Chapter

Reducing the Effects of Drought and Degradation of Agricultural Soils, in the Context of Climate Change, through the Application of Regenerative Ecological Technologies

Eugen Popescu, Florin Nenciu and Valentin Nicolae Vladut

Abstract

The agricultural sector has a limited capacity for expansion, consequently, deficient technologies based on the widespread use of synthetic chemicals have been implemented in the last decades, having a major negative impact on natural ecosystems, biodiversity, and environmental services. Desertification, land degradation, and drought, combined with human activity and environmental changes, cause important soil losses and a reduction in natural defenses against droughts and floods. The combined impact of climate change, land mismanagement and unsustainable freshwater use has long been affecting agricultural productivity, the most common cause being unsustainable land management practices. This chapter aims to briefly assess the most effective strategies for reducing the impact of climate change on agricultural crops, as well as to prevent or reverse the process of desertification and systematic loss in food quality and quantity. Regenerative management practices such as minimum tillage technologies, cover crops and mulching, inoculation with microorganisms, nutrients cycling, the balance of the organic fertilizers or foliar application help farmers in managing healthy soils, capable of growing rich and ecological crops without the use of chemical hazardous substances.

Keywords: climate change, regenerative ecological technologies, desertification, land degradation and drought

1. Introduction

Regenerative agriculture is a farming and land management concept based on several principles and techniques that strengthen and restore ecosystem functions and health. Long-term usage of regenerative agriculture has shown many benefits in terms of quality and profitability for farmers, as well as improving the environment and contributing to the maintenance of a healthy agricultural landscape. Given that it is not always very clear how each action contributes to better agricultural management and drought mitigation, this chapter aims to recall the key elements that farmers must consider in regenerative agriculture in order to have the best results. It should be noted that there is more than one approach that may differ depending on local circumstances, however, the elements described in this chapter serve as a starting point for practitioners and academics who wish to learn more or deepen one of the related domains.

The existence of life is largely dependent on the richness and health of soils, which is why soil structure, together with water availability are the most valuable resources for humanity. The annual degradation of the agricultural lands puts even more pressure on farmers, forcing them to use more chemical inputs and these practices may eventually lead to extreme phenomena such as drought, floods, and eventually soil abandonment [1]. However, both farmers and policymakers continue to be neglecting the need for soil health preservation and they do not take firm restoration measures even when the situation becomes concerning.

Water, minerals, and organic matter combine to make the soil in a natural process. Soil minerals are produced in the process of natural erosion, while the organic matter is formed by the decomposition of plants and other organisms that have died. Many scientists consider soiling a finite resource that cannot be renewed during a human lifespan. We propose, in the present chapter, several techniques used and validated for faster restoration of soil properties, which may help recovery in very shorter time periods, depending on the degree of soil impairment.

Degraded soil is described as a change in the physical, chemical, and biological characteristics that results in a reduced capacity to support plant growth. The most common phenomena that usually occur are related to the fact that soil loses the capacity to deliver nutrients and water, while toxic compounds restrict plant growth, topsoil lacks of organic matter content, subsoil resources are insufficient to support plant roots, the compaction rate is substantially increased, drainage occurs with difficulty, and many of the needed microorganisms are absent.

In most common cases, the quality of the soil decreases as a result of the anthropogenic intervention, while some natural causes are aggravating the circumstances, often leading to erosion. Human activity is the most frequent cause of agricultural soil degradation and for accelerating natural soil erosion. Agriculture has deteriorated the Earth's soils during the last 100 years, with disastrous consequences, David R. Montgomery [2] estimates that humanity is losing 0.3% of our global food production each year due to soil erosion and degradation. Soil degradation and loss has been a problem since the beginning of agriculture and played a major role in the demise of past civilization including Mesopotamia, Antic Greece, and the Rome Empire. The element that contributes probably the most to the negative damage to the soil, more important even than deforestation is the plowing activity. Stanford University in a study from 2015 estimated the degradation rate of topsoil worldwide at a rate of 70%, with margins between 54% in Africa and 74% in North America [3]. At this time, there is no allotted restoration period, since we are eroding soil 20 times faster than we are regenerating it.

Degraded soils have a poor health state, reducing the ecosystem's ability to provide water and nutrients to plants, and affecting the soil nutrient web. Degraded soils have a weak structure attributable to a lack of soil biodiversity, which causes flooding, erosion, and low production. Water cannot penetrate inferior soil structures, so the rains follow the flow of gravity, transporting major amounts of minerals and salts to the groundwater, rivers, or lakes. During a drought period, there will be no moisture, and groundwater will not be replenished easily. Plants will be stressed, and yields will decrease very fast. In the tropics especially on fertile land, soil deterioration is prevalent. Natural erosion caused by wind, sun, severe rainfall, and poor human management are the most common causes.

It is critical to understand that poor agricultural management before and during a drought has a synergetic effect on soil properties. Land degradation in arid, semiarid, and sub-humid areas may be generated by various external factors including climate change, and draught may lead to desertification. Desertification may be irreversible if not intervened in time, especially when the environment becomes too dry and the soil becomes further degraded through erosion and compaction.

One of the most important hazardous environmental events in recent history was the American Dust Bowl during the years 1930–1936, when large dust storms swept topsoil from significant land areas, making 75% of the original topsoil quality to be lost [4]. Commenting on the American Dust Bowl, US President Franklin D. Roosevelt said "The nation that destroys its soil, destroys itself", a remark that is still relevant to modern crop management practices.

Storms, torrential rains, floods, and droughts are becoming more frequent and intense as a result of climate change. Every year, soil deterioration worsens, plants get stressed, and yields decrease. Soil management is, therefore, an essential element of sustainable agriculture.

