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Focus: Soil stewardship reinvented

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Editorial

It is indeed no exaggeration to state that soil is fate as well as one of the biggest assets for the future of mankind. Yet, soils are mined and become exhausted mostly through industrial, factory-like farming in the context of stiff competition in increasingly globalized food and agricultural commodity market chains. And although there is an increasing body of knowledge, information and evidence on these disturbing trends neither political, economic and societal priorities nor the awareness of a majority of the world's citizens reflect the seriousness of the situation, the corresponding challenges and the urgent need for transformational change. What is more, agriculture, food security and key resources used in agriculture such as soil and water and their interplay with climate change play an overarching role for virtually all Sustainable Development Goals under the UN development agenda 2030. Against this very background, the *Agricultural Transformation Review* (ATR) is dedicated to contribute to fostering a constructive and action-oriented policy dialogue to overcome these weaknesses and gaps. ATR is intended to make an inspirational contribution to the progress of a fundamental renewal for agricultural and food systems towards a human practice, which is part and co-operation partner of the magnificent multitude of life sustaining and life generating processes and cycles in and between ecosystems. Considering the *status quo* of the world in the *Anthropocene,* two tremendous tasks emerge, namely to halt the course of destruction and simultaneously to forge long-term relationships conducive to all living creatures. Therefore long-term goals as well as manifold intermediate steps are necessary in order to shape a conversion of the agricultural systems toward regenerative instead of depletive and impoverishing nexuses. That we call *transformation.*

Today the global agricultural systems are trapped in a dual role as driver for as well as affected by widespread environmental degradations, climate change, and social conflicts, often decided violently. These regimes evolved during decades, in some facets centuries, but neither is set in stone. Rather they represent dynamic processes and complex socio-economic-ecological struggles, strategies, conflicts and contentions. At the heart of many arguments and controversies rests the question for a common future for mankind and the planet. Fundamental for any transformation of societies towards long-term life sustaining development are use and cultivation of fertile land including the aquatic and forest ecosystems and the corresponding economic sectors such as transport, processing, trade, and consumption. Without a transformation to truly

sustainable agriculture there will be no sustainability transformation of our entire socio-economic and ecological systems at all.

International and national agricultural and food policies are mostly shortsighted interested in quantities of output. OECD governments continue to stick to policies of factory-like, external-input-intensive farming, specializing on few crops and driving up scale. International alliances against poverty, hunger and for agricultural development aim at bringing more industrial regimes to Africa, Asia, and Latin America. International organizations such as the World Trade Organization have until today been unable to resolve antagonistic perspectives and interests around agriculture, food security and rural livelihoods. Scarcely any government or supra-national institutional community pursues consistent policies towards building an agricultural sector, which is environmentally, socially and economically vital and vigorous and preserves it reproductive capacity.

But: Fossil industrialization of agriculture, nutrition and food during the last century didn't remain unchallenged. Initiatives, associations, movements and organizations that are committed to profound transformations of agricultural production, food processing, and consumption have been active for decades. To see these awakenings as starting points and pillars for a constructive future is at least as important as to analyze the strategies and actions of the presently powerful actors.

In short, the mission of the *Agricultural Transformation Review* is:

- ATR has an international perspective, always keeping in view the vital interests of all global great-grandchildren and knowing that fundamental change needs time, decades rather than years.
- Dealing with questions and issues which are important in the longer run, but not pursued with appropriate vigour.
- Building bridges in order to contribute to the mitigation of deadlocks in society and politics. ATR is oriented towards constructive and action-oriented dialogue between science, agricultural practitioners, policy makers and other stakeholders from agricultural and food systems.
- Receptive for improvements and innovations with a keen eye for direct and indirect impacts. Every agricultural practice and system can be advanced by reflection, deliberation, review, and criticism.
- Independent, not presumably neutral but dedicated. Sustainability politics is starting from accurate premises and guidelines which indeed must be interpreted and organized. So there are many pathways for fundamental change towards real long-term sustainable development.

We wish an inspiring and startling reading journey.

Ulrich Hoffman, Nikolai Fuchs & Stephan Albrecht

Soil stewardship reinvented. Progressing from conservation to improvement

Stephan Albrecht, Ulrich Hoffmann & Nikolai Fuchs (Project ATR)

"There is an uncanny resemblance between our behavior toward each other and our behavior toward the earth."
Wendell Berry (1977)

This article is intended to contribute to a necessary political, scientific and practical rethinking – how can soil stewardship become an integral part of all agricultural practice and how to advance from conservation to improvement?

Starting from the UN year of soils 2015 we were thinking: what is really turning soil management into a long lasting, friendly to life future?

Humankind is living from four essential natural resources: fertile soils, clean air, fresh water, and biodiversity. The global land area amounts to 13.2 billion hectare (ha) of which 3.7 bn ha (28%) is forest, 4.6 bn ha (35%) is grassland and woodland ecosystems, and only 1.6 bn ha (12%) is used for agricultural crops (FAO 2011). It is a really startling phenomenon: although considering today's multiple challenges with soil degradation, medium-term growing global population and mounting impacts of climate change, in many societies, countries and national states fertile soils are still treated tremendously carelessly or even in a destructive way, just so as if it didn't matter to preserve and regenerate this pivotal element of essential natural resource and fabric of human societies. Let us lift the whole issue onto another level: At the latest from Howard (1947) we know that there is a fundamental link between fertile soils and human health. Since then scientists have found growing additional evidence that soils with rich diversity of life are ipso facto capable to produce nutrient-rich food. Furthermore, there is a correlation between bacteria in soils and in the human gut (Wall et al. 2015). And everything in the food system between the soil and human gut may touch our health,

from farming methods and crop varieties to food processing, cooking and eating. When we change one thing in an interplay-ecosystem, we change many more (cf. Roberts 2008; Rundgren, 2015). So, from all we know, there is more than enough reason to treat soils very carefully, to use, maintain and eventually – that is one of our key points – improve every hectare and every square kilometre.

Soil is the most precious natural resource which humankind has to care for

It is no exaggeration to state that human existence is essentially dependent on the wispy skin of terrestrial ecosystems, some 20-50 centimetres of topsoil. Topsoil is one of the most important resources and, for the recent centuries, it has been under increasing pressure by i.a. intensification of production, erosion, contamination with agrochemicals, and industrial pollution. The pace of soil destruction, sometimes only a matter of minutes, has far outpaced that of soil regeneration. It takes between 100 and 500 years to build up one centimeter of new productive soil by natural processes (SWSR 2015).

Healthy soil is not only a highly productive layer of the earth's surface, rather it is a natural body with regular structures and specialized features, a subsystem within the diversity of ecosystems. Soils are not simple substrates to root plants, but an ecosystem in themselves, an unbelievable complex and marvellous interplay of physical, chemical and biological elements, networks, species, and food chains. The soil cover, or pedosphere, is a zone at the boundary of biosphere and geosphere, a specific membrane, regularly differentiated in space and depth, that facilitates biosphere-geosphere interactions. The pedosphere is part of the lithosphere, and is also penetrated and saturated with elements of all other geospheres: with gases, water, solutions, as well micro-, meso-, and macrobiota (Rozanov et al. 1990).

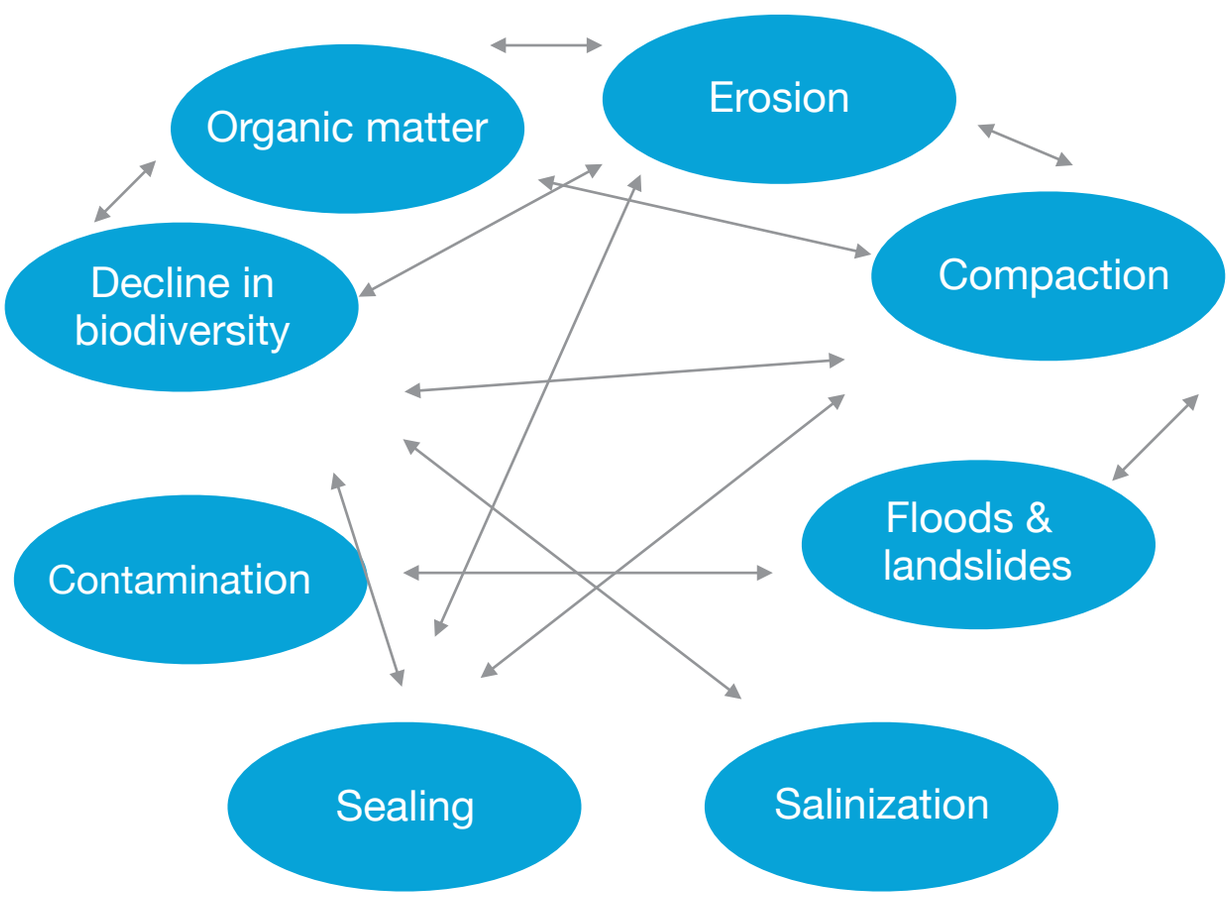
Often the complex interrelationships between microbial, animal and plant webs in fertile soils are not duly incorporated in agricultural thinking and practices as well as in policy, obviously because we cannot see it, and, partly, because relevant, specific, and long-term data is scant and/or fragmented. The complexities of the ecosystem soil requires particularly systemic thinking and research strategies for better understanding it (Albrecht 2011).

Soils build the biggest carbon reservoir, containing more carbon than the atmosphere and all terrestrial vegetation combined. Relative small changes in the amount of organic matter in soil can have a major effect on the atmosphere and so on global warming (Soil Atlas 2015). Also, it is widely accepted that humus and soil organic matter play a crucial role in generating and maintaining healthy soils, both in terms of physical structure and supporting the life of micro-organisms that live in the soil (EC 2015). “Carbon is the main currency in use in the majority of transactions between living beings, and this is most patently in soil.” (ideaa 2015) Also, humus has beneficial effects on several ecosystem services, such as primary production, soil formation, biogeochemical cycles

and the regulation of water quality and climate. Any loss of humus and decrease in organic matter, e.g. by oxidation following cultivation, the withdrawal of grass-leys from rotations or the absence of animal or green manuring will thus have negative effects, not only on soil health, but also on the release of carbon into the atmosphere. There is clear evidence of decline in organic matter content in many soils as a consequence of the unprecedented expansion and intensification of agriculture during the 20th century. The decline in humus and organic matter content is a threat also to the stability of agricultural production systems.

Four types of soil degradation are generally distinguished: (i) erosion (wind and water); (ii) physical (compaction, laterisation, hardsetting); (iii) biological (loss of soil biodiversity); and (iv) chemical (depletion of organic matter and nutrients, contamination by mining activities, industrial activities, agricultural activities) (EC 2015). Some degradation processes may go off quickly, others more creeping, but all are closely interrelated (see Figure 1) and have an important bearing on the soil functions for plant production (see Figure 2).

Figure 1: Major types and interactions of soil degradation



Source: based on Várallyay 2002

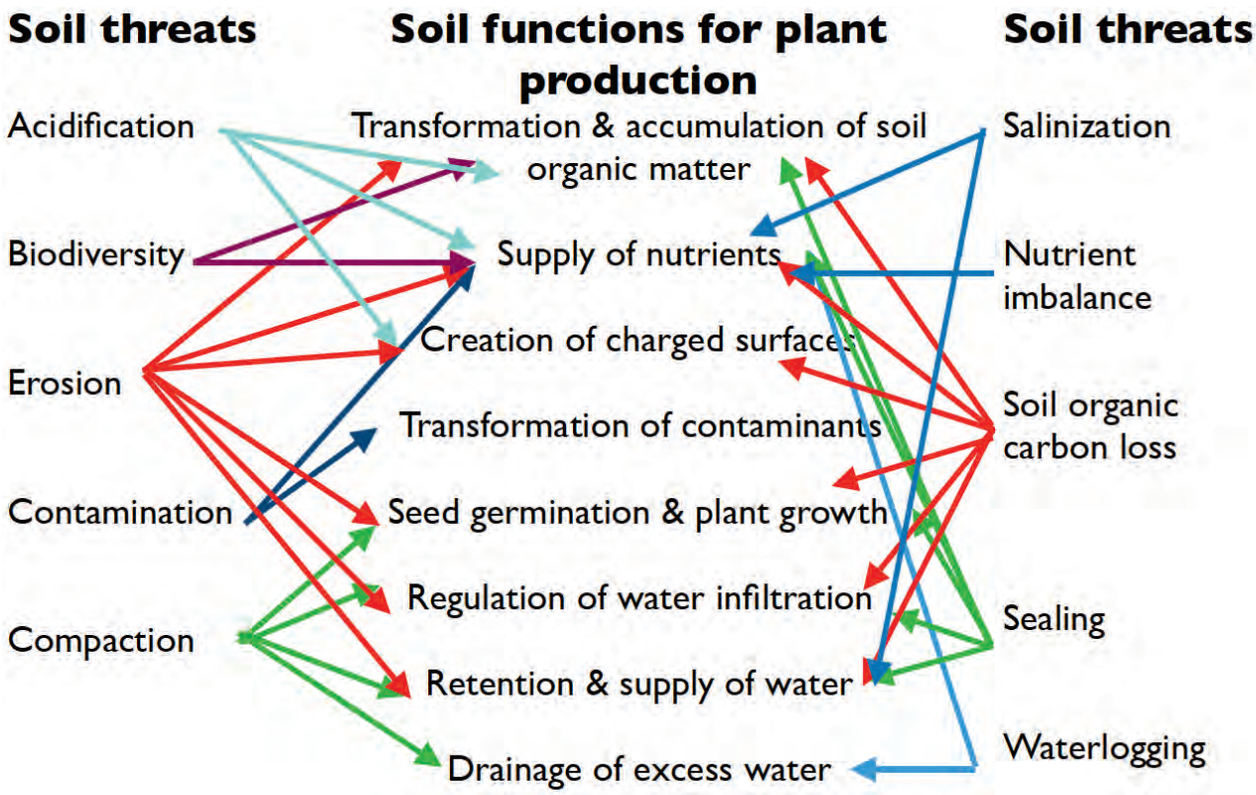
Despite the tremendous scale of global soil degradation, only fragmentary and inconsistent data on the rate and pace of degradation processes are available. For erosion by water, figures range from 20 to 200 billion tons globally per annum. Erosion rates for wind show a range from 0.5 to 3.3 bn t/annum. Amazingly enough, there are very few quantitative assessments of wind erosion rates on arable land outside of the United States. “Estimated rates of soil erosion of arable or intensively grazed lands have been found to be 100 - 1000 times higher than natural background erosion rates. These erosion rates are also much higher than soil formation rates which are typically well below 1 ton per ha/per year with median values of some 0.15 ton per ha/per year. The large difference between erosion rates under conventional agriculture and soil formation rates implies that we are essentially mining the soil and that we should consider the resource as non-renewable” (SWSR, 2015: 103).

