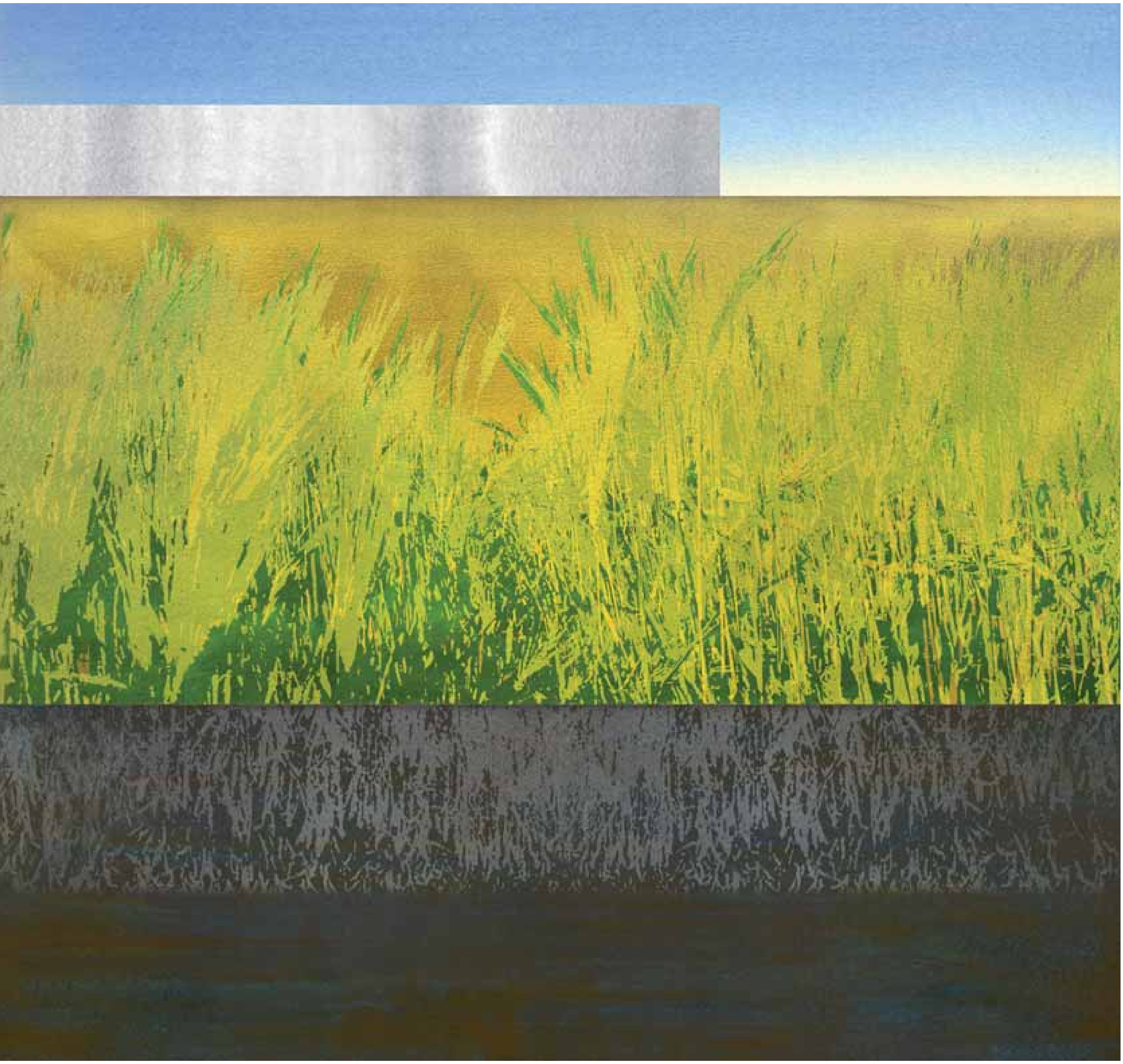
Soil – A Precious Natural Resource



Soil as a Resource
National Research Programme NRP 68

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Foreword

Soil is more than construction land 'in a prime location' or pasture- and farm land. The soil is a habitat. Our view of the soil, however, is often just a surface view – quite literally. But a look beneath the surface is well worth it. The importance of the soil for life on Earth is greatly underestimated. Without intact soils, we would be lacking the most important essential basis of life.

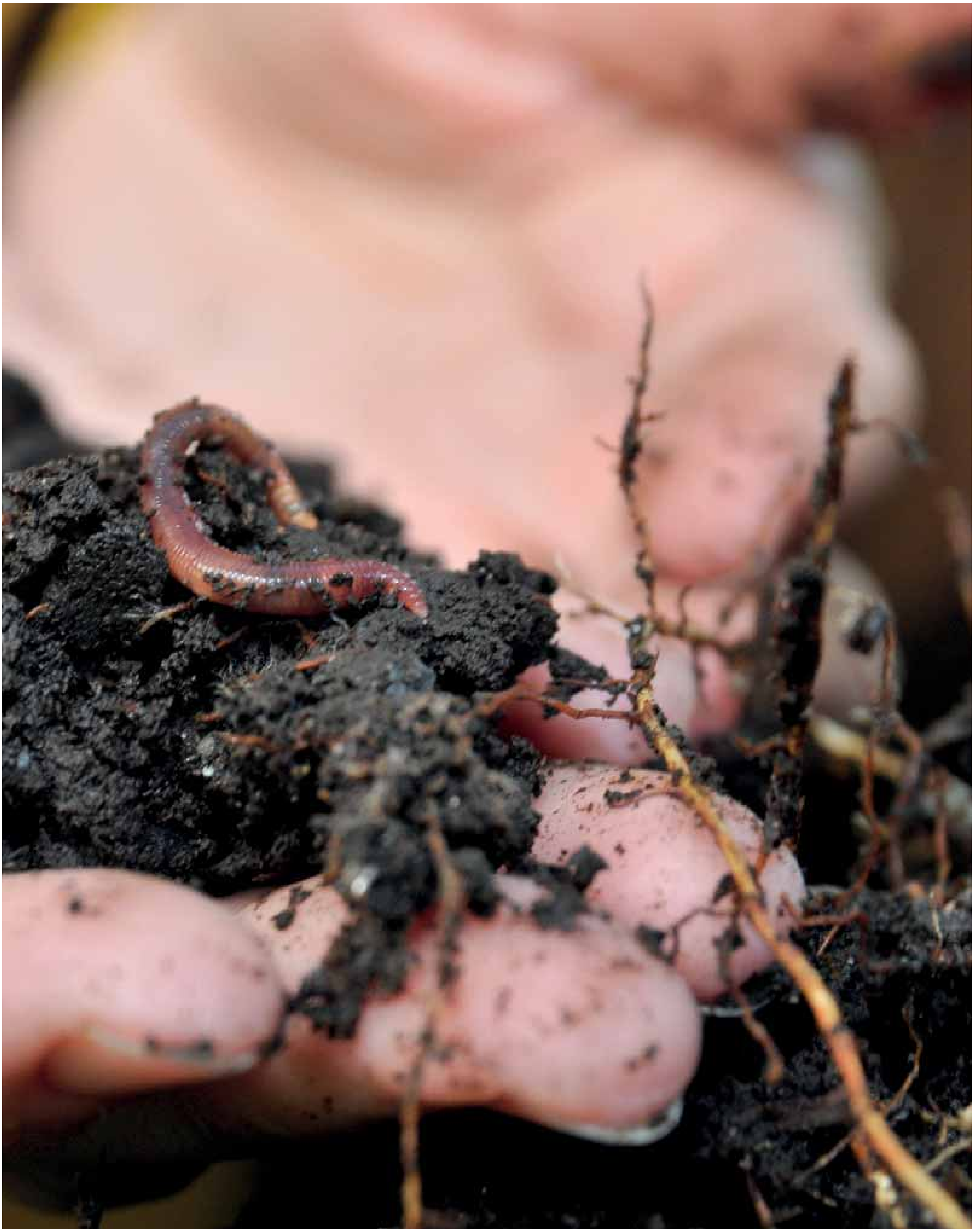
The cosmos of soil between the plant cover and bedrock is the indispensable connecting element between atmosphere and groundwater. This central hub for all important material and energy flows on Earth performs numerous economic and ecological functions: Soil is the basis of food production, a habitat for innumerable organisms, a water filter and a natural store for carbon and water. Billions of living organisms in each handful of soil decompose old plant material into their basic building blocks and make these nutrients available to new plants.

Soil therefore deserves our attention. Particularly in Switzerland, where soil is scarce, a better understanding is needed. For this reason we welcome that with this brochure, researchers and the Federal Administration (Federal Office for the Environment, Federal Office for Agriculture, and Federal Office for Spatial Development) bring home the importance of soil and its essential functions. How many of us are aware that each shovelful of earth has a formation history reaching back hundreds of years? Or are conscious of the fact that the soil secures the living and economic environment of Switzerland?

