UNIVERSIDADE DA CORUÑA

MASTER UNIVERSITARIO EN CIENCIAS, TECNOLOGÍAS Y GESTIÓN AMBIENTAL

FACULTY OF SCIENCES

MASTER´S THESIS

ACADEMIC YEAR 2015 – 2016

Improve the system of agriculture to provide ecosystem and social services

Mejora del sistema de agricultura para el ecosistema y servicios sociales

Mellora do sistema de agricultura para o ecosistema e servicios sociáis

Folestean Artiom

Name of Academic Tutor (UDC): Prof. Dr. Moisés Canle López

Name of Academic Tutor(USARB): Prof/Dr. Boincean Boris

May 2016

RETHINKe

Co-funded by the
Tempus Programme
of the European Union

SUMMARY

System of agriculture consist in a set of procedures, methods, knowledge and instruments using soil to grow crops. Soil provides this ecological services: Soil stores, moderates the release of nutrients and other elements, and cycles them. Soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in water. Soil supports the growth of a variety of unstressed plants, animals, and soil microorganisms, usually by providing an important physical and chemical diversity, and also a biological habitat. Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals. Soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots. Soil can also provide important social services: food, clothes, building materials .

The main cause of contamination of soil with heavy metals is the use of mineral fertilizers: ¬Mineral fertilizers induce a decrease of organic matter in soil ¬Have a negative influence for microorganism ¬Heavy metals also have a negative influence for human and animal health. Problems, however, should not be posed on the farmer who is using the mineral fertilizers, agriculture just give us that what we want. As an example, if people use abundant dairy products in alimentation, this will introduce changes in agricultural uses (increase in the amount of natural fertilizers, etc.) If farmers grow livestock, it will profitable for nature, and different advantages will be found: ⎫ Cleaner water will be available for drinking. ⎫ Healthy food without heavy metals and other types of contaminants. ⎫ Improve soil structure, making it better and more resistant against erosion. This example illustrates how external problems arise from internal problems.

RESUMEN

Un sistema de agricultura incluye toda la serie de procedimientos, métodos, conocimientos e instrumentos que utilizan un terreno para crecer los cultivos. El suelo proporciona estos servicios ecológicos: - Almacena nutrientes y modera su liberación y sus ciclos. - Pode regular el drenaje, flujo y el almacenamiento de agua y solutos, que incluye nitrógeno, fósforo, pesticidas, y otros nutrientes y compuestos disueltos en el agua. - Soporta el crecimiento de una variedad de plantas sin estrés, los animales y microorganismos del suelo, proporcionando diversidad química y biológica y un hábitat físico adecuado. - Actúa como un filtro para proteger la calidad del agua, aire y otros recursos. Los compuestos tóxicos o el exceso de nutrientes pueden ser degradados o, alternativamente, quedar a disposición para para las plantas y los animales, con el consiguiente riesgo. - Tiene la capacidad de mantener su estructura porosa para permitir el paso de aire y agua, resistir las fuerzas erosivas, y proporcionar un medio de sujeción para las raíces de las plantas. El suelo también puede proveer importantes servicios sociales: alimentos, ropa, materiales de construcción

La causa principal de la contaminación del suelo con metales es el uso de abonos minerales: - Los fertilizantes minerales producen una disminución de materia orgánica en el suelo - Tienen una influencia negativa para el microorganismo - Los metales pesados influyen negativamente en la salud humana y animal. No obstante, los problemas no deben achacarse a los granjeros que usan los fertilizantes minerales: la agricultura nos da lo que le demandamos. A modo de ejemplo, si las personas que utilizan en su alimentación abundantes productos lácteos, por ejemplo, esto introducirá cambios relativos al uso de ganado en la agricultura. Si los agricultores crían y usan ganado, será rentable y producirá una serie de ventajas - Agua limpia para beber - Alimentos sanos sin metales pesados ni otros contaminantes. - Mejor estructura del suelo y mayor resistencia a la erosión. Este ejemplo muestra cómo nuestros problemas externos son resultado de nuestros problemas internos.

RESUMO

Un sistema de agricultura inclúe toda a serie de procedementos, métodos, coñecementos e instrumentos que utilizan un terreo para crecer os cultivos. O chan proporciona estes servizos ecolóxicos: - Almacena nutrientes e modera a súa liberación e os seus ciclos. - Pode regular a drenaxe, fluxo e o almacenamento de auga e *solutos, que inclúe nitróxeno, fósforo, pesticidas, e outros nutrientes e compostos disoltos na auga. - Soporta o crecemento dunha variedade de plantas sen estrés, os animais e microorganismos do chan, proporcionando diversidade química e biolóxica e un hábitat físico axeitado. - Actúa como un filtro para protexer a calidade da auga, aire e outros recursos. Os compostos tóxicos ou o exceso de nutrientes poden ser degradados ou, alternativamente, quedar a disposición para para as plantas e os animais, co consecuente risco. - O chan ten a capacidade de manter a súa estrutura porosa para permitir o paso de aire e auga, resistir as forzas erosivas, e proporcionar un medio de suxeción para as raíces das plantas. O chan tamén pode prover importantes servizos sociais: - Alimentos - Roupa - Materiais de construción A causa principal da contaminación do chan con metais é o uso de abonos minerais: - Os fertilizantes minerais producen unha diminución de materia orgánica no chan - Teñen unha influencia negativa para o microorganismo - Os metais pesados inflúen negativamente na saúde humana e animal. No entanto, os problemas non deben achacarse aos granxeiros que usan os fertilizantes minerais: a agricultura dános o que lle demandamos. A modo de exemplo, se as persoas que utilizan na súa alimentación abundantes produtos lácteos, por exemplo, isto introducirá cambios relativos ao uso de gando na agricultura. Se os agricultores crían e usan gañado, será rendible e producirá unha serie de vantaxes - Auga limpa para beber - Alimentos sans sen metais pesados nin outros contaminantes. - Mellor estrutura do chan e maior resistencia á erosión. Este exemplo mostra como os nosos problemas externos son resultado dos nosos problemas internos.

Content

INTRODUCTION

In my work I want to show how our external problems results from our internal problems, and how we can solve big external problems just to change something in our internal world. This is a very brave idea that I will try to explain. The objective of this work is to improve the system of agriculture to provide ecological and social services. With "improve" we imply not disturbing the soil system to carry out its duty: to perform ecological and social services. Soil system provides clean water through filtration, food and clean air, etc. In other words soil maintains our live. I try to demonstrate how our type of alimentation creates problems in the environment, especially in agriculture, and in our health too. Our life style dissociates two issues that are inseparable: growing livestock and growing crops. For growing crops you need fertilizers. If you get something from the soil you need to return it back. This is the environment law, the nutrients circle. We are using today mineral fertilizers which are very toxic for our organisms because they contain heavy metals that are very dangerous for our health and for health environmental. If we increase dairy product consumption, farmers will grow cows because it would be profitable. The use of organic fertilizers would become cheaper. When the farmers use organic fertilizers, clean water will be available, without heavy metals, as well as more ecological and healthy food. The idea is simple: it would just be necessary to increase the consume of dairy products. The big problem in agriculture is the current separation between growing livestock and growing crops. All ecological problem have roots in ourselves. This is the central idea of this work.

1.WHAT IS SOIL?

Exist a lot of explication what in the soil and witch is his composition, but very simple and very clearly gave David L. Linbo,Deb A. Kozlowski,and Clay Robinson in their book ‘’ Know soil know life’’, they sad: First and foremost, soil is not dirt. Dirt is the stuff under your fingernails; it is what you sweep up off the floor; it is unwanted and unnecessary. Soil, on the other hand, is essential for life, so soil is not dirt! Dirt may be soil out of place, just as a weed is a plant out of place. For example, a rose in a cornfield, while beautiful, is a weed; a corn plant in a rose garden is also a weed. So when you track mud (wet soil) inside, you are putting the soil in a place it is not wanted. At that point it becomes dirt. If soil is not dirt what is it? There are several definitions.... Perhaps the simplest is that soil is a living, dynamic resource at the surface of the earth. To expand that definition, soil is a natural, three-dimensional body at the Earth’s surface. It is capable of supporting plants and has properties resulting from the effects of climate and living matter acting on earthy parent material, as conditioned by relief and by the passage of time. Worldwide tens of thousands of different soils occur on every continent and virtually anywhere plant life can set roots. An understanding of the environment requires an understanding of soil—what it is, how it is formed, what it is made of, and how it is used. Soil serves as a repository of many geological and climatic events that have occurred in its location. It is a window to the past, but it can also serve as a view of the future as its properties relate to how we can and should manage this finite resource. Now

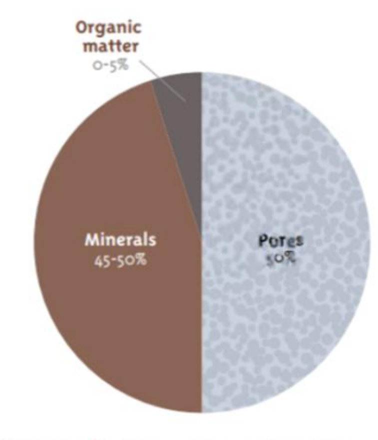


Figure 1–8. Percentages of each component of soil: mineral, pore space (filled with air and/or water), and organic matter.

consider a handful of soil. At first it may seem lifeless and solid, but in reality soils are teaming with life and contain pockets of air and water. There are four components to every soil: minerals, organic matter (living and dead), water, and air. The minerals and organic matter make up the solid phase. The water and air make up the pore space. A typical handful of soil contains 50% pore space, 45–50% minerals and 0–5% organic matter (figure 1–8).(Know soil know live)

2.1.HOW MUCH SOIL IS ON EARTH?

Interesting facts about haw many soil we have an planet, because for instance I consider that we have a lot of soil and we never will not have problem with this resource but further David L. Linbo,Deb A. Kozlowski,and Clay Robinson say : Surprisingly, there is not that much soil on Earth, yet it is one of the most important natural resources. As the world population increases, the finite soil resource must provide enough food, fiber, and shelter for the world. Relatively speaking, how much productive soil do we have? The earth has approximately 149 million square kilometers (58 million square miles) of land area (figure 1–5).