The International Soil Reference and Information Centre (ISRIC) estimates that of the 11.5 billion ha of vegetated land on earth 24% had undergone human-induced soil degradation, with erosion the main process (ISRIC 2009). These figures not only are serious and precarious regarding the ecosystems but also for the social fabric of many countries. In 2010, of the 4.25 billion global rural population, 1.5 billion lived on less favoured agricultural land (LFAL) and 1.4 billion on degrading agricultural land, whereas 1.5 billion lived on improving agricultural land (Barbier & Hochard 2014). Drylands in arid, semi-arid and dry sub-humid regions are estimated to make up about 41% of the earth's surface. These regions are inhabited by nearly 2 billion people (Reed & Stringer 2015). Food insecurity and poverty still hit predominantly rural populations (FAO SOFI 2016). There is clear evidence on the nexus between poor ecosystem functioning and services, soils, and poor and hungry human beings (IAASTD 2009). Impoverished peasants – female or male – in many cases have no secure access to land and related land tenure, thus no long-term perspective on their soils. Conservation and enhancement of soil health and fertility indeed requires appropriate activities as well as a long-term perspective. Many examples from all continents deliver evidence on successful practices for improvement of soil fertility along with livelihoods (see some exemplary cases in this volume: Nothing is more inspiring than good examples, p. 45).

Key dilemmas regarding soil degradation

First of all, there is insufficient up-to-date knowledge both on the area affected by soil degradation and on the linkages between degradation, soil functions and eventually resulting food and agricultural production. As a result, the ability to predict the effect of soil degradation on food security is limited (Stocking 2003) - and what we don’t sufficiently know is difficult to manage.

Figure 2: Summary of soil threats and functions



Source: SWSR 2015, modified

Secondly, the prevailing market system does not orient farmers to practise land stewardship. On the contrary, so called modern farming has removed much of the land husbandry, regenerative care and stewardship that was previously an integral part of most farming systems. It is not realistic to assume that the market will take care of managing soils as de facto non renewable natural resource – at least as long as external effects are not significantly priced in. The adoption of measures for soil fertility improvement or conservation is often not sufficiently near-term beneficial to farmers. This applies the more they are market-oriented and in particular the more they are integrated into globalized markets (SWSR 2015), as external inputs for some time can seemingly compensate deficits in natural soil fertility. This is as true in intensive mechanized systems in OECD countries as it is for smallholder and family farming in less industrialized countries. Likewise, detrimental effects of soil degradation often become evident only after years or even decades, especially if farms are capable to invest in technological substitutes such as synthetic fertilizers, drainage, irrigation etc.

Thirdly, the prevailing conventional agronomical understanding of *yield* and *productivity* does not or poorly appreciate the pivotal role of soil, its fertility and its non-renewable nature. Productivity in agriculture can be measured in many ways: yield

or nutrient per area unit; per person-hour; per unit of deployed capital; per energy input or per water unit. The comparisons can consider as well total biological production, ecosystem services or exclusively what is directly useful to humans in the form of food, fiber, feed and fuel. One can however also ask if productivity so measured is serving to maintain the productive resources or if it is based on extraction of non-renewable resources, resources which perhaps were abundant but now are increasingly scarce. What means productivity if the production is based on the unsustainable use of irrigation, fossil fuel and soil management practices which sooner or later erode and thereby destroy the soil? As globally the ensemble of natural resources dwindles, regeneration, prevention of degradation, and improvement of soil fertility must be seen as top priority in order to regain truly productivity. Soil recovery would be one measure to enhance productivity and should thus be duly considered in productivity indicators (Rundgren 2015).

Fourth, secure access, tenure and ownership of land, i.e. of soils provide resources and livelihoods and thereby imply social and economic power. Therefore the social regime of access, disposition, tenure and ownership is of key importance. The unjust distribution of fertile soils across the globe not only contributes to poverty and hunger but also to unsustainable soil management. The unresolved issue of an equitable distribution of individual and/or common land rights and ownership in many countries has been masked during some decades by the illusion that industrialization and urbanization would marginalize the relevance of soils and agriculture for the economic and social development. The increasingly manifest impacts of climate change however are a strong reminder of the fact that soils together with clean air and freshwater are the most fundamental commons for the survival of humankind.

In most countries, the majority of land is owned by a very small number of people (the feudal lord, the local squire, the village chief, the hacienda owner, the rancher, the plantation baron and recently also institutional foreign investors). According to recent reviews, land tends to be even more unevenly distributed than income (Pearce/ILC 2016). Privatization of land tenure often has been promoted by conventional economic wisdom to overcome the so-called Tragedy of the commons (Hardin 1968), where overuse of land and other resources eventually lead to ecosystem failure. The increasing market orientation of farmers, unlimited mobility of capital, globalization of markets and the resulting indebtedness of producers have been key drivers of privatization of land ownership, because land or livestock are often the only assets of farmers that can be collateralized. Yet, the prevailing market system and its pressure on specialization, economies of scale and cost reduction tends to relegate soil to a top-soil layer that most efficiently converts mineral fertilizers into agri-food commodities. Decades of alignment of agricultural production towards higher yields of a single crop per hectare nearly inescapably resulted in the application of external fossil inputs such as synthetic fertilizers and pesticides. Long-term sustainable and healthy soils are however in need of diverse polycultures, including trees for the preservation of soil structure, organic

matter content, water holding capacity, aeration und microbial communities. The importance of this requirement grows vis-á-vis the grievous consequences of climate change. Treating land and soils as a common or as a private good is by far not only an economic issue. We see from commonly managed land on all continents that the social fabric of communities is closely intertwined with land and that the appreciation of land and soils is far stronger (Blackman et al. 2017; Pretty et al. 2011).

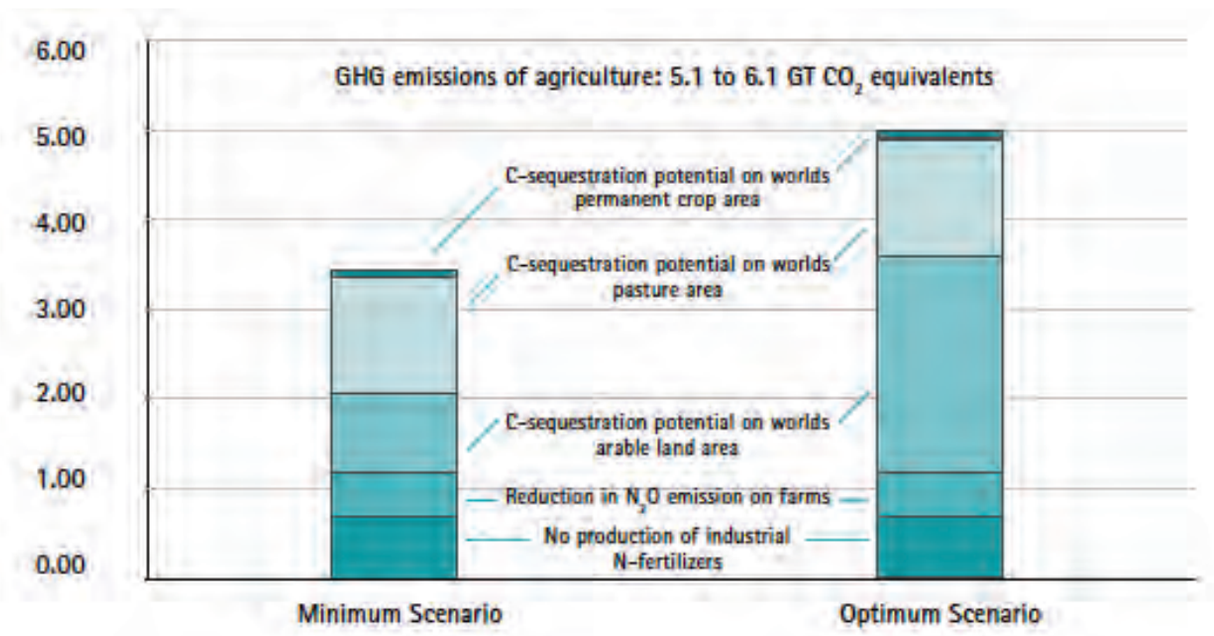
Fifth, the prevailing globalized corporate market system and its underlying rules are dysfunctional for shaping the agro-food systems in the best way towards planetary stewardship, a role that is increasingly important as agriculture occupies more and more of the surface of the planet and natural resources are under growing pressure. There are almost no market mechanisms in place to support agroecological economies and there is limited potential for them to emerge. How distorted the prevailing economic structures are is highlighted by the fact that soils as ecosystems are globally the most precious assets which, according to some estimates, annually generate more than twice the size of the world's Gross Domestic Product (GDP) in 1997, namely US$ trillion 33; in 2014 this figure went up to US$ 125 trillion. On the other hand ongoing land use change resulted in an annual loss of roughly US$ 20 trillion (ELD 2015).

Sixth, the area of land and water needed to supply a mean global citizen is scattered all over the planet resulting in the phenomenon of virtual soil (and water) imports by global trade of feed and food. As a consequence, soil degradation and loss of production are not just local or national issues – they are genuinely international ones. Whereas locally focused and local resource-dependent production very much depends on resource stewardship and reproductive approaches, globalized food supply chains and their treadmill pressure, caused by cost externalities, lead to resource-mining, including soil erosion, depletion, pollution etc. (McMichael 2013). This makes it very challenging to create the awareness and build the momentum that soil stewardship and related soil quality are international problems that require a comprehensive international governance framework.

In the light of the above, it is unrealistic to assume that rapid changes towards soil stewardship and regeneration of productive resources for truly sustainable farming can be expected as such by now. As a matter of fact, soils and soil fertility are neither recognized as common heritage of mankind, nor as an international environmental problem and looming global threat which needs action. This is all the more astonishing and worrisome as global carbon emissions will have to be drastically cut in the next two to three decades, in fact going as far as negative emissions (i.e. the removal of carbon from the air) in the post 2050 period (Mitchell et al. 2016; Hansen 2009). Given the enormous scale and time pressure, agriculture is the only sector that already disposes the ways and means to make carbon sequestration happen. Soils and soil management play a pivotal role in this regard, because carbon sequestration in soils accounts for the bulk of the technically feasible mitigation potential in agriculture. According to the Assessment Report IV of the Intergovernmental Panel in Climate Change (IPCC 2007),

the global technically feasible mitigation potential for agriculture is estimated at 5.5 to 6 gigatons (Gt) of carbon dioxide-equivalent per year by 2030. Almost 90 per cent of this reduction can come from carbon sequestration in soils (see Figure 3). At present soils and vegetation already store a quarter of the anthropogenic carbon (Global Carbon Project 2017).

Figure 3: GHG reduction & mitigation potentials



Source: Niggli et al. 2009

Elements for moving from degradation to regeneration

The main mechanisms of soil fertility decline in agriculture are (a) loss of soil cover, loss of humus and organic matter, decline in structure – mostly as a consequence of soil erosion by water; (b) agricultural intensification, separation of plant production and animal rearing with lack of organic fertilization and amendments, a significant increase in inorganic fertilizer application, a simplification or abandonment of crop rotation, and a trend towards growing more cereals that are vulnerable to losing their productivity due to nutrient mining; and (c) soil salinization and pollution through intensification in industrialized agricultural systems, including irrigation (Liniger et al. 2017). To prevent such negative unfolding, farming practices in general need to

- minimize soil disturbance in order to maintain soil organic matter, soil structure and overall soil function;

- enhance and maintain a protective organic cover on the soil surface, using cover crops and crop residues, in order to protect the soil surface, conserve water and nutrients and promote soil biological activity;
- cultivate a wide range of plant species – both annuals and perennials – in associations, sequences and rotations that include trees, shrubs, pastures and crops, in order to enhance crop nutrition and improve system resilience;
- use well-adapted varieties with resistance to biotic and abiotic stresses and with improved nutritional quality, and to plant them at an appropriate time, seedling age and spacing;
- enhance crop nutrition and soil function through crop rotations and judicious use of organic and, under particular conditions, inorganic fertilizer;
- make efforts to re-integrate crop and livestock production (for enhancing closed nutrient cycles) and pay greater attention to the key role of grassland management and pastoralism;
- ensure integrated management of pests, diseases and weeds using appropriate practices, biodiversity and selective, low-risk pesticides when needed;
- manage water efficiently, and control machines and field traffic to avoid soil compaction (cf. VGSSM 2016).

Thousands of different soil and land management practices have been developed during the history of humanity around the world in response to local biophysical, social and cultural settings (cf. WOCAT 2007). Most human cultures have deep connections with the land, and soil is venerated in diverse ways (Churchman & Landa 2014). In many regions, traditional knowledge still plays an important, and often decisive role in determining land management. However, many traditional systems have been disrupted, destroyed or modified. The two most common causes have been the loss of access to land (e.g. invasion and displacement; increasing population densities causing shorter fallow periods on smaller areas; loss of access to grazing lands) and the introduction of external input-intensive technologies (Churchman & Landa 2014).

To apply the substantial stock of sustainable land management practices requires however a number of framework conditions, which all too often do not or only partly exist. The most important framework conditions are: land use, management and stewardship are largely governance issues. Balancing the different societal claims and needs related to land is a political and societal task, especially whenever short-term or singular benefits stand against long-term sustainability. Elinor Ostrom's research shows that the argument of the Tragedy of the commons seems to be biased. Common

goods, including the soil, are owned by communities, often by people who live near each other and know each other well. Communities set up their own rules regarding access and create sanctions for those who violate them. Under certain conditions this allows them to manage local resources successfully without recourse either to state ownership or to private enclosure (Ostrom 1990; Poteete, Janssen & Ostrom 2010). Truly sustainable systems are often built on local resources. When farmers and/or communities rely on local resources they will care for and manage them properly (Blackman et al. 2017; Rundgren, 2015). Furthermore, changes of the current structures, institutions and administrations related to land management are required as far as they are not designed to provide the appropriate kind of governance. Science starts to deliver information about social, political and institutional set-ups, but has to be expanded and intensified (see the Synopsis of politico-scientific networks on soils in this volume). Socio-economic factors which would help farmers to apply sustainable land management practices concern inter alia:

- Overcome the lack of appropriate legislation and/or law enforcement;
- increased use of adapted and participatory science in policy decisions;
- overcome perverse subsidies and incentives, in particular for energy and external-input-intensive forms of production;
- address population density, where adequate;
- overcome fragmentary education, training and knowledge diversification;
- better access to financing;
- engagement of local communities in landscape management;
- secure land use rights and tenure;
- improvement of cooperation among different administrative units and ministries (Liniger et al. 2017).

A turning towards truly sustainable soil management also requires a U-turn in political and scientific perspectives

One of the most important tasks for promoting the more widespread use of sustainable soil and land management practices is (i) to pay close attention to the different perspectives that play a role; and (ii) carefully analyse and weigh up the trade-offs that matter. To embrace the different perspectives, science and policy need to pay attention to the following aspects:

- The nexus perspective, which takes into account the whole system with its interdependencies between soil and soil biota, water, energy, climate, vegetation, animals and people.

- The multi-scale perspective that pays attention to the interactions of land use and natural systems on and between different scales, from local to landscape to national and global.
- The multi-time perspective reflecting short-, medium-, and long-term impacts and feedback from land management options.
- The multi-stakeholder perspective that reflects the interests of all people living on, and using land in different parts of a landscape, different sectors depending on, and using land, different levels of decision-making and governance related to land management and different sources of knowledge – scientific, local and practitioner's.

There are also trade-offs that need to be carefully analysed and taken into account by science as well as governments in an effort to encourage the use of sustainable land management practices such as: (a) production, income and livelihoods versus ecosystem preservation. Not rarely, there is a conflict between short-term economic interests and the long-term preservation and improvement of ecosystems. The more farmers are integrated into value chains of global markets, the higher the economic pressure on specialization and artificially boosted output by agro-chemical inputs and the lower the interest and freedom to pay attention to and invest in soil stewardship. (b) Long-term versus short-term costs and benefits. Some practices need higher investments in the short term but only yield benefits and returns in the long run. (c) On-site versus off-site effects. Sustainable management of soils often has positive effects beyond the direct area of its implementation. This is why for most management measures at landscape level, some people receive more benefits or incur greater costs than others. (d) Private versus public goods. When the depletion of a common resource such as soils has benefits for individual users without immediate consequences from the thus caused degradation, there is little incentive for soil preservation (Liniger et al. 2017).