So let us be concerned about the soil, this basis of all life. Let us take care of our soil. Let us preserve our cultivated land. For our quality of life is directly dependent upon the quality and quantity of the soil. Let's keep our feet on the ground!

Federal Councillor Doris Leuthard

Federal Councillor Johann N. Schneider-Ammann



The fascination of soil

We seldom have a clear view of the fascinating world beneath our feet. It comes to light primarily when excavators tear open the ground in the creation of construction pits, thus offering a visible perception of the three-dimensional cosmos of soil. It is worth climbing down into one of these pits and taking the time to study the intricate walls. On offer in these hidden worlds can be a colourful layered story sequencing years and years of mankind. The hollow cavities of burrowing fauna transverse the earth like veins, each with a story of their own. Only when you are surrounded by and are witnessing this world first hand, can the complete impression that you are standing within not just a self-contained ecosystem, but an ancient ecosystem, come to life.

Soils are formed from rock

Approximately 10,000 years ago, towards the end of the last ice age, there was no intact soil in the larger areas of Switzerland. Glaciers had ground it down and left behind nothing but bare rocks or moraine materials as they retreated. Sun, rain, frost and soil organisms then worked symbiotically together in weathering the rock material, chemically and mechanically, ultimately breaking it down into smaller particles. As a result, soil was continuously taking form and plants could begin to thrive.

Minerals were transformed and, through the method of leaching, were washed further into deeper layers as the rock broke up progressively into loose soil. Over thousands of years the typical sequence of successive layering of soil developed: typically a layer of topsoil rich in humus over a layer of subsoil consisting of strongly weathered parent rock and washed out material from above. Below that lies the only slightly weathered parent material and finally the bedrock.

Many types of soil

Depending on the parent rock material, local topography, climate and water availability, differing soil types developed after the final stages of the last ice age. There are shallow or deep, acidic or alkaline, nutrient-poor or nutrient-rich, wet or dry, sandy or clayey soils – as well as every conceivable variation between these extremes. The astonishing number of variations is represented within a large range of the colour spectrum, from red to yellow to blue and all the shades in between.

Moist and warm conditions are optimal for soil formation as it is under these conditions that soil organisms who are responsible for the rock-weathering processes are most active. For this reason, the soils in the Central Plateau of Switzerland, which are 1 to 2 metres deep, are clearly much thicker than the soils in the Alps, which are often only a few centimetres deep.

As long as weather and water are continuously interacting with soil populated by organisms, the development of the soil is never completely at an end. In a seemingly motionless earth there is always something in a state of flux: humus constantly forms and decomposes, seepage water dissolves soluble materials and washes them into lower layers of soil, clay and soil particles shift into deeper layers and iron oxidizes, giving many soils a typical brownish red colour.

The long lasting life of soil

Physical and chemical weathering

Soil organisms

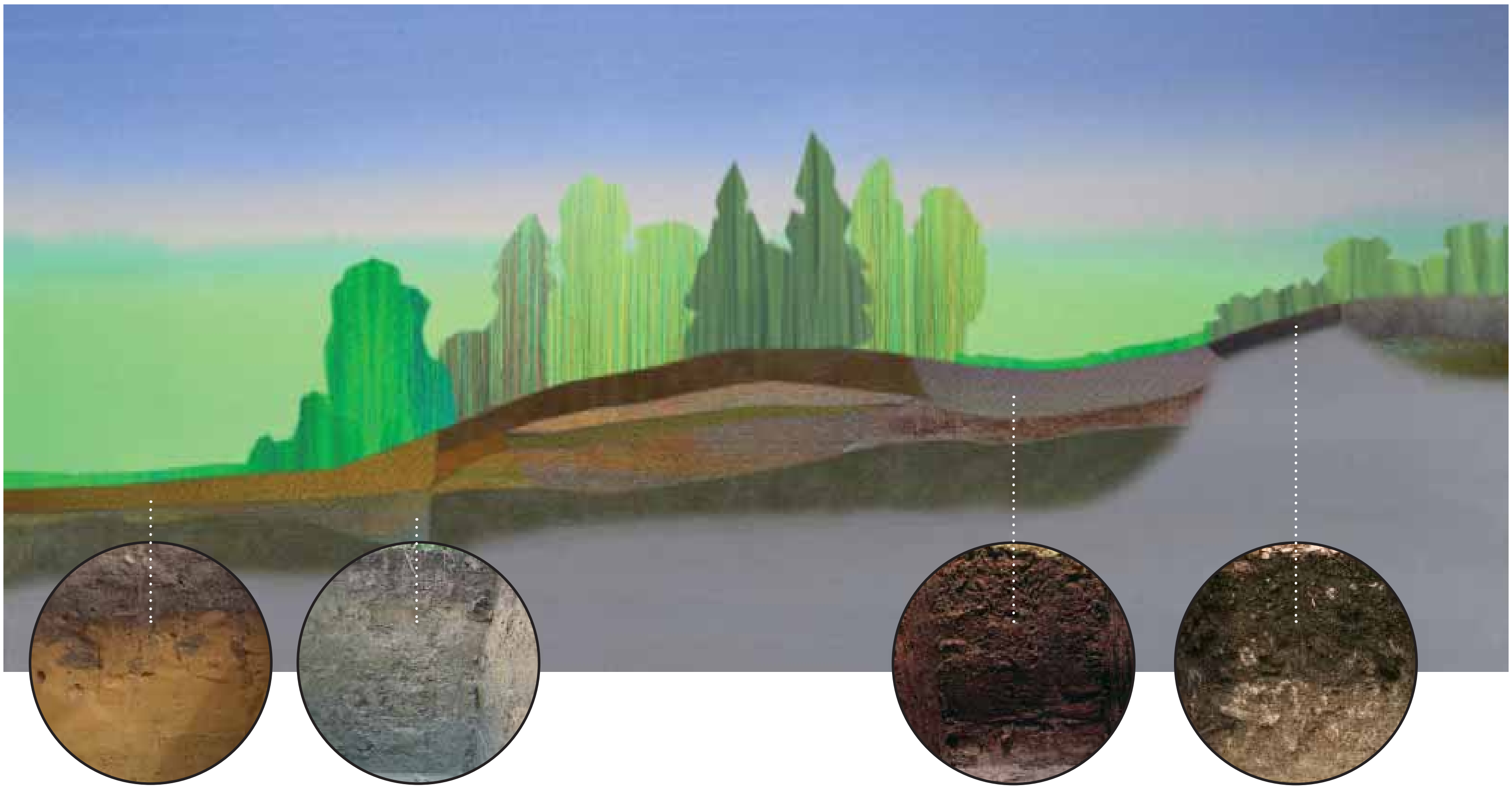
Rock — Time progressive development → **Soil**

The habitat "soil" has been formed over thousands of years from inanimate rock. Sun radiation, rain, frost and soil organisms weather the rock or moraine material of the glaciers. As a rule of thumb, it takes 100 years for one centimetre of soil to form.

On the surfaces that result from the rapid retreat of the glaciers in the Alps, the various stages of soil formation can still be seen today.

Land pits offer a great insight into the colourful sequential layering of the soil.

Versatile ground



Regardless of the location of a hole in the ground, we will always come across different soils. Depending on the type of rock, the slope, the local climate and water availability, a specific combination of processes of soil formation acts at a particular location and leaves behind soil profiles with different characteristics.

Tardigrades: the bizarre inhabitants between the layers of leaves, soil and moss beds.

The world beneath our feet

When we hike through the woods, we enjoy the calm serenity. What we fail to notice is that beneath our feet the ground is teeming with diverse life forms – the engine behind our own existence. It is accredited to these most tiny organisms in the soil that life on Earth's surface exists at all.

Soil as a habitat

Without seeming so, soil is a lively habitat filled with many living organisms. Even though the ground appears to be simply a compact layer, between its components are countless minute margins where an army of organisms are maintaining the underground "factory of life". In fact, approximately half of the space that soil consumes consists of microscopically small hollow spaces. The solid part of the soil forms a filigree structure composed primarily of clay particles, humus particles and sand. The spaces in between – known as soil pores – are filled with water or air and house countless animals, plants and fungi. This is a habitat of gigantic dimensions: the entire habitable area of a handful of clay soil is greater than a square kilometre. It is home to billions of microorganisms and to these organisms, every clump of soil is practically an infinite landscape.

Overwhelming diversity

Only a small fraction of the organisms living within the soil are known to science. "We know more about the movement of celestial bodies than about the soil underfoot", lamented Leonardo Da Vinci more than 500 years ago. Unfortunately, little has changed since. We do, however, know that one handful of soil contains more organisms than there are humans on the planet. In only one gram of soil, close to 50,000 types of bacteria and up to 200 metres of fungus threads can be found. The weight of all living organisms in the soil layers of one hectare of land can be as much as 15 tons, equivalent to the weight of 20 cows. In comparison, the grass on one hectare of land in the lowlands feeds only about two cows.

