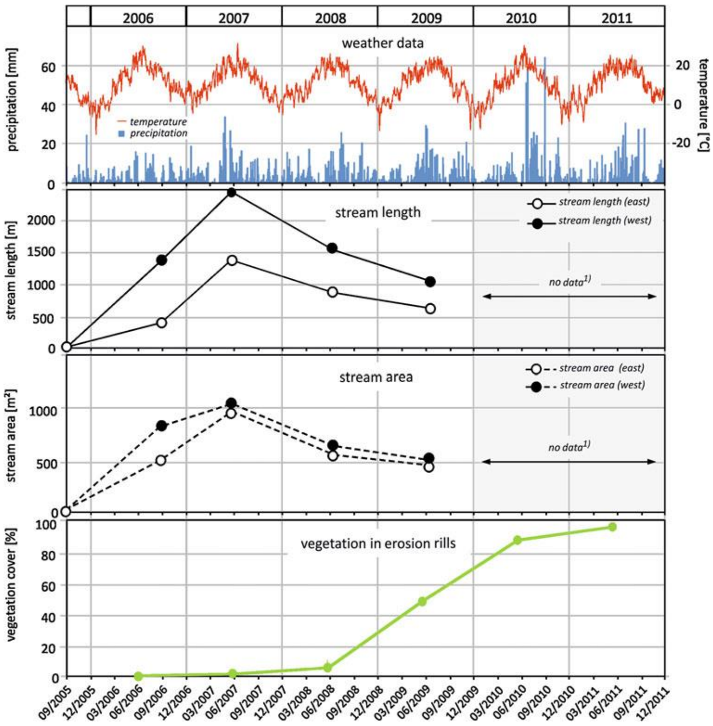

Figure 5: Geomorphic development of the Chicken Creek catchment since autumn 2005

- dominated by intensive surface runoff processes
  - ➢ intense sheet and gully erosion
- length and area of active streambeds within erosion rills increased
- Biological colonization obvious in 2009
  - ➢ changed geomorphic development
  - ➢ length and area of eroding rills decreased

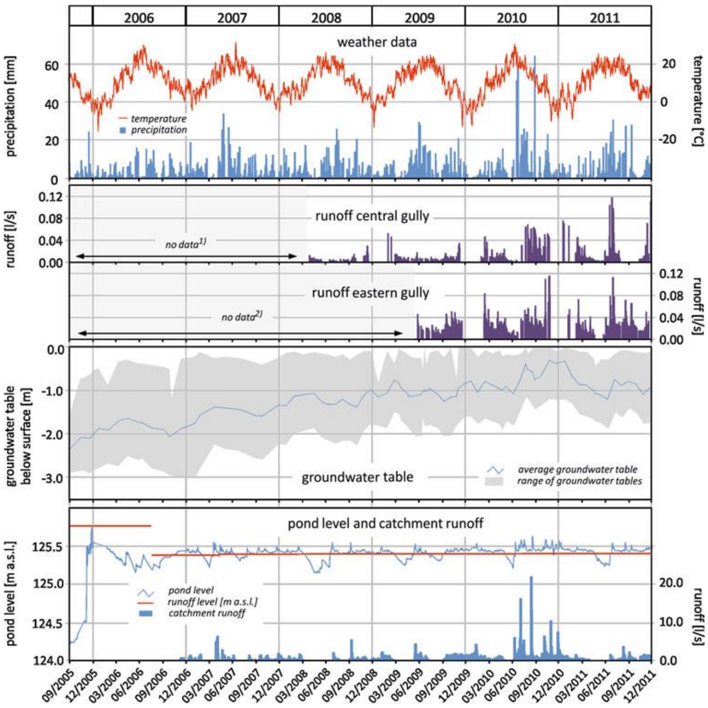

Figure 6: Hydrologic development of the Chicken Creek catchment since autumn 2005

- establishment of a groundwater body proceeded over several years
- completed in 2009, only the seasonal fluctuations remained
- high amounts of rainfall in 2010
    - ➢ temporary increase in groundwater levels up to the surface
- close relationship between the temporal patterns of rainfall and discharge at the pond weir