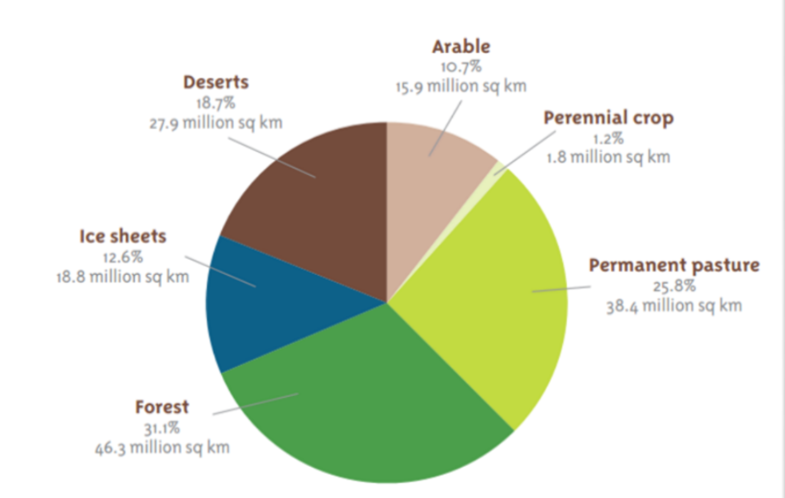


Figure 1–5. Comparison of total area on Earth in various land uses.

Of this, deserts and ice sheets account for about 31% and forests another 31%. The remaining 38% is considered agricultural land, but 26% is in permanent pasture, used only to produce feed for livestock, such as cattle, sheep, and goats. Only about 12% of Earth's land surface is used to produce food and fiber (cotton) for human consumption. Of that, just over 1% is perennial cropland primarily used for orchards and vineyards. The remaining 11% is considered arable land, which is capable of sustaining annual crops. In the United States, about 23% of the land is in deserts or mountain ranges, 33%

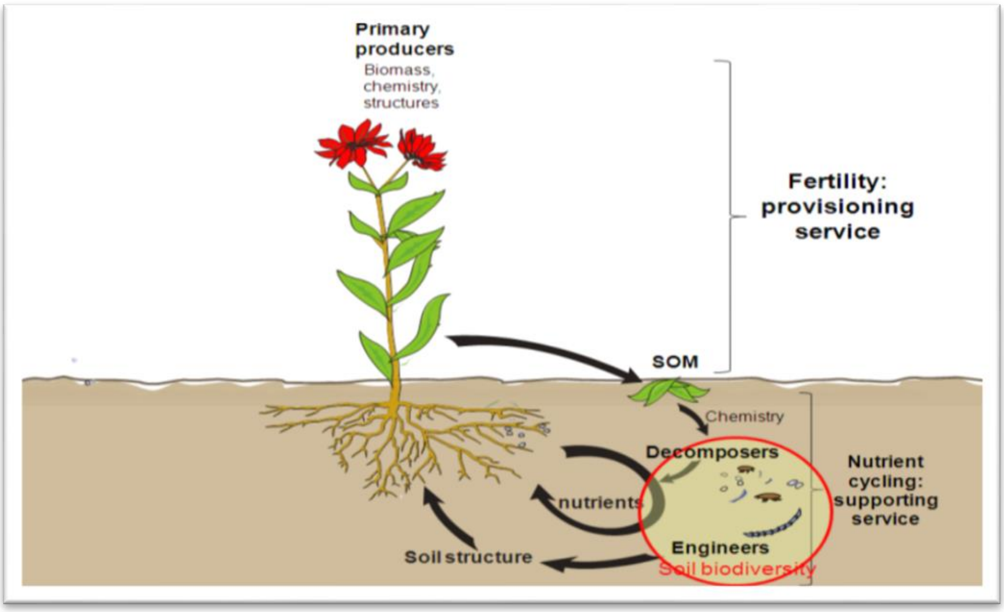
is in forests, 26% is rangeland used for grazing, and 18% of the land is used for producing crops. Since 1961 the global amount of land in annual crops has varied between 9.5% and 11%. In the same period, the world average of arable land per person has decreased from 0.37 hectares per person in 1961 to 0.20 hectares in 2012. (Note that a hectare, or 10,000 square meters, is approximately 2.5 acres, and one acre is 43,560 square feet). Nor is the arable land evenly distributed. In East Asia and the Pacific, less than 0.10 hectare per person is available, while Africa has about 0.20 hectares and North America has about 0.61 hectares. As the human population grows, arable land comes under increasing pressure to produce more food per hectare. Some countries don’t have the economic strength to buy fertilizers, better seed, and other inputs required to increase yields, or they lack the means or water supply to irrigate, so they look for more land to produce crops. But converting other land into food production poses problems. Many of the world’s forests are in areas that are too cold to produce food crops. Others are in steep areas or shallow soils over bedrock. Removing the trees from these soils leads to rapid erosion and loss of productivity. Other forests are in high rainfall regions with acid soils requiring many amendments and careful management to maintain productivity. The capital to purchase the inputs and management expertise in some of these regions is limited. Deserts are fragile ecosystems that receive too little precipitation to grow crops. Grazing lands (permanent pasture) are often in semiarid regions, and are highly susceptible to drought. Plowing such lands to produce food already led to one Dust Bowl in North Americain the 1930s (see chapters 6 and 8) and is having similar impacts in Asia and Africa now. Some soils in deserts and semiarid regions have so much salt in them that plant growth is limited. Irrigation can increase crop yields and decrease drought risk for crop production in arid and semiarid regions. However, water supplies are becoming more limiting in both quantity and quality. Overall, less than 1% of the arable land in the world is irrigated. About 5.5% of arable land in the United States is irrigated, while more than 50% of the arable land in Pakistan, South Korea, and Bangladesh is irrigated. Worldwide approximately 40% of all food crops are irrigated. Medieval alchemists considered there to be four elements: earth, air, fire, and water. You can think of these as soil, air, sunlight, and water (figure 1–6), the four items critical to life on Earth. We know we cannot spin gold out of the four medieval elements, but we do need these four things to support something more valuable: all life as we know it.(Know soil know life,David L. Linbo,Deb A. Kozlowski,and Clay Robinson,2012 soil science society of America)

2. Why soil is important?

2.1. SOIL ORGANIC MATTER RECYCLING, FERTILITY AND SOIL FORMATION

Soil fertility can be defined as the ability of soils to support plant growth by ensuring the adequate recycling of organic matter and nutrients. The contribution of soil organisms to soil fertility can thus be decomposed into its supporting and provisioning services:

- **Supporting services** such as nutrient cycling and decomposition of organic matter, that support life and other ecosystem services such as plant production and soil formation. Soil formation or pedogenesis is the process by which soil is created.
- **Provisioning services** such as production of crop or plant biomass, also called primary production (Figure 1), that provide goods to society.



2.1.1 WHICH PROCESS IS RESPONSIBLE FOR THE DELIVERY OF THIS SERVICE?

2.1.1.1 SUPPORTING SERVICES

Soil biodiversity drives two main supporting services which are interwoven: organic matter decomposition and nutrient cycling. Soil biotas decompose dead organic matter resulting in the formation of more complex organic matter called humus (Box 1) that participates in general soil formation and quality maintenance through its specific properties (cation retention, hormone like effects on plants, water retention, and stabilisation of soil aggregates). Humus is an important buffer, reducing fluctuations in soil acidity and nutrient availability. Thus, the organisms living in and on the soil can contribute to the formation of distinct humus giving rise to distinguishable soil types. For instance, coniferous forests have acidic leaf litter and, with the help of local soil organisms, form what are known as inceptisols, while mixed or deciduous forests leave a larger layer of humus, changing the elements leached and accumulated in the soil, forming what we call the alfisols.

Although chemical engineers are the main actors of organic matter decomposition, all three functional groups are involved in organic matter recycling. As a consequence, organic matter recycling is regulated in a very complex manner, by all the biotic and abiotic factors controlling the ecology of soil organisms (section 2.2).

2.1.1.2 PROVISIONING SERVICES

Plants are primary producers able to produce biomass from inorganic compounds, and their products are often referred to as primary production. Photosynthesis is the main chemical process through which plants produce organic compounds (the primary production) from the fixation of atmospheric CO2:

CO2 + H2O (water) + *light* = CH2O + O2

The molecule obtained by the fixation of CO2 is generally called reduced carbohydrate. Importantly these simple molecules produced by plants can be used to synthesise more complex molecules such as lipids or proteins. Alternatively the reduced carbohydrates can be consumed by plants to obtain energy for their growth.

In addition to photosynthesis, plants absorb ions made available by soil organisms via their roots, or through mass flow and simple diffusion. The mineral ions absorbed by the plant travel from the roots to the growing parts where they are integrated to form new indispensable molecules for the plant.

Both the abundance and the quality (i.e. nutritional quality) of primary production are intricately linked to the diversity of functions performed by soil fauna and flora, since the functional groups contribute to the availability of nutrients and to the soil structure, two crucial parameters for plant growth. However there are little data to quantify this linkage.

2.1.2 WHY IS THIS SERVICE IMPORTANT TO HUMAN SOCIETY?

Soil fertility and nutrient recycling are evidently important to human society for several reasons. First of all, this service is indispensable for food production and more generally for all forms of agriculture and forestry. Plants take up the non-mineral nutrients — carbon, hydrogen and oxygen — from air and water, while the soil plays a role in providing them with the mineral nutrients essential for their growth. This service is also important through the deleterious impacts that its improper management may bring, such as eutrophication of water bodies by effluents and air pollution (Lavelle, Dugdale et al. 2005).

Plants provide products (ecosystem goods) that are important for the development of human society. The most evident of these is food, in the form of fruits and vegetables and other derived food products (e.g. vegetal oils). All of these products provide vitamins, mineral elements, proteins, lipids, oligo-elements, fibres and sugars which are crucial for the human diet. But the plant-derived products are not limited to food.

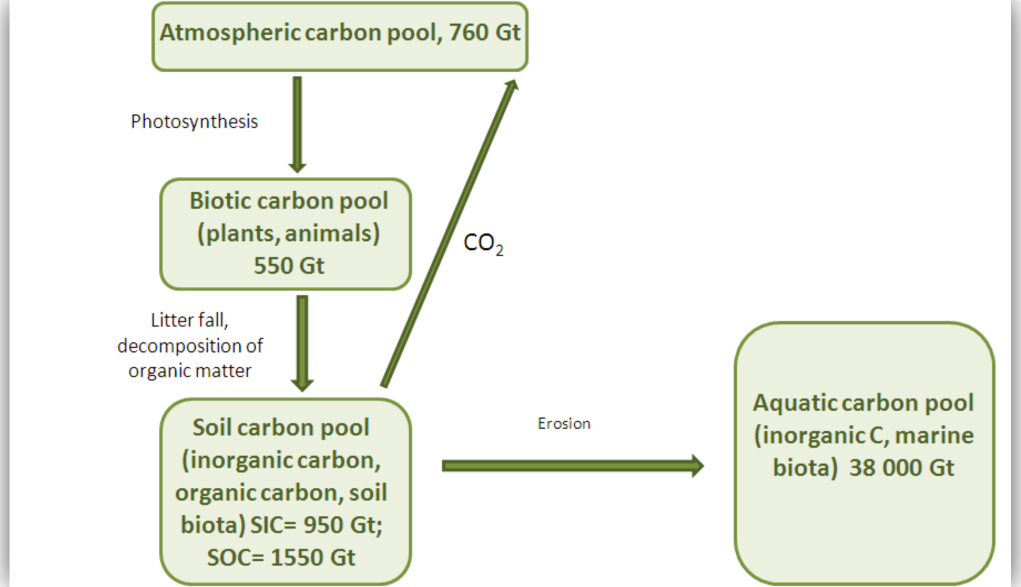
A large spectrum of additional products, ranging from energy to genetic resources, is provided by primary producers. To cite some examples: textile fibres, wood, fuel (e.g. biofuel), and a large quantity of active molecules used in pharmaceuticals. Thus, the provision of the soil fertility and nutrient recycling service is crucial for human society and its impairment would have important impacts on our development.