For researchers, with all of its organisms, soil can be viewed as a gigantic yet minimally studied "pharmacy". In 1928, Alexander Fleming discovered the first antibiotic, penicillin, and its antibacterial characteristics. Penicillin is a natural substance released by Penicillium soil fungi. In light of this knowledge, researchers worldwide have continued to collect a myriad of soil organisms and tested whether the unicellular organisms, bacteria, fungi, algae, lichens and plants can also produce antibiotics. In doing so, the researchers have discovered numerous new substances which have almost all since become important medications. The potential for furthering medication knowledge and production is vast but has not yet even begun to be utilised.

Teeming with life

Pictures of soil organisms, once zoomed in, show an impressive diversity of how fascinating and beautiful they can be. The soil thrives with life and not in a motley jumble similar to the many species living above ground, but in a complex network of relationships; including carnivores, herbivores, scavengers and omnivores.

In soil, teamwork is essential and omnipresent. One particular plant group, the leguminous plants, which clover and beans belong to, has a symbiotic relationship with the bacteria that live in the soil. These minute little industrious workers are able to

There is special trade relationship between the roots (yellow) and mycorrhizal (green). The roots supply the fungus with sugar and the fungus supplies nutrients, protects the roots from pathogens and pollutants, improves water absorption and helps with drought resistance.

Amoebas are voracious protozoa Characterised as predators, they use their pseudopodia to claim their prey and help develop the microfauna to contribute to the ecological balance.

take the nitrogen from the air and convert it so that the plants in turn can use it to thrive, and as a response the plants provide the bacteria with sugars.

Much more widespread is the close interrelationship between plant roots and soil fungi. Over 80 per cent of plant species form a mutually beneficial symbiotic relationship with a particular fungi called "mycorrhiza" (fungus roots). The fungi colonize amongst the fine roots of host plants and increase the root growth system and enhance the plants' contact with the soil. The fungi provide the plants with the water and soil nutrients they need to survive and the plants provide the fungi with sugars. Porcino and amanitas are prominent examples of root fungi, as they are recognized as assisting in the growth of important tree species such as spruce. The dense fungal structures on or within roots also work to protect the plants against pollutants and pathogens.

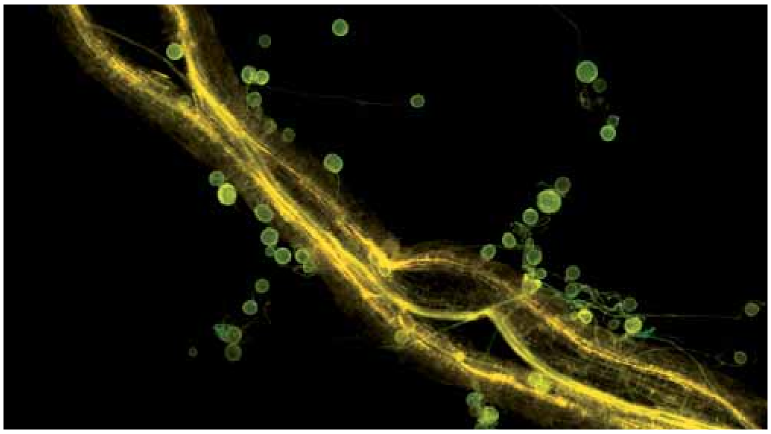
The fuel for the underground ecosystem is provided by aboveground plants via their root excretions and the dead leaves, stems and branches. This material is utilized especially by earthworms, insect larvae, snails, springtails, mites, woodlice, nematodes, protozoans, bacteria and fungi, which themselves are the primary food source for many other organisms. The "shark" amongst the underground creatures is the mole. Moles predominately hunt and feed on earthworms as they move and eat through layers of the soil, filling their intestines with decomposing organic material and earth. Their channels and burrows loosen and aerate the soil, which improves drainage, especially after a heavy rainfall.

Plants on the surface of the earth are largely dependent on soil organisms and vice versa. In an area the size of a standard football field, soil organisms can break down up to 25 tons of dead plant materials and animal remains every year. Without them, gigantic compost heaps would tower skywards within our forests and woods.

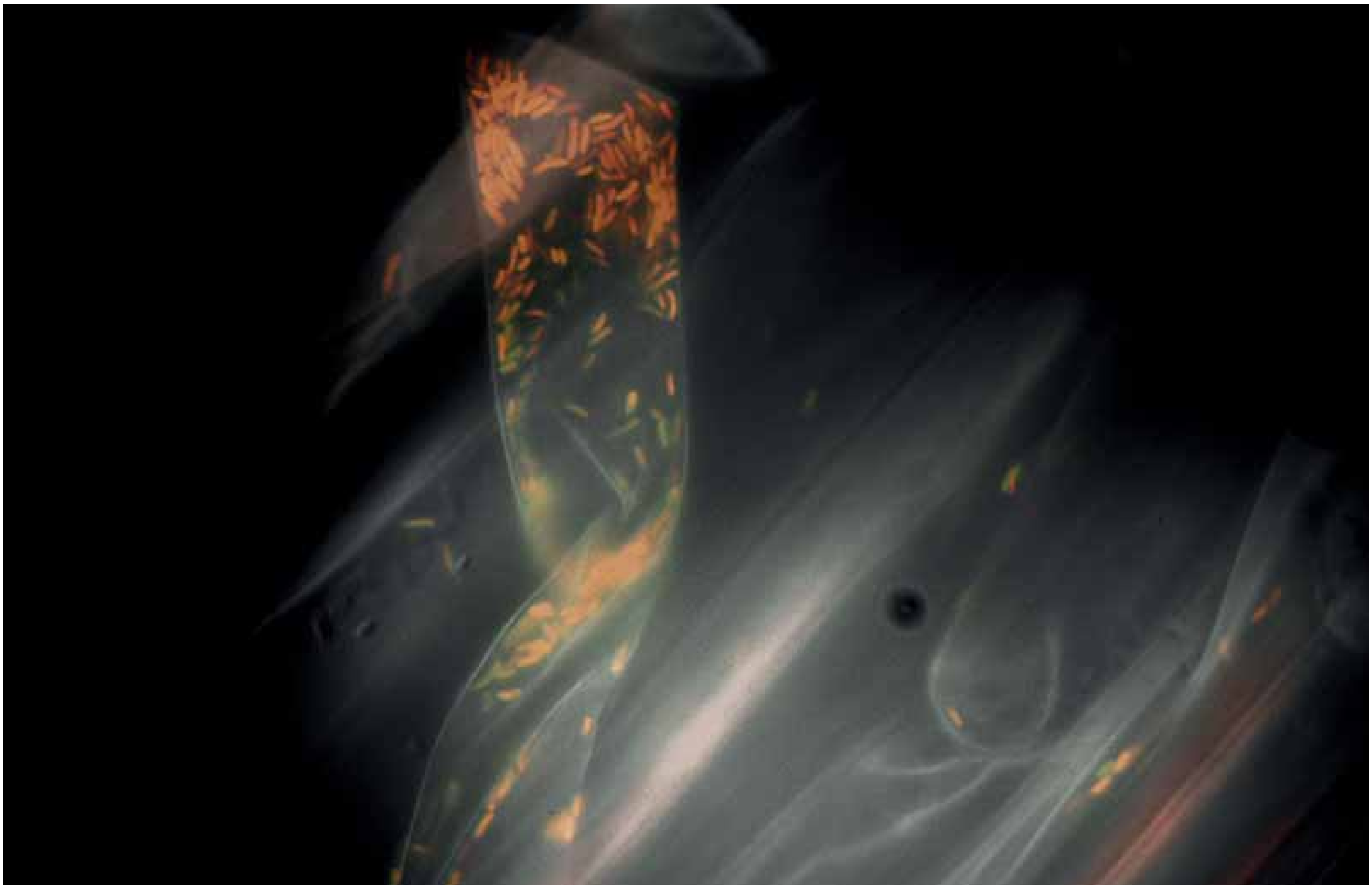
Valuable humus

Soil organisms endure hard labour around the clock. They decompose dead organic material and turn it into a stable substance called humus. Without enriching humus, the ground would be no more than a giant sandbox. The organic matter within soil is a reliable source of nutrients for plants and also a storage medium for water, pollutants and carbon; therefore humus plays a central role in the maintenance of the nutrient, water and carbon cycles.

Soil organisms continuously mix humus into the lower soil layers. Within a single cubic metre, earthworms alone assist by moving up to 12 kilograms of earth per year. This loosens the soil and forms stable soil crumbs that are less susceptible to erosion and are considered the most important structural elements of the soil. Earthworms' tunnelling activity also improves soil aeration and its ability to retain water.