  = initial conditions of the catchment

- sudden, complete filling of the pond basin in winter 2005/06

    - ➢ specific meteorological conditions, bare sediment surface und physical soil crusting

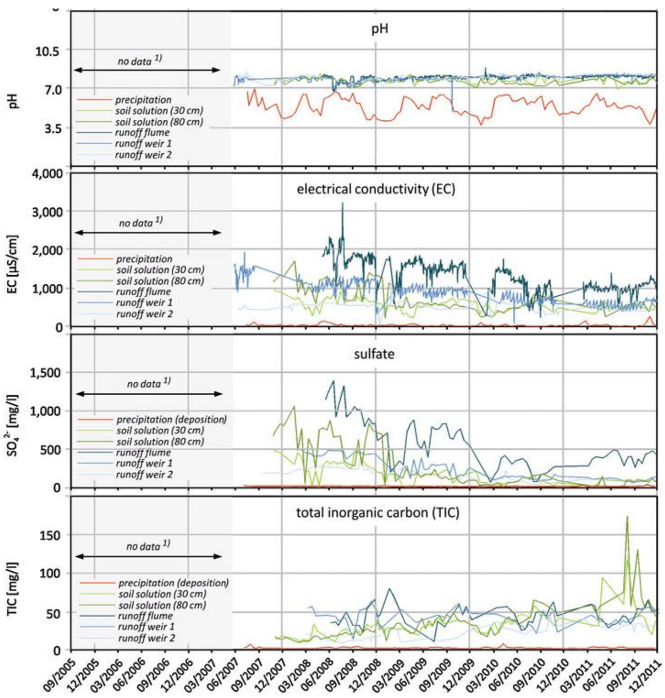

Figure 7: Chemical development of the Chicken Creek catchment since autumn 2005

- concentrations and EC values of the soil solution corresponded to the chemistry of runoff water
- mean pH values varied between 7.0 and 8.4
- decreases of SO_4, Ca^{2+} and Mg^{2+}
  - ➢ electrical conductivity
  - ➢ traces of gypsum

    = source for both Ca^{2+} and SO_4
  - ➢ gypsum was dissolved and mobilized within a few years
- increasing vegetation cover and litter input to the soil
  - ➢ increasing inorganic carbon (TIC) concentrations

→ strong source for calcium, magnesium, sulfur and inorganic carbon

→ strong sink for nitrogen

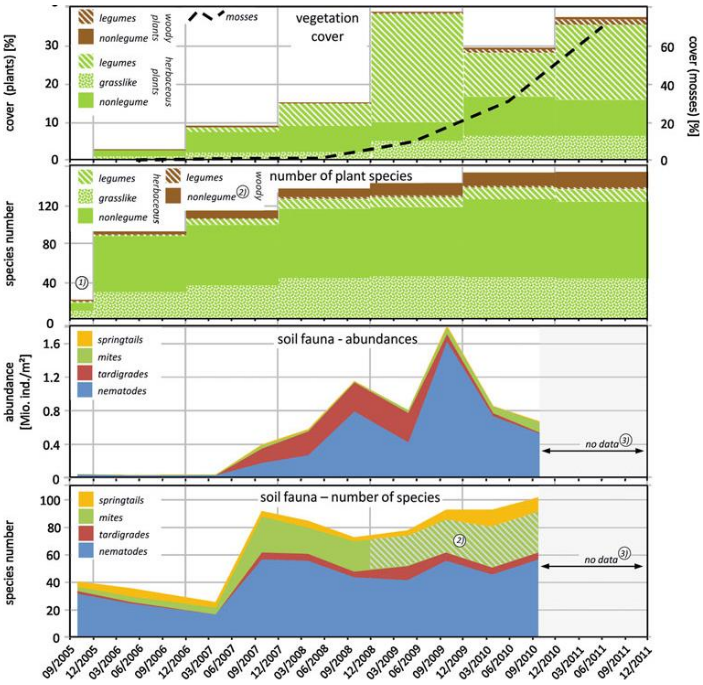

Figure 8: Biological development of the Chicken Creek catchment since autumn 2005