Proper regenerative soil management will slow down or stop soil degradation and start to rebuild soil fertility. Management should be focused on obtaining healthy and superior plants that do not need intense chemical treatments since it is proven that a high immunity system protects crops from diseases and insect attacks. Increasing plant immunity will be pointed out in high yields, quality products, plants will get increased resistance to diseases and pest attacks. At the same time soil will become healthier, full of nutrients with an active and rich soil food web. Healthy soils with a balanced nutrients ratio, promote biological high activity and replenish groundwater, and will help the plants to withstand better the drought. To stop soil degradation, special attention must be paid to the phenomena that produce natural erosion, and rejuvenate the soil, while human activities have to change rapidly. Soil regeneration practices sequester an important part of the required amount of carbon in the soil, allowing mankind to maintain control over climate change. Soil carbon allows the land structure to function as a sponge, each gram of carbon-absorbing 8 grams of water. In addition to the positive effect on the mineralization process, carbon helps to build the soil structure, which aids in the supply of air, water, and nutrients to plants. Plants, in response, emit liquid carbon from their roots, increasing, even more, the synergies and water absorption. This phenomenon occurs more frequently when aggressive tilling works are avoided, and the synthetic fertilizer and synthetic biocides application are not used. The techniques, if they are applied indiscriminately have the opposite result, eliminating the carbon. **Figure 1** depicts the most common approach to regenerative agriculture at three levels of management: acknowledge the objectives and benefits, comprehend the fundamental concepts, and put the best practices into action.

Regenerative agriculture requires a complete redesign of the farming system, as well as a shift in the procedures and metrics used in traditional agriculture, and a longer-term commitment of farmers.

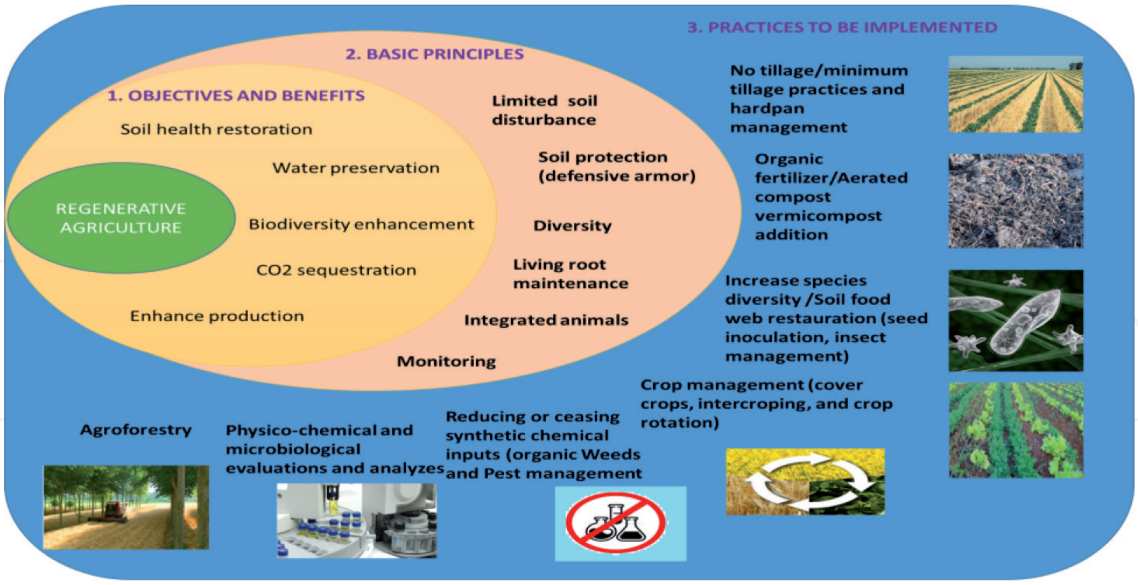

Figure 1.
A simplified approach to regenerative agriculture implementation.

2. Main causes of soil degradation

FAO [5] defines soil degradation as a change in the soil health status, resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Degraded soils have a state of health that prevents them from generating the standard products and services in a given ecosystem. Soil degradation is caused by unfavorable interaction between physical, biological, and chemical soil characteristics, accelerating erosion, and leading to poor drainage, salinization, nutrient imbalance, decrease in soil organic matter, and suppressing biology. Physical soil deterioration includes changes in soil structure (crusting, compaction, etc.), imbalance in water content and air ratio, leading to extreme surface temperatures. Chemical soil deterioration includes nutrient leaching, fertility depletion, or even toxicity. Biological deterioration includes a decrease in the microorganism population and a drop in their activity, as well as, a severe reduction of organic matter content. Degraded soil is being studied at specialist institutions in nearly every country, and warnings are coming from all across the scientific world [6–8].

Major causes of soil degradation are divided into natural, as climate variations (soil degradation caused by wind, sun, drought, or heavy rains favoring the fertile soil to be washed away) and anthropogenic activities (overgrazing, deforestation, excessive use of chemicals fertilizers, pesticides, herbicides, bare soils, excess of tillage, overdraft of groundwater, etc.) [9].

Conventional agriculture is considered to be one of the biggest contributors to soil degradation [10]. After Second World War, the Chemical Industry provide agriculture with new and advanced chemical formulas used as fertilizers, herbicides, and pesticides. The first results showed great success for everyone; however, the long-term effects were not anticipated since they have affected over time the soil structure and soil food web. Over few decades, the soil became degraded, plants are now mostly unhealthy, animals and humans experience unexplained medical conditions, and yields are going down every year. Chemicals use and tillage technology are producing the most detrimental influence on soil deterioration; as a result, their usage must be closely monitored and, if possible, avoided.

2.1 Bad practices that negatively influence the quality of agricultural soil

Farmers, working in conventional agriculture, that usually apply intensive chemical technologies, come across many harmful practices like those described below. The practices described in this section aim to draw attention to the most common activities that farmers do voluntarily or unknowingly, which may lead to soil degradation and floods.