Multiple concepts and knowledge, but inadequate actions & decisions: A new momentum is necessary

Most of the depicted approaches and measures are more or less known to practitioners as well as political decision makers. But, as of today, all this knowledge has not gained enough momentum to turn the direction of policy, practice, and science. So, what elements and issues can strengthen and accelerate a momentum of change?

A.) From a practical point of view, one key factor for enhancing soil fertility is to channel as much sugars and amino acids from the sunlight's assimilation processes via plant roots in the soil's nutrient cycles and food webs. Therefore priority one is to maximize leaf biomass' density on the field. Largest possible

root extent is also important, which grows in organic agriculture, where roots have to look for nutrients and sufficient supply of essential micronutrients. All-season plant cover means all-year support for healthy soil life.

B.) Decisive as well is the constitution and regulation of secure access to and land ownership. Given that land is treated as common good, local stakeholders should organize themselves according to the principles that i.a. Elinor Ostrom has characterized as well as is evident from manifold experience from community and participatory practices.

C.) To sustain and thrive under increasingly adverse climate and environmental conditions, agriculture needs a new mind-set and general principle. Instead of looking to productivity in a reductionist way from the perspective of a single crop yield per hectare, regeneration of substantial resources must be incorporated as an essential element in the productivity paradigm. Especially for soils, where degradation and loss often becomes visible only in longer terms, regeneration and improvement of fertility is crucial to face the mounting challenges of climate change, water scarcity and related national and international political conflicts. Therefore an understanding of inclusive and comprehensive productivity should be implemented.

D.) Research has to revive and design methods and concepts to better understand and be able to work with the vast complexity of soils as an ecosystem in itself.

Regeneration and reproduction, in particular as regards to soils, are as essential in the farming system as production (Gregorich, Sparling & Gregorich 2006). Building up humus and soil formation as part of sustainable land management can be a self-reinforcing process: healthy soils will reproduce and thus can better improve over the years. According to the revised World Soil Charter: "Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The balance between the supporting and provisioning services for plant production and the regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern." (FAO 2015: Para 5).

Soil policy formulation – the weakest link in the chain

The significance of soils in policy agenda setting and formulation has been weak in most parts of the world. Reasons for this neglect include the multitude of local and regional soil status, lack of ready access to the evidence needed for policy action, the challenge of dealing with a natural resource that is an important common good but often privately owned, as well as the long-time scales involved in soil change.

Furthermore, there are only few countries, in which the government has a dedicated soil policy linked to targets on sustainable soil management. And even if elements of soil policy have developed, implementation might be weak. As a result, communities and institutions often do not respond until critical and irreversible thresholds have been transcended.

Perhaps even more significant also for policy and politics is the disconnection between increasingly urbanized human societies and the soil. The task of developing effective policies to ensure sustainable soil management is neither simple to articulate nor easy to implement. This is true regardless of a country's stage of development, its natural endowment with soil resources, or the threats to its soil function (FAO 2011).

Although soil is truly a common heritage of mankind, a public good of strategic importance for food sovereignty and security, health, adaptation and resilience to environmental disasters, ground and surface water management, climate change mitigation, and, related to all of that, an important public good for maintaining peace and security nationally, regionally and globally, it is strange that there are no comprehensive international treaties or agreements to protect the soil, support soil restoration and recovery and an appropriate application of sustainable land management methods. Until today the UN system is fragmented: the UN Convention to Combat Desertification (UNCCD), which carries out utmost important work, though has no broad mandate for soil issues, FAO with its mainly production-boosting perspective, and UNEP with its environmental focus produce rivalries as well as synergies, notwithstanding some signs of hope.

As already mentioned above, bold and consistent actions by national governments or international organizations are unlikely to counter or mitigate effectively the ongoing soil mining, erosion and destruction trends caused and driven by the treadmill pressure for specialization, economies of scale and cut-throat cost pressure of the globalized market structures with its powerful vertically integrated corporate actors. For some decades, the global trade of agricultural commodities represents a detrimental regime of international division of labour as well as of social and environmental impacts. Exporting countries such as Brazil bear severe harm to soils whereas importing countries such as the EU spared pollutions of rivers and groundwater. Unless soil or soil capacities, properties and services are internalized in agricultural costs and prices, governments will have to resort to payment, reward (i.e. rewarding environmental services that generate or maintain public goods) or subsidy schemes so that farmers get an immediate and short-term incentive for investing in long-term improvements in soil management, improving soil fertility, avoiding or reversing erosion, and enhancing soil functions. Such schemes are explicitly allowed under the WTO Agreement on Agriculture. In fact, the huge subsidies doled out in OECD as well as a number of less industrialized countries for chemical fertilizer use and irrigation would be better directed at such payment-for-environmental-services (PES) programmes.

A new paradigm for productivity beyond the distorted fossil economy

Truly sustainable, therefore regenerative agriculture cannot use the shortcuts of industrial, i.e. fossil fuel-driven agriculture. In other words, a higher focus on soil rather than oil implies that local markets, local resources and local nutrient cycles become far more important, which puts a huge question mark on the pressure for yet more globalization and related market orientation. In fact, a single politico-economic measure – the drastic increase of prices for crude oil based fuels – would trigger considerable changes, including in favour of more sustainable soil management.

Key tasks for research

Intensification and industrialization of crop and livestock agriculture have taken place in many regions around the world for at least five decades. But overall no appropriate and continuous research on impacts, interferences, and interdependencies as regards soils have been performed. This grave deficiency is not only a challenge for scientific institutions and networks but also for policies and politics.

A similar area for which data and knowledge are scant concerns industrial soil pollution by substances such as mercury, heavy metals, industrial wastewater, or sulphur. The actual global extent and magnitude of polluted soils remains unclear. A long-term global soil monitoring network is needed. "While the direct impacts of sulphur, nitrogen and trace elements on inorganic soil chemical processes are generally well understood, many uncertainties still exist about pollutant impacts on biogeochemical cycling, particularly interactions between organic matter, plants and organisms in natural and semi-natural systems" (Greaver et al. 2012). Process understanding is dominated by research in Europe and North America (e.g. Bobbink et al. 2010). Research therefore needs to be conducted also in other regions where soil properties and environmental conditions are different.

The Status of World's Soil Resources Report (2015) highlights the following priority research questions:

- Sustainable intensification – How can we get the benefits from intensification while minimizing the associated environmental and social costs?
- Trade-offs between soils and efficiency – How can we manage for resilient soil and related ecosystem services while continuing to maximize efficiency? To what extent can we have both?
- Soil degradation and intensification – What is the extent of degraded soils? There are currently no sound estimates. What portion of degraded soils can be attributed to un-sustainable intensification?
- Options and trade-offs for improved soil management – What can we learn from management practices used in intensification areas to help restore degraded

soils? Are there any options that can integrate best management practice for sustainable intensification? What are the short- and long-term trade-offs of resource use and sustainability? What are the environmental and social costs and economic benefits of land use intensification?

- Farming practices and soil health – How do changes in harvest frequency and crop rotation affect soil resilience? How much change is needed to restore degraded soils?

In addition, there is the need for better cropland information in terms of extent, purpose and intensity of use (see the Synopsis of politico-scientific information networks and tools in this volume, p. 62).

There is also consensus among scientists that trans-disciplinary and participatory research should be strengthened. In this regard, the following issues should take centre stage: (i) empowering land users and decision makers. In particular, this shall concern the larger picture in terms of system complexity, space and time; (ii) working cooperatively between scientists and practitioners; (iii) developing an advanced and joint understanding of complexity; (iv) flexibility and adaptive management of research processes, and (v) think and act in long term perspective (IAASTD 2009; IPES 2015; Liniger et al. 2017).

Issues of soil functions, biology, chemistry, the interplay of soil with other global resources, soil degradation, rehabilitation and fostering soil fertility as well as the interrelationship between soils, food sovereignty, and climate change should play a far more important role in education, training and extension, beginning with primary education.

Conclusions and Recommendations

The present-day state of soil science, soil management, and soil policy is fragmented, sketchy, and inconsistent – though many encouraging initiatives and examples illustrate sustainability oriented and sustainable practices. The altogether unsatisfactory state of soil affairs not only is due to the complexity of soil issues but also to a deficiency of constant attention for the fundamental importance of fertile, healthy soils for healthy human societies (Amundson et al. 2015), and a fortiori for transitions towards sustainable development. What is until today critically lacking is public awareness, political priorities, public long-term and comprehensive research, bold legal and administrative rules on the national as well as international level, and economic incentives and tools in order to promote caring and sustainable use and enhancement of fertile soils. Most of all, a new consciousness for the sensitivity of the pedosphere and adequate care is needed.

Meanwhile conceptualizations of transitions to improved, healthy, and fertile soils have emerged. In addition, the soil food webs and networks can give us an allegory for the structures and functions which we need to establish a holistic and sustainable approach to soils as main-stream practice. Diversity, mutuality, circularity, and synergy are crucial principles of the productive interrelations between biotic and abiotic spheres and between diverse trophic levels. These principles can also be applied to the interrelations of humankind with the living webs which sustain human societies.

From the foregoing analysis, we derive the following recommendations for action in the coming five to ten years:

- ★ Make rehabilitation, improvement, and conservation of living soils a cross-cutting top priority for policy. Fertile soils are literally lifelines of human societies and non-renewable resources. De facto, a situation of multiple crises has emerged that again is largely unperceived by the wider public as well as by many governments. There is urgent demand for immediate, long-term oriented action on all levels from local to global. Constructive options for policies and actions are on the table but coherent frameworks and decisions are largely lacking.
- ★ Promote the recognition of living soils as common goods and a common heritage of mankind. Constitution of fertile soils proceeds in timeframes from decades to centuries. So, soils are a non renewable resource which can't be manufactured technically. Human utilization of soils thus must be aligned with the responsibilities of stewardship instead of consumerism.
- ★ Agricultural practice and policies must follow the guiding principle: Feed soils, not crops. Soils are ecosystems which synthesise as well as decompose organic matter and make available inorganic matter for soil life, thus enabling growth and evolution of myriads of plants and soil organisms. Healthy soils produce healthy plants. Healthy soils need a balance between cultivation (withdrawal) and regeneration (restitution) of i.a. nutrients, trace minerals, and organic matter. All-

season cultivation of diverse plants including trees is by evidence an appropriate practice.

- ★ Build soil-addressing institutions for permanent dialog, deliberation, and participation between the wider public, science and politics. As we can learn from the interfaces between climate change science and politics, progress on the national level can be fostered by strong and credible international structures. The institutional fabric as to fertile soils is fragmented and rather weak. The Intergovernmental Technical Panel on Soils (ITPS) should be transformed into an Intergovernmental Panel on Living Soils (IPLS) with a mandate to report and assess regularly status and changes, to facilitate international and regional cooperation and especially impart successful practices to enhance fertile soils. As degradation and destruction of fertile soils increasingly become obvious as relevant driving elements of violent conflicts in many countries, cooperation and coordination between all parts of the UN system as well as between national governments is imperative.
- ★ Ramp up cooperation and coordination between existing institutions. Build effective national frameworks and implementation. As long as no comprehensive UN Framework Convention on Living Soils (UNFCLS) is emerging, cooperation and division of work between UNFCCC, CBD and UNCCD should be expanded. National Soil Policy Frameworks (NSPs) should be designed with emphasis on reliable soil fertility indicators in order to build up or improve long-term data bases, programmes to foster soil fertility improvement inter alia by promoting local initiatives and cooperatives as well as exchange of experience, and constitute rights and responsibilities of public and private stakeholders and actors regarding land access, ownership, tenure, and use. Public and open debate during the deployment of NSPs should embrace goals and measures for rehabilitation and improvement of fertile soils, such as constituting
    - an integral concept of productivity and production which comprises all goods and services from and within fertile soils,
    - land laws and regulations for all land use oriented to full recognition of the importance of the commons, especially fertile soils,
    - a general policy concept aimed at a regenerative agriculture which balances cultivation (withdrawal) and regeneration (restitution) of i.a. nutrients and organic matter,
    - a transition to reconstructive use of fertile soils e.g. by all-season cultivation of multiple plants including trees,
    - a comprehensive system of curricular modules in education, training, research and extension regarding the importance and enhancement of fertile soils.

Equitable and just distribution of fertile soils in all countries is one of the most important conditions for success of NSPs. Outline and negotiation of NSPs should be organized by means of inclusion, openness and participation and related to national action and implementation plans for the Sustainable Development Goals (SDGs).

★ End agricultural subsidies worldwide that are harmful for soils and the environment in general. Soils in most countries are damaged by use of mineral fertilizers and pesticides. Production and use of these chemicals only are competitive because of huge subsidies for fossil fuels.

★ Science eventually must tackle the challenge of understanding the systemic complexities of living soils and soil improvement. Considerable, long-term oriented expansion of analytical and empirical knowledge on qualities and functionalities of fertile soils is needed. Soil science is a truly trans-disciplinary field of scientific endeavour which until today is neither institutional nor financial appropriately endowed. Especially international research networks with coordinated agendas should be promoted. But the quality of international research communities depends on accordingly building and maintaining national capacities. A crucial element of agenda setting and research design is the practice of participatory research.

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Pastoralism: Keeping soils alive through herd movements and careful grazing management

Evelyn Mathias

Pastoralism is an ancient way of animal husbandry, using natural resources in areas less-suited or unsuited for crop agriculture: drylands in temperate, subtropical and tropical regions, mountainous and high-altitude zones, as well as some very cold areas (FAO 2009, Mathias 2011).

Worldwide there are probably about 200 million pastoralists; estimates vary between 50-500 million, depending on how broad the definition is. Pastoralists account for a large proportion of the livestock numbers in many countries, especially in the Sahel, East Africa, the Middle East and Central Asia (FAO 2009). But there are pastoralists in Europe too, such as the mobile shepherds in central and southern Europe, cattle producers who take their animals to graze in the mountains in summer, and the reindeer herders of northern Scandinavia. Extensive livestock raisers such as the hill farmers of Britain and Ireland also share many of the characteristics of pastoralists.

In some areas, pastoralists and their livestock have continued what wild herbivores started millennia ago: moving long distances from one place to another, following seasonal rainfall and avoiding seasonal disease problems. Examples are reindeer herders in the tundra of the northern hemisphere who drive their animals towards the coast during the short arctic summers and to the inland forests in winter; and the many pastoralist groups in Africa's savannahs, who follow the rains and avoid areas with tsetse flies. In other regions, mobile forms of livestock keeping may have evolved as by-product of intensifying crop agriculture: to prevent animals from eating crops, they were taken away for grazing. With the expansion of crop agriculture, pastoralists were increasingly driven to inhospitable regions with harsh climates and difficult terrain (FAO 2009).

This commentary examines the strategies that have enabled pastoralists to survive and produce under such conditions for centuries. It also discusses how they affect the soils, vegetation and organisms of the pastoral land.

Strategies and characteristics of pastoralism

Pastoralism is as varied as the landscapes where it occurs. Some pastoral groups are entirely mobile and take all their herds on long-distance seasonal movements. But nomadic forms of pastoralism without a fixed homestead are becoming rare. Other pastoralists live in settlements and move their animals each day to grazing areas within easy reach of the settlements, taking advantage of sites such as hedgerows, field borders, and fields that are fallow or that have been recently harvested. Others again use a combination of both: female animals and their young offspring are grazed near the settlements while the rest of the herd goes on long-distance migration. Some combine their mobile livestock keeping with crop agriculture (FAO 2009).

Despite all these variations, the animal husbandry approaches of pastoralists share some key characteristics (FAO 2009, Homann et al. 2008, Köhler-Rollefson 2010).

- Pastoralists keep large groups of animals that can digest fibre-rich feed. The animals are mainly ruminants: sheep, goats, cattle, buffaloes, yaks and camels.
- They control the intensity and duration of grazing through herd movements and careful management. The alternation between grazing and resting periods gives the land time to recover.
- They organize their herd movements and coordinate them with other pastoral groups and other land users in the area. Nowadays they commonly also need the permission of local authorities, especially if they want to cross national boundaries or administrative borders. Some pastoral societies, like the Borana in southern Ethiopia, have developed a complex network of institutions and committees that fulfil these functions and regulate access to water and pasture.
- Their breeds are often multipurpose animals, adapted to the local climate and vegetation. Products include meat, milk, wool, cashmere and leather. Young animals and unwanted adult stock are sold for slaughter or draught. Livestock are a walking savings account and play a central role in culture and social interactions.