In addition, primary producers (plants) release oxygen into the atmosphere and through the process of evapo-transpiration, which is the sum of evaporation and plant transpiration from the soil surface to atmosphere. The primary producers partly regulate the movement of water to the air, which is an essential step in the water cycle and local climate regulation. Thus, this service is indirectly linked to the water and climate regulation services discussed later in this chapter.

2.2 REGULATION OF CARBON FLUX AND CLIMATE CONTROL

Soil biological processes driven by soil biota can have an important effect on the global carbon cycle. This is because **soils are both a sink and a source of carbon**. Soil stocks carbon mainly in the form of soil organic matter and releases carbon in the form of carbon dioxide (CO2) formed during the decomposition of soil organic matter. The soil carbon pool is thus in a dynamic equilibrium of inputs and outputs (Figure 3-3). Soil is the second largest global carbon pool, estimated to contain about 2500 Gt of carbon to one metre depth, and with vegetation contains some 2.7 times more carbon than the atmosphere (Woodward 2009).

Soil carbon stock can be organic or inorganic. If we consider the soil inorganic pool included, the soil pool contains three times as much carbon as the atmosphere. The carbon stored in aquatic, especially marine systems, contains more carbon than soil and air together.

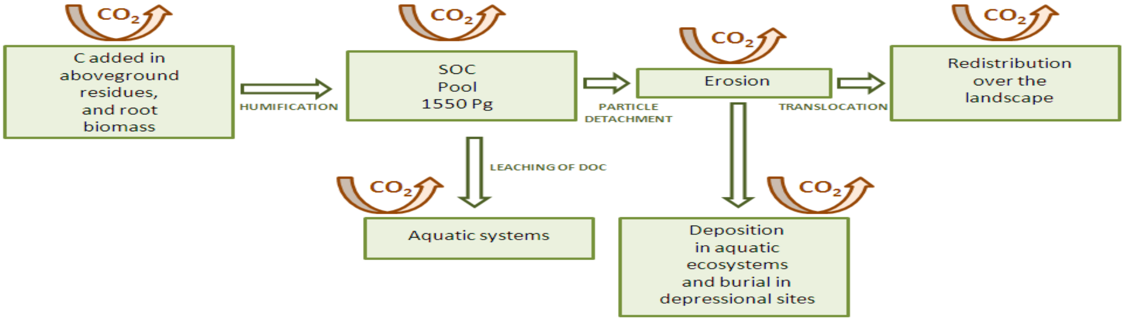


The carbon output is mainly in the form of carbon dioxide (CO2), which is one of the main greenhouse gases (GHG) contributing to global warming. In addition to CO2, soil biota can also control fluxes of other GHGs, such as methane (CH4), which is produced during the carbon cycle, and nitrous oxide (N2O) which is produced as part of the nitrogen cycling (Box 7). While these gases represent much smaller fluxes than those of CO2, they are much more potent than carbon dioxide as a greenhouse gas (21 times and 310 times, respectively).This process, together with the GHG released by human activity, contributes to global warming.

Thus, through their capacity to stock carbon, soils can act as a buffer compartment in a context of climate change. A good carbon storage capacity of soils could be one of the tools for climate change mitigation, especially because of its immediate and low cost availability. However, the limited magnitude of its effect and especially its potential reversibility, for example due to converting grassland into arable land, should be kept in mind (Schils 2008). Moreover, the soil carbon pool is itself susceptible to warming, causing enhanced carbon loss to atmosphere and carbon cycle feedback (Huntingford 2000).

2.2.1 WHICH PROCESS IS RESPONSIBLE FOR THE DELIVERY OF THIS SERVICE?

The regulation of carbon flux is a process driven by soil biota. The global soil organic carbon pool is estimated at 1550 Giga tonnes (Gt), 73-79 Giga tonnes of which (around 5%) are stored in Europe (Schils 2008). Soil organic carbon is the main fraction of the soil carbon pool. The soil organic carbon pool is mainly formed by soil biota and accumulated organic matter (e.g. litter, aboveground residues).Soil organic carbon is gained through the decomposition of organic matter leading tohumification of lignin, cellulose and other organic compounds by soil microorganisms(Figure 3-4). A part of the organic matter is mineralised in the inorganic carbon pool.Thus, all the soil organisms involved in organic matter decomposition play a key role inthe delivery of this service.



Soil organic carbon can be lost in the form of CO2. The CO2 released during the respiration of soil organisms involved in the various soil organic matter decomposition processes is widely thought to be one of the most important sources of CO2 to the atmosphere. The size of this flux is 55 Gt per year (Schils 2008). Indeed, feedback between soil organic carbon and atmospheric CO2 is a process which is not fully understood yet. In addition to this loss in gaseous form, soil carbon equilibrium can be altered by other processes. Soil particles containing both organic and inorganic carbon can be detached from the soil matrix and transported away, being redistributed in the landscape or deposited in aquatic ecosystems. Carbon can also leach from soil to water.

All these processes are influenced by soil texture, biomass, level of disturbance, soil structure, nutrient cycling, profile characteristics, and climate. Thus, some types of soils, having different textures or land uses can store more carbon than other types: in Europe, for example, peat land soils store 20% of the total carbon stored in EU soil. Indeed, the published literature shows large variations in the amounts of carbon accumulated in different soil categories. Grassland soils were found in all studies to generally accumulate carbon. However, the studies differ on the amount of carbon accumulated. In one study, the sink estimate ranged from 1 to 45 million tonnes of carbon per year and, in another study, the mean estimate was 101 million tonnes per year. Croplands were found to act as a carbon source, but estimates are highly variable. In one study they were estimated to be a carbon source equal to 39 million tonnes per year, while in another study, croplands in Europe were estimated to be losing up to 300 million tonnes of carbon per year. The latter is now perceived as a gross overestimation. Forest soils generally accumulate carbon. Estimates range from 17 to 39 million tonnes of carbon per year with an average of 26 million tonnes per year in 1990 and to an average of 38 million tonnes of carbon per year in 2005. It would seem that on a net basis, soils in Europe are on average most likely accumulating carbon. However, given the very high uncertainties in the estimates for cropland and grassland, it would not seem accurate and sound to try to use them to aggregate the data and produce an estimate of the carbon accumulation and total carbon balance in European soils (Schils 2008). Thus, precise future estimations are difficult to extractfrom the literature, given the number of uncertainties, including the dynamic trends in land-use change in Europe. Given the political importance of the management of soils for carbon storage, some recent works have estimated the potential for agricultural soils to sequester more carbon through changes in management, and this has been recently considered in the context of different biological strategies for C sequestration (Woodward 2009).

In any case, any activity altering the input of organic matter to soil (e.g. conversion from natural to urban landscape), modifying organic matter decomposition by soil

Co-funded by the
Tempus Programme
of the European Union

organisms, or that favours erosion or leaching, can have significant impacts on the delivery of the carbon storage service of soils (see also section 4.).

In Europe, for example, the largest emissions of CO2 from soils are resulting from landuse

change (e.g. from grassland to agricultural fields) and the related drainage of organic soils. This is due to the fact that land-use changes modify soil conditions (e.g. oxygen concentration) and thus activate soil biota mediated production of CO2. In the pre-industrial era, soils were one of the major sources of atmospheric CO2 mostly due to land-use change (e.g. conversion of natural environments into agricultural land). However, in the industrial era, carbon emitted by soil represents only half of the quantity emitted by fossil fuel combustion.

2.2.2.WHY IS THIS SERVICE IMPORTANT TO HUMAN SOCIETY?

The service of regulating climate through regulating GHG fluxes is very important to human society. Even relatively small changes in the CO_2 flux between soil and the atmosphere, for example, could have a significant impact on climate. A perturbation of climate stability can lead to several deleterious effects for human society. Direct effects could be to affect human health, water resources, crop productivity, food resources and security. Indirect effects could be to disturb social equity, governance, production and consumption patterns and population growth (IPCC 2007). In addition, a deregulation of climate due to an impaired GHG flux in soils may strongly affect all other natural ecosystems leading to losses in global ecosystem services.

2.3.REGULATION OF THE WATER CYCLE

Soil water regulation services include the capacity to infiltrate water, store it underground, as well as regulate its flux and purity in a balanced way in order to keep water quality and quantity. 100 European Commission - DG ENV Soil biodiversity: functions, threats and tools for policy makers February 2010

2.3.1 WHICH PROCESS IS RESPONSIBLE FOR THE DELIVERY OF THIS SERVICE?

Rainfall, snow, and dew, are the main sources of water reaching soil. Water reaching the soil surface can follow different paths (Figure 3-5):

- infiltration and/or surface run-off
- interflow below the soil surface
- evaporation and root uptake, followed by evapo-transpiration by plants
- deep percolation to groundwater Figure 3-5: Water pathways in soil (Bardgett, Anderson et al. 2001)

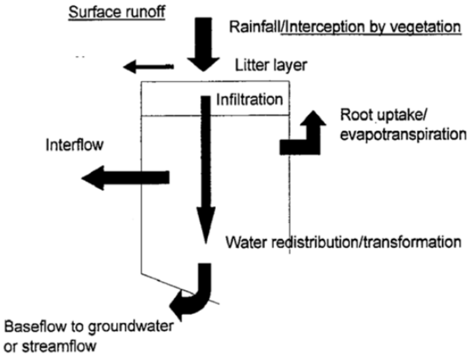


Figure 3-5: Water pathways in soil (Bardgett, Anderson et al. 2001)

The majority of processes linking soil properties and soil biodiversity to water control services have been qualitatively described, but precise quantification of these direct and indirect relationship are lacking (Bardgett, Anderson et al. 2001).