2.1.1 Lack of efficient soil parameters evaluation

In Romania only a few farmers perform soil analysis annually, the majority of them use a standardized technology learned from books or advice from chemical companies. Soil parameters analyzed in a laboratory report do not contain enough information, the evaluation gives most often information regarding land chemistry, but ignores several important physical and biological properties. Sustainable agriculture changes the view of soil performance and soil quality [11]. Farmers need to invest more in complete soil assessment and perform some measurements by themselves, like soil acidity (pH) or soil conductivity (EC). The Haney report is another good analysis report that offers information about soil health, microbial respiration, water-extractable organic carbon, water-extractable nitrogen, etc. Haney soil test report offers farmers additional values to improve plant-available nutrients and estimate the soil health as related to carbon (C), nitrogen (N), and phosphorus (P) cycling [12].

2.1.2 Leaving the soil uncovered

Topsoil is being washed and lose its properties, microorganisms die, while its structure degrades. Uncovered soil favors natural soil erosion generated by rains, sun, or wind [13]. Soil loss of moisture and high soil temperature suppress bacteria and fungi living in the soil. In this environment, weeds germinate easily, and farmers cannot control them without using highly aggressive herbicides [14].

2.1.3 Excess of soil tillage

Tillage works as plowing and disking suppress the fungi network, appear losses the soil moisture, and may destroy soil structure [15]. Plowing is creating the hardpan at 15–30 cm deep. Hardpan is a compact layer of soil below the soil surface that inhibits roots movements through the soil [16]. Water is moving gravitationally on the hardpan, forming ponds, and soil gets salted [17].

2.1.4 Excess of synthetic fertilizers

Synthetic fertilizers suppress biology [18], contributing to soil compacting, loss of fertility, and humus total rate decrease. Plants are using only 15–30% of total inorganic fertilizers, while the rest is leaching in lakes, rivers, groundwater, etc. Accumulation of nitrogen in groundwater has different sources, being caught in irrigation lakes [19, 20]. As groundwater is the main source of drinking water, contamination poses several human health problems. At present in the United States of America, there are used 20 times more chemicals than in the American Dust Bowl period, and soil degradation continues dramatically.

2.1.5 Excess of one specific nutrient

Using in excess a specific nutrient especially N in a cation form, inhibits absorbing others nutrients cations as calcium (Ca), potassium (K), sodium (Na). The nutrient balance is one of the most important factors in plant nutrition [21–23], when plants receive too much N, during a 24 h photosynthesis process, N under forms of nitrate (NO_3) or ammonium (NH_4), is not transformed into proteins and became attractive for insects [24]. Excesses of N develop elongation, delay maturity, change biochemistry, cause plant stress and make plants vulnerable to drought [25].

2.1.6 Monoculture technology

Monoculture is not resilient to climate change, soil is losing carbon, while carbon dioxide (CO_2) is increasing in the atmosphere. Monoculture is a source of scarcity because the diversity principle is strongly affected [26]. Monoculture combined with bare soil practices decreases the fertility of agricultural lands dramatically [27].

2.1.7 Overdraft of groundwater

Groundwater overdraft is related to a dry aquifer, loss of water in streams and lakes, soil compacting, and polluted groundwater [27, 28].

2.1.8 Neglecting the soil's biology

If the biology of the soil is ignored in drought years, is a major problem, since the soil loses nutrients and water, putting plants under a high level of stress. The plant's nature enables to fill in the gap of water and nutrients. In recent decades, scientists from many laboratories have studied the interactions between microorganisms and plants, and they have concluded that the soil food web plays the most important role in plant nutrition [29].

2.1.9 Micronutrients are underused

In the last decades' scientific reports demonstrated that micronutrients are as important as major elements, the only difference is the needed quantity. Micronutrient deficiency is widespread in the world due to low organic matter, bicarbonate content in irrigation water, long time of drought, and imbalanced application of fertilizers. Micronutrients application contribute to plant health, soil health, and increase yield by up to 15–50% [30–32].

2.1.10 Too much importance given to quantity and not to quality

There is no special interest nowadays in the quality of the products obtained in conventional agriculture [33]. Healthy plants that are resistant to illnesses, insect attacks, and drought are used to produce high-quality products, while also improving yields. Highly nutritional plants have a substantial positive impact on soil health [34], animal, and human health.

3. Principles of restoring soil and plants health

Regenerative Agriculture is organic agriculture, using only natural available resources. In organic agriculture, farmers are certified if they produce non-GMO plants without using synthetic chemicals, approaching soil conservation and preservation for biodiversity. Farmers are allowed to use only inputs from certified organic agriculture. In 2018, at Rodale Institute was introduced for the first time a new higher standard for the farmers working in a regenerative system called Regenerative Organic Certified (ROC) [35]. Regenerative Agriculture is the way to sustainable farming practice, regenerate soil fertility, grow healthy plants that create healthy soils, less sensible to draught. Using methods from Regenerative Agriculture technology, carbon is sequestered in the soil, soil structure and soil fertility improve, water retention, and crop yield increase, while drought and flood ameliorate [36]. Regenerative agriculture can be defined by a holistic system approach that starts with the soil characteristics and also includes the health of the plants, animals, farmers, and community. The main aims envisage to regenerate topsoil, restoring degraded soil biodiversity, enhancing ecosystem services, improving water cycling and improving the resilience of soil to extreme weather. Regenerative Agriculture focuses on improving soil health by following four main mandatory principles and one optional. All specialists in Regenerative Agriculture accept the four principles that include soil cover, living roots, biodiversity, and minimalizing soil disturbance. The last principle which is the integration of animals is partially accepted and can be even more important in a few specific situations.