The combination of herd management, controlled grazing with adapted breeds and organized movements has allowed pastoralists to graze their animals throughout the year without depleting the resource base. In many countries, pastoralism contributes a sizeable percentage to the agricultural gross domestic product. However, the contribution of pastoralists to national economies and food production is often neglected (WISP 2006), in parts because it is a section of informal economies.

Effects of pastoralism above and below the soil

The effects of pastoralism on soils are closely tied to the characteristics of the livestock, their interaction with the flora, fauna and microorganisms above and below the soil surface, and the management of grazing.

Grazing restricts shrubs and trees and stimulates the growth of grass

Livestock browse on the shoots of shrubs and trees, hampering their growth. When these have reached a certain size, they remain mostly undisturbed by grazers. Raika camel herders even say that browsing stimulates the growth of older trees (Köhler-Rollefson, pers. com.). Livestock has the opposite effect on grass: grazing stimulates its growth along with the activity of organisms in the rhizosphere (the layer of soil that contains *inter alia* the roots). The grass absorbs carbon dioxide from the air and turns it into biomass above the ground (leaves and stems) and below it (roots). The denser the growth of the grass above and below the soil, the faster it will recover after grazing – provided it has not been grazed too short. Otherwise the remainder of the grazed leaves will not have enough energy to start their photosynthesis and get the "carbon-cycling pump" going (Idel 2015).

Grazing hastens the decay of fibre

During the long dry periods in tropical and subtropical drylands, grass dries out, making nutritious standing hay. It may not decay unless it is eaten by grazing animals or termites. Cattle, sheep, goats, camels and other herbivores have microbes in their stomachs that enable them to digest fibre-rich vegetation, turning the hay into dung and furthering the decay of the plants during the long dry season. This is critical to the soil and a healthy ecosystem (Mathias and Wilson 2015).

Ruminants' ability to digest fibre-rich feed also plays an important role in temperate zones, where pastoralists have traditionally been allowed to graze their animals on stubble after harvest in autumn. The animals' dung has always been an important source of fertilizer, especially before the advent of chemical fertilizers (see below).

Dung adds biomass and fertilizes soil

The dung of grazing animals contains plant residues and nutrients. It provides nourishment and habitats for a myriad of insects and other arthropods. Herds of animals trample the dung into the ground, forming a protective layer and increasing the level of organic matter in the soil (Sullivan 2013). Earthworms and other soil organisms set to work on this organic matter and turn it into humus, which retains moisture and encourages plant growth.

Hooves make habitats

The soils in tropical and subtropical drylands are generally low in organic matter: they cannot absorb much water, and dry out quickly. When raindrops hit the exposed soil, they compact the soil surface, forming crusts. Little water sinks in, and much

evaporates or runs off, taking with it valuable carbon and minerals. Livestock hooves break up the crusts on the soil surface, allowing water to seep in and restoring a healthy growth of grass (Mathias and Wilson 2015).

Unless large herds of heavy herbivores spend extended periods in an restricted area, the trampling of livestock will disturb the soil less than the heavy machinery nowadays used for mowing and crop cultivation: when tractors, ploughs, harrows and mowers pass over a field, they break up the soil structure, compact the soil and eliminate the habitat of soil organisms (LLUR 2010). Grazing animals are much gentler: under good grazing management, anthills form on permanent pastures (Bauschmann 2014). More ants on top of the soil mean more ants and life in the soil.

Raika shepherds are grazing their sheep on harvested fields during migration

Livestock transport seeds and small organisms

When walking from one pasture to another, livestock can transport seeds, fruits, spores and other plant parts in their coats. Sheep, with their dense, long fleeces, are especially suited as “seed taxis”. Sometimes they even carry along small animals such as lizards, snails, beetles or grasshoppers. They connect areas in today's fragmented landscape: that stops plant communities from becoming isolated from each other and depleting genetically, and preventing rare species from disappearing completely (Institute of Agroecology 2017, Manzano and Malo 2006).

In long-grazed areas the seeds of many plants are specially adapted for the transport through grazing animals. They have hooks, thorns or bristles that get caught in the coat of the animals. But seeds with a smooth surface are also transported in the fleece of sheep. Some seeds can even remain there for months, covering distances of more than 100 km along with their woolly chauffeurs (Institute of Agroecology 2017, Manzano and Malo 2006).

The gut of animals is another form of transport mechanism: the seeds of some trees have to pass through an animal's digestive tract before they will germinate.

Pastoralists have been known to enhance seed dispersal by their animals through hanging bags of seed around neck of their sheep. During grazing the seeds drop out through holes in the bags and are worked into to the ground by the sheep's hooves (Koocheki in Bayer and Watersbayer 1998, pp. 113-114).

Benefits of pastoralism for the soil

As a result of careful grazing management, pastoralism maintains grasslands and hinders the expansion of bush and forests. Many of the world's grasslands are as much a product of grazing as of a climate that disfavours tree growth. Landscape managers in Europe recognize this: they use sheep to graze areas that would otherwise become overgrown and revert to forest (see, for example, LLUR. 2010). Many popular tourist destinations, such the Lueneburg Heath in northern Germany, would lose their attractiveness without their quadruped lawnmowers (Lüneburger Heide GmbH. 2017).

But grasslands are not just tourist amenities. The dense rooting systems of grass and the rich humus layer store large quantities of carbon, so help reduce the impact of climate change. Ploughing land to cultivate crops speeds the decomposition of organic matter, encourages erosion, and releases carbon into the atmosphere as CO_2 (Idel and Reichert 2013). Grazing, on the other hand, maintains the vegetation and increases the humus layer in the soil, creating a species-rich pasture that absorbs more CO_2 than it releases. In temperate climates, grasslands continue to produce oxygen when deciduous trees have shed their leaves in autumn (Bauschmann 2015, Idel 2015).

Areas where grazing is carefully managed tend to be rich in biodiversity, offering retreats for many endangered plants and animals. Some plants may disappear under grazing pressure, while others need it to thrive. In Europe, traditional migration routes are especially rich in biodiversity and play a key role in biodiversity conservation (Azcárate et al. 2012). As the biodiversity above and below the soil influence each other, biodiversity changes on top of the soil will affect the soil biodiversity and functions and vice versa.

Species-rich, deeply rooted permanent pasture is an excellent protection against soil erosion. The grass forms a continuous cover, protecting the surface from raindrop impact, slowing runoff and trapping soil particles. The grass roots hold the soil in place, even on steep slopes. The humus retains water and allows it to infiltrate and feed the

Shepherdess Laura Schneider is exploring migration routes for the German biotope-(re)connecting project

groundwater below the soil layer. Grassland soils are an excellent water filter, sieving out contaminants and preventing them from entering wells and springs (Bauschmann 2015, FAO 2009).

Negative effects

But poorly managed grazing can be very damaging. Too many animals on too little land eat up all the vegetation, including the growing shoots, leaving the soil surface bare and exposed, allowing gullies to form. Thousands of hooves pulverize the soil and make it easily eroded by rain and wind. That further reduces vegetation growth and the amount of carbon in the soil.

Pastoralists are aware of such problems and avoid them through a combination of careful management and mobility. They use traditional migration routes that follow the rains, making use of fresh vegetation and allowing the vegetation on already-grazed areas to recover. They maintain reserve pastures for use in emergencies such as drought. They strike agreements with farmers and other groups of herders to avoid overusing areas close to streams and waterholes (FAO 2009, Homann et al. 2008).

But in many places, such measures are breaking down. Human populations are growing and crop cultivation is expanding in wetter areas that used to act as winter pasture or grazing reserves. Livestock are banned from nature reserves that previously served as emergency grazing sites. Farmers and investors fence off land. The spread of settlement blocks migration routes. Violent conflict prevents herders from using valuable tracts of pasture. Politicians in faraway capital cities make decisions that affect pastoralism,

without understanding its benefits or needs. Pastoralists and their herds are continually pushed into poorer, drier areas, which become overgrazed.

Changing technology also has an impact. In Spain, where sheep have traditionally moved in winter from north to south and in summer in the reverse direction, sheep are nowadays transported by lorries between winter and summer pastures. That eliminates their impact on the vegetation en route (DVL 2016).

Grazing animals – problem or solution?

What type of production system is suited to supplying the world's rising population with animal products? Supporters of industrial livestock-raising are currently engaged in heated discussions with the proponents of ecological livestock-keeping.

The discussion has so far mainly centred on the greenhouse-gas effects of different livestock species and systems. High-performing cattle kept indoors and fed with concentrates have a clear advantage in this respect. They produce less greenhouse gases per litre of milk or kilogram of meat than extensively grazed, multipurpose animals adapted to fibre-rich diets (Garnett et al 2017). This has been used as point to promote industrialized animal agriculture and against extensive grazing.

But a focus on greenhouse-gas emissions per unit product is too narrow. It neglects the range of positive impacts pastoralism and grazing animals have on biodiversity, soil life and groundwater. Estimates of carbon emissions often neglect the effects of grazing on carbon sequestration in the soil. If appropriately managed, extensive (as opposed to intensive) grazing can increase carbon sequestration (Bauschmann 2015, Garnett et al. 2017, Idel 2015). In many areas, it is the only viable form of land use. And intensive, industrialized livestock production is itself subject to much criticism: in terms of animal welfare, pollution of soil and water by effluents, and other negative ecological impacts such as the stimulation of crop monocultures for animal feed and the loss of biodiversity (Idel & Reichert 2013).

Putting animals back on pastures

If grazing were to cease, what would be the effects? There is little information on this. Suitable areas that are now grazed would be converted to cropping – with its attendant problems of erosion and pollution. Other areas would revert to bush or forest. Millions of pastoralists and other livestock keepers would lose their livelihoods, leading to severe economic, social and political consequences. In any case, an immediate halt to grazing is clearly unrealistic.

The costs of converting to other land uses have received little attention. If grass no longer acts as a water filter, how does this affect the costs of water purification? What would it cost to prevent open landscapes that are the basis of a tourist industry from becoming overgrown? How would abandoning livestock affect the biodiversity and the

carbon balance of such areas? How would this affect nearby areas – for example by reducing the number of pollinating insects?

How should grazing be managed to maximize the advantages and minimize the disadvantages? Extensive grazing seems to be better than intensive, though the level of intensity depends on the regional and local situation. Various initiatives are exploring options. In Zimbabwe, scientists have developed a holistic method called "planned grazing" that mimics wildlife and pastoral herds (Mathias and Wilson 2015). In Germany, a group of institutions and shepherds are studying how grazing sheep can be used to (re)connect isolated biotopes with each other (Institute of Agroecology 2017). In Germany and the Netherlands, grazing sheep are used to maintain dykes. This is cheaper and ecologically more useful than mowing (Brink 2003).

But time is running out. Herders lack access to land, water and markets. They face obstacles set up by uncomprehending or hostile governments: in many countries, bureaucratic hurdles are becoming a huge challenge. It is becoming more and more difficult to make a living from herding animals. Increasing numbers of herders are giving up their lifestyle; their centuries-old knowledge and skills are being lost. They need recognition for their ecological and economic contributions, political support, adequate payments (not subsidies) for their services to agro-ecology and breed conservation, and help to get organized to strengthen their voice in negotiations. Consumers, too, can play a role – in developed countries by reducing the amount of meat they eat, and globally by giving preference to meat produced under management that maintains biodiversity and conserves resources.

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German Association of Professional Shepherds (BVBS): http://www.berufsschaefer.de/

European Shepherd Network (Shepherd Net or ESN): http://shepherdnet.eu/

League for Pastoral Peoples and Endogenous Development (LPP): www.pastoralpeoples.org

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Cattle in San Marcello, Brazil

The dream of food without dirt

Gunnar Rundgren

That is the best description of how we will get food in the future if we would believe the impressive number of food tech start-ups which will produce food without soil or animals. But few of them deliver on their exaggerated promises.

There is no doubt that technology has improved life for huge numbers of people. Plant and animal breeding have given us a variety of useful crops and livestock products. Mechanical devices and tractors have made farming a lot easier. Food processing methods have made food safer to eat and sometimes tastier (e.g. cheese). Sometimes, innovations have improved nutritional quality and the environment, but probably more often not. It would be no exaggeration, and should not come as a surprise that many of the technological advances also have had a down-side. After all it is not surprising in a world where profitability and increasing human labour productivity are the main drivers for technological change that nature and sometimes human health has suffered.

Because of how badly we humans have treated soils and animals it is understandable that people now are looking for other ways of producing food. Under banners of digital ecosystems, open source, individual foods, actionable intelligence, disruptive food systems and digital transformation, there are legions of entrepreneurs (mostly with background in the IT sector) seeking venture capital and researchers looking for grants.

We read articles in magazines or books which are claiming that some new technology will save the world's poor or hungry, produce food with almost no environmental impact or make cities independent on that boring "junk space" called countryside. For example Jayson Lusk, a food and agriculture economist at Oklahoma State University, presents in his new book, Unnaturally Delicious: How Science and Technology Are Serving Up Super Foods to Save the World, how 3-D food printing, robot cooks, synthetic biology and meat tissue culture will revolutionize our food.

3-D printing of food is expensive, incredibly slow and not capable of making most of the food we like to eat - today. Perhaps it will in the futures. My concern is rather that 3-D printing of food and robocooks seems to be far-fetched solutions to marginal problems,

and it certainly has nothing to do with "solving the world's largest food and farming problems" as the jacket of the book claims. Many tend to forget that 3-D printing of food is not really producing nutrients, it is just a new way of distribution and cooking individualized meals.

Most of the new food tech start-ups are actually about distribution and not about production. And it is probably in the field of distribution that food tech will be most successful, and also have a disruptive influence. In the food industry, like ever before, there is a lot of innovation. Many different kinds of vegetarian or vegan alternatives to meat, milk and cheese have developed. But in principle, there is not much new in this. Tofu has been around for two thousand years, fried potato cakes have been common in many cultures and tempeh in others. An interesting perspective of the food industries interest in vegan food and other "free from foods" is that it has wonderful margins. A survey in Swedish supermarkets reveals that conventional soy protein products regularly have a much higher price than organic minced meat, despite one tenth of the costs for raw materials.[i] The food industry can thus capture a share of the market price which earlier went to farmers.

On the farm level, more and more new technologies are introduced. Milk robots have been around for decades and soon there will be weeding robots. GPS control of tractors reduce wasteful driving and enables a more precise application of fertilizers. Self-driving tractors are close to market introduction. All of these technologies are about fine-tuning the use of resources or saving labour in agriculture operations and don't represent any new ways of producing food.

In this article, however, I turn my attention to methods of primary production which are not soil or animal based (I will leave wild foods and fisheries outside of the discussion). Many such ideas abound; synthetic food, algae, aquaculture, hydroponics, insects, vertical farms and urban farming are the ones I will discuss here.

In 2013, Mark Post at the Maastricht University, sponsored by Google co-funder Sergey Brin to the tune of US$300,000, presented the first synthetic hamburger to the world's media.[ii] An American company, Memphis Meats, announced in March 2017 that it could produce cell cultured chicken meat for about $9,000 per pound.[iii] Even if the companies claim they are close to having marketable products there are big question marks if these efforts will be scalable and commercially viable, if ever.

Growing food in large tanks has been made for a long time, however. Yeast biomass was used as human food in Germany already during the First World War. The development of large-scale processes for the production of commercial protein began in earnest in the late 1960s, against the backdrop of an assumed food crisis. Most of the initiatives failed due to technical reasons, but the ICI Pruteen process for producing bacterial single cell protein for animal feed succeeded.[iv] However, even if the production worked it was never economically viable – it could simply not compete with soy and fish, and the site was eventually abolished. On the same site in Billingham, England

there is now a smaller factory that uses a continuous fermentation process to produce a Fusarium venenatum biomass, marketed as Quorn, a vegetarian alternative to meat, with a price higher than meat.

Few people seem to realize that lab-foods also need a feedstock, and the companies marketing the products are mostly silent regarding the raw materials used. To grow maize as a feedstock for 'artificial' food or to produce chicken is not so very different. Chicken production, in many parts of the world, is already landless production, a kind of feed converter factory. And it is obvious that you can do a similar thing with fungi or bacteria. It is not obvious, however, that the process will be much more efficient (but possibly more ethically acceptable). Judging from the prices of the synthetic meat products considerable resources are used in their production. Tissue culture of beef is currently done on a serum extracted from unborn calves and it also involves the use of antibiotics.[v] Other resource demands are rarely documented, so the claims of being resource efficient still needs to be proven.