WATER INFILTRATION

When water reaches the soil, it can infiltrate underground or run-off along the soil surface. The choice between these two options depends on the quality of the soil matrix which is in turn determined by soil properties, including biodiversity. Apart from some algal crusts in the Arctic ecosystem that block water infiltration, the majority of soil organisms have a positive impact on the infiltration rate. For example, soil engineers such as earthworms and termites can significantly increase infiltration rates through soil by creating macro-pores and channels. Thus, for example, the elimination of earthworm populations due to soil contamination can reduce water infiltration rate up to 93% (Clements 1982). In addition to earthworms, ants and termites can affect water infiltration rates. Underground aquifers can be recharged by the water flow passing though nest galleries, particularly in arid environments. For example, the elimination of small populations of a species of termite in the Chihuahuan Desert resulted in a modification of surface run-off pattern and infiltration (Bardgett, Anderson et al. 2001). Other organisms can also have indirect effects on water infiltration rates through modifying the quantity and quality of soil organic matter. February 2010 European Commission - DG ENV Soil biodiversity: functions, threats and tools for policy makers 101 Another major factor controlling the water infiltration rate in soil and its capacity for water retention is the surface of ground covered with plants or plant litter. The vegetation quality and distribution in the soil matrix is regulated by soil characteristics and soil biodiversity which, as we have seen, ensure the appropriate functioning of the ecosystem, providing the conditions for plant growth. The presence of vegetation can regulate the quantity of water reaching the soil by protecting it with leaves, capturing the water and structuring the soil with underground roots. The result of this action is that water is kept locally and can pass through into underground reserves. When vegetation is limited or absent, water will run off, instead of going underground, enhancing the erosion of soil particles. Plant roots prevent that soil particles from being washed away with water flows, keep soil macro-aggregates together and avoid landslides. In the case of deforestation, the run-off and the associated risk of erosion are increased, while the water infiltration rate is decreased (see also section 4. 2. 1). Thus, a healthy soil sustaining plant growth is also particularly important to avoid erosion (Ineson et al. 2004). In the USA, for example, it has been observed that land without vegetation can be eroded 123 times faster than land covered by vegetation, which lost less than 0.1 ton of soil per ha/yr. In Utah and Montana, in cases where the amount of ground cover decreased from 100% to less than 1%, erosion rates increased approximately 200 times (Pimentel and Kounang 1998)(Figure 3-6). Figure 3-6: Soil erosion rates related to percentage of ground cover in Utah and Montana (Pimentel and Kounang 1998) As a consequence, the frequency and the intensity of run-off, flooding, and aquifer recharge can be strongly influenced by changes in land cover. This includes, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or forests into croplands, or the conversion of croplands into urban areas.

WATER PURIFICATION

The infiltration of water through the soil is also an important part of water purification. Contaminants and pathogenic microbes (e.g. some forms of bacteria and viruses) can then be absorbed on the surface of soil particles during this infiltration, resulting in cleaner and safer water. Several physico-chemical processes take place during the water infiltration: sedimentation, precipitation, oxidation-reduction, sorption- 102 European Commission - DG ENV Soil biodiversity: functions, threats and tools for policy makers February 2010 desorption, ion-exchange and biodegradation of contaminants. The ability of soil to perform these functions depends on its texture, salt content, humus content and richness in microorganisms located in the subsurface. All these factors are, at least partly, dependent on soil characteristics, including soil biodiversity.

WATER STORAGE AND TRANSFER

Once infiltrated, water is redistributed underground. This redistribution is highly dependent on soil porosity, which in turn is influenced by the activity of ecosystem engineers. The existence of pores of different sizes allows water to be retained at different tensions (the smaller the size of the pore, the greater the force with which it is retained in soil) providing plants with a continuum of water resources as soil dries (Bardgett, Anderson et al. 2001). In addition, the productivity and composition of plants can also influence water transfer, by controlling the rate of evapo-transpiration of water, from the soil to the atmosphere. Thus, water movement is indirectly regulated by plant and root biomass distribution, which are both partly dependent on soil biodiversity. For example, when a root-feeder, such as a nematode, alters the plant growing rate, this will influence the overall evapo-transpiration rate and water movement (Figure 3-7). Figure 3-7: Scheme of the role of soil properties and biodiversity in soil water pathways (Bardgett, Anderson et al. 2001)

2.3.2 WHY IS THIS SERVICE IMPORTANT TO HUMAN SOCIETY?

Water quality and quantity are essential to human life, and most of it comes from underground sources. Thus if the groundwater quality is degraded because of impairment in soil functioning, all the degradable pollutants will not be degraded or neutralised. As a consequence, the need for water treatment facilities will increase. If the groundwater quantity is reduced following impairments in soil regulation of rainfall infiltration and storage, the underground reservoirs of drinking water indispensable in periods of droughts will be impaired. In addition, the surface run-off will be increased February 2010 European Commission - DG ENV Soil biodiversity: functions, threats and tools for policy makers 103 leading to a higher frequency of peak flows and flood risk. Such stronger run-off will then result in higher erosion rates and an increased accumulation of sediments in flood water. An increased quantity of sediments transported by flood waters will in turn result in a higher risk for human health (Ebi, Kovats et al. 2006). Obviously, a degradation of water quality and a decrease in quantity could also have deleterious impacts on human wellbeing and quality of life, and in the more extreme scenario, affect human health. Additional negative impacts resulting from the impairment of the water regulation service include eutrophication of water bodies, sedimentation of gravel-bedded rivers, loss of reservoir capacity, and muddy flooding of roads and communities. Thus, maintaining an efficient water regulating service will avoid important costs for the construction and the operation of water purification plants and remediation to prevent the drying out of streams as well as to ensure flood control. First attempts to economically evaluate the value of healthy ecosystems providing a good water quality have been performed. Since 1997, there is a worldwide trend to organise systems for payment of water services, in which people living in the higher parts of water catchments where water is stored and purified get subsidies from people from low lying areas (urban and industrial areas) to maintain ecosystem in good health and hence, water services (280 000 ha enrolled a cost of $30 million)(MEA 2005).

2.4. DECONTAMINATION AND BIOREMEDIATION

Soil is a natural sink for pollution. Soil contamination is deleterious for both the environment and for human health. However, soil-related processes can mitigate the impacts of pollution on the environment and human health through modification and control of their chemical fate and behaviour, thus limiting the transfer of pollutants to other media. This service is called decontamination or bioremediation. Natural occurring bioremediation can be enhanced by human intervention, called humandriven bioremediation. This is often applied to try to return a contaminated area back to its pristine state. However, this is in general a very long-term process, which in some cases is not possible where the contaminant loads are too large or the risks too high. Bioremediation can be performed using:

- microbes (most cases) which transforms organic compounds
- plants which can accumulate a pollutant and facilitate its removal from soil matrix (phytoremediation)

Bioremediation can ensure, for example, the partial decontamination of an aquifer once the pollution source has been removed or when hotspots of pollution have been treated. A number of frequently encountered pollutants, such as chlorinated hydrocarbons, benzene, toluene, xylene, and ethyl benzene can be removed through natural soil decontamination. Other components such as inorganic molecules and pesticides can also be remediated by soils, while heavy metals can be chemically neutralised into inactive forms by chelation processes, accumulated in plants and removed from the sites (Table 3-3). Indeed, several pollutants such as persistent organic pollutants (e.g. dioxins) cannot be decomposed by soil microorganisms. Moreover, soil microorganisms can also be intoxicated by dangerous substances in the soil. Therefore it is necessary to take into account the toxicity to soil organisms as part of the risk assessment of contaminated sites.

The overall service is ensured by both biotic and abiotic soil properties and depends on local geology, hydrology and ecological communities. Both biological and physicochemical processes underlie the provisioning of this service.

2.4.1 WHICH PROCESS IS RESPONSIBLE FOR THE DELIVERY OF THIS SERVICE?

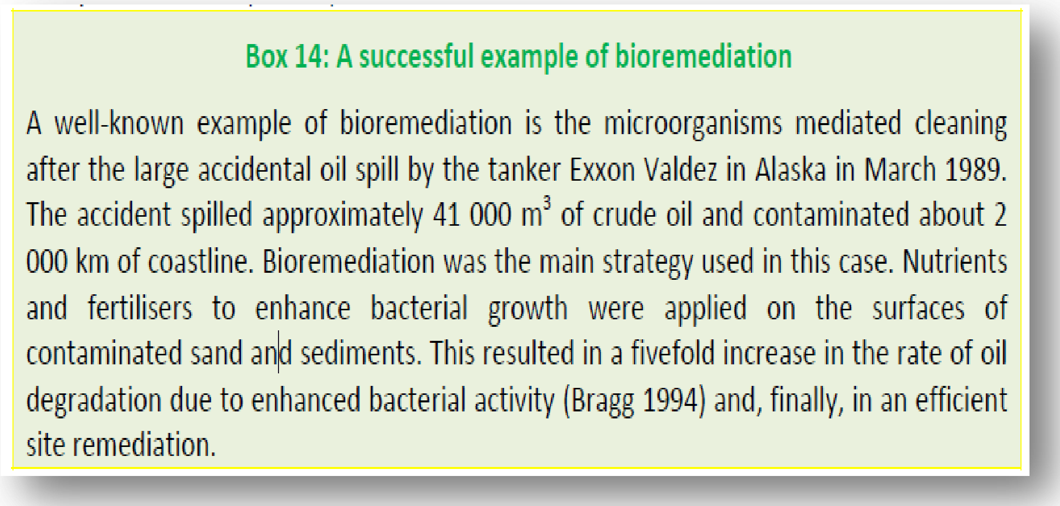
The microorganisms included in the group of chemical engineers play a key role in the four biological processes mentioned above. However the overall process of biodegradation of a compound is often a result of the actions of multiple organisms. Effects of biological controllers and ecosystem engineers which are the proximate determinants of microbial activities are also likely to play a great role in microorganism performances.

The microorganisms performing bioremediation may be:

- indigenous to a contaminated area (natural bioremediation)
- indigenous from a non contaminated area and transported on site (humandriven bioremediation)
- selected in a laboratory and transported to the contaminated site (humandriven bioremediation)

In order to have an effective bioremediation, microorganisms must enzymatically attack the pollutants and convert them to harmless products. As a consequence, all factors influencing their survival, growth and activity rate can have an impact on the efficiency of bioremediation. Thus, human-driven bioremediation often involves the manipulation of environmental parameters to allow pollutants degradation to be more efficient. Of course the optimal environmental parameters depend on the pollutant to be treated and the specific microorganism used.

Bioremediation can be performed *in situ*, which means directly in the polluted area or *ex situ* which means that the contaminated soil is transported elsewhere to be treated. The *in situ* strategies are in general less expensive and provoke a minor disturbance to local ecosystems than *ex situ* strategies, because the human alteration of the local ecosystem is lower (Box 14).



Box 14: A successful example of bioremediation

A well-known example of bioremediation is the microorganisms mediated cleaning after the large accidental oil spill by the tanker Exxon Valdez in Alaska in March 1989. The accident spilled approximately 41 000 m^3 of crude oil and contaminated about 2 000 km of coastline. Bioremediation was the main strategy used in this case. Nutrients and fertilisers to enhance bacterial growth were applied on the surfaces of contaminated sand and sediments. This resulted in a fivefold increase in the rate of oil degradation due to enhanced bacterial activity (Bragg 1994) and, finally, in an efficient site remediation.