Pseudomonas bacteria protects wheat roots form harmful organisms. They produce a cocktail of toxic substances which act against harmful fungi and insects. The tiny helpers are rewarded with approximately 10 per cent of energy obtained through photosynthesis.



The functions of soil

Healthy soil performs numerous functions and ensures that planet Earth remains habitable for humans. Soil is first and foremost the ground on which we walk. It gives the landscape its round and soft forms as well as a stable foundation for buildings, streets and tracks.

The most evident link between the soil and us is the production of food, animal feed and wood. Less apparent are other functions, which will be discussed in the sections below. These functions are the result of the soil's ability to control and maintain the materials and energy cycles between the atmosphere, groundwater and plant cover. Soil is known for storing nutrients and providing them to plants, regulating climate, filtering water, assisting in the control of floods and conserving the natural and cultural history. The living organisms throughout the soil are the engines that render the soils diverse, keep irreplaceable functions running and are beneficial for the ecosystem.

Soil – a multitalented matter

Soil ...

- ... contains raw materials (such as drinking water, gravel),(p. 18)
- ... stores carbon (p. 16)
- ... archives natural and cultural history (p. 22)
- ... supplies food (p. 12)
- ... stores nutrients (p. 14)
- ... filters water (p. 18)
- ... makes plant growth possible (p. 12)
- ... is a habitat for soil organisms (p. 7)
- ... is the foundation for buildings and roads (platform function),
- ... offers ingredients for medicines (p. 17)
- stores water (flood protection, water reservoir for plants), (p. 20)

When winter takes its leave, soil starts showing what it is capable of. For example, each year farmers within Switzerland harvest 500,000 tons of potatoes from the earth, deliver approximately 50,000 tons of rapeseed to oil factories, grow more than 16,000 hectares of bread and feed grain and harvest several hundred thousand tons of fresh vegetables. In this case, fertile and intact soil is the central resource for sustainable agricultural production.

The functions of soil

No harvest without fertile soil

The Central Plateau of Switzerland is home to some of the most fertile and productive soil worldwide. This is courtesy of the balanced climate, sufficient rainfall and advantageous underlying economic conditions for production and sales. Therefore, Switzerland has a special responsibility to conserve this important base of life.

Thirty-five per cent of soils within Switzerland can be utilized in cultivated fields, meadows and pastures. Another ten per cent are alpine farmland, hence also serve the production of food. The remainder is too steep, wet, dry, shallow or nutrient lacking for agricultural use.

Limited resource

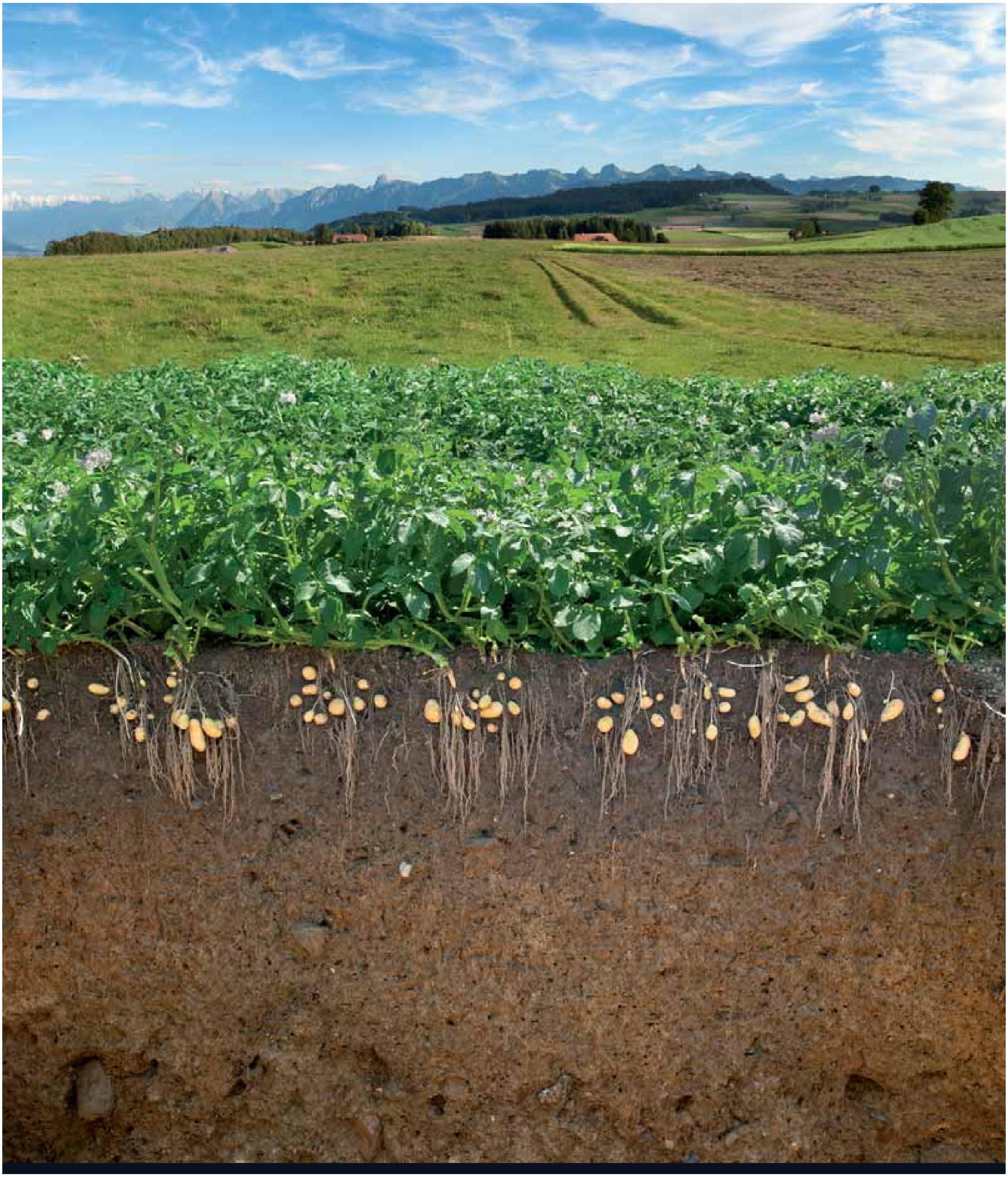
It takes 1,400 square metres of farmland to feed one person. Therefore, one hectare of land could essentially feed up to seven people. At this point in time, on an average day worldwide, one hectare feeds about 4 to 5 persons. The limit value of seven people will most likely be reached by the year 2050. This projection shows how important it is to maintain and protect the soil. Not one square metre should be wasted!

When land is used for construction it is then forever unfit for agricultural use. As a result of the rapidly increasing yields of industrialized and highly intensive agricultural production, certain types of soil have forever disappeared in the highly developed countries. This in turn makes utilisation of site-adapted sustainability difficult. With this we have lost our awareness and appreciation of soil as a functioning habitat. For instance, when we eat ice cream we tend to disregard the “soil–grass–cow–milk–ice cream” chain or the “soil–grass–cow–cow manure–soil” cycle.

Sustainable use

To preserve soil’s natural fertility in the long term, agricultural use that suits the location and fosters the rich soil life is needed. Heavy machinery and overuse of mineral fertilizers, liquid manure and plant protection products damage the soil organisms and the loose structure of the soil habitat. Put simply, habitat. This means that the soil must be used with consideration and sustainably.

In the forest, too, healthy soil is the basic requirement for a sustainable timber harvest. Furthermore, healthy soil ensures that it will perform all of its essential functions, such as flood protection and carbon storage. Grave problems can result from the use of heavy forestry machinery on naturally bedded forest soils as well as the planting of non-native tree species. For the formation of the indispensable humus layer it is essential that branches and wood waste remain in the forest and not succumb to gentrification.



Farmers harvest four kilograms of potatoes per square metre and year from this fertile farmland in Switzerland's Central Plateau. The Niesen mountain and the Stockhorn mountain chain can be seen in the background. The development history of this soil near Zimmerwald in the Canton of Bern began about 10,000 years ago. The Aare glaciers left behind a hefty deposit of calcium-rich moraine material. In the upper 120 centimetres, fertile, sandy loam soil developed. Particularly striking is the thick and humus-rich topsoil in which the potatoes grow.

Plants require a large number of nutrients for survival, including nitrogen, phosphorus, potassium, magnesium and calcium as well as trace elements such as molybdenum and boron. These are found as in dissolved form in the water within soil pores, where plants ultimately can absorb them. Thankfully an on-going supply is available. The most significant source of the nutrients is from the decomposition and transformation of dead plant material such as leaves and stems that fall to the ground and are decomposed by soil organisms. Soil organisms therefore provide plants with a continuous supply of nutrients, free of charge.