Aquaculture of fish, shellfish, aquatic plants and algae is increasing and will continue to do so. Aquaculture can capture nutrients that are lost from the soil and carried to the sea by sewage and recycle them into the food system, for example, by cultivating mussels or growing macroalgae. Microalgae can be eaten, but can also be used as a fertilizer or feed for animals. The difficulty is to find practical ways to grow them. As Algae Industry Magazine (2012) notes: "Though the cultivation of algae using man-made or natural ponds was initially simple, turning it into a viable feedstock has always been problematic. So our industry has always needed a system that could enable higher production levels, lower capital and operating costs, greater biomass density, better environmental control, and above all, industrial scalability."[vi] Even bio-fuels could be made from algae, but the cost of production is prohibitive and would use enormous areas and water resources. In addition, it is very energy consuming and CO_2 emissions caused would be much bigger than for fossil fuels.[vii] Therefore, almost all algae entrepreneurs are producing nutritional supplements and other specialty products which have prices two orders of magnitude higher than fuel or staple food.

Much aquaculture today is based on predatory fish, such as salmon, which are fed on undersized caught wild fish, other fish leftovers and fodder from agriculture. There is not a dramatic difference between modern fish farming and broiler production. Both are based on keeping a population in a confined space, feeding them with bought-in feed composed of maize, soy and fish[viii] and adding minerals, vitamins and antibiotics to keep them alive in a stressful environment. A comparison between Norwegian salmon production and chicken production concluded that chicken production was less-resource consuming than salmon when salmon is fed wild caught fish.[ix]

For aqua culture to really play a meaningful role in feeding a growing population in a sustainable way, we need systems that integrate aquaculture and farming. Such systems have developed over a long time in Asia where rice, fish and vegetables have been

grown in the same system, sometimes also including ducks or pigs. There are also modern versions of such systems under development.

Vertical farming in Mongolia

Since 2003, FAO has promoted insect rearing. More than 1,900 species have been consumed in the world, most of them wild collected.[x] Various waste materials, including manure and our own faeces can be used as feed stock for insects. However, if insects were to become a big part of the food system they would certainly have to be raised on cultivated crops. Then we should ask if they are more efficient than chicken or carp in converting food crops into new food. Energy requirements are high and feed conversion rates are quite similar to chicken.[xi] The cost of production is currently far too high and while FAO promotes insect rearing as an interesting option for small-scale production they also advocate increased mechanization to drive down costs, which will not favour small-scale production, rather the opposite. [xii]

The growing of plants in water with drip-fed nutrition is another much-hyped technology. There are some traditional hydrocultural systems that work well, where people farm on floats in rivers or lakes, e.g. in Bangladesh and Burma, and of course there are edible aquatic plants which are grown or collected. In its modern scientific form hydroponics was developed by researchers at Berkeley University in the 1930s. [xiii] In 1937, Time Magazine reported that hydroponic had "yielded some remarkable

results”.[xiv] Seventy two years later the same magazine elected a vertical hydroponic system to one of the 50 best innovations in 2009.

An extreme version of hydroponics are indoor vertical farms in cities. We see sketches of green skyscrapers feeding the people with clean, local and nutritious food. Most such plans remain on the drawing boards for very simple reasons. For sure, it is possible to produce lettuce in high towers with automated systems. But the fact that it is possible doesn’t mean it is viable on a larger scale, and even less that it will take place in the cities. Vertical hydroponic farms are totally dependent on inputs that will need to be transported in, they are not part of any ecological context in the city, and if they are large, the crops will be put into the normal food distribution networks. In that sense, they are like any other assembly plant. And, like any other assembly plants, they are better located outside of city centres. But the rational for stacking crops on top of each other is gone where land prices are lower. Hydroponics is already the dominating form for commercial production of tomatoes, capsicums, cucumber and lettuce in greenhouses in many countries in the world. By and large, it can only compete in high value crops where production is close to the market, and greenhouses are often located close to transportation hubs or energy resources rather than in cities.

It can of course be a marketing gimmick for a supermarket to grow its own lettuce on the roof of the outlet or in a green dome inside the shop, in the same way as they have an in house bakery. And, similarly, it can be an interesting architectural and engineering challenge to have green skyscrapers, and it can increase the commercial value of the property. But it has little relevance for feeding the population, which is underscored by that the commercial application are all about growing baby lettuce, pak choy or herbs, crops which provide almost no food energy or proteins.

The claims of environmental benefits are mostly not backed by any facts. In-door production of lettuce, herbs and other small leaves require in the range of 250 Watt per square meter of energy efficient LED lamps (a lot more is required for the production of tomatoes or potatoes).[xv] With 12 hours light per day one would need 3,000 Wh per square meter and day, or 1,095 kWh per year. This means that only three square meters of such a farm would consume the global average per capita use of electricity.[xvi] LED lit vertical farming also doesn’t save land as it often claims. Assuming, optimistically, that we could produce the electricity with solar panels, depending on where we are located we would need solar panels on an area which would be between 4 and 8 times bigger than the area of each layer of cultivation.[xvii] And this is only for the light. In addition to light one needs energy for ventilation, cooling, water pumping and purification etc. The claim that the production is climate-smart is also questionable; T. Shiina and colleagues (2012) found that growing lettuce with artificial light causes at least 6 kg CO_2 emissions per kg, which is considerably more than for common greenhouse production and at least five times more than arable lettuce production. [xviii]

Indoor farming in the cities are part of a narrative of 'sustainable cities' in which cities become self-sustaining ecological units. Unfortunately, those technologies are not integrated into the ecological web of the city, rather the opposite, they need to be sealed off even from the people and the water used must be of premium quality. They can't even use the rain falling in their roofs.

It is worthwhile looking back at the reasons for urban farming. Most cities have had some gardens within the city walls, and almost all of them, except for pure trading seaports have had a close relationship to the rural hinterland. In Paris in the 19th century and well into the 20th century, there was a substantial production of fruits and vegetables, employing 9,000 gardeners on 1,400 ha of land.[xix] Farming in the cities had as much to do with using the cities' waste as with the city as an outlet of production. Most big cities had well developed systems for collecting human waste and bringing it back to the farm land, 'the more the city stank the richer it was deemed to be'. In Genner villiers, outside Paris, the first municipal sewage treatment plant in 1869 was based on recycling nutrients. It was a great success and farmers fought for the contracts and by 1900 there were 5,000 hectares irrigated by the sewage water.[xx] When global markets became the main supplier of food to cities and artificial fertilizers became cheap, all these linkages disappeared as well as the link between the city and its surrounding rural areas.

We need to have realistic expectations of what can be produced in the city. In the semi-deserted and bankrupt city of Detroit it is estimated that almost 5,000 acres could be allocated to urban farming. This could supply Detroiters with between one third and two thirds of the vegetables consumed and between one sixth to two fifths of the fruit. This seems impressive – but fruit and vegetables play a minor role in feeding people. The same area could perhaps give 10,000 tons of wheat, which sounds a lot, but equals the calorific needs of 30,000 people, just a few percent of the population of Detroit. Other research shows similar results.[xxi]

While it is commendable to strive to reduce the ecological footprint of cities some realism is called for. For their provisions and waste disposal, cities need forest, agricultural, marine, and wetland ecosystems on lands many hundred times the area of the city itself.[xxii] If we are serious about feeding the cities more locally, we should look more to the perimeters of the city and to the interplay between cities and their hinterland. It is here that there really is a potential to feed the cities.

Meanwhile, urban farming - with soil and animals - has a role to play in reviving community spirit and for recreation. It is also a good way to engage people in food production and in appreciating food quality. Despite the hype and attention given to urban farming in modern wealthy cities, most urban farming takes place in developing countries by poor people using very simple technology producing a lot more food than any vertical farms.

In general, the most-hyped ideas which are promoted in the media are often the least realistic alternatives. High-tech solutions inevitably attract attention, but mostly they stumble on practicalities or economics. The step from a theoretical possibility or even a prototype production to a commercially viable production is much bigger than most people seem to realize. The messages of the techno-optimists are both deceptive and dangerous as it makes people believe that most problems can be solved by technological innovation which in turn takes attention and resources away from other solutions. In essence we already have the technologies needed to feed the world's population with healthy food in a sustainable way. The challenges are more social, economic and political.

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Pepper production in the Netherlands

How to cope with largely dysfunctional market signals for soil stewardship?

Ulrich Hoffmann & Gunnar Rundgren

The examples on reproductive soil management provided in this report are undoubtedly a sign that transition can and, at small scale, is happening. One needs these examples and related success stories, and one needs the stuff that just started without waiting for permission or big pushes. But these harbingers of transition cannot be uncoupled from an analysis of the bigger economic and policy issues for sending the right signals and incentives to farmers.

The reading of this report reinforces the apprehension that the pressure for action on soil stewardship is very high, but there is a clear lack of adequate and effective behavioral change of farmers despite the fact that suitable soil management approaches and techniques are well known and readily available. The main causal factor for that inaction is the absence of economic (and to some extent cultural) incentives for applying reproductive agricultural practices. There are no market mechanisms for agricultural production that encourage ecosystem and reproductive soil management.

Farming is the most significant human management system of the planet (i.e. farmed landscapes account for more than half of the terrestrial area of our planet and even a bigger share of its biological production). In other words, human existence on the planet largely rests upon how we manage our farmland and soils. This has important implications for agricultural policy, because it means that managing farmland, soils and ecosystems is almost as important as producing agri-food products. But farmers are not encouraged by market signals and mechanisms to be land stewards. On the contrary, modern day farming has removed much of the land husbandry and stewardship that was previously an integral part of a regenerative farming system. Market forces encourage an industrial, almost factory-like agriculture system with a mechanistic view of nature and a linear external-input-intensive production approach largely removed from its ecological context. Globalization has reinforced the importance of profit-seeking and competition and has globally turned the role of the food system into a mechanism that transforms nitrogen, phosphate, and potassium into nutrients for

people in the most efficient, which means cheapest, way. But this perspective neglects the immense life in our soils, the millions of organisms living there and all their interactions.[1]

There is also the need to redefine productivity. But it is not sufficient to theoretically redefine productivity, we also need to redesign the economic system that has created a distorted view of what is productive and what is not. Today, productivity is measured by how many trees one person can cut down with a chainsaw or how much fish a fisherman can scoop up from the sea. But as natural resources dwindle, the real productivity lies in how these resources re-generate. One is productive if there is more forest next year than today, if there are more fish and if the soil becomes more fertile by the years instead of being exhausted and eroded. In a similar way we are efficient if the food we produce and consume is healthy rather than if it is cheap.

While many observers recognize and deplore that dilemma, too much hope is pinned on the potential of modern techno-fixes to mitigate the effects of resource-mining agriculture. There is no doubt that some of the new technological developments such as soil-data availability and processing, the use of agri-robots and drones that allow a more efficient use of external inputs can reduce environmental impact of industrial agriculture. But this does not necessarily mean that there is a systemic change towards reproductive agriculture. Rather, this will require a change of the incentive structure and the thus related market signals. Soil and resource regenerative agriculture cannot use the shortcuts of industrial agriculture that, by and large, are all fossil-fuel-driven.

There are almost no market mechanisms in place for undertaking the important task of managing the agriculture landscape and the resource base for farming, and there is a limited potential for them to emerge. Even if they did they will never reach the extent required, considering that the value of agricultural ecosystem services might well be as high as the total value of agricultural production. At present the market is still driving farmers the other way; into more and more specialization and monocultures and less stewardship of nature resources, including the soil.[2] Already today massive government interventions are directed to compensating for market failure. We need to look in other directions if we wish to sustainably manage the agriculture landscape.

Against this very background, for decades many scholars have pointed to the need for internalization of social and environmental costs and compensation for ecosystem services as the silver bullet for overcoming market failure and thus ill-conceived economic incentives for farmers. Yet, there are enormous challenges involved in internalizing costs and rewarding farmers for providing environmental services, because that would require very extensive and complex regulation (e.g. the EU's agri-environmental program is but a small step in this direction). Such mechanisms have been proposed for more than half a century and very little progress has been made so far. Such system would probably still be neither fair, nor efficient, and would, in many ways, represent a control of farms more severe than under Soviet-style command and control. Moreover, the payments to farmers for providing public goods will not reflect

the value of the public good but the compensation the farmer needs to obtain to make the required effort – which may be considerably higher or lower than the value of the goods or services themselves (e.g. if the farmers are compensated for not or sparsely applying fertilizers and other agro-chemicals to protect groundwater or a watershed, the level of payment will compensate the farmer for actual or perceived yield losses). The WTO agreement on agriculture also explicitly prohibits any compensation above the actual cost of providing the service rendered.

There are a number of examples of national programs for compensating farmers for generating environmental services, but their results are mixed and potential systemic problems underestimated.

By way of illustration, as early as 1996, Costa Rica introduced a system which compensated landowners for carbon sequestration, biodiversity protection, water regulation and conserving landscapes. In 2001, the payments under this program had reached US$ 30 million and covered a total of 280,000 hectares (around 6% of the country's land mass). The payments thus amounted to about US$ 107 per ha per year. [3] Farmers in the Scoltel Té project in Chiapas in Mexico also sell carbon sequestration in the soil and in vegetation for between US$ 300 and 1,800 per farm, big sums for households where the average income is about US$ 1,000.[4]

In 2003 more than 10% of England's agricultural land was enrolled in long-term contracts between the government and farmers to provide environmental services. There was a high uptake of the elements of the programs that didn't require fundamental changes to farming practices. But, in intensively farmed areas the uptake was low, as the incentives were not sufficient to persuade farmers to make more demanding changes. In a sense the program was just 'greening the edges'.[5]

There are many other potential problems with, and unintended side effects of payments for ecosystem services, some of which are not initially seen. It also means that more ecosystems are integrated in the global economy. These payments can also be seen as a new frontier of exploitation, where the rich countries use the land in developing countries as a 'dumping' ground for their waste, e.g. by paying for climate compensation to allow continued emissions.

One can also question the benefits of valuing ecosystem services in monetary terms, especially as the most valuable of these services have unlimited value and no known alternative. But there is also the question of how we perceive nature. It seems that we increasingly confuse 'value' and monetary assets, and there is a case for us avoiding underwriting this confusion by assigning prices for natural and social capital.

In the light of the conceptual considerations above and the level of urgency for action it seems more fruitful and stimulating to farmers at the present juncture to think of one or two powerful building blocks that change their incentive structure rather than conceiving a fully different system. The most powerful measure one should consider in this regard is the removal of energy subsidies.

Higher costs for energy will cascade through the system and make things that today seem 'efficient' and 'rational' appear like lunacy. In this way, many of the fallacies of today's system will 'automatically' disappear, in particular production systems based on external-input-dependent, highly specialized production, mass transport of food and cold chains for fresh convenience foods. The thus 'freed' financial means from reduced energy subsidies can be redirected towards compensating (or rather rewarding) farmers for providing environmental goods and services. Incentives for carbon sequestration in soils may have the triple purpose of mitigating climate change, arresting soil erosion and encourage farmers to implement other regenerative agriculture practices.

Another opportunity that farmers may autonomously seize is to sever completely or to a large extent the links with the classical market. Producer groups or cooperatives may develop various forms of community-supported agriculture, where, on the one hand, producers market their produce directly without trade or retail intermediaries, thus profiting from higher prices and lower costs,[6] and, on the other hand, consumers take a stake or invest in farming. While monetary transaction may still be important in such systems they are in fact built on relationship rather than an anonymous market. Such approach allows farmers to put much more emphasis on the qualitative and reproductive aspects of production, including soil fertility and largely isolate themselves from the treadmill pressure of mass commodity production. In addition it may offer consumers – or citizens – a much needed way of reconnecting with food production. That will motivate them to support local production and relationship as well as policies which are directed towards regenerative agriculture.

Policy makers can also facilitate such a development by a host of policy measures, such as changes in hygiene, tax and employment rules (which nowadays can create problems for community-based enterprises), planning (e.g, by reserving land in city perimeters for farming purpose, such as the Agriculture Park in Barcelona), public procurement (a Swedish municipality has become a member of such a community-supported farm and gets the vegetables to the schools from that farm) and through other kinds of incentives (e.g. free space for farmers' markets, making public land available on favourable terms).

Without such measures and approaches, prevailing soil erosion is unlikely to be slowed down, let alone stopped and reversed. In fact, the situation will rather resemble that of the fight for climate change mitigation: A spate of positive practical examples on GHG reduction opportunities and a large body of knowledge on the catastrophic consequences of likely temperature increases of 3-4 degrees and more will not be sufficient to alter the current GHG-intensive, GDP-growth-fetishizing development paradigm. It seems as if change can only be triggered as a result of recurrent natural catastrophes and related human and development crisis situations.