Everything plants need is cycled by soil microorganisms before becoming available to plants' roots. Earth life is based on photosynthesis, a process that transforms photonic energy into chemical energy. It varies, depending on the availability of light, water, carbon dioxide, chlorophyll concentration, and plant nutrition. Photosynthesis is the most efficient cycle and sustainable process in nature [37, 38], and it is the engine we can rely in Regenerative Agriculture. Farmers know that water, nitrogen, and high-temperature influence the photosynthesis process. During drought, plants switch from photosynthesis to photo-respiration process, when are consuming their reserve of proteins [39]. To avoid this happening, proper management has to be used that optimize nutrition. When monitoring fields frequently, one should notice nature needs [40].

3.1 Limited soil disturbance

Only a limited mechanical, chemical, and physical disturbance of soil is permitted. Tillage destroys soil structure, resulting in bare or compacted soil that is destructive to soil microorganisms and creates a hostile environment for them. Soil stability is a quantitative indicator of soil health that is based on a mix of biotic and abiotic soil parameters. The impact of physic and chemical qualities on soil resistance and resilience is mediated by the microbial community [41]. Living organisms in soil improve the structure, create pore spaces that allow water and air to infiltrate the soil. Intensive tillage destroys macro and microorganism habitat, disrupt the fungi hyphae and soil aggregate.

Synthetic fertilizers, herbicides, pesticides, and fungicides suppress life in the soil, having a negative impact on soil fertility. Inputs application disrupts the symbiotic relationships between fungi, bacteria, and plants roots. Overgrazing is a form of biological disturbance that reduces roots mass, increases soil temperature and runoff. All forms of soil disturbances affect microorganisms and diminish the soil food web.

3.2 Soil protection (defensive armor)

The principle is oriented toward keeping soil covered at all times, especially by setting up cover crops or intercropping. This is a critical step toward rebuilding soil health because bare soil is not a normal state, nature always works to cover the soil surface. When providing a natural vegetal shield, the soil is protected from wind and water erosion, while providing foods and a habitat for macro- and microorganisms [42]. It will also prevent moisture evaporation, reduces temperature, intercepts raindrops, and reduces germination of weed seeds. Soil cover offers a habitat for soil food web members that spend some of their time above ground. Keeping the soil cover on allows microorganisms to break down leftovers while recycling nutrients back into the soil.

3.3 Diversity

Nature aims for the diversity of both plant and animal species. Farmers should do the same, since monocultures are present only where humans have established them. The preservation, conservation, and restoring biodiversity should be a priority nowadays. Biodiversity is a major determinant in ecosystem stability, productivity, and nutrients dynamics. High diversity can be twice as productive as monoculture [43]. Different plant species use carbohydrates to feed certain microorganisms in return for water and nutrients via their roots. Biodiversity of plants is required to support the biodiversity of microbes. Each microorganism plays a specific role in maintaining soil health, and diversity enhances ecosystem functioning [44]. The key to improving soil health consists in a soil food web that is populated with several types of plants and animals. A fully functioning soil food web provides nutrients, water, energy, and allows the soil to express its full potential. The diversity has to be increased using crop rotation and cover crops.

3.4 Living root maintenance

Living roots have to be maintained in soil as long as possible because they are feeding soil biology by providing basic food source carbohydrates [45]. This biology feeds plants with water and nutrients, having the capacity to store nutrients and water that will be provided during drought. Farmers within conventional agriculture used to think there are 120 days to rest soil until the growing season. It is now considered wrong since living plants continue growing into early winter and break biological dormancy earlier in the spring. Their roots are feeding soil organisms and keep the biological population at a high rate. Healthy soil is dependent upon how well the food web is fed. Providing food to soil microbes helps them cycle nutrients that plants needed to grow.

3.5 Integrated animals

Nature does not function well without animal organisms. Integrated livestock into an operation provides many benefits. The major benefit is that grazing stimulates the plants to pump more carbon into the soil. This drives nutrient cycling by feeding biology, also has a major positive impact on climate change by cycling more carbon out of the atmosphere and putting it into the ground. Pasture cropping is another way of practicing regenerative agriculture for growing food and restoring degraded soil. Farmers should provide a home and habitat not only for farm animals but also for pollinators, predator insects, earthworms, and all the microbiology that drive ecosystem function.

3.6 Monitoring

Monitoring the field every day is also a key factor in keeping plants healthy. Checking the soil compaction, earthworm activity, soil structure, erosion risks, poor crop growth, etc., and keeping a recording of everyday activity helps the agricultural management system. Minimum information recorded are data, weather, fertility and irrigation program, yield, insects attack, diseases, etc.

There are different technologies according to these principles that are already used by some farmers. The most commonly used are the NO-TILL or STRIP-TILL, but they are rather used for profit maximized than for reducing drought effect and regenerating soil health. NO-TILL is studied in many countries, over a long period of years, concluded that is a big step forward [46]. However, these technologies are included in regenerative agriculture methods of growing plants during drought. A special part that is additional to these methods in regenerative agriculture, concerns breaking the hardpan and biological inoculation.

4. Methods to control draught by using the principles of regenerative agriculture

Drought stress is reduced when plants are healthy and thrive in healthy soil. For plants to overcome the draught on degraded soils, a new management strategy is required. Water, balanced nutrients, and biology are the three most important requirements for plants. Plants that are well-managed produce soil that is rich in humus. Growing healthy plants to overcome the drought and the elements that impact the process are provided in the appropriate sequence.

4.1 Weeds management

The field control has to begin in the autumn before the new agricultural year begins. Weeds like quack grass and foxtail can be found in dry clay soil, indicating calcium deficits and compact soil. Mow the grasses and compost the cuttings into the soil to help with calcium deficits. Broadleaf weeds, like ragweed, indicate copper deficiencies problem, and a phosphate/potassium imbalance. The rate between phosphate and potassium should be 2/1 for row crops and 4/1 for grass crops. Succulent weeds increase soil water capacity, replenish carbonate ions while covering the ground to protect against soil erosion. Weeds role is to deposit nutrients and metabolites in the soil or rearrange the nutrients existing in the soil. There is plenty of information in the literature about weeds role and weeds usage as a soil indicator [47–49]. This information is important to design a fertilization plan, in order to balance the nutrients. Herbicides must be avoided as much as possible since weeds get resistant to synthetic inputs, plants get unhealthy while the microbial population will decrease. Brix index in plants leaf must be measured before foliar application and 2 h after. After a few foliar applications, the crop will thrive and weeds will be attacked by insects and diseases, and not the established culture. As the nutrients are balanced, pH changes and weeds are under control.