The fungus Drechsler Ella Anconia (white thin thread) captures a worm with the help of the fungal ring. The drama was captured with an electronic microscope.

The functions of soil

Efficient recycling in the soil

Without soil organisms soil would not be able to make the nutrients made from decomposed plant material available to living plants as food. These industrious workers in the bioreactor that is the soil provide a continuous nutrient supply to plants, leading to our ancestors speaking of "the old soil strength".

The weathering of minerals in the soil also ensures an ongoing provision of nutrients. The natural content of supplement nutrients is especially high in the deep and bountiful soils of the Central Plateau of Switzerland, which has some of the best farmland in the world.

Soil stores nutrients

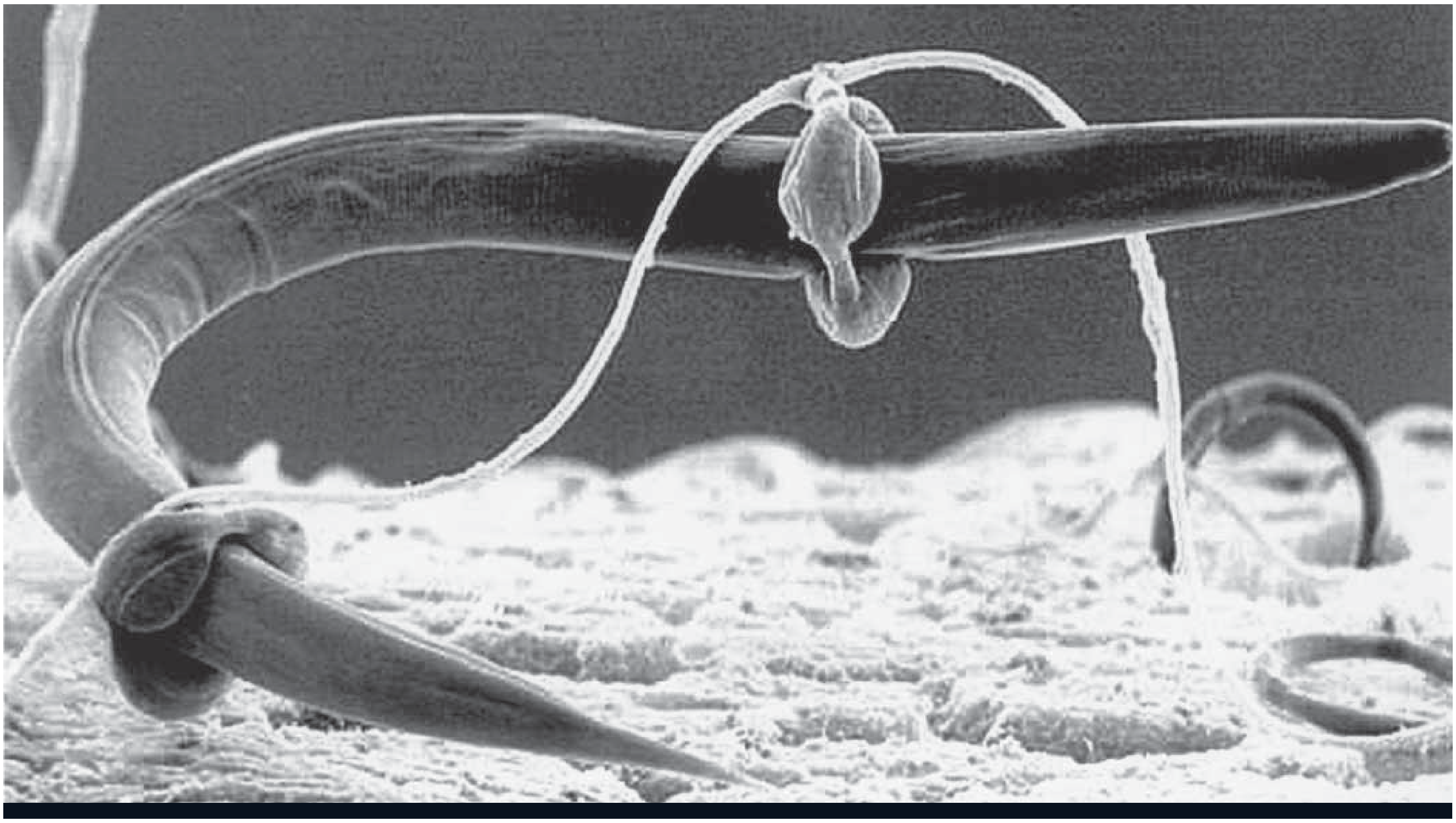
Primarily in springtime, as soil organisms awake from their hibernation, many nutrients become mobile. This poses the risk that through leaching, water seepage will carry the nutrients already released down through the soil and therefore out of the reach of plant roots.

Fortunately in this case, soil also holds nutrients in interim storage as they are bound in and around humus and released when needed. The microorganisms also consume a large amount of nutrients; however, they are released when the organisms die. All in all, there is a continual binding and dissolving of substances in the soil through biological and chemical processes.

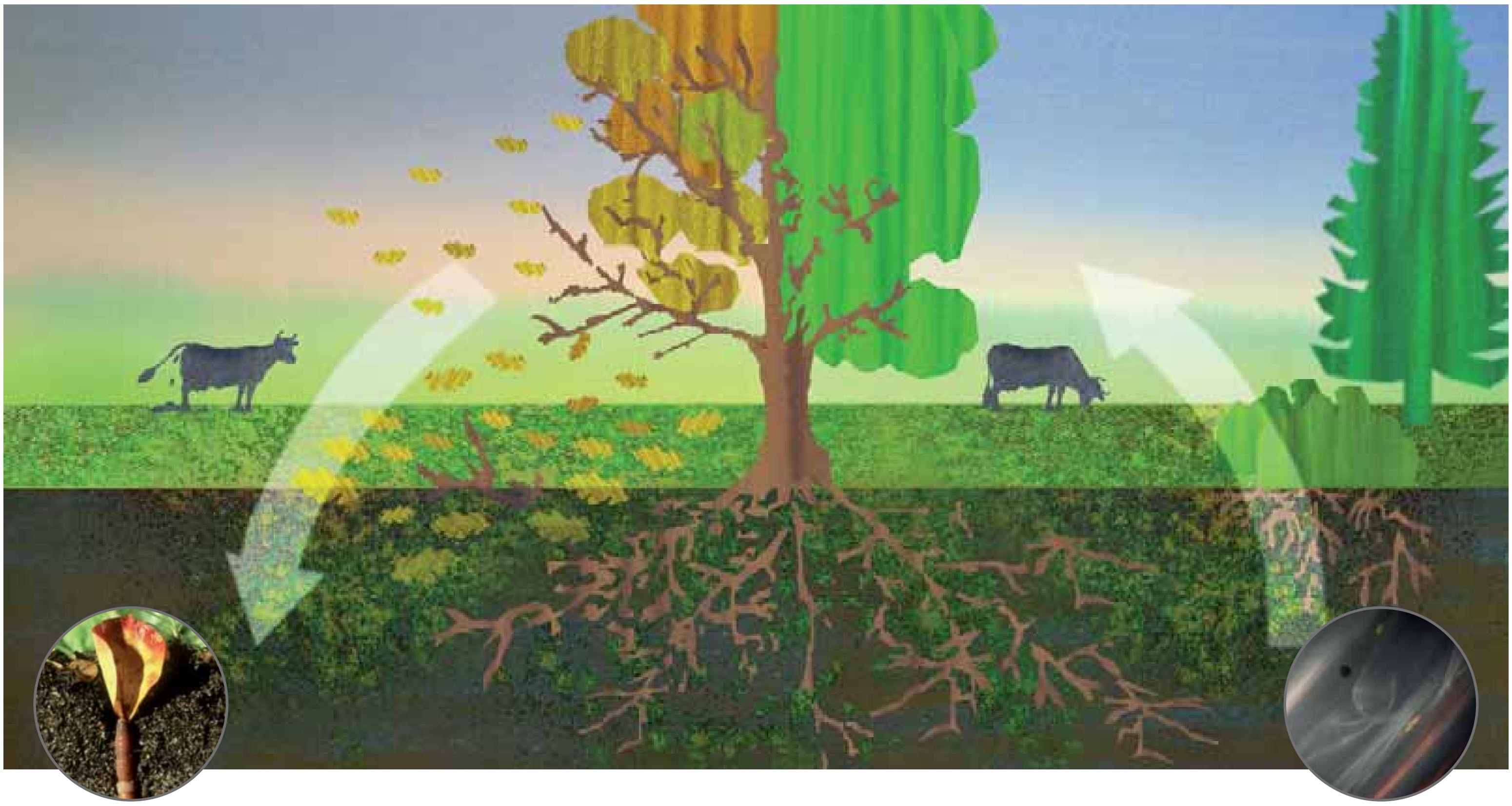
Leaks in the system

However, the soil loses many important nutrients with every potato that a farmer harvests. The cycle of nutrients between plants and the soil should remain closed so that soil fertility can be maintained. In earlier times, the threat of nutrient loss and cycle leakage was managed by temporarily ceasing to use the soil (leaving fields to fallow) by alternating between growing crops and applying nitrogen-rich cow manure. Today, large amounts of artificial fertilizers and liquid manure are used which can have a taxing effect on the soil. If a redundant amount of fertilizer is applied, the cycle inflates like a bubble and then begins to leak. Artificial fertilizers and liquid manure is a form of nitrogen and when applied too liberally can result in nitrate, which when leached into the groundwater with rain, impairs the quality of our drinking water. Over 30,000 tons of nitrogen are leached from agricultural land in Switzerland every year. The consequences are significant in many places as the nitrate content of underground water reservoirs considerably exceeds the limit. There is an excessive amount of nitrate in the groundwater at every sixth measuring site, and in crop farming areas it is too high at every second measuring site.