References

[1] For a more comprehensive analysis see: Rundgren, G. 2015. Global Eating Disorder, Regeneration, Uppsala, p. 121 ff.

[2] Low interest rates in quite a number of developed countries have boosted investment in acquisition of farmland in expectation of speculative gains. This has contributed to significant increases in farmland prices. One would expect that higher land prices would encourage land/resource stewardship, but actually they increased the pressure on productivity and profitability improvements further expanding, for instance, the production of flexi-monocrops such as maize for feed, food and fuel.

[3] FAO 2007. The State of Food and Agriculture 2007.

[4] World Bank 2007. World Development Report 2007.

[5] Dobbs, T.L. and J. Pretty 2008. Case study of agri-environmental payments: The United Kingdom. Ecological Economics 65, pp. 765-775.

[6] It is estimated that buying from independent shops generates about 2.5 times as much local income as buying from supermarkets, because local shops also tend to buy local services (Transition Town Totnes, 2012. Economic Blueprint for Totnes & District: Our local food economy. Transition Town Totnes).

Nothing is more inspiring than good examples

Paragons for conservation & improvement of soil fertility from different continents & cultivation systems, compiled by Stephan Albrecht, Matthias Hollenstein & Hellmut von Koerber contributing

The following illustrations – though by far not exhaustive - are intended to demonstrate that against all degradation and destruction in many places around the globe dedicated people, organizations, and institutions are successfully working for rehabilitation and regeneration of, and improvements in soil fertility. Clearly there are feasible real life alternatives to the powerful vested interests in a further fossil industrialization of the world's agricultures.

Africa

Pretty, Toulmin & Williams (2011) analyse and assess in the context of the UK Foresight Process *Future of Food & Farming* 40 case studies from Africa, where different changes and improvements in agricultural practices and regimes were developed and applied, gaining in parts striking results. Overall 12.8 m ha were included in the evaluated projects and due to the interconnected nature of agriculture, not only remarkable gains in yield were observed but also environmental improvements, i.a. for soils.

Table 1: Overview of projects evaluated

Thematic focus	Number of projects	Countries represented
Crop variety & systems improvements	11	Ghana, Ethiopia, Kenya, Malawi, Mali, Mozambique, Tanzania, Uganda, Zimbabwe
Agroforestry & soil conservation	4	Burkina Faso, Cameroon, Malawi, Niger, Zambia
Conservation agriculture	4	Kenya, Lesotho, Tanzania, Zimbabwe
Integrated pest management	4	Benin, Burkina Faso, Kenya, Mali, Niger, Rwanda, Senegal, Uganda
Horticulture & very small-scale agriculture	3	Kenya, Tanzania
Livestock & fodder crops	4	Burkina Faso, Kenya, Mali, Rwanda, Tanzania, Uganda
Novel regional & national partnerships & policies	7	Benin, Cameroon, Congo, Cote d'Ivoire, Ghana, Kenya, Malawi, Nigeria
Aquaculture	3	Cameroon, Egypt, Ghana, Malawi, Nigeria
Total	40	

Source: Pretty, Toulmin & Williams 2011

"The environmental side effects or externalities have been shown to be highly positive in a number of cases. Carbon content of soils is improved where legumes and shrubs

are used and where CA [conservation agriculture] increases the return of organic residues to the soil. Legumes also help fix nitrogen in soils, thereby reducing the need for inorganic fertilizer on subsequent crops. In IPM [integrated pest management] based projects, most have seen reductions in synthetic pesticide use (e.g. in cotton and vegetable cultivation in Mali, the pesticide used has fallen to an average of 0.25 litre ha^{-1} from 4.5 litre ha^{-1} [a reduction of more than 94%] ; Settle and Hama Garba, 2011). In some cases, biological control agents have been introduced where pesticides were not being used at all (e.g. again in Mali, with the introduction of *Habrobracon hebetor* parasites [a small brownish wasp] to control millet head miner; Payne et al., 2011). The greater diversity of trees, crops (e.g. beans, fodder shrubs and grasses) and non-cropped habitats has generally helped to reduce run off and soil erosion, and thus increased the groundwater reserves." (Pretty, Toulmin & Williams (2011), p. 9 f.)

International Union for Conservation of Nature (IUCN) in cooperation with i.a. UNCCD, CBD, and more than 35 governments from around the world have in 2011 launched the so called Bonn Challenge. The goal is to bring 150 m ha of degraded and deforested land into restoration until 2020, and until 2030 even 350 m ha. In July 2016, the Kigali Declaration on Forest Landscape Restoration was adopted by 14 African governments, augmenting the Bonn Challenge. In October 2016, 17 African nations announced 63.3 m ha as priority areas for the respective national policies, until July 2017 the total hectares pledged accumulated to more than 156 m ha (IUCN 2017).

A cooperation between the government of the Republic of Malawi and the UN World Food Programme (WFP) in the southern Malawian region has by simple technical means established a diversification of cultivated food crops and fish. The staple food maize, which is prone to drought, is supplemented by cabbage, tomatoes, carrots, and yams. By manually operated pumps ground water is used to irrigate small plots which are fertilized by home made compost. Furthermore, small deep pits have been dug which collect rain water and are used for the cultivation of tilapia fish which in turn is a precious part of a diverse and healthy diet (Süddeutsche Zeitung, 31. May 2016, p. 7).

For more than 30 years, WFP in Ethiopia has supported MERET (Managing Environmental Resources to Enable Transitions to sustainable livelihoods). 'Meret' means 'land' in Amharic language. MERET operates in six regions with 451 communities. More than 400,000 ha of degraded land have been rehabilitated in 72 chronically food insecure districts. Annually 648,000 people have been assisted through MERET (2012-2015). MERET has demonstrated that with proper planning and technical support communities can improve their environment and livelihoods. In 2012, nearly 70 percent of MERET houses reported significantly increased income as a result of improved farm productivity through land rehabilitation interventions. Households who were previously on humanitarian relief are able to cater for their families on their own (WFP 2016).

Ethiopia's Tigray region has made significant progress in restoring its degraded lands and improving its food and water security. The results derived from the major land restoration undertaken by local communities and the regional government. Key to this success is Tigray's regional development strategy, known as Conservation-Based Agricultural Development-Led Industrialization, which focuses on food self-sufficiency and economic growth by conserving land and promoting sustainable agriculture. Thanks to a unique combination of collective action, voluntary labour and the involvement of young people, the people of Tigray are restoring land on a massive scale. For its remarkable achievements under harsh conditions, Tigray's policy was recognized with the Future Policy Gold Award 2017, awarded by the World Future Council in partnership with the UNCCD (http://www.futurepolicy.org/healthy-ecosystems/biodiversity-and-soil/tigrays-conservation-based-adli/).

In Burkina Faso eroded and degraded land has been recreated by means of agroecology. In 2012, Lankoande Francois' land in eastern Burkina Faso was barren. He was unable to produce enough food for his family. Then Groundswell International and its partner organization, the Association Nourrir Sans Détruire (ANSD), began to work with Lankoande and other families in the area to improve their farms. Lankoande and his family tried a number of agroecological techniques to stop soil erosion, capture rainwater, improve soil fertility, and diversify their farm. By 2016, they regenerated 2.5 ha of land, literally re-creating farmland. They now produce on 2.5 ha what other farmers in the area need 9 ha to produce – a productivity increase of over 300% (cf. http://www.groundswellinternational.org/burkina-faso/lankoande-francois-re-creating-farmland-in-burkina-faso/).

Asia

"In the Philippines, traditional rice varieties have been collected by farmers and improved through farmer-centred participatory rice breeding, supported by NGOs and scientists. After 20 years, this initiative has grown to the point that more than 600 farmers' organizations (35,000 farmers) using organic production systems are involved, and other crops, livestock and integrated farming systems are covered. There are 223 farmer-managed trials in 47 provinces, with ten back-up farms serving as gene banks, each maintaining 300 to 1,800 rice varieties. A total of 826 varieties, including 284 rice crosses, have been released (compared with 173 varieties released by the government between 1955 and 2005). Farmers' yields are sometimes better than those of high-yielding varieties, and farmers' incomes are usually greater than those of conventional rice producers because of savings from non-use of chemicals and a lower cost of seeds." (IFAD Poverty Report (2011), p. 174) An evaluation of the profound effects of the activities of MASIPAG, the network of farmer's groups, scientists, and NGOs, on biodiversity (environmental as well as on-farm) gives evidence that changes in

agricultural practices resulted in increases in soil fertility and reduction in soil erosion (Bachmann et al. 2009).

In north east PR China a huge plateau is located, comprising 640,000 km^2 [roughly twice the land area of Poland], composed mainly of loess soils. This region is seen as the second place on earth where agriculture by settled people begun some millennia BCE. Deforestation aligned with unadapted agriculture, and free ranging sheep and goats laid bare the soils over centuries resulting in massive soil erosion by wind and rain, driving soil in the Yellow river which in turn resulted in recurring catastrophic flooding down stream. Measures such as afforestation and terracing of hill and mountain slopes have resulted in flourishing landscapes in which a substantial diversity of annual and perennial plants and trees have rebuilt core ecosystem functions and thereby services for the local population (Liu 2011).

The *Sustainable Mekong Research Network* (SUMERNET) is a cooperation between some 60 institutions, a network made of scientists, decision makers and practitioners, supported by the Swedish government as a key player. The report *Stories of Change from the Mekong Region* (2016) summarizes experience from the last 10 years. A range of studies is accounted covering issues from reduction of flood risks for local communities along the Cambodian-Vietnamese border to green tourism in North Thailand, problems of directing benefits to the rural poor in contract farming, better forest conservation using REDD+ in Cambodia, Myanmar and Thailand, and building resilience and recovering regional wetlands in Northeast Thailand. "The farmlands of the four countries under investigation face similar problems and risks; climate uncertainty, shortage of labor, soil degradation, more agriculture inputs, and high cost of transportation of farm products." (p. 19)

SUMERNET has also documented evidence on the impact of urbanization on rural hinterlands such as e.g. "changes in ecological balance, loss of agricultural land, land speculation, changes in farming practices, livelihoods and life-styles, and pollution." (p. 10)

One of the studies looked at the implications and potential for application of Payment for ecosystem services (PFES) in Lao PDR and Cambodia. The study developed "model forest partnerships" by providing technical advice and guidance notes, and linkages to other forest management networks." (p. 15)

Another study dealt with co-producing knowledge to rebuild resilience and recover regional wetlands. "Across the Mekong Region, a great diversity of wetlands and the agro-ecological farming that they support are central to many rural communities' livelihoods and culture, and contribute to local and national economies. Unfortunately, many areas have been degraded or lost as a consequence of large-scale infrastructure development, including for irrigation and hydroelectricity." (p. 27) In order to gain mutual knowledge partnerships are forged between local communities, government

agencies, civil society groups, academics and others which through participatory action research contribute towards recovering wetland agro-ecological systems affected by past development projects.

One of the projects aims to *conserve the benefits of floating rice in Vietnam*. "Deepwater rice – also known as floating rice – is native to the Mekong River Delta, and in the past was grown widely across its floodplains in Vietnam, particularly in the Long Xuyen Quadrangle and the Plain of Reeds. Floating rice held significant cultural, ecological, environmental and historic value, yet since the mid-1970s the area of production has been greatly reduced due to the extensive building of dykes and the introduction of high yielding rice varieties. Despite increased food production, intensification of the agricultural system has increased water scarcity and agro-chemical pollution, and reduced soil fertility. In the Mekong Delta, Dr. Nguyen Van Kien and his team at the Research Centre for Rural Development (RCRD), An Giang University, Vietnam have been collaborating with farmers and local authorities in documenting the value of an agro-ecological system that consists of floating rice during the rainy season and upland vegetable production during the dry season. „Values identified have included: safe food production, maintaining biodiversity, recovering inland fisheries, improving the environment, and maintaining good soil quality and other necessary resources (straws) for upland crop production. Given the drought in the delta this year (2014), the research is now documenting its impacts on floating rice production and asking what strategies can be adopted to increase resilience." (p. 28)

Another project discusses the rediscovering of organic rice production in Savannakhet Province. “Dr Outhai Soukkhy and his team from the Northern Agriculture and Forestry College, Luang Prabang, Lao PDR has been working with farmers and local authorities in Xaybouri district of Savannakhet Province, downstream of the Nam Theun 2 hydropower dam.

Through a series of jointly held meetings involving farmers, the District Agriculture and Forestry Office (DAFO), and the Nam Theun 2 Resettlement Management Unit (RMU), the project introduced and supported the production of organic rice in Phonethan and Dong Yang villages, which farmers believed would offer higher market prices, safer production, and healthier final products that will support community resilience in the context of their changed socio-ecological situation.” 25 farmers “from Phonethan and Dong Yang villages grew organic rice with the support of the Xaybouri District DAFO. The organic rice production was designed to use local resources and utilized low quantities of input. Various trainings were also provided on making compost, bio extract (BE) and soil improvement techniques. The farmers have been producing organic rice and vegetables during the dry season. ...” (p.29)

In 1986, in South Korea the *Hansalim* organization was founded. Hansalim has been seeking an alternative way for humans and nature to coexist while recognizing the limitations of industrialism, which only focuses on resource and economical development. Hansalim started the direct transaction of healthy food between rural and urban communities as well as created a way for organic farmers to go beyond the market order. In 2016 more than 2,000 farmer families, cultivating ca. 4,200 ha, and more than 2,700 processing firms build a network of 22 cooperatives with more than 540,000 consumers, thus delivering healthy food to more than 2,55% of the Korean population (cf. http://eng.hansalim.or.kr).

Europe

In the European context especially measures such as diversification of crop rotation, intercropping, organic fertilizers and compost contribute to soil fertility and diminish erosion (Down to Earth 2015, p. 27-36).

The WEcoDyn system has been developed during some decades by farmer Friedrich Wenz and colleagues in Germany. It comprises two fundamental elements: Building up humus, and soil-protecting tillage by plow-less, really flat and precise soil preparation machinery. Any improvement of soils springs from the basics of chemistry, physics, and biology of soils and their synergies and connections. Additionally, living plant roots and plant communities are networks of nutrient exchange as well as parts of the humus building processes. Likewise, the vast diversity of microbial organisms in living soils plays a decisive role, which can be fostered by using different, mostly liquid, microbially active mixtures in order to accelerate the activity of soil biology and support soil-building processes. The nexus of humification and soil processing for sowing or post

harvest results i.a. in high yields, excellent water storage capacities in dry areas, and effective erosion control (cf. http://www.eco-dyn.de).

SlowGrow is a small-scale farm of some 5 hectares, located not far from Zurich in Switzerland. 3 ha of the farm are used as cropland for red wheat, wheat seed mixtures and black barley. 0.5 ha is used for field vegetables in mixed cropping, such as carrots, sugar maize, parsnips, bounce, beetroot, lettuce and radish. Another 0.5 ha is planted with mulching-destined vegetables, such as onions, garlic, potatoes, cabbage, celery, cucumbers and other special cultures. 1 ha is used as pasture.

In collaboration with Hotel Jakob in Rapperswil by the Lake Zurich and the direct marketing service BachserMärt also in the Zurich region, the SlowGrow farm implements the concept of community-supported agriculture in a commercial context. The commercial partners pay an annual fee and obtain on a weekly basis the products of the SlowGrow farm seasonally available. The customers and guests, both of the hotel restaurant and the outlets of BachserMärt, are free to provide assistance on the farm and the farmer, in turn, is regularly present in the hotel restaurant and the BachserMärt shops.

The production patterns match the annual demand of the hotel and the BachserMärt shops in terms of vegetables, herbs and grains. A common support fund created by the commercial partners facilitates further research on and development of regenerative agriculture, including through direct marketing channels, such as the Regular Table of Slow Food Youth, diverse popup food projects and the reaching out to further restaurants.

The theoretical knowledge on regenerative agriculture is largely available. Its practical implementation, however, is complex and there is an apparent lack of well-informed practitioners and start-off opportunities for career changers. In fact, practices for preserving and enhancing soil fertility are far from new. Many have been used for hundreds of years. The contemporary methods, the further development of which our farm is also contributing to, enables farmers to produce on large areas according to regenerative criteria with little additional or appropriate effort. Agriculture machinery is all too often inappropriately used without due care for soil structure. In the past, many agricultural pioneers emphasized time and again the essential elements of sustainable soil management. Agricultural practice from conventional to organic production methods however demonstrates that basic knowledge on sustainable soil management is neglected, sidelined or improperly used (recalling inter alia the recommendations of soil scientists and practitioners such as Franz Sekera: “The nature of bare soil and its porosity”; Rudolf Steiner: “Fertilizing means revitalizing the soil”, Müller/Rusch/Dähler: “Green fertilization is of central importance in organic agriculture”).