- patterning of species composition
- first dominating plant species *Conyza canadensis*
- Total plant cover increased and reached a preliminary maximum in 2009
    - ➢ groundwater reached its maximum level
- A general decline in vegetation cover was then observed in 2010
    - ➢ decreasing cover of the dominant species *Trifolium arvense*
    - ➢ unfavorable weather conditions
        - – harsh winter season 2009/2010
        - – high rainfall amounts during summer 2010
- importance of woody plants is increasing
    - e.g. leguminous tree species *Robinia pseudoacacia*
      = major component of the establishing vegetation
- increase of bryophytes (mosses) since 2009/2010
    - ➢ favored by the wet weather conditions in 2010
- increase in total species numbers has slowed down
- numbers of soil animals were low during the first 2 years
- densities steadily increased since 2007
- None of the soil faunal groups under investigation have yet reached their usual species numbers

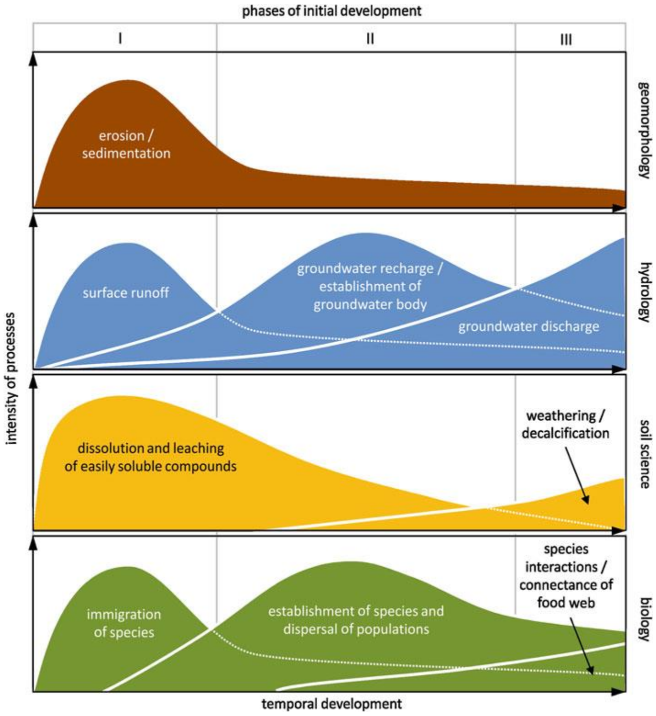

Figure 9: Intensity of geomorphic, hydrologic, pedogenic and biologic processes and their temporal development during the initial ecosystem stage

I: Geophase

Sandy substrate with low organic matter

- ➢ Erosion and Sedimentation
- ➢ formation of new structures
- ➢ high surface runoff due to a lack of surface cover

pioneering biota:

1. agricultural: lucerne
2. from forests: black locus, pine, oak

scattered populations e.g. near the water rills

II: Geo-hydrophase

- Less erosion because of biological soil crust
    - ➢ higher stability, e.g. mosses
- Ion transport into groundwater, e.g. gypsum
- decalcification
- Initial groundwater recharge through infiltration
- Infiltration increases because of the biotic soil crust

- fewer runoff

Phase III:

- Biotic interactions:
  - vascular plants replacing moss crust
- increasing soil fauna and complexity of soil food web
- Groundwater discharge because of higher evapo-transpiration rate
- Increased heterogeneity for:
  - water availability
  - nutrient availability

Conclusion:

- highly dynamic development
- three phases of ecosystem development can be distinguished
- soil fauna still low
- few feedback mechanisms

→ Chicken Creek catchment still in a very early, initial state

Expectations for future development:

1. quantitative increase of biomass
2. higher connectivity
3. qualitative growth: energetically more efficient patterns
4. increasing feedback mechanisms

→ investigation of interactions between the different compartments is needed