Another problem with the overburdened nitrogen cycle is nitrous oxide (laughing gas), as it is produced in the soil when nitrogen fertilizers are processed and leak to the atmosphere. This nitrogen compound damages the ozone layer and is a highly potent greenhouse gas as nitrous oxide has 298 times more of a negative impact than carbon dioxide. This shows that a balance within soil nutrients is imperative. Excessive nutrients that are not taken up by crops should simply not be applied to the soil.



Nutrients are in continuous circulation from plants to the soil and back



1. Dead leaves, branches, grass stalks, herbs and animals end up on the ground. In agriculture, the manure and urine of farm animals are spread on the soil.

2. Soil organisms go to work on this food and decompose the organic material.

3. Nutrients are made available to plants or stored in humus and in (or attached to) soil particles.

4. Plants above ground can grow. Livestock and wild animals eat the plants.

Soil and climate are closely related. However, soil rarely plays a role in public awareness and in the discussion of climate change. Nevertheless there are enormous quantities of carbon stored within soil, which when in the form of carbon dioxide (CO_2) is one of the main causes of climate change. Soil is the third-largest repository for carbon, after the ocean and fossil fuels like coal, oil and natural gas. All types of soil together contain about twice as much of this element as the atmosphere and three times as much as land plants.

The functions of soil

Soil protection is climate protection

Carbon continuously moves between plants, soils and the atmosphere. Plants adsorb atmospheric CO_2 and, using energy from sunlight, create leaves, stems and roots. Carbon from dead plant materials is transferred to the soil. A part of this is released back into the atmosphere after being broken down by soil organisms and the rest is transferred into a more stable form – humus.

Soil carbon storage

The amount of carbon stored in the soil depends on temperature, soil moisture and the amount and type of dead plant material. Changes in climate or utilization of the land obviously also have an impact on the exchange of carbon between plants, soils and the atmosphere.

If marshland is drained and used for agriculture, if meadows are changed to cropland or if fields are utilized too intensively, the humus content of the soil decreases. When the humus content is reduced, large amounts of CO_2 are released into the atmosphere. The conversion of natural ecosystems into cropland and grazing pastures as well as overutilization of the soil – sometimes this even leads to deserts – are the main causes of the release of CO_2 from the soil. Over long periods of time, more carbon is released into the atmosphere via this method than through the burning of fossil fuels.

Efficient and inexpensive

There is no simple or quick repair solution to the damage to the soil caused by non-sustainable use. This is particularly true regarding humus loss.

Amongst other options, organic farming and forms of land management with reduced soil tillage have a positive effect on the humus content of the soil. Rewetting and restoring former marshland is also an efficient and chiefly inexpensive form of climate protection. As soon as a regenerated marsh returns to a natural state after several years, carbon will once again be stored in the soil.

A farmer harvests four kilograms of carrots per square meter from this field in the Grosses Moos area near Witzwil, Bern. But for how much longer? The humus layer was originally two metres deep. But drainage of the marshland resulted in oxygen entering the soil pores and subsequently, decomposition of the peat body took place and then a vast amount of CO_2 was released into the atmosphere. Today, the humus-rich layer is only 30 centimetres deep. The fertility of this soil is highly endangered. When the humus is used up and the old lake sediment (grey layer) is reached, it will no longer be possible to use this land for agriculture.

When you turn on the tap and get fresh, clean water, you have soil to thank. Over 80 per cent of Switzerland's drinking water is sourced from groundwater. It is the soil that makes it the pure elixir of life. During seepage flow, soil filters suspended solids, pollutants and pathogens out of the water. It essentially is the filter between surface water and groundwater.

For provision of the drinking water supply, Basel has actively utilized the cleaning effect of the soil and the forest for a long time. To artificially recharge the groundwater, mechanically filtered Rhine river water is pumped to forested flooding sites, where it seeps through the woodland soil.

The functions of soil

The soil provides clean drinking water

The filtering efficiency of soil is nowhere better visible within Switzerland than in Basel. Half of the water that the city pumps up from the depths has been added to the groundwater artificially and the forest soil is the central component of the drinking water production system.

Efficient water filter

Each day, 60,000 cubic metres of pre-treated water drawn from the Rhine river is pumped into wooded flooding areas at the Lange Erlen waterworks for drainage. The 14 flooding sites are subdivided by small embankments and cover a total area of approximately 20 hectares. Each flooding site is taken out of use after 10 days of operation and the forest soil is allowed to regenerate for 20 days. During the 20-day drying period, soil organisms again produce new pores that stretch from the surface to the gravel, which is what is responsible for the productive seepage.

As water flows through the soil, almost all organic substances are retained, detoxified or built into the soil structure. Pesticides, viruses and bacteria that can be harmful to human health are eliminated.

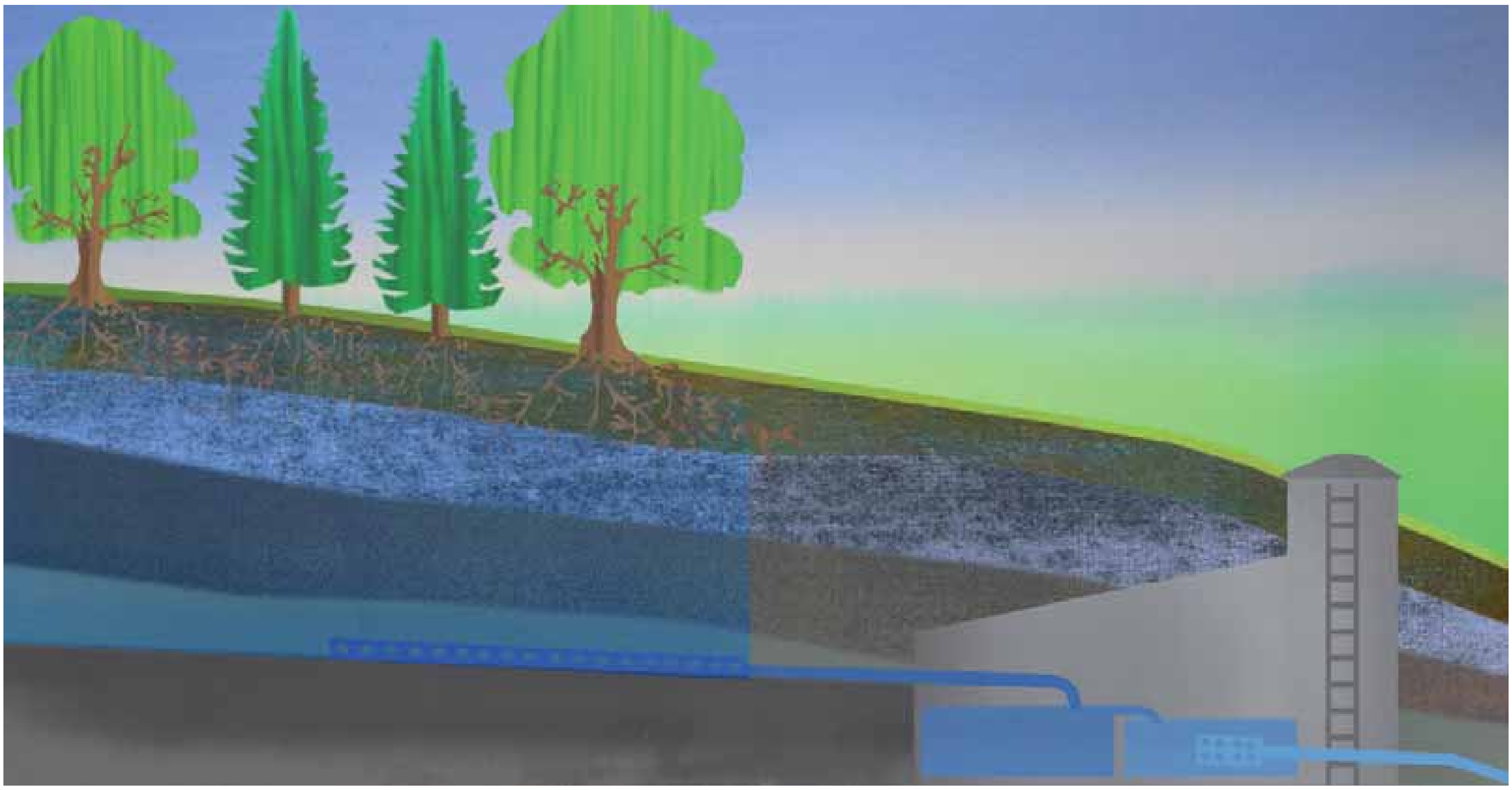
The drainage water that is cleaned by the soil in the Lange Erlen waterworks area augments the amount of existing groundwater. The groundwater is then pumped from several wells and treated chemically and physically at a pumping station and fed into the Basel drinking water supply network.