It is important that plants have sufficient space for root development in the soil during the complete growing period. There should be no hoeing or tilling in between the rows,

because this destroys the stable crumb structure of the soil, reduces the humus content, inhibits the development of the sensible roots and jeopardizes the symbiotic relationship between the plants and fungi. The natural structure of the soil needs to be build up and preserved, which we term appropriate plant management. This includes the maintenance of the nutritional soil web, healthy mycorrhiza, worm channels and a soil food web. The farm also practices field in addition to heap composting.

Soil life needs to be regularly supported by fresh or slightly rotted, purely organic material. Ripe compost alone does not sufficiently nourish soil life and cannot entirely replace field composting.

Machinery should only be used on the field for deep tillage, seeding, harvesting or the application of fresh organic material as fertilizer. This excludes the use of machinery for hoeing, tillage, harrowing, rolling or spraying. Machinery should in no case be used under humid soil conditions.

New or taken-over fields will often require a onetime deep tillage and then need to be green-fertilized by diverse, root-intensive plants, such as sunflowers, phacelia, radish, peas, maize, crimson clover or berseem.

For launching crop rotation on taken-over fields, one kicks off with a deep tillage with a heavy cultivator, followed by seeding green fertilizers, seeding the main crop, including cover crop underneath.

The mulching system enables a new form of vegetable production, combining perennial vegetables with fruit and berries. The advantages are high resilience of the plants and of the entire system. There is no or little soil erosion, silting and thus related loss of nutrients. The mulching system also requires little hoeing and weed removal.

From an economic and planning point of view there is hardly any rigid crop rotation. One saws or plants wherever there are open patches, reflecting specific demand and preferences of the restaurant cooks and shops. This also allows year-round harvesting, including for seeds and herbs. The permanent cultures yield several harvests from a single input (fennel, for instance, can be regularly harvested). The flowering of such crops at the end attracts beneficial insects and thus contributes to regenerate the entire eco-system.

The key challenge of such approach is that side-specific knowledge and skills need to be developed. Vegetable production is very labour and time-intensive and, for some 200 varieties, a broad stock of knowledge is imperative. The most suitable plants for mixt cultures have to be well-selected, their best-harvesting methods to be developed, and the most suitable green fertilizers determined. These are really new and unexplored tracks for permanent cultures. It requires experience, sensibility and creativity of the farmer.

Undoubtedly, the approach of the SlowGrow farm needs to be underpinned by a suitable commercial network from farm to hotel kitchen and greengrocery shelf. The

wide range of products provided by the farm is seen as a key advantage by the marketing partners and consumers. The latter learn a completely new form of shopping that needs to be properly communicated. Kitchen hints and cooking recipes are provided by Hotel Jakob and by a foundation named Leaf to Root. The contours of a new movement around regenerative agriculture are emerging – Slow Food Youth.

One of the key lessons of the approach taken by the SlowGrow farm is that soil building and soil improvement can be achieved within a few months. What is lacking is appropriate machinery and equipment, as well as suitable seed mixtures, developed by regional seed providers.

For emulating the SlowGrow approach it would be necessary to have a hub for young farmers that are interested in implementing regenerative agriculture. Such hub would have to include assistance for acquiring suitable land or farms and support and flanking packages so that regenerative agriculture can be commercially successful for young farmers. In this way, a conducive social web could be created that would give a chance to small-scale farms to survive. Regional agricultural support programs should place much more emphasis on the promotion of young innovative farm entrepreneurs.

Federal or regional governments may also wish to create research funds for regenerative agriculture. In this regard, in addition to the focus on promoting classical sustainable farming methods, such as bio-organic or bio-dynamic agriculture, comprehensive regenerative agriculture should also get due attention. Regenerative agriculture can unite farmers globally and help bridge gaps between production methods and labels. The majority of farmers consider the soil as most valuable basis for production and are therefore open to methods for soil building and soil improvement (www.slowgrow.ch, many thanks to Matthias Hollenstein).

Are there any reliable methods to regenerate and improve soils swiftly and reliably? How can soil generation and regeneration really be successful? These were core issues during interviews with four European experts and practitioners which Hellmut von Koerber exclusively conducted for this volume. It is fascinating how different the experts view the process of soil generation and regeneration.

Gerhard Dumbeck is soil scientist. He monitored the recultivation of 12,000 ha lignite mines for the Rhein-Braun Corporation (formerly RWE) in western and eastern Germany. He underlines the importance of subsoil. Distributing freshly deposited, overly loosened loess with standard machinery, they obtained fatal compaction problems: Due to massive barrier layers, no cultivation was possible. With extensive repairs and specialized machinery, eventually a reliable practice could be found. Many tests and measurements were performed which found an annual increment of 0.02-0.03 C_{org} and a saturation in the humus content of 1.5% C_{org} applying conventional farming methods.

Sepp Braun optimizes a 7-year wide crop rotation on a classic organic diary family farm with high diversity near Freising northwardly of Munich in Bavaria in Germany. He

maximizes vegetation, thus capturing solar energy and promoting root penetration; he improves feedstuff and animal health by drying hay, and bedded pack manure by composting it with biochar. He has nearly reached 5% humus content. He intends to improve it with perennial crops and a continuing vitalization of subsoil.

Sepp Braun is a board member of the *Bioland* association of organic farms in Bavaria and was the ambassador for the topic of soil in the German pavilion at the Expo 2015 in Milano. He is tightly linked to agricultural research and passes on his knowledge in lectures and courses for practitioners.

Friedrich Wenz runs his stockless farm with undersown crops and diverse, partly even multiple catch cropping within the course of a year (see above the principles of the WEcoDyn system). More than 60 years ago, his father started with intensive maize monocultures. After 15 years, the humus was completely degraded. Due to resistances, more and stronger pesticides became necessary. That is why Manfred Wenz co-founded the *Bioland* association and converted his farm to no-till cultivation. Since the mid-90s, Friedrich Wenz has run the farm according to biodynamic principles. Lost humus and more could be regenerated.

While Sepp Braun relies on perennial crops (deep root penetration, agroforestry, permaculture), Friedrich Wenz counts on the vegetative phase (before florescence), when plants are growing particularly quickly, on the acceleration of field composting and the specific vitalization of plants in phases of weakness with preparations from minerals, plants and microorganisms. One could say he engages the turbo stage in catch crops and field composting and avoids damages before they occur by specific observation, measurement and vitalization of soil, plants and microorganisms.

Where Sepp Braun expects lower yields in the main crop and slow increase of the humus content, Friedrich Wenz reports above-average yields and a humus increase of 1.6 % C_{org} in four years. A participant of his annual soil field school (Bodenkurs) was able to obtain this without applying any fertilizer or pesticides on his conventional farm.

Both farmers do not see any limit on humus generation. The more vitality of soil and vegetation increases, the less losses occur and the more solar energy may be captured and bound to the soil in living or stable form.

Paul Mäder, an agricultural researcher and head of the Department of Soil Sciences at the Research Institute of Organic Agriculture (FiBL) in Frick in northern Switzerland, is rather careful. In recent studies, the advantages of reduced tillage turned out to be a shift of humus content from the bottom upwards. Until now, in subsoil and overall, research could not prove any substantial increase of humus and thus no substantial carbon sequestration. Organic farming is successful in conserving soil fertility and protecting water and biodiversity, but until now, it may not contribute substantially to humus generation and the reduction of greenhouse gases. Paul Mäder assesses an annual maximum of 0.1 - 0.2% C in humus generation. Therefore, measuring is usefully

every 3 years. Otherwise, measuring errors and natural variations may distort the results.

All experts underline the necessity of year-round soil cover, light machinery and equipment, and the avoidance of losses, flaming, compactions, deep soil turning and tilling in wet conditions. Soil generation originates from the biological activity of the area and not from external organic matter. The consequent, systemic perception and recent practices of the two farmers make the difference: the year-round dense vegetation, field composting, deeper root penetration, analyses of soil and leaf sap to balance elements and the specific vitalization of soil and plants.

Year-round dense vegetation

In monocultures, only a fraction of the available solar energy is transformed into sugar and biomass. Undersown crops, catch crops, mixed cropping as well as perennial plants increase the total leaf area and maximize the bound solar energy. A large part of soil organisms depends on the direct supply through living roots.

Liquid carbon pathway Plants release up to 70% of photosynthesis products in fluid form into the soil (exsudates). They feed the soil organisms and serve the generation of stable humus compounds via bacteria inside the root fungi *(Mycorrhiza)*. Glomalin e.g. surrounds the fine roots of plants and serves as a glue for stable soil aggregates. The key to humus generation lays in this vast, invisible potential of additional energy, sugar, carbon and biomass, that living plants release in fluid form into the soil (cf. Christine Jones 2008, http://www.amazingcarbon.com/PDF/JONES-OurSoilsOurFuture(8July08).pdf).

Avoid losses

The usual high application rates of fertilizer, compactions, monocultures, long fallows and wrong tillage pose big risks, that humus being in the soil will mineralized and washed out and thus degraded instead of built up. When the wrong degrading microorganisms become prevalent, degradation may occur very quickly and nullify a yearlong build-up. Lack of humus and a disrupted soil structure decrease the binding capacity of the soil for water and nutrients and cause leaching during the next moderate rainfall – on average, 1.2t/ha of dissolved salts per year in Germany. Apparently, the losses are much bigger than commonly supposed and a multiple amount of the minerals in fertilizer and yield.

Balance of elements

Comprehensive literature and practical experience show a connection between lack of certain chemical elements and specific damage in plants, animals and humans.

Soil analyses on the principle of base saturation (e.g. according to Neal Kinsey, http://www.kinseyag.com) determine every important element and give recommendations for specific adjustment. These additions of minerals are temporary practices. Soil life releases minerals from the soil – *active mobilization*, - and rebinds them. Soil generation gradually adjusts the composition of elements.

Balance of microorganisms

Preparations like horn manure have a long tradition in biodynamic agriculture. Nowadays, compost tea and other preparations from minerals, plants and diverse microorganisms are applied for controlling the decomposition process when incorporating large amounts of catch crops. This stimulates a quick rotting and rebinding through biological activity instead of anaerobic decay and complete mineralization. This field composting takes 2-3 weeks. Afterwards, standard sowing may be performed without any special direct-seed technology.

Vitalization of plants

In times of stress (e.g. drought, lack of nutrients), photosynthesis in plants decreases. Plants no longer supply soil life sufficiently with sugar, and soil life no longer supplies plants sufficiently with water and nutrients. The activity of the whole system decreases substantially. Later, this may cause an infestation with diseases or pests.

Using leaf sap analyses, stress of plants may be recognized early and be treated using leaf spraying with compost tea or other preparations in good time before infestation. Plants respond with a *measurable* resumption of photosynthesis.

This plant protection recognizes and resolves the causes for substantially decreases in the activity of plants and soil. With increasing build-up of soil, these practices become less and less necessary. There is no symptom treatment. Pathogens, weeds and pests are indicators of a disrupted ecosystem and infest only weakened organisms.

Holistic approach

A new understanding is essential, we need to move away from combat to cooperation, symbioses and partnership. We have to do everything what we can for the well-being of plants and animals. Health, activity and yield will follow. *What needs does wheat have? How does it want to grow, as a chief of a community with many other plants, animals and microorganisms?* In agricultural policy and research, a complete rethinking is necessary. In living systems, cooperation – as opposed to competition – is essential. The same needs

are to be applied to agricultural practice and research: Holistic thinking, overcoming compartmentalization and exchange with practitioners at eye level.

Knowledge about how soil regeneration can be successful is available. It is incorporated in a growing corpus of literature and in the knowledge and experience of innovative farmers – female and male – , pioneers and initiatives around globe. Awareness, action and policies are necessary along the following lines:

- Simultaneously and continuously, improve soil, vegetation, water cycles, biodiversity, productivity by increasing the vitality of soil, plants, animals and humans.
- Incorporate a lot of solar energy into the system by year-around dense vegetation and use it for yield, soil generation and biodiversity.
- Escape the economic and technological treadmill: Replace expensive external inputs with intensified life processes.
- Emphasis should be placed on perennial plants, and on avoidable losses, subsoil, dynamics of humus, nutrients and root penetration, new measuring methods and overall vitalization and regeneration.
- Regardless of the problem in the foreground - soil protection, biodiversity, productivity, food security or climate change - at the heart of the solution are always diverse, highly productive agro-ecosystems. They always incorporate more energy, air, water and minerals in their living processes, provide nutrition and living space for soil life, plants and animals, deliver long-term yields and directly contribute to the regeneration of local water cycles and the climate by water retention, evaporation, balance of temperature and avoidance of emissions.
- Adequate economic and policy frameworks for these solutions, fair access to land, knowledge and other natural resources are needed (many thanks to Hellmut von Koerber, hellmut.koerber@fleXinfo.ch, www.flexinfo.ch).

The Americas

Grasslands span roughly 1/3 of the earth's land surface. *Holistic Planned Grazing* is a planning method for livestock farmers on grasslands with different climatic conditions, which integrates the diverse and sometimes conflicting aspects of livestock rearing such as wildlife, forests, land regeneration, animal health and welfare, and livelihood. Originated by Allan Savory in the 1960s, Holistic Planned Grazing meanwhile has built a global network with farms in Africa – Namibia, Zimbabwe, Botswana, Malawi –

Cattle in Namibia

Australia, New Zealand, South America – Chile – North America – Canada, North Dakota, South Dakota, Colorado, New Mexico, Wyoming, Montana, Texas, California – Europe – Spain – and Asia – Pakistan, PR China –, spanning ca. 15 – 20 million ha. 30 hubs for training and teaching facilitate on all continents theconsolidation and expansion of the network. Eminently remarkable outcomes of the Holistic Planned Grazing scheme are i.a. protection against erosion, much more dense and diverse plant cover, more diverse soil biodiversity, increased methane uptake, and better provision against drought.

Located in Virginia's Shenandoah Valley (US), Polyface Farm produces salad bar beef, pig aerator pork, pastured chickens (eggs and meat), pastured turkeys, forage-based rabbits, hair sheep, pastured ducks, honey, maple syrup and occasional vegetables.

Purchased by Bill and Lucille Salatin in 1961, the farm was arguably the most eroded, gullied rock pile in the region, having been absentee-owned for half a century from about 1900-1950. Today, the second and third generation of Salatins operate the farm with the fourth generation already developing their own enterprises and a cadre of staff, subcontractors, and interns rounding out the 20-person team.

The farm's principles are both simple and profound:

- All healthy ecosystems have animals.
- Animals move.
- Perennials build soil; annuals deplete soil.
- Nature doesn't move carbon very far; it's grown and digested *in situ*.
- Local food systems offer both abundance and security.
- Multi-speciation is safer and more productive than mono-speciation.
- Equity should be in management, information, and customers.
- Infrastructure should be mobile, modular, and management-intensive.
- Sustainable farms must employ at least two people from two different generations.
- Every bite we take creates the landscape our children will inherit.

The Polyface farming system is carbon-centric and its prime “technology” is the synergistic use of plant-animal relationships, such as:

- Carbonaceous diapers: wood chips from sawmilling is used to line animal houses in winter for cow feeding on hay. Corn is placed in the bedding, for the animals to trump-out the oxygen and stimulate the fermentation process.
- Pig aerators: when the cows come-out to graze in the spring, pigs are introduced to seek the corn in the cow bedding and hence, turn the bedding from anaerobic to aerobic compost.
- Landscape massage: as 5.000 years ago when the Planet’s carrying capacity of mega-fauna was much superior to today, the historic disturbance role of pigs is used to bring back magnificent silver pastures. Seeds latent in the soils germinate again with short-term pig grazing, creating a whole tiers of production, or prairie under the trees, that doubles the biomass.