Soil organisms can also affect important soil characteristics such as porosity, pH and organic matter content, that have an indirect effect on pollutants decontamination (Bennett, Hiebert et al. 2000). In addition, a number of chemicals secreted by bacteria and fungi can influence desorption (contrary process of absorption) and the removal of metals and hydrocarbons from the soil matrix. Using a fungus, for example, a maximum solubilisation of 68% for copper for a medium containing potato peels was achieved (Mulligan and Kamali 2003).

Remediation by plants is called phyto-remediation. In the case of phyto-remediation the link between the service and soil biodiversity is indirect compared to microbial mediated bioremediation, for example because soil biodiversity plays a role in regulating plant abundance and distribution. This process is particularly useful to remove metal pollutants and widespread residual organic compounds from soil and water. Plants are efficient in accumulating and immobilising persistent pollutants. Several strategies of phyto-remediation exist: phyto-extraction, phyto-transformation, phyto-stabilisation, phyto-degradation, phyto-volatilisation and rhizo-filtration (Table 3-5). A combination of these processes can occur in nature.

All the abiotic processes involved in soil decontamination and their efficiency aredetermined by the physico-chemical properties of soil surface, soil porosity, the chemical properties of pore-water compartment, and, of course, the physicochemicalproperties of the pollutants (e.g. behaviour of organic and inorganic molecules may be

significantly different in the soil matrix).
The presence of surface active fractions such
as organic matter, possessing high surface areas and charges can, for example, facilitate oil retention in the soil matrix. All these physico-chemical properties are directly or indirectly linked to soil properties and biodiversity. For example, earthworms and microbes are key actors in the determination of soil aggregation and porosity. Similarly, microbial activity can locally alter soil pH, affecting soil aggregation
and its capacity to absorb contaminants.
Therefore, a high diversity and biological activity within soils, especially at the level of chemical engineers, but also in the case of ecosystem engineers, is indispensable to ensure this crucial service through a direct influence on soil biotic degradation processes and an indirect influence on soil abiotic degradation processes of pollutants.

2.4.2 WHY IS THIS SERVICE IMPORTANT TO HUMAN SOCIETY?

Three alternatives exist to bioremediation: physical removal of pollutants, dilution, and treatment. However, soil clean-up is, in general, a difficult operation with very high costs. The European Environment Agency has estimated the total costs for the clean-up of contaminated sites in Europe to be between 59 and 109 billions of Euros (EEA 2000).
Bioremediation is the cheapest option for soil decontamination.
The natural capacity of soil to decontaminate has permitted to restore numerous sites (Bragg 1994). This extremely important service has thus been the object of extensive studies. A number of bacteria, fungi (including mycorrhizae) and plants have been tested to evaluate their decontamination capacity. Bioremediation using microorganisms presents some general benefits:

- It is useful for the complete destruction of a wide variety of contaminants, rather than simply transferring them among natural media (e.g. pollutants transfer from soil to water or atmosphere)

- The residues for the treatment are usually non-toxic products and include carbon dioxide, water, and cell biomass
- It is a natural process generally perceived by the public as an acceptable method for waste treatment
- In most cases, when the contaminant is degraded, the bio-degradative microbial population declines
- The transport of waste is limited when *in situ* strategies are chosen

- It is a relatively low-cost option

However, natural soil decontamination is often not sufficient to restore a polluted site completely, since natural biodegradation processes are in general very slow (several decades), soil organisms cannot break down some pollutants, and sometimes the contaminant load is too large. This extremely important service has thus some limitations:

- It does not apply to all contaminants, e.g. to some hydrophobic organic compounds
- It is very slow and sometimes the risks and the exposure to dangerous substances do not allow for such long techniques
- It may not work if the contaminant load is too significant (see section 5.5.1)
- In some cases, the properties of the biodegradation products are not known well enough to be sure that their nature is not more toxic than the original molecule
- There is a difficulty in controlling all the environmental conditions for an optimal bioremediation
- More research is needed to improve treatments for soil contaminated by complex mixtures of pollutants
- It is a long term treatment, compared to alternative strategies, and thus it requires the monitoring of the contamination (which may increase the costs of such technologies)
- It is rarely 100% efficient in the elimination of pollutants. Regulatory

uncertainty remains regarding acceptable performance criteria, e.g. can an efficiency of around 70% in the pollutant removal be acceptable and is the site then defined as completely decontaminated?

Understanding the categories of chemicals that can be biodegraded and the responsible biotic and abiotic transformation processes underlying natural attenuation is crucial to ensure the development of bioremediation, due to its potential of efficient and inexpensive soil cleaning. However, natural soil decontamination is often not sufficient to restore a polluted site completely, since natural biodegradation processes are in general very slow (several tens of years).

In the case of plants, 400 species capable of accumulating metals have been reported (Yang 2004). After sufficient plant growth and metal accumulation, the aboveground portions of the plant are harvested and removed, resulting in the permanent removal of metals from the site. Phyto-remediation is preferentially used in the following conditions:

- Very large field sites
- Sites with a low concentration of contaminants
- As the final step of a decontamination procedure

There are some limitations:

- Long duration of time (and thus long term monitoring of the contamination)
- Potential contamination of the vegetation and food chain (when the pollutant is not degraded within the plant or when the plant is not removed)
- Difficulty in establishing and maintaining vegetation in heavily polluted sites.

In conclusion, the application of bioremediation using either microorganisms or plants is feasible and relatively cheap. However, the option of transforming the pollutants through microbial conversion seems preferable to the option of bio-accumulating the pollutant into a plant, thus leading to a simple transfer from one ecosystem to another medium. Setting a bioremediation protocol in a contaminated site requires excellent knowledge of the nature and distribution of the pollution as well as of the local soil organisms and plants. Different levels of cleaning up can be reached, depending on the case, but to date precise criteria that define the quality of bioremediation are still lacking.

About the soil biodiversity .Coleman D.C., Crossley,D.A.,Hendrix P. in their book Fundamental of soil ecology write: There is increasing concern among biologists in the fates of the very diverse array of organisms in all ecosystems of the world. What do we know of the full species richness, particularly in soils, to make even educated guesses about the total extent of the organisms, or how many of them may be in an endangered status (Hawksworth, 1991a, 2001; Coleman et al., 1994b; Coleman, 2001)? Soil biodiversity is best considered by focusing on the groups of soil organisms that play major roles 247 in ecosystem functioning. Spheres of influence of soil biota are recognized; these include the root biota, the shredders of organic matter, and the soil bioturbators. These organisms influence or control ecosystem processes and have further influence via their interactions with key soil biota (e.g., plants) (Coleman, 2001; Wardle, 2002). Some organisms, such as the fungus and litter-consuming microarthropods, are very speciose. For example, there are up to 170 species in one Order of mites, the Oribatida, in the forest floor of one watershed in western North Carolina. Hansen (2000) measured increased species richness of Oribatids as she experimentally increased litter species richness in experimental enclosures from one to two, four, and finally seven species of deciduous tree litter. This was attributed to the greater physical and chemical diversity of available microhabitats, which is in accord with the mechanisms suggested earlier by Anderson (1975). Only 30–35% of the Oribatids in North America have been adequately described (Behan-Pelletier and Bissett, 1993), despite many studies carried out over the last 20–30 years. The studies suggest that there may be more than 100,000 undescribed species of oribatid mites yet to be discovered. Particularly in many tropical regions, Oribatids and other small arthropods are very little known in both soil and tree canopy environments (Behan-Pelletier and Newton, 1999; Nadkarni et al., 2002). This difficulty is compounded by our very poor knowledge of identities of the immature stages of soil fauna, particularly the Acari and Diptera. Solution of this problem may require considerable application of molecular techniques to more effectively work with all life stages of the soil fauna (Behan-Pelletier and Newton, 1999; Coleman, 1994a; Freckman, 1994). We concur with Behan-Pelletier and Bissett (1993): “Advances in systematics and ecology must progress in tandem: systematics providing both the basis and predictions for ecological studies, and ecology providing information on community structure and explanations for recent evolution and adaptation.” Chapin et al. (2000) note that 12% of birds and nearly 20% of mammals are considered threatened with extinction, and that from 5 to 10% of fish and plants are similarly threatened. With many of the soil invertebrates yet undescribed, it is impossible to affix a numerical value to losses of these members of the biota. There are currently 70,000 species of fungi described (Table 7.1). By assuming that a constant ratio of species of fungi exists to those plant species already known, Hawksworth (1991b, 2001) calculated that there may be a total of 1.5 million species of fungi described when this mammoth classification task is completed. Indeed, it may be possible to gain insights into biotic functions belowground by considering a “universal” set of functions for soil and sediment biota that include the following: degradation of organic matter

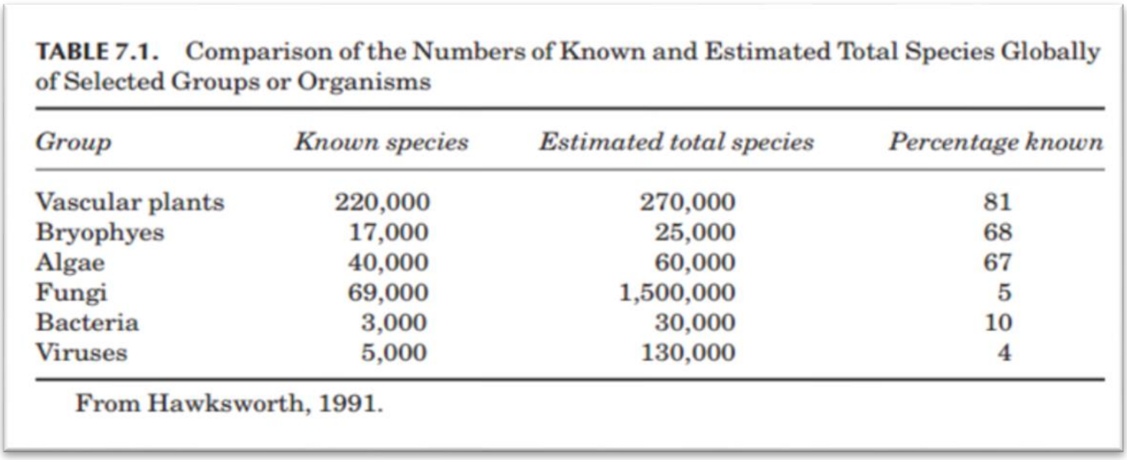


TABLE 7.1. Comparison of the Numbers of Known and Estimated Total Species Globally of Selected Groups or Organisms

Group	*Known species*	*Estimated total species*	*Percentage known*
Vascular plants	220,000	270,000	81
Bryophyes	17,000	25,000	68
Algae	40,000	60,000	67
Fungi	69,000	1,500,000	5
Bacteria	3,000	30,000	10
Viruses	5,000	130,000	4