Irreplaceable

All over Switzerland the soil system is a low-maintenance filter. However, only with intact soils can groundwater be used as drinking water without expensive water treatment. The soil guarantees excellent cleaning of water over the long term. In Basel it even ensures that non-consumable Rhine river water becomes safe drinking water, and all that is required is an absolute uncomplicated control of the system as a whole.

Soils that are disturbed, sealed over or contain high levels of heavy metals and other pollutants cannot perform their cleaning function well or even not at all. The natural soil filter that developed over thousands of years cannot be simply replaced (like buying a new vacuum cleaner), its functional capability depends on regeneration through natural processes

The forrest floor as waterfilter



Thanks to the cleaning power of the soil and the ecosystems, sufficient drinking water of perfect quality is available in Switzerland. Thirty-eight per cent of the drinking water requires no treatment and another 33 per cent requires only one-stage treatment.

The summer of 2014 "fell into the water": it was too cold and exceptionally wet. Besides the heavy storms, there were also long periods of rain that made conditions ideal for flooding. The fact damage was limited is all thanks to the soil, which is by far the most important catchment area for rainwater. Like a large sponge, soil absorbs water, and after a certain amount of time, delivers it to the groundwater or streams and rivers. Forest soils are particularly capable in absorbing water: in a deciduous forest the soil can absorb some two million litres of water per hectare.

The burrow networks created by earthworms significantly increase the water-holding capacity of soils and are therefore very important for flood protection. Any given block of soil under a square metre of fertile meadow will contain from 300 to 500 earthworms, with a total weight of 200 to 300 grams, living up to a depth of 1.5 metres. They create up to 900 metres of burrows in this area.

Soil sealing leads to flooding.

The functions of soil

The soil protects against flooding

Water storage in the soil should not be pictured as an underground cavernous lake. Water on the surface of the ground is stored in a network of hollow spaces known as pores. It does not simply seep down towards the groundwater; instead, thanks to the surface tension of the water, it is held in the soil pores until needed.

The capacity of soil to store water depends on the proportion of the pores. Usually 30 to 60 per cent of the soil is made up of pores of differing sizes. In organic soils formed in raised bogs, this amount can be as high as 90 per cent. If the pores are too large, as in sandy soils, water travels rapidly deep into the soil, whereas soils with a high clay content store more water. The depth of the soil also determines its capacity to retain rainwater.

Soil = a sponge

The amount of soil pores also depends on the surrounding plant roots and the soil organisms. With their extensive networks of burrows, earthworms enhance porosity and are especially important helpers in protection against floods.

When it rains, the small pores fill with water first. Pores with a diameter greater than one-tenth of a millimetre are particularly important for the flow of rainwater. If it continues to rain, earthworm burrows then begin to fill with water. When the water stores are full, surface run-off will occur and then the rain ends up in the nearest bodies of water such as swelling streams and rivers.

The water masses can be known to flood towns, fill cellars with water and mud, wash away cars and flood streets. This occurred during the summer of 2014 in the sloping region between Bern and Lucerne and in the Canton of St. Gallen, where the flooding caused damage running into the millions.

Intact soil is indispensable not only for flood protection. A part of the water in the soil is also available to plants, which would otherwise dry up. For example, wheat crops require a hundred litres of soil water to produce one kilogram of grain. Without the water storage in the soil there would be no green and flourishing landscapes and of course, no production of food.

Soil compaction

If the soil's water infiltration capacity is disturbed or even destroyed, heavy rainfall runs off to the nearest bodies of water much more rapidly, which happens when driving heavy machinery on soil or improperly handling excavated soil as this eliminates the pores and compacts the soil.

Water filtration ceases completely when the soil disappears under roads or buildings. This is increasingly the case as the surface area of housing and infrastructure has grown in Switzerland by 584 square kilometres from 1985 to 2009 – which is equivalent to the size of Lake Geneva. In sixty per cent of this newly developed area the soil is sealed, meaning that water storage in the soils in Switzerland is continuously shrinking. Intact soil in developments can greatly reduce the burden on sewer networks and also retain pollutants. Consequently, for good flood protection, more sustainable treatment of the soil is needed not only in cultivated land and forests but also in developed areas.

Soil takes form over an extremely long time period; therefore it can be considered to have a "good memory". Soil scientists have the ability and knowledge to read the different soil layers like a book gaining boundless information reflecting the environmental conditions that prevailed when the soil was first formed.

In 2012, the Cletic treasure of Füllinsdorf in the canton of Basel was discovered in the soil – 293 silver coins – the largest Celtic precious metal coins in Switzerland.

Also discovered in the Basel underground was a flour mill which was part of the paving of a courtyard.

The functions of soil

The archival record in the soil

Old soil preserves information regarding climate, vegetation and the impact of natural catastrophes in past epochs. Bog or moor soil, which inhibits the decomposition of organic material, provides an especially important archival record as each individual peat layers contain pollen, leaves or seeds of plant species that were common in their landscape in earlier times. They can be identified even after thousands of years and allow us to trace the exact expansion of certain tree species in different regions of Switzerland since the last ice age.

Valuable archives

Core samples from raised bogs provide an archival record of atmospheric pollution. In the peat body of the upland moor at Etang de la Gruère in the Canton of Jura, there are two layers with increased levels of lead. Responsibility and blame for contaminating these deeper layers of the soil lies with the Romans. The Romans exploited the soft metal on an industrial scale for making water pipes, containers and other objects. Another example lays two thousand years later when humans in the automobile era used leaded petrol. The lead released into the environment fell to earth, covering it as a veil, and it is still detectable in the soil to this day.

Mirror of human civilization

Since the Stone Age humans have left manifold vestiges of cultural development in the soil. From inconspicuous remnants such as bones, coins and tools, archaeologists can gain critical insight into the everyday life of humans in earlier times.

Soil also reveals how the landscape once appeared, how it developed and what impact humans had on it. It helps to provide information on the history of the landscape, the development of agriculture and settlements and a mirror of human civilization. Providing such valuable information regarding the natural and cultural history further implores the relevance of soil's survival

Conserving the basis of life

The soil beneath our feet is the perfect mixture of minerals, humus, water, air, animals, plants and fungi that interact in a variety of ways. The well-being of our society is closely connected with this underground society as it fulfils numerous economic and ecological functions.

The individual functions of soil are closely interconnected. For example, while healthy soil has a high water-retaining capacity, there are other roles that soil can play more effectively in certain locations than in others. For instance, the expansive fertile soils in the Central Plateau are particularly well suited in supplying food to the population. In contrast, carbon and water storage are the primary focus within marshlands. While the primary function is important, for effective sustainable use of the land it is important to manage the land and not to lose sight of the other functions.

The world is losing soil

In this country only a few of us, mainly farmers, still have direct contact with the soil. As the distance between the soil and ourselves in our daily lives grows, the soil becomes distant in our minds. We have become neglectful in the the way we treat our soil.

Throughout the world, 24 million tons of soil is washed into the sea or blown away by the wind each year. Soil erosion and the formation of deserts are problems in 168 countries. At the same time, developments and roads are claiming ever more valuable land. Altogether, this means that soil loss is a growing threat to global food security.

The issue of increasing soil scarcity worldwide will lead to disputes and conflicts in the coming decades. More and more industrial and emerging countries are acquiring large areas of land in developing countries to ensure their own food security – often at the cost of the local farmers. Today, sixty per cent of the foods or raw ingredients consumed in Switzerland have been produced in other countries.