4.2 Hardpan management

Hardpan management is the compact layer of soil just below the ground surface. Excess plowing leads to soil moisture loss by evaporation [50]. Avoiding working with moldboard plows, farmers must use instead a strip subsoil breaker in the first year to break the hardpan and apply a NO-TILL technology in the next years. Hardpan reduces the soil depth for plants roots and enhances soil waterlog. Plant roots grow in the surface layer reducing access to water and nutrients.

Well, aggregate soils are rarely found, usually, soils are crusted, compacted in layers or plow pans [51]. The agricultural year start in autumn and farmers first issue should be checking the hardpan with a penetrometer. After that, has to be measured the distance from soil surface to hardpan and hardpan thickness. If hardpan thickness is more than 5cm, then must be used a subsoil strip breaker. Soil improvement usually includes subsoil adding biological fertilization to break the hardpan and inoculate with microorganisms (bacteria, fungi) at the same time. Breaking the hardpan will allow water and nutrients to infiltrate deep in the ground, while microorganisms will keep the moisture and nutrients for a long period. Underground water and nutrients are stored naturally and through capillarity, the plants have access to water and nutrients during the drought period. In order to maintain the microbiology alive, they should be multiplied by feeding them and keeping constant moisture and temperature in the soil. In time, they will improve the soil structure, porosity, and the humus percentage will increase. In the photosynthesis process plants secret carbohydrates (sugar) and protein through the roots, which are food for bacteria and fungi. Bacteria and fungi are eaten by bigger microorganisms like nematodes and protozoa. Plants are thriving in such an environment even in drought conditions. With a restored soil food web, plants can control the water and nutrients cycling in the rhizosphere neighborhood. A restored food web reduces irrigation and tillage requirements, provides protection against pests and diseases and inhibits weeds. Pesticides and herbicides are not required, since applying these methods yields and farms profitability will be increasing.

Living life provides soil structure that resists wind and rain erosion. The first step will be in accordance with principles to use no plowing or disking, by implementing a no-till system. **Figure 2** compares three types of agricultural soil processing: in the first plan the work was performed with soil loosening equipment, in the second plan it is proposed the minimal processing technology by breaking the hardpan, and in the third plan a plowed land is highlighted.

The proposed technology within INMA institute is performed with an equipment that can be carried by an agricultural tractor, that cut the soil linearly without overturning the furrow, break the hardpan, and inoculate the ground with beneficial microorganisms. An active microorganism life restores the soil food web, which keep the pore open. This could be the first phase in rebuilding a healthy soil and ecosystem.

4.2.1 Amendment and treatments

Amendment and treatments have a significant effect on soil's physical and chemical properties and increase microbial activity. Amendments improve soil water

Figure 2.
Comparison between three types of agricultural soil processing: soil loosening equipment (first plan); minimal processing technology-hardpan breaking (second plan); plowing (third plan).

retention and soil structure as permeability, drainage, air holding capacity, etc. Soil acidity is potentially serious land degradation, acid soil is crusted and compacted, requires calcium, phosphorus, and minerals. The recommendation is to apply on soil a minimum 200 kg of lime and 200 kg of soft rock phosphates per hectare every autumn and spring during the first 2–3 years. These small quantities are recommended only in soils with degraded food web, or if microorganisms are being incorporated into the soil. Microorganisms are highly important because they break down the amendments and make them available to plants. High quantities of minerals suppress microorganisms. The amendments are spread best in autumn, before planting the cover crops and in spring before planting the main crop. Any other nutrient must be added as a result of the soil analysis. Organic amendments like compost or vermicompost have a benefic effect, increasing macro and micronutrient, organic matter, physical, and chemical soil properties like pH and EC. Humic acid found inside vermicompost, improves phytoremediation of soils contaminated with heavy metals [52]. Vermicompost soil amendments combined with foliar fertilizer, based on vermicompost, reduces the period to regenerate the soil fertility. Vermicompost can be produced in every farm, is cheap and have a tremendous effect on plants that grow during draught.

4.2.2 Mineral nutrients addition

Plants need minimum 17 mineral nutrients divided into macro- and micronutrients to grow and complete plants' life cycle. Each of the nutrients perform specific functions within the plant and the amount of each needed by the plant depends on what role the plant has each element [53, 54]. Microelements are needed in a small amount, but they are as important as macro-elements. Micronutrient deficiencies induce stress in plants, cause yield losses, resulting in poor health for animals and humans [29]. Supplying plants with micronutrients, through soil application or foliar spray, increases yields, produces higher quality, but also increases macronutrient use efficiencies. Micronutrients application is cheaper and needs less labor and transport because there are small quantities to manipulate. There are nine macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), carbon (C), oxygen (O), and hydrogen (H) from which conventional agriculture is using six, but focus only on three N, P, K. Farmers in conventional agriculture, concentrating on NPK, can deliver excellent yields in irrigated conditions or rainy years, but less quality is usually obtained. Finite products, full of nutrients, for healthy animals and humans, are obtained when plants absorb balanced nutrients. To design a fertilizer plan, one need proper knowledge of the interaction between nutrients [55]. The key to controlling the mineral nutrients is restoring the soil food web. First-year must fertilize with biofertilizers and 70% of the recommended macronutrients N and P to obtain better yields and better-quality crops, low nitrate and nitrite levels in crops [56]. In two-three years, with a soil food web restored, microorganisms will takecare of plant nutrition, bacteria will fix the nitrogen in the soil, while other specific bacteria will solubilize the needed minerals. Biofertilizer is keeping beneficial microorganisms in the soil healthy and allow plants to overcome the drought [57].