From Hawksworth, 1991.

cycling of nutrients, sequestration of carbon, production and consumption of trace gases, and degradation of water, air, and soil pollutants (Groffman and Bohlen, 1999). What are the consequences of biodiversity? Does the massive array of hundreds of thousands of fungi and probably millions of bacterial species make sense in any ecological or evolutionary context? As was noted in Chapter 3 on microbes, the numbers of bacterial species are greatly underestimated because most investigations have relied on culturing isolates and examining them microscopically. There have been two key developments in studies of microbial diversity. First, the use of signature DNA sequences has greatly increased the numbers of identi- fied taxa, with hundreds of novel

DNA sequences being identified yearly. Two bacterial divisions, which appear to be abundant and ubiquitous in soils but have very few cultured representatives, are Acidobacterium and Verrucomicrobium (Hugenholtz et al., 1998). Second, we have only recently come to an appreciation of the incredibly wide distribution of prokaryotes (both Archaea—methanogens, extreme halophiles living in hypersaline environments, and hyperthermophiles living in volcanic hot springs and mid-sea oceanic hot-water vents—and Bacteria) worldwide. Prokaryotes constitute two of the three principal domains, or collections of all organisms, with Eucarya consisting of protists, fungi, plants, and animals (Fig. 7.1) (Pace, 1999; Coleman, 2001). The total numbers of bacteria on earth in all habitats is truly mind-boggling: 4–6·1030 cells, or 350–550 petagrams (1015 g) of carbon (Whitman et al., 1998). The amount of the total bacteria calculated to exist in soils is approximately 2.6·1029 cells, or about 5% of the total on earth. A majority of bacteria exist in oceanic and terrestrial subsurfaces, especially in the deep mantle regions, extending several kilometers below the earth's surface. Some of these organisms, which are the most substrate-starved on earth, may have turnover times of centuries to millennia (Whitman et al., 1998).

2.5 PEST CONTROL

Biological pest control is the natural or human-influenced ability of natural competitors, predators or parasites, to act as biological control agents for pest species. This control can be through top-down or bottom-up mechanisms. Top-down pest control occurs when a predator controls the structure/population dynamics of a species within the ecosystem. Bottom-up control in ecosystems occurs when the nutrient supply controls the development of species. Evidences from natural systems show that the low diversity of an ecosystem is associated with a higher vulnerability to pests, due to altered top-down and bottom-up control mechanisms. In agricultural fields, for example, the soil functioning is modified and, as a consequence, its equilibrium can be altered leading to outbreaks of crop pests. Thus, the natural biological pest control service can be used as an alternative to pesticides. Biological pest control strongly influences the provisioning services as well, because it promotes primary production: diseased crops do not produce food or fibers as efficiently as healthy crops.

2.5.1WHICH PROCESS IS RESPONSIBLE FOR THE DELIVERY OF THIS SERVICE?

Soil biodiversity ensures pest control by acting both directly on belowground pests, and indirectly on aboveground pests. In ecosystems presenting a high diversity of soil organisms, harmful microbes or nematodes attacking crops are less aggressive, as their effects are diluted in larger communities (Altieri and Letourneau 1982; Lavelle, Bignell et al. 2004). In addition, vegetation diversity (aboveground diversity), which is in part regulated by soil biodiversity, favors aboveground pest control through supporting natural insect communities and some plant species that are specific targets for pests, thus alleviating the pest charge on other plants.In natural communities, the size of populations is mainly regulated by the presence of

other organisms. Pests spread occurs either when top-down or bottom-up controls are not efficient enough. Soil biodiversity can influence both top-down and bottom-up effects:

- **Top-down pest control:** a typical top-down control mechanism is, for example,

an induced enhancement of the natural enemies. This strategy has been applied by Settle et al. (1996) who demonstrate how organic inputs in rice fields, by maintaining high levels of decomposer communities, maintain constant levels of generalist predators26 that feed on pest species. Whenever an insect pest arises, control is immediately triggered as generalist predators are already present. The idea is thus to favour the resources needed by the pests' natural enemies.
Possible strategies to enhance the natural top-down effects include improving the availability of alternative foods preferred by the natural enemies, facilitating the creation of a microclimate in which natural enemies may overwinter

or seeking refuge from factors such as environmental extremes or pesticides, etc. In addition, the temporal availability of such resources may be manipulated to encourage early season activity of natural enemies. Finally, the spatial arrangement of such resources to enhance natural enemy activity within the crop must be considered.

- **Bottom-up pest control:** bottom-up strategies act directly on the resources available for pests. In practice, the density of invasive predators can be controlled by limiting their resources at the base of the food web.

Several studies show that pest control relationships within the food web depend on general soil biodiversity, rather than on the presence of a specific species of soil organisms. For specific soil-borne crop enemies, such as for example the cereal rootpathogens and the root knot nematodes, it seems that there should be specific microbial enemies that play a key role in controlling the pest (Kerry 1998). However, recent multi-disciplinary approaches have shown that there is in fact a wide range of control factors for this kind of pest, which all play a role in their suppression (van der Putten, Cook et al. 2006). Similarly, it has been observed in the case of the pea aphid pest, that when three of its enemies were present, the pest was suppressed more than predicted from the summed impact of each enemy species alone (Cardinale 2003).

Threats to soil biodiversity can alter soil community structure and internal food web interactions. This results in deleterious impacts on the ecosystem's self-regulation properties and favours pests. However, if relatively simple precautions are taken to maintain some diversity surrounding the crops, pest invasion can be controlled. Some evidence indicates the importance of the ground cover vegetation or of the adjacent wild vegetation to protect crops from pests. Specific types of weeds, for example, can harbour and support beneficial arthropods species capable to fight pest populations (Boatman 1994). In general, the more diverse and stable the agro-system, the more stable the insect community.

In conclusion, in a diverse ecosystem, the species present cover all the available ecological niches and use the resources available in an optimal way (Elton 1958). This balance impedes the development of pests and invasive species (Altieri 1994). Thus, keeping a high bio-diverse ecosystem is an important part for a good defensive strategy, at least for generalist pest species.

2.5.2 WHY IS THIS SERVICE IMPORTANT TO HUMAN SOCIETY?

The provision and the regulation of primary production is one of the most important services ensured by soils. The service of pest regulation is indirectly related to the primary production, since such a control avoids the loss of plants and plant products. Understanding the importance of this service is thus evident for everybody: diseased crops don’t provide food and fibres. A loss of plants and of their products due to a pest invasion could not only dramatically affect human health through a loss of crops yields and consequently food resources, but also seriously impair the economic, scientific and cultural development through the elimination of all the plant derived products. For example, the value of potato crops which are at risk from Colorado beetle in UK is about 322 millions of Euros 27. The importance of this regulatory service for human society is thus obvious (Figure 3-9). Moreover, the human-driven pest control is one method which can be used to reduce the need for large scale applications of broad spectrum pesticides. This category of pesticides can be highly problematic as they often act on insects which are beneficial to crops as well as harmful insects. It has been demonstrated that the use of pesticides can be at the origin of huge economic cost: a loss of more than 8 billions of dollars per year for the United States (Pimentel 2005). To that the ecological costs should be added. Inconclusion, the appropriate functioning of this service is crucial from both an environmental and an economic point of view.

3. Why the soil don't deliver the services?

Josepf Tarradellas, Gabriel Bitton and Dominique Rossel in their book Soil ecotoxicology say:

Soils are increasingly becoming receptacles for a wide range of hazardous chemicals generated by human activities. Modern agricultural practices also necessitate the use of a wide range of pesticides which may adversely affect non-target soil organisms. Although many of the organic toxicants, including pesticides, may be biodegraded by soil and groundwater microbial communities, some recalcitrant ones may persist for longer time periods in the soil and subsurface environments. The toxic or genotoxic compounds and sometimes their merabolites may adversely impact soil and groundwater resources with potential impact on human health. Hazardous organics and metals affect enzymes, nutrient cycling and organic matter degradation by microorganisms, and the soil fauna. Some may be trans located into agricultural crops, thus threatening human and animal health.

Ibrahim Mirsal in his book Soil pollution, origin, monitoring and remediation says about pollutants from agrochemical sources: Pollutants from agrochemical sources include fertilizers, manure, and pesticides. We may add to these the accidental spills of hydrocarbons used as fuel for agricultural machines. As it was mentioned before, the main pollution effect ,caused by fertilizers and manure, is the introduction of heavy metals and their compounds into the soil.

About mineral fertilizers More details give Bezuglov in their raport,he says:

Showing a negative impact on soil properties of long-term application of mineral fertilizers decreased humus content and its quality deteriorates due to changes in the relationship between the humic and fulvic acids.

One of the most important issues of modern agriculture is to maintain soil fertility. Soil degradation leads to a gradual decline in the volume production of education and catastrophic changes in the environment [1, 2].

The humus content is a key indicator of soil fertility. It was established experimentally that the increase in the content of humus in the sod-podzolic soil at 1% of arable land increases productivity by more than 25% [3]. Similar results were obtained in other studies. However, along with this, the observations show that in 30 years of intensive use of soils, for example, in the Saratov region of humus content in them has fallen from 7.0 to 6.5%, while in the whole of Central Black Earth region of Russia - 5, 6 to 5.1% [4]. In Bashkortostan soil during their agricultural use have lost about 20% of humus. Annual his loss is an average of 300 kg / ha [5].

According to leading soil scientists over the past 100 years, stocks of organic matter in the black earth of our country halved [6, 7].

The role of fertilizers in increasing the humus content of soil, until recently, was considered a positive side. However, in recent years there is a reassessment of their values. Increasingly, experts have expressed doubts about the possibility of increasing the content of organic matter through the use of mineral fertilizers [8, 9, 10]. Moreover, they can cause depletion of soil humus. These [(9), on L.K.Shevtsovu] obtained on the basis of generalization of the results of more than 400 long-term field experiments indicate that its content in the sod-podzolic soils in making complete mineral fertilizer in the first 20-30 years decreased in an average of 12-14%. It is concluded that the introduction of only mineral fertilizers does not compensate for the loss of soil organic matter. and other researchers have come to the same conclusions. The mechanism of this phenomenon is as follows.

Determination of coefficients of nutrients from the soil revealed that their values for mineral fertilizers, compared with unfertilized embodiments, tend to increase. In explaining the circumstances of this phenomenon was found to significantly increase in humus mineralization processes occurring under the influence of nitrogen fertilizers [11, 12]. It turns out that each unit of nitrogen fertilizer contributes to additional mobilization of 0 to 1.2 units of soil nitrogen [9]. This leads to an increase in soil of mobile connections and, as a consequence, capacity utilization of nutrients by plants. Movable nitrogen compounds formed by mineralization of organic matter, as well as nitrogen fertilizers, are included in the geochemical migration. Their share of the total number of infiltration of nitrogen losses from arable land is 10 to 50% [13, 14].