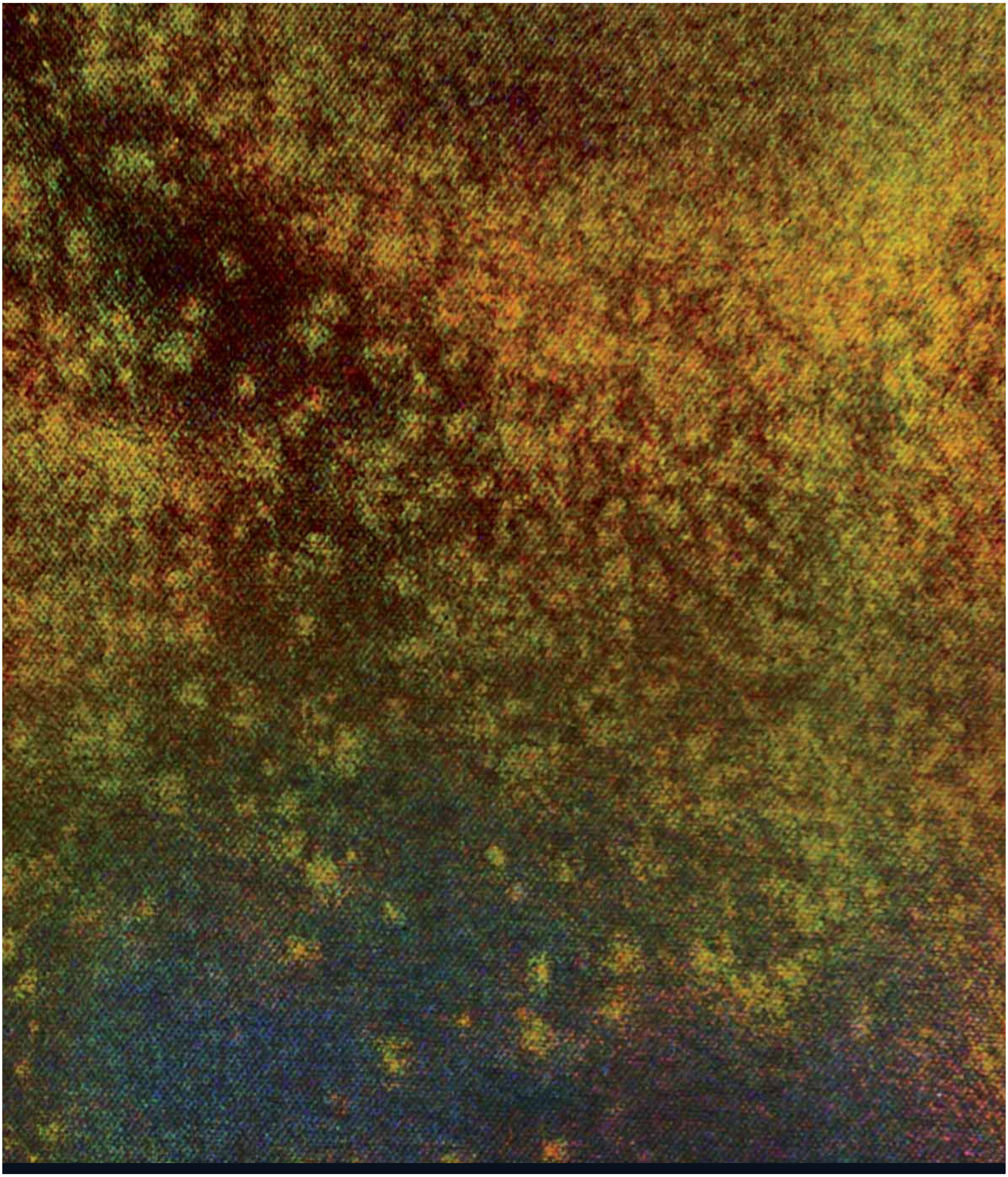
While this is occurring, the soil in Switzerland is degrading and several threats can be identified, as when soil is damaged, it affects all of its functions.

Complete breakdown

Developed areas, with their high proportion of concrete or asphalt surfaces, are claiming more and more land. In the Central Plateau of Switzerland, from 1985 to 2009 nearly one square metre of land was used for construction per second, which is equivalent to:

- Fifteen metres of residential road per minute,
- Six single-family houses per hour,
- An area the size of the Canton of Basel per year.

Sixteen per cent of the Central Plateau already consist of built-up, industrial and commercial areas. With construction, all natural soil functions come to a standstill, primarily food production. If the sealing over of the land in the Central Plateau continues at its current rate, there will be dramatic economic, social and ecological consequences.



In Switzerland more and more soil is disappearing under asphalt and concrete. The photos show the area around the A3 motorway near Effingen, Canton of Aargau, in 1982 and today (2015).

Falling quality

Many different factors are impacting and degrading the soil permanently, making it increasingly difficult for the soil to properly perform its functions:

■ Soil compaction: Driving heavy construction machines, tractors, seed sowers and harvesters on the soil compacts the soil pores. This disrupts soil aeration and drainage and therefore the soil organisms, meaning soil fertility decreases. Compacted soils have limited infiltration capacity and permeability. Water cannot enter the soil, therefore runs off the surface, promoting soil erosion and increasing the risk of flooding.

■ Soil erosion: Surface run-off essentially washes away the fine soil, which is rich in nutrients. This erosion impairs many soil functions, among others its water-storing capacity and fertility. Approximately forty per cent of Switzerland's farmland is considered to be endangered by erosion, meaning that more than two tons of soil material per hectare can be lost each year. In all, farmlands in Switzerland lose more than 800,000 tons of soil material each year. That is approximately equivalent to soil 100 metres high covering an area the size of a soccer field. On top of this, the soil washed away causes considerable ecological damage to bodies of water.

■ Pollutant inputs: Approximately one-tenth of the soil in Switzerland is heavily polluted which is a part of the past environmental pollution and damage legacy. In addition, soils in intensively occupied meadows are showing a continuing rise in zinc and copper concentrates, which are then fed into agricultural soils through liquid manure or additives in animal feed.

■ Soil acidification: Transport, industry, households and agriculture all emit large amounts of nitrogen and sulphur compounds that, when combined with rain, eventually end up in the soil. The ensuing acidification of the soil results in nutrients being washed out and pollutants being released which can then in turn contaminate drinking water.

Soil protection is a task for the whole of society

Conclusively, it is abundantly clear that the long-term maintenance of the functional capability of our soil resources is becoming increasingly precarious in Switzerland and also around the world. Once the soil is degraded or damaged, it can only be returned to its original bountiful state with great technical difficulty and expense – if at all. The success achieved with the air and water pollution control issues cannot be easily repeated with soil protection, as we know it has a long memory and cannot be quickly restored.

It is imperative that the protection of soil has a central role in the discussion of the sustainable use of natural resources. As all areas of life essentially utilize and/or damage the soil while at the same time profiting and benefiting from its functions, the topic of soil protection is a task for the whole of society politicians, government, industry, spatial planners, researchers, everyone of us. We all have to take responsibility.

The goal is to protect and ensure the functions of the soil and thus its ability to perform them. To ensure this, soil use and functions have to be reconciled. It is important to minimize erosion and pollution, prevent unnecessary sealing of soil and correct handling of excavated soil during construction.

Fertile soil does not develop overnight but rather over thousands of years. A single excavator scoop destroys in seconds something that from the human perspective took an eternity to develop. When soil is lost, this impairs not only our own quality of life but also the quality of life of future generations.

Homo and humus

It is not surprising that the Latin words homo, meaning human, and humus, the soil, derive from the same Latin root. Our ancestors correctly assessed the importance of the soil for human beings.

Through our high-tech civilization we have distanced ourselves from direct experience with soil. However, our well-being today depends on intact soil just as much as it did in the past. We need to appreciate and value soil once again as it is a precious treasure that must be protected.

Links

National Research Programme "Sustainable Use of Soil as a Resource" (NRP 68)

The National Research Programme "Sustainable Use of Soil as a Resource" (NRP 68) establishes a basis for political decision-making which takes into account both the ecological and the economic functions of soil and paves the way for soil resources to be used sustainably in Switzerland.

www.nfp68.ch

Federal Office for the Environment (FOEN)

The FOEN is committed to ensuring that all functions of the soil are conserved so that in the long term sufficient soil is available for all necessary uses in Switzerland.

www.bafu.admin.ch → Themen → Boden

Federal Office for Agriculture (FOAG)

The FOAG is committed to ensuring that farmers produce high-quality foods sustainably and according to market demand. The goal is multifunctional agriculture.

www.blw.admin.ch → Themen → Nachhaltigkeit → Ökologie → Boden

Federal Office for Spatial Development (ARE)

The ARE is the federal government's centre of excellence for issues concerning sustainable spatial development.

www.are.admin.ch/org/index.html?lang=en

Swiss Soil Science Society (SSSS)

On many different levels, the SSSS is actively engaged on the behalf of quantitative and qualitative soil protection. It disseminates and deepens soil sciences knowledge. It is also an exchange platform for dialogue between specialists in administration, research and the private sector and promotes cooperation between research and practice.

www.soil.ch

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