4.2.3 Organic fertilizer

Organic fertilizer is added to the soil to improve soil structure, feed both the plants and microorganisms. Microorganisms break down the organic materials and release nutrients slowly to the plants. Organic fertilizers increase soil's ability to hold water and nutrients. Solid organic fertilizer made from bat guano, fish meal, or manure can be spread on the soil before planting the main crop. Liquid fertilizer can be sprayed on soil or leaves. Chelated liquid fertilizer should be used for a slow-release technique. A cheap method is to spread the fertilizers in furrows, in this way, it will produce the same effect, but the quantity needed is much less (approximately 20–30% of the total quantity needed).

4.2.4 Seed inoculation

Seed inoculation is a cheap and beneficial tool to grow healthy plants, considering that each plant has a group of bacteria or fungi that work in association with the plant roots. The colonization of plants roots by associated bacteria and fungi result in better performance than plants colonized by the wild population of microorganisms [58]. Inoculations have to be performed for both the main crop and cover crop. Inside the cover crop, there have to be various legume seeds that can be inoculated with nitrogen-fixing bacteria. No need to fertilize the soil with nitrogen if seeds are inoculated with these types of bacteria [59, 60]. Biological control agents protect seedlings from disease as fusarium, pythium, etc. [61]. Arbuscular mycorrhizal fungi play an important role in plant growth. Corn inoculated with arbuscular mycorrhizal have a higher phosphorus absorption, increases vegetative biomass and grain yield, especially in low or medium available phosphorus [62].

4.2.5 Soil food web

Soil food web is a new model of soil fertility based on biology. This new model works better, presenting a lower cost, preventing diseases, do not pollute and use minimal chemical inputs [63]. Microorganisms are the link between water, nutrients and plants. Plants are in control of a viable soil food web, and exudates, in the form of carbohydrates and proteins, attracting specific bacteria and fungi. Bacteria and fungi consuming root exudates are at the bottom of the soil food web. Bigger microbes, nematodes, and protozoa are consuming bacteria and fungi, and are excreted as nutrients right in the rhizosphere. Protozoa and nematodes are eaten by arthropods.

Arthropods may eat other arthropods or they might be eaten by snakes, birds, moles, etc. Worms, insect larvae, and moles are moving through the soil, in search of food, creating pathways and letting water and air enter. Members of the soil food web bind soil particles together, create tunnels for air and water to help create soil structure. Soil food web has a natural design and presents seven major benefits such as diseases suppression, nutrients retention, increase mineral nutrient availability to plants, improve soil structure, decomposition of toxic chemicals, production plant growth, and improve crop quality. Microorganisms and other soil food web members release root growing hormones. These growth hormones help the plant to cross the draught or a flood and increase yield.

4.2.6 Cover crops

The presence of plant cover crops in the agricultural system aids in the production of large amounts of biomass. This boosts the soil's organic content, improving fertilization. The physical, chemical and biological qualities of the soil are improved by maintaining permanent cover crops, and in time, contributing to the restoration of its health. It is recommended to use biodiversity, which include at least one species of leguminous plants. Inoculation has to be achieved with nitrogen-fixing bacteria, especially for leguminous plants. Then the amendments can be spread and may plant various cover crop seeds. Incorporation of amendments can be done with a disk harrow, while the cover crops may consist of oats, rye, buckwheat, radish, mustard, vetch, clover, etc. Plants' biodiversity will attract various bacteria and fungi, each plant species attracting its own specific microorganisms. In this way, the soil food web will be restored sooner and better. Cover crops have to be chopped or mowed in spring before full bloom, and a minimum of two weeks before planting the main crop. The cover crop will maintain the soil moisture, while soil temperature will not vary too much during drought or between day and night. After mowing, cover crops are used as mulch. Raindrop energy will be dissipated by living crops and mulch, and in this way, erosion will be under control. Cover crops are being decomposed by fungi and bacteria. Another advantage is that in winter cover crops are one of the best options to defend against topsoil loss due to erosion. If it is managed correctly, the decomposition of cover crops by bacteria and fungi provides nutrients to the main crop (cash crop), while biodiversity of cover crop suppresses weeds, prevents NO_3 leaching and produces above-ground biomass N [64, 65]. Plant diversity helps to reduce pathogens, pests, and weed invasion, reducing the need for insecticides and pesticides.

A diversified crop rotation enhances soil structure by varying the length of planting zones, allowing for better water penetration. Different crops with varying nutrient requirements, as well as waste products, will help to create a more balanced and resilient soil ecosystem. The duration of these rotations is usually between 4 and 6 years.

4.2.7 Maincrop (cash crop) management

When sowing, it is recommended to inoculate the main crop seeds with different solutions based on microorganisms and nutrients. The seeding should start in spring, two weeks after mowing the cover crops and apply foliar fertilizer during the critical point of influence. Each crop has different important phases that may be influenced by inoculation with microorganisms: when planting (to enhance germination), strengthening plant structure, growing the fruit and finishing fructification. Foliar fertilizer must contain at least calcium, manganese, boron, zinc, amino acids. Balance calcium with potassium starting filing fruit point of influence and replace calcium with potassium at the finishing fruit. Get the maximum feedback from the plant when adding biology in the fertilizer solution. A healthy plant will cross the drought. Harvest the corn seeds, but let the corn stalk on the soil to be decomposed by fungi and bacteria.

4.2.8 Foliar application

Foliar application is the most efficient and cheap way to grow healthy plants. Growing healthy plants increase the immune plants' system, get resistance to diseases and insects attack, plants can cross the drought. In order to grow healthy plants, increase the photosynthesis process from 2- to 3 times by using the right foliar fertilizer solution. Aerated compost tea is a foliar biofertilizer with a benefic impact on plant growth [66]. Inside the aerated compost tea add other nutrients needed by plants.