This was confirmed in the study of qualitative composition of humus. Under the influence of mineral fertilizers changing the ratio between humic and fulvic acids, increases the proportion of saccharide and oxygen-containing compounds, proteinaceous residues [15, 16]. According to some researchers, the long-term application of mineral fertilizers significantly reduced the proportion of humic acid [17]. Given that humic substances is an important environmental factor affecting the vital functions of soil organisms, their destruction will inevitably entail changes to the structure of the natural.

There may be a more significant adverse environmental effects dehumification soil. Humic substances on 52-62% consist of carbon. If mineralization occurs the formation of CO2 that enters the atmosphere and contributes to the formation of the greenhouse effect. It is estimated that 20% of the carbon dioxide accumulated in the atmosphere from human activities, was formed as a result of the destruction of soil organic matter [2].

The negative effects of the mineralization of humus under the influence of any agricultural practices, including the introduction of nitrogen fertilizers, are not only in the reduction of direct supply of nutrients in the soil, the deterioration of its properties, environmental problems, but also to reduce the potential for non-biological nitrogen fixation. Currently, there is evidence of the existence in the soil chemical nature of mechanisms for nitrogen fixation without the participation of living organisms [18]. According to experts, the need for crop nitrogen in the field by 40-50% is met by his fixation with natural humic substances. Changing the quality of humus can obviously have a significant negative effect on the activity of abiotic systems nitrogen fixation in the soil, since their operation depends on the physicochemical properties of the organic substance.

The negative effect of the systematic application of fertilizers on the plants, in addition to the acidification of the soil solution, and is due to increased mobility of aluminum, manganese and iron, wherein the modified numbers and species composition of microorganisms.

The most common adverse effect of mineral fertilizers on agro-physical properties of the soil found in the study of its microstructure.

Micro morphological studies have shown that even small doses of mineral fertilizers (30-45 kg / ha) have a negative impact on soil microstructure, continuing for 1-2 years after their introduction. Increases the density of packing of micro aggregates, reduced apparent porosity, reduced the proportion of grainy aggregates [36]. Prolonged application of mineral fertilizers leads to a decrease in the proportion of the particles of the sponge microstructure and an increase of 11% not unit material [37]. One reason for the deterioration of the structure is the depletion of arable soil layer of excrement of animals [38, 39].

Probably, agrochemical and agro-physical properties of soils are closely related, and therefore increasing acidity, the depletion of arable layer bases, reduction of humus content, the deterioration of the biological properties of naturally must be accompanied by a deterioration of the agro physical properties.

In order to prevent the negative impact of fertilizers on soil properties should be periodically liming. By 1966, the annual area of liming in the former USSR has exceeded 8 million. Ha and the amount of lime introduced was 45.5 million. M. However, this does not compensate for the loss of calcium and magnesium. Therefore, the proportion of land to be liming, not diminished, and even increased slightly in some regions. In order to prevent the increase in the area of acid land, it was supposed to double the supply of agricultural lime fertilizer and bring them to 1990 to 100 million tons [40, 41, 42].

Liming, reducing the acidity of the soil, at the same time causes an increase in gaseous nitrogen loss. In carrying out this method they increase 1.5-2-fold [43]. This soil reaction to the introduction of meliorantov is the result of changes in the direction of the microbiological processes that can cause violations of geochemical cycles. In this regard, he expressed doubts about the usefulness of liming [2]. In addition, lime exacerbates another problem - soil contamination by toxic elements.

The use of agricultural food contaminated with heavy metals and toxicants, is the cause in humans and farm animals of various diseases.

Soil contamination with heavy metals and toxic leads to their accumulation in plants. For example, in Sweden, the concentration of cadmium in wheat for the current century has doubled. There's also the application of superphosphate in a total dose of 1680 kg / ha, introduced parts for 5 years, saw an increase in the content of cadmium in wheat grain in the 3.5 times [50]. According to some authors, there was a threefold increase in its content in potato tubers with soil contaminated with strontium. [51] In Russia, it has not yet been given sufficient attention to pollution crop production chemical elements.
Using plants as contaminated food or feed is the cause in humans and farm animals of various diseases. The most dangerous heavy metals include mercury, lead and cadmium. Ingestion of lead man leads to sleep disorders, general weakness, worsening of mood, memory impairment, and reduced resistance to bacterial infections [52, 53]. Accumulation of cadmium in foodstuffs, which toxicity is 10 times higher than lead, causes the destruction of red blood cells, the kidneys work, intestines, softening of bone tissue [54]. Dual and triple combinations of heavy metals increase their toxicity.

4. How to solve problems?

Of course polluting soil is negative for human society and environment in general , but if we polluted the soil, what need to do in this case? Here is present some methods how we can clean soil if it is polluted

4.1 How to solve a problems for short term?

4.1.1 Biological Treatments

Biodegradation generally refers to the breakdown of organic compounds by living organisms eventually resulting in the formation of carbon dioxide and water or methane. Inorganic compounds are not biodegraded, but they can be biotransformed, that is, transformed into compounds having more or less mobility or toxicity than their original form. In many cases, the biodegradation processes involve a particular microorganism that attacks a specific molecular site. Complete and rapid biodegradation of many contaminants may require, not only specific environmental conditions, but also changing conditions to satisfy the needs of the microbe. Tsang et al. have investigated the mobility of several different metals in soil and the influence of the biodegradation process on that mobility.

They have shown that active microorganisms influence the ability of soil to retain or release metals and that cysteine is an effective agent for the release of some metals from soil.

A Canadian commercial operation (Biogenie, Inc., Sainte-Foy, Quebec, Canada) utilizes an inexpensive, above-ground bioremediation technique. Hydrocarbon contaminants are removed from soils by bioremediation and volatilization. The potential of hydrocarbon biodegradation depends on the availability of desired microorganisms. Supplementing soils with prepared cultures is practiced when the indigenous content is low. Environmental conditions such as pH, temperature, oxygen, nutrients, and soil moisture also can influence biodegradation results. Air emissions from the "biopile" are treated by bio filtration where the pollutants are degraded and mineralized by heterotrophic aerobic microorganisms.

A typical bio pile system contains an asphalt or high-density membrane pad on which contaminated soils are stockpiled, an overhead spray irrigation system for optimizing soil moisture and adding nutrients to the soil, a drain system connected to a reservoir for leachate collection, a pump to force air through the pile for aeration, and an impermeable sheeting which covers the pile for air and moisture control . Advantages of this technology include low land requirement, low capital and operating costs, and good process control. Cost of treatment depends on soil volume and treatment time, which typically ranges from \$50 to \$90/m3 of soil. This treatment method has removal efficiencies greater than 80% for mineral oil and grease products and greater than 95% for monocyclic aromatic hydrocarbons. Biodegradation rates for hydrocarbons under biopile treatment conditions have been reported as high as 44 kg/m3 per day. In addition, the process generates no liquid wastes and presents no risk of site contamination .

4.1.2 Chemical Treatments

Remediation Using Actinide Chelators. Gopalan et al. are working to design and synthesize organic chelators for selective binding of actinide ions from soils and waste streams. Their studies show that multidentate oxoligands such as hydroxamate, iminodiacetate, and hydroxypyridinones are potential candidates for binding actinide ions present in acidic, aqueous solutions. They have also identified and synthesized chelating agents for plutonium. These chelators contain either a flexible acyclic structural backbone or a rigid benzene spacer to which the ligands are attached. Specific application under the complex conditions relevant to environmental remediation strategies for actinides is in an early stage of development. Potential solubility problems, stability, and pH requirements exist that could limit the use of chelators.

4.2.2.1Chemical Immobilization.

In-situ immobilization can be carried out by introducing treatment chemicals into the ground by various means. If soluble chemicals are used, they can be applied by saturating the soil with the chemical solution. This fluid application may be carried out at a high rate by surface flooding the site or more gradually by spraying and allowing the solution to drain freely into the soil. The variation in application rate will affect the period of soil exposure to the treatment material, the degree of void filling accomplished, and the amount of air present in the soil during the treatment period. A complementary confinement or pumping system may be appropriate if the soluble treatment chemical has undesirable environmental effects or is worth recycling due to high chemical costs. Insoluble chemicals can be introduced into the ground by spreading, filling, forced injection, suspension transport, or by placing it in a low permeability encapsulation barrier. Spreading may suffice as a means of treating metals if the soil has a high moisture content and the metal contaminants lie close to the surface.

This may be most applicable to soils with high organic content. Tilling is the most common method of introducing a soil chemical treatment into the ground. Routine tilling can mix dry chemical additives into the soil to a depth of one to two feet. Special deep tilling equipment is available which can reach as deep as five feet into the ground. Fine insoluble chemicals can be transported short distances through soil voids by placing them in suspension in water or in a weak solvent or acid. The suspension material is then injected in a fashion similar to chemical grouting or through nozzles in close spaced probes. Typically, fine material can be transported several feet from the nozzle in this fashion. The particle size can be correlated to soil grain size using traditional grouting guidelines. In formations with high permeability and low organic content where metals have migrated to depths greater than 10 feet or more, mixing insoluble treatment materials into the soil may be impractical.

Under these circumstances, the treatment chemical can be placed into a barrier material, such as bentonite soil or asphalt emulsions used for slurry wall construction, jet grouting, or block displacement.Test results have demonstrated that with chemical treatment, heavy metal mobility is drastically reduced, and between 82 to 95 percent of the metals are confined to the part of the column containing chemical additives. The cost of in-situ immobilization typically range from $13.9/ton to $33.8/ton and include costs of chemical additives, soil preparation, and chemical additive application. This is a cost-effective alternative to alleviate metals, which will not present any adverse environmental or health hazards in their treated state. The cost of tilling in dry chemicals to soil has been estimated at $0.42/ton. Projects on a pilot field scale are needed to give a complete evaluation of the immobilization processes.

4.2.2.2 Critical Fluid Extraction.

Organic compounds, primarily PCBs and PAHs, appear to be the most amenable to extraction from soils and sludges with a technique utilizing liquefied gas, typically carbon dioxide, propane, butane, and sometimes alcohol. High pressure and moderate temperatures are used to compress the gas to fluid state. At the critical temperature and pressure, where the fluid state occurs, the mass transfer capabilities of the "critical fluid" are at their best. The critical fluid extraction process begins with the addition of hazardous waste to a vessel containing a critical fluid. The organics move to the top of the vessel with the critical fluid and are pumped to a second vessel. There, the temperature and pressure are decreased causing the contaminants to volatilize from the critical fluid. The concentrated organics are then recovered and the critical fluid is recycled. Extraction efficiencies between 90 and 98 percent have been demonstrated using PCB-laden sediments. Volatile and semivolatile organics in liquid and semi-solid wastes have been removed with 99.9 percent efficiencies in the laboratory [6]. An estimate of performance and cost for the implementation of such a system can be developed with a bench- or pilot-scale test, and a full-scale design can be formulated from a successful pilot test. However, the cost of implementing this technology is generally high --$100,000 to $1,000,000 in 1990 dollars -- due to the complexity of the process and the need to maintain high pressures. This complexity also makes it difficult to predict the efficiency of the process. Finally, critical fluid extraction, together with treatment and disposal methods, can constitute a full and permanent solution to a contaminatedsite.