- Biomass accumulation re-start buns: cows, the herbivore pruners that replaced buffalos, take the pasture senescent forage and prune it back to very rapid juvenile growth.
- Mob stocking herbivorous solar conversion lignified carbon sequestration fertilization: cows are moved every day on pastures, with 80 heads on 0.2 ha in winter and 300 heads on 0.8 ha in summer. If every farm in North America were to implement this system, agriculture would sequester within 10 years all the carbon that has been emitted since the beginning of the industrial age.
- Portable control mechanisms for migratory choreography of animals: portable shade mobiles hooked together can shelter up to 240 heads.
- Gravity-powered irrigation: in a permaculture fashion, ponds are constructed on highlands in order to obtain 6 miles of water lines holding 80 pounds pressure irrigation water flowing by gravity - no electricity to pump water, no relays, just gravity.
- Holistic management combined with no-till planting technology: use of animals as preparation tool to beat down the perennials and create a window of opportunity for planting an annual crops. While this technique is used in Australia to grow cereals, Polyface plants cow peas, sudex and other forage crops.
- Pasture sanitation: just as birds follow rhinos in wild areas, cows are followed by egg mobiles (with 800 layers), for free range chicken to scratch the cow paddies, eat the fly larvae and turn the grasshoppers and crickets into eggs. More protein per ha in insects can be produced than with meat or milk. So what would be a parasite or worm liability is turned into an asset and what is worth USD 300.000 of eggs are produced as a by-product of pasture sanitation program.
- Functional genetics: eggs incubate in stackable houses with pigs underneath and chicken above, and as animals come out in spring, vegetables are grown in loophouses that have been debugged and fertilized by animals. Rabbits on 0.4 ha of pastures generate USD 50.000, and with portable floorless shelters for broilers, turkeys in the field and cows in the background create a functional stacking enterprise. (Cf. https://www.savory.global)

Agroforestry has many benefits i.a. for the communities in the Carribean. “Agroforestry is differentiated from other land-use systems since it must have a tree component deliberately planted or retained; and there must be significant interaction between the woody and non-woody components of the system. Agroforestry therefore involves two or more plant species (at least one must be a woody perennial) and/or animals, with

two or more outputs. Due to the variety of possible combinations, even the simplest agroforestry system is more ecologically and economically complex than a mono-cropping system. Agroforestry is described as a sustainable, adaptable, multipurpose land-use system which allows for:

- Production of multiple products while protecting natural resources
- Emphasis on the use of indigenous trees/shrubs, crops and livestock
- Suitability for low-input farms and fragile ecosystems
- Provision of social, economic and environmental benefits to land users." (Agroforestry Systems and Practices in the Caribbean, Ravindra Ramnarine and Denny Dipchan-singh, in, Sustainable Food Production in the Carribean, 353 ff.).

A couple of overarching concepts & initiatives

Rodale Institute: Organic agriculture was the standard of global agriculture for millennia. Since the industrial revolution roughly 200 years ago mechanization and later chemical inputs have changed agriculture in some parts of the world radically. Tillage technologies as well as synthetic inputs (fertilizers, pesticides) modified the living webs above ground as well as below. Therewith the fundamental role of soils as metabolic systems *inter alia* for gases such as CO_2 or CH_4 got in decline and jeopardy. The modern organic agriculture movement strives to regain the fundamental role of healthy soils for stable yields as well as for carbon sequestration. Crucial elements are *inter alia*: No bare soils, conservation tillage, cover crops, enhanced crop rotation, retention of plant residues, and composting (Rodale Institute 2014, https://rodaleinstitute.org/regenerative-organic-agriculture-and-climate-change/).

Twelve principles for better food and more food from mature perennial ecosystems in tropical and sub-tropical agriculture (Roger RB Leakey, in Perennial Crops for Food Security. Proceedings of the FAO Expert Workshop, Rome 2014, cf. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/fao-expert-workshop-on-perennial-crops-for-food-security/en/

The Carbon Farming Solution. A Global Toolkit of Perennial Crops and Regenerative Practices for Climate Change Mitigation and Food Security, Eric Toensmeier, Chelsea Green Publ., Vermont (USA) 2016, cf. https://www.chelseagreen.com/product/the-carbon-farming-solution/

The Drylands Advantage. Observations and examples from PR China, Jordan, Nicaragua, Senegal, and Swaziland. (IFAD 2016, cf. https://www.ifad.org/newsroom/press_release/tags/p69/y2016/35037921).

Fertile Ground. Scaling Agroecology from the Ground up, Steve Brescia (Ed.), 2017. Instructive compilation of case studies from Africa, Caribbean, the Americas, and Europe. (Food First Books, Oakland, Ca. (USA), cf. https://foodfirst.org/publication/fertile-ground-scaling-agroecology-from-the-ground-up/).

Archangel Ancient Tree Archive, David Milarch, documented in Jim Robbins: The Man who planted trees. A story of lost groves, the science of trees, and a plan to save the planet. (Spiegel & Grau, New York 2015, cf. http://www.penguinrandomhouse.com/books/200375/the-man-who-planted-trees-by-jim-robbins/).

Synopsis of politico-scientific networks & information tools on soil issues

The multitude of studies and assessments on soil fertility issues remind rather to a many-voiced, not exactly harmonious choir. Similarly soil-related networks and information tools represent a juxtaposition of different and sometimes diverging approaches, strategies, interests, and goals. Altogether, availability and volume of knowledge and data during the last two decades has grown significantly. For many problems and issues feasible and substantiated answers and devices are at hand. As part of the digitization of knowledge some technological and/or social-economic hurdles of access remain, especially in countries with poor infrastructure and many poor people. Likewise the trouble of selection and appraisal of information must be managed.

Networks on soils - Peasants, science, corporations & politics

Name	Type	Scope	Members	Partners	Active since
Global Soil Map http://www.globalsoilmap.net	Industry-policy-science network	Setting up digital soil maps including prediction of soil properties in fine resolution as basis of global spatial information system. Soil groups, characteristics & distribution (e.g. SWSR 2015, 527-595)	Founding members AGRA, Gates Foundation, Australian Government	INRA, ISRIC, Columbia University New York, European CommissionC SIRO, USDA/ NRCS	2009
International Soil Conservation Organisation http://www.tucson.ars.ag.gov/isco/	Scientific network	Promoting conservation and sustainable use of soils, biennial conferences	Scientists, backed by affiliated institutions		1978
International Union of Soil Sciences (IUSS) http://www.iuss.org/index.php?article_id=1	Scientific network	Promotion of all branches of soil science, support for soil scientists	Individual membership	More than 10 scientific journals	1924; since 1993 member of ICSU

Global Soil Partnership http://www.fao.org/global-soil-partnership/en/	Comprehensive CSO-policy-science network hosted by FAO; regional partnerships, national focal points	Improve governance, promote sustainable use of soils. Five pillars of action: Raising awareness, research, soil management, information & data, harmonization	FAO member states	Scientific institutions, soil organisations, CSOs, extension services; http://www.fao.org/global-soil-partnership/overview/partners/en/	2012
The 4‰ Initiative http://4p1000.org/understand	Industry-policy-science-CSOs network, launched by France	Promoting sustainable use of soils, i.a. by increasing carbon storage	33 countries, and research institutions, CSOs, private sector		2015
International Soil Reference & Information Centre http://www.isric.org	Scientific institution hosted by Wageningen University	Soil data and mapping, application of soil data in development issues, education & training	Founded by International Soil Science Society and UNICEF, since 1989 World Data Centre for Soils with ICSU	Cooperation i.a. with UN institutions, conventions such as UNCCD, GSP, WOCAT	World Soil Information 1966, World Data Centre for Soils 1989

Economics of Land Degradation Initiative (ELD) http://www.eld-initiative.org	Policy-science network	Costs and benefits from prevention of land degradation	German government, European Commission	UN agencies, environmental institutes, CGIAR, IUCN, universities	2012
European Soil Data Centre (ESDAC) http://eusoils.jrc.ec.europa.eu	EU scientific institution	Provision of soil data for Europe and global, International cooperation	Joint Research Centre of the EU (JRC)	Sino-EU Panel on Land and Soils, International Union of Soil Societies, European Soil Bureau Network	2006
Agricultural & Rural Convention (ARC 2020) http://www.arc2020.eu	Alliance of NGOs	Greening the Common Agricultural Policy (CAP) of the EU, promoting sustainable agriculture	Agriculture and environment NGOs, umbrella organizations		2010
Farmer-Scientist-Partnership for Development (MASIPAG) http://masipag.org	Cooperative network of farmers, scientists, local communities, scientists	Sustainable food production, improve the livelihoods of resource poor family farms, preserve rice land races, develop improved varieties	563 peoples's organizations	38 NGO partners, 20 church-based development organizations, 15 scientist-partners	1985

World Initiative for Sustainable Pastoralism (WISP) http://www.iucn.org/theme/ecosystem-management/our-work/global-drylands-initiative/iucns-work-drylands/world-initiative	Network of more than 1200 pastoralists, UN agencies, CSOs, hosted by IUCN	Share and communicate knowledge, foster research, promote global advocacy	Pastoralist's organizations, NGOs, IUCN, scientific institutions, international organisations, businesses		2013
Family Farming Knowledge Platform http://www.fao.org/family-farming/en/	CSO-farmers organizations-policy-science network	Support for family farms, knowledge & exchange of experience, best practices; five main thematic focusses: agroecology, forest farming, indigenous peoples, mountain farming, pastoralism, small family farming, small-scale fisheries and aquaculture	Hosted by FAO	Universities, research organizations, regional farmers organizations, UN agencies, WB et al.	2015

La Via Campesina https://viacampesina.org/en	International umbrella organization of peasant movements	Platform for exchange between peasants organizations, political advocacy for peasant & family farming	164 local and national organisations in 73 countries from Africa, Asia, Europe, the Americas; represents about 200 million farmers		1993
Global Soil Week, Global Soil Forum, Soil & Land Network for Change http://globalsoilweek.org/	CSO-policy-science network	Promote sustainable use of soils and land, trans-disciplinary research	hosted by IASS, Germany	European Commission, German Government, FAO, giz, German Environment Agency, International Union of Soil Science, UNCCD, UNEP	2015
World Overview of Conservation Approaches and Technologies (WOCAT) https://www.wocat.net	CSO-policy-science network	Promotion of innovations and decision-making processes in sustainable land management including soil, water, vegetation, and animals; global online database on technologies, approaches & mapping	More than 60 participating institutions	Swiss Agency for Development & Cooperation, University of Bern, FAO, ISRIC, giz, CIAT, ICARDA, ICIMOD, University of Kwazulu-Natal; many national and regional initiatives in Africa, Asia, and Europe; tight cooperation with UNCCD	1992

World Association of Soil and Water Conservation (WASWAC) http://www.waswac.org/index.asp	Scientific network	Promotion of research and cooperation on soil and water conservation	1125 individual members from 82 countries	Governmental & scientific institutions, i.a. WASER, IRTCES, Chinese Society of Soil & Water Conservation, IECA	
Global Soil Organic Carbon Map http://www.fao.org/world-soil-day/global-soil-organic-carbon-map/en/	Science-policy cooperation	Improve the empirical data base for political decision-making		Hosted by FAO, in cooperation with GSP & IPTS, supported by EC, governments of The Netherlands, Switzerland, Russian Federation, International Fertilizer Association	Version 1 launched on World Soil Day 2017

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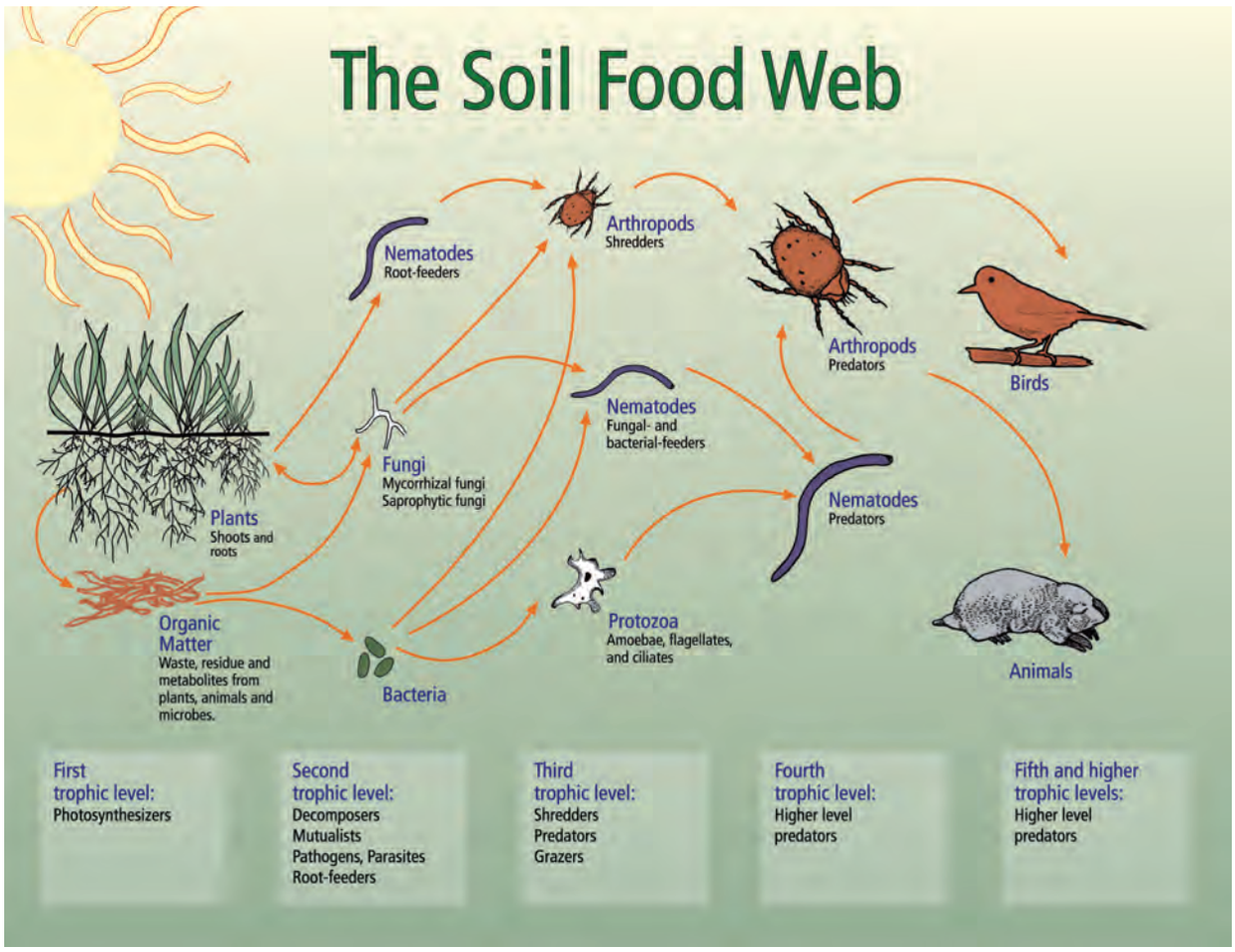

There is no biodiversity above ground without corresponding diversity below ground

Key messages

- Make rehabilitation, improvement, and conservation of living soils a cross-cutting top priority for policy at national and international level.
- Soils are technically and biologically a de facto a non renewable resource which can't be manufactured technically. Human utilization of soils thus must be aligned with the responsibilities of stewardship instead of consumerism.
- Agricultural practice and policies must follow the guiding principle: Feed soils, not crops. Healthy soils need a balance between cultivation (withdrawal) and regeneration (restitution) of i.a. nutrients, trace minerals, and organic matter, and moisture. All-season cultivation of diverse plants including trees is by evidence an appropriate practice.
- The institutional fabric as to fertile soils is fragmented and rather weak. The Intergovernmental Technical Panel on Soils (ITPS) should be transformed into an Intergovernmental Panel on Living Soils (IPLS) with a mandate to report and assess regularly status and changes, to facilitate international and regional cooperation and especially impart successful practices to enhance fertile soils.
- As degradation and destruction of fertile soils increasingly become obvious as relevant driving elements of violent conflicts in many continents, cooperation and coordination between all parts of the UN system as well as between national governments is imperative.
- Ramp up cooperation and coordination between existing institutions. Build effective national frameworks and implementation. As long as no comprehensive UN Framework Convention on Living Soils (UNFCLS) is emerging, cooperation and division of work between UNFCC, CBD and UNCCD should be expanded. National Soil Policy Frameworks (NSPs) should be designed.
- End agricultural subsidies worldwide that are harmful for soils and the environment in general. Soils in most countries are damaged by excessive use of mineral fertilizers and pesticides.
- Science eventually must tackle the challenge of understanding the systemic complexities of living soils and soil improvement. Soil science is a truly trans-disciplinary field which until today is neither institutionally nor financially appropriately endowed. International research networks with coordinated agendas should be promoted, based on accordingly funded and maintained national capacities. A crucial element of agenda setting and research design is the practice of participatory research.