A complete foliar fertilizer contains clean water, mineral nutrients, microorganisms, plant bio-stimulants, bacteria bio-stimulants, fungi bio-stimulants, and inoculants. It has a synergetic effect on plant growth. Plant reaction is tremendous, especially in degraded soils.

Water is the most important ingredient in foliar fertilizer solution. Using poor-quality water can determine a loss of 50% from the effect of the foliar solution. Do not use water from ponds, lakes, or others sources without water analysis tests. Good water for foliar application has less than 70 ppm, pH between 5.2 and 6.5, electrical conductivity EC between 1.6 and 2.8 ds/mm and temperature between 58 and 78 degrees Fahrenheit. For best results use rainwater or reverse osmosis water. Municipality water is usually unsuitable for foliar recipes because of the chlorine or chloramine, with high pH and potentially hardness.

Foliar solution when humidity is high has to be applied in larger particles (not fine spray), so the liquids remain on the leaf surface a long time without drying out. Sprayers with large droplets make a huge difference. The farmer should measure the effect of the foliar solution before application and 2 h after. If Brix reading is 2 points higher, the foliar solution is good and could apply on the entire field. A diagram of the Brix index reading should be done for every crop. Around 8 o'clock in the morning, after collecting healthy old mature leaf samples from 10 to 20 plants, they are squeezed on a refractometer.

In the Brix diagram example, the values are starting from 5, increasing to 9 at the first foliar application, but dropping after a few days to 6. After repeating the foliar application, the Brix index increases to 11, but drop in a few more days to 7. Every time when a good foliar application is applied, the Brix readings are higher and has been found that when Brix values are over 12, the plants present a health status that helps them overcome more easily the drought.

4.2.9 Sap analysis

A refractometer gives general information about plant health, but for more information including nutrients balance, a sap analysis is necessary. Plant sap analysis provides 21 nutrients parameters values that enable farmers to optimize the crops' fertilization plan. The information is valuable because the uptake of plant nutrients are revealed in a few hours, the increasing performance can be tracked graphically,

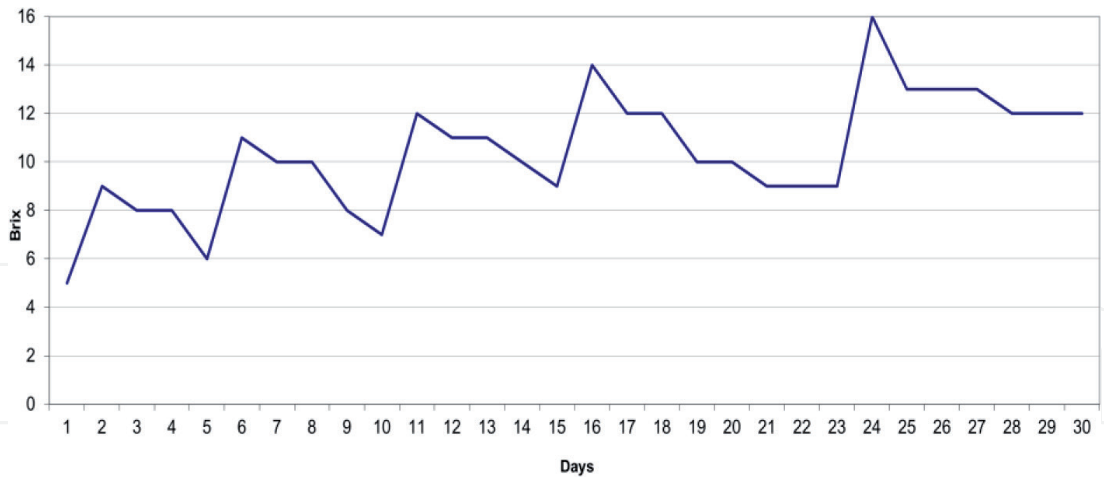

Figure 3.
Example of the variation of the Brix index for tomato juice, for a period of 30 days.

similar to the example shown in **Figure 3**. To a better understanding, one can compare a sap plant analysis with human blood analysis. A plant sap analyze tells the current uptake of nutrients, excesses or deficiencies of nutrients long term before can be seen on a plant leaf, plant reserves of nutrients, nutrient imbalance in soil, what nutrient plant can use at that moment for its own growth, or even fruit quality [67]. Sap analysis laboratory in less than one week will provide the analysis sheet with a fertilizer plan recommended. A balanced mineral uptake increases plants' health that gets resistant to diseases and insects attack and crosses the drought.

4.2.10 Water management

Water is the most important nutrient for plants. A source of water is critical for drought years, but as long as the regenerative methods presented are met, plants can cross the draught without an irrigation water source. Knowledge of irrigation water quality is critical in understanding long-term soil management. The most influential water parameter is the salinity measured by electrical conductivity EC [68]. High sodium related to calcium and magnesium contends, in irrigation water, causes surface crusting, pore plugging, swelling, and dispersion of soil clay. The acidity or basicity of irrigation water is expressed as pH. Normal irrigation pH is between 6.5 and 8.5. Specific ions like boron, sulfate, chloride, and nitrate, may affect plants grown. An irrigation water analysis is required.

4.2.11 Crop rotation

Keep a crop rotation, with cover crop intermediate, for minimum 3 years after starting your regeneration soil program. After concluding that the soil food web is active and the soil is healthy crop rotation is not as important anymore, since biology will take care of plant nutrition and will suppress diseases, insects attack will decrease.