4.1.3 Physical Treatments

4.1.3.1 Capping.

Cover systems provide a stabilization mechanism by reducing the amount of water through-put in a burial trench or retention basin. The cover typically is composed of a surface layer that supports vegetation, a drainage layer, a low-permeability layer, and a gas-venting layer. The requirements of the site dictate which layers are necessary, and some sites will not need all layers. The surface layer is generally soil with adequate organic matter to sustain vegetation. This layer requires good drainage to support the vegetation's growth. The vegetation stabilizes the surface layer. To prevent harm to the lower layers of the cover, the vegetation must be of a type that has shallow roots and is adapted to the climate. The decomposition of organic matter results in the generation of methane gas. If uncontrolled, gas that migrates within the cover system can balloon and possibly combust. Therefore, the gas must be vented in a controlled manner. Interim stabilization was successful at the Hanford site in an old PUREX chemical sewer liquid effluent ditch. Stabilization was carried out by a three phase process that included (1) scraping the surface soil from the sides of the ditch to its center, backfilling the ditch with clean soil and regrading to a shallow slope, and revegetating the entire area. The interim stabilization methods are expected to maintain the integrity of the ditch for at least a five-year period .Cementitious Waste Forms.

Sulfur polymer cement (SPC) has been used to stabilize high loadings of volatilized toxic metals. SPC is a sulfur composite material with a melting point of 110-120°C, that resists attack by most acids and salts. Studies show that the compound has a very long life and its strength greatly increases within the first few years after forming. Sulfur polymer cement concrete (SPCC) is also strong, with an average compressive strength of 4,000 psi, when the Nuclear Regulatory Commission (NRC) requires only 500 psi. The advantages of SPC are : it has a greater waste-to-agent ratio than concrete; it has the ability to be remelted and reformed; it is less permeable than concrete; in its final waste form it is devoid of water; and it can be processed at relatively low temperatures. In determining cost and environmental advantages, the volume-reduction factor offered by the sulfur polymer cement is its most redeeming aspect with the high cost of waste disposal.

Additionally, the absence of water in the final waste form offers less chemical breakdown, biodegradation, leaching, and gas generation after disposal.

However, SPC is new and therefore, continued testing is essential. Low-level radioactive wastes that have been separated from high-level wastes are being processed and stored in a waste form referred to as "saltstone". Saltstone is a mix of the low-level waste, cementitious blast furnace slag, and fly ash. The saltstone is disposed of by emplacement or entombment in an engineered structure. The resulting structure is a large warehouse-size block of concrete that receives backfill on all four sides to bring its top level with the surface. A cap of gravel and clay is used to control runoff, and leachate monitors are put in place to monitor the structure's performance.

4.2 How solve the problem for a long term?

4.2.1 Sustainable Agriculture

The demand for multi-functional merits from agriculture grows alongside the need to feed a growing global population. At the same time, the expansion of agricultural land and the intensification of production methods reach their ecological, economic and social limitations. Sustainable production, with its holistic principles, holds the key to finding an answer to these challenges. In a world of globalized agriculture, sustainability should be measurable across regions, countries and commodities. For a fair comparison of different farm types and regions around the world, all strengths and potentials, as well as deficiencies and bottlenecks, must be considered. It is crucial that agricultural performance is evaluated according to the holistic principles of sustainable production. This means all three dimensions of sustainable development—ecology, economy and social aspects—are assessed and can compete for prominence. If only economic aspects are evaluated, this can lead to distorted decision-making, which in turn, can lead to social and ecological dumping. Sustainable agriculture is a way toward solving the problem, because this type of agriculture based on 3 principle economical, ecological and social, otherwords this type of agriculture is solution.

But how can we apply this in practice?

Main source of pollution of soil is mineral fertilizers, if we grow togheter cows and crops we will make first step for this principal to work. But How ?

1. **We will use organic fertilizers and we will solve the ecological problem.**
2. **Social problem we will solve too because water and food will be out of contamination after using the organic fertilizers.**
3. **We will solve economical problem because farmers will have a profit from selling a dairy products.**

It is possible if in agriculture will grow caws and crops together, more detail about it give Srikanth B.E. in his article.

4.2.2 Return of cows into agriculture as first step for sustainable agriculture

During the last several decades, especially after green revolution, the use of chemical fertilizers, pesticides and tractors have dealt a severe blow to the importance of cows in agriculture. While productivity levels improved in the short term with their use, their long term negative impact on health and environment has totally been ignored. In fact most of the diseases of today are being traced to the food we consume and fertilizers and pesticides are the major culprits. The cost of production has also gone up substantially due to the increase in the cost of farm inputs leading to higher food prices. The indiscriminate use of pesticides has also broken the food chain and hence contributed to most of the current problems faced in agriculture today. Research has also proved that these high productivity levels cannot be sustained over a long term as the soil quality deteriorates due to rampant use of fertilizers and pesticides. Once the fossil fuels (petrol and diesel) get exhausted or become very expensive, most of the mechanized farm equipment will not be of any use .

In short, these modern farming techniques have only contributed to

a. Increased vulnerability and dependence on external sources
b. degradation of environment and soil quality
c. increase in diseases and
d. increase in profits of fertilizer and pesticide companies.

Almost 2 lac crores is annual fertilizer subsidy bill.

In contrast, cow is the base of economic sustainable agriculture with only positive impact on environment. With only a pair of bulls

- Fossil fuels are definitely running out. Definitely they will get expensive. Even today, if diesel or the tractor or the harvester is not available, work stops. There is no fall back option. A lot of small farmers are losing money because of delays in getting the equipments.

1. Tractors do not give cow dung and urine- major agri inputs.
2. Organic farming enriches the soil.
3. Organic farming produces healthy and wholesome food.
4. Organic farming is as productive, if not more, as the chemicals based farming.
5. Organic farming reduces the input cost.
6. Organic farming reduces diseases and medical costs.
7. Organic farming improves quality of life.
8. Organic farming will improve the economic wellbeing of the farmers and stop farmer suicides.
9. Once the development in sectors like roads and other infrastructure projects , which use most of the unskilled farm labour now, slow down,

the farm labour will not have any other source of employment. In the mean time they will also lose their farming skills and knowledge.

It is time that we realize the contribution of cows and go back to our time tested traditional farming techniques for a sustainable future.

Conclusion

Soil is not only dead matter is also microorganism witch I more important like dead matter.

Soil provides this ecological services:

- Soil stores, moderates the release of, and cycles nutrients and other elements.
- Soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water.
- Soil supports the growth of a variety of unstressed plants, animals, and soil microorganisms, usually by providing a diverse physical, chemical, and biological habitat.
- Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals.
- Soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots.

For the services to be provided by the soil, it is necessary to move from the usual system of agriculture to sustainable agriculture which is based on three pillars

1. Social needs
2. Environments needs
3. Economical needs

Cow is the only animal that can make this transition because

1. We can get organic fertilizers which satisfy social and environmental needs
2. Selling dairy products satisfy economic needs

And in finally I make just one conclusion if before pay money we ask ours selves:

1. Who and how it was grow or make
2. Is it good or not for my health

Just in this case we can speak about a normal ecological good for environment and our health agriculture. If the people not put this quastions we can´t to speak about a ecological agriculture. We can to make a rules, we can panishements the farmers but it will not be effective because the firt reason why we buy something is the product need to be beautiful or have a beautiful and attractive box and the farmer and bussnes man give us what we want this is their work and they make perfect their work, but we not.

Referenses:

1. David L. Linbo,Deb A. Kozlowski, Clay Robinson ,Know soil know life, ,2012 soil science society of America.

2. European Commission DG ENV, Soil biodiversity: functions, threats and tools for policy makers, February 2010, European Communities

3. Coleman D.C., Crossley, D.A.,Hendrix P.F.(2004) Fundamental of soil ecology, p. 386 elsevier academic press.

4. Joseph Terradellas, Gabriel Bitton, Dominique Rossed Lewis ,Soil ecotoxicology, Publishers 1997 Boca Raton,Florida.

5. Mirsal A. Ibrahim, Soil Pollution Origin,monitoring and Remediation, Springer-Verlag Berlin Heidelberg, 2008

6. http://soilquality.org/(This site is a collaboration between the NRCS East National Technology Support Center, NRCS National Soil Survey Center, ARS National Laboratory for Agriculture and the Environment,

NCERA-59 Scientists, and Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign.)

7. Минеральные удобрения и свойства почвы ,Безуглов В.Г., Гогмачадзе Г.Д«ВНИИ Агроэкоинформ»

8. Fritz J. Häni, László Pintér and Hans R. Herren ,Sustainable Agriculture: From Common Principles to Common Practice ,International Institute for Sustainable Development 2007

9. Doran, J.W. and T.B. Parkin. 1994. Defining and assessing soil quality. In J.W. Doran, D. C. Coleman, D.F. Bezdicek and B.A. Stewart, eds. Defining Soil Quality for a Sustainable Environment. SSSA, Inc., Madison, Wisconsin, USA.

10. Harris, R.F., D.L. Karlen and D.J. Mulla. 1996. A conceptual framework for assessment and management of soil quality and health. In J.W. Doran and A.J. Jones, eds. Methods for Assessing Soil Quality. SSSA, Inc., Madison, Wisconsin, USA.

11. Karlen, D.L. and D.E. Stott. 1994. A framework for evaluating physical and chemical indicators of soil quality. In J.W. Doran, D.C. Coleman, D.F. Bezdicek and B.A. Stewart, eds. Defining Soil Quality for a Sustainable Environment. SSSA, Inc., Madison, Wisconsin, USA.

12. Larson, W.E. and F.J. Pierce. 1991. Conservation and enhancement of soil quality. Evaluation of Sustainable Land Management in the Developing World, International Board for Soil Research and Management, Bangkok, Thailand.

13. Seybold, C.A., M.J. Mausbach, D.L. Karlen and H.H. Rogers. 1997. Quantification of soil quality. In R. Lal, J.M. Kimble, R.F. Follett and B.A. Stewart, eds. Soil Processes and the Carbon Cycle. CRC Press. Washington, D.C., USA.

14. Singer, M.J., and S. Ewing. 2000. Soil Quality. In: M.E. Sumner (Ed.-in-Chief) Handbook of Soil Science. CRC Press, Boca Raton, FL.

15. Mirsal, A.J. Soil pollution,origin,monitoring and remediation.