4.2.12 Aerated compost tea

Aerated compost tea, produced by a compost tea brewer, allow microorganisms to be extracted from compost and multiplied. The result consists in beneficial aerobic microorganism production that provides plants with nutrients and helps build the soil food web [69]. The tea is used for spraying both the leaf and soil. Vermicompost is also used to avoid pathogens. Red worm castings are free of pathogens. There are farmers, involved in regenerative agriculture, buying different products that contained few families of fungi and bacteria, but inside aerated compost tea there are thousands of families. A compost tea brewer can be purchased or can easily be built. All a farmer needs is a tank, an air pump, a hose, and an air splitter distributor. To brew the compost needs clean water, vermicompost, mineral nutrients and bio-stimulants for plants, bacteria and fungi. Brew all these ingredients for 24–36 h, then measure the pH and EC. If pH is higher than 6.5 must add 100–300 ml of vinegar and measure again. When measuring EC a few hours before stopping the air pump, If the values are too low must add more vermicompost. The tea has to be used within 4 h after the air pump stops, to improve the synergetic effect on plants and soil [70].

4.2.13 Managing livestock

Good and efficient management of animal grazing can rebuild soil health. This is a way for a healthy ecosystem, farm profitability, human health, food system resilience. Studies that use a complementary approach to animal husbandry with organic farming use found that adopting some grazing strategies could regenerate the soil and make them more profitable. Holistic management of livestock management includes grazing, land, and financial planning and ecological monitoring.

4.2.14 Agroforestry

Agroforestry can provide suitable tools for landscape restauration because it can enhance physical, chemical, and biological soil characteristics. Agroforestry is restoring and increasing land productivity because the presence of the trees can fix nitrogen, stabilize the soil, reduce soil erosion, increase fertility, and regulate water available in degraded lands.

Trees increase fertility by retrieving nutrients from deeper soils and adding them to the soil surface through the leaf litter. Because of their deep root system, trees prevent nutrients from leaching, combat soil salinization, and acidification. The use of trees with fixing-nitrogen bacteria is increasing crop productivity. Experiments in Zambia, for example, showed that maize yields increased by 88–190% when grown in an agroforestry system under a canopy of *Faidherbia Albida Trees* (FAO report Agroforestry for landscape restauration).

Trees can reduce and prevent soil erosion planted in windbreaks trees protect soil from erosion and increase yield.

Agroforestry buffer strips increase water runoff, and soil evaporation and increase water infiltration and water retention capacity, helping plants to cross the drought.

4.2.15 Instrumentation

Minimum instrumentation required to grow healthy plants and cross the draught more easily is the penetrometer, refractometer, pH-meter, EC-meter. A penetrometer is the first instrument to be used in an agricultural season to measure soil compaction. The penetrometer is a device used to measure the resistance of soil to a vertical force.

The penetrometer can determine the depth of the hardpan and help producers to determine if a subsoil is in need.

Refractometer measure Brix index values for liquids. Brix values indicate the total soluble solids. The refractometer is widely used in measuring the quality of the grapefruits and the time to harvest. The refractometer can be used to evaluate the overall assessment of plant health. Healthy plants with a minimum 12 Brix readings are resistant to diseases and insect attacks.

Soil pH-meter is used to measure the acidity or alkalinity of soil. The values give information about the balance of the nutrients found in the soil. However, can be also used as a pH meter for liquids, and determine pH when adding 5 parts distilled water on 1 part of the soil.

EC (electrical conductivity) meter is used especially to estimate salinity levels. A high level of salinity reduces the plant's ability to take up water. For assessment is being used 5 parts distilled water and 1 part soil to determine the values of salinity in mSiemens/cm. In clay soils, values are between 0.2 and 1.0 mS/cm, but different plants tolerate different values.

4.2.16 Drought

During drought, when air temperature became too warm, plants switch from photosynthesis to photo-respiration and begin consuming their inside proteins. Healthy plants with a waxy sheen, on the leaf surface, have a cooler leaf temperature than plants with a lack nutritional integrity. Foliar applications with teas made from compost, with the addition of 3 L of molasses per hectare, during and after the drought, is a very good practice.

5. Conclusion

Regenerative agriculture is focused on farming techniques with the primary goal of regenerating the land, particularly increasing the organic composition in order to improve fertility. This strategy conserves and restores soil organic matter, thus, influencing the development and prosperity of micro- and macro-organisms with beneficial results against soil erosion and drought.

Farmers may be forced to adopt unsustainable practices due to economic pressures, as they rarely have enough ability to deal with the conditions imposed by larger corporations, that control prices and credit. As a result, agricultural policies must be implemented at the national level to assist farmers and ensure they are not compelled to deplete the resource that provides them with a means of subsistence.

Regenerative agriculture is based on a holistic approach that places the land at the core of the process to produce efficiently and sustainably a synergy between the soil, the animal world, and the plant world. This enables the development of food chains between all three ecosystems, while the restoration of soil health is ensured by the balance and diversity of species found within the environment.

Climate change is no longer a myth, but a fact and the consequences are becoming increasingly severe every day, influencing the drought phenomena. Every year, topsoil is leaching, soil gets compacted, crusted, loses the ability to supply nutrients and water to plants. Degraded soils, in drought conditions, are not able to support plants with the required water and nutrients, while yields decrease dramatically. In order to reduce the drought effect, farmers have to integrate their use of regenerative agriculture principles and methods, focusing on growing healthy plants and getting rewarded with good yields and increased farm profitability.

Water retention in agricultural lands is associated with soil organic carbon and is influenced by soil health. Soil organic carbon increases the percentage of water retention because carbon acts like a sponge that absorbs moisture. Regenerative management practices such as minimum tillage, cover crops, inoculation with microorganisms, mulching practices, nutrients cycling, maintenance of an optimal balance of organic fertilizers, foliar application, and other methods help to increase soil organic carbon. This strategy restores degraded soils, enhances biomass production, purifies groundwater, reduces the rate of CO_2 emissions into the atmosphere and increases the percentage of water being retained in the soil.

An active soil food web is the link between water, nutrients, and plants. Healthy soils have an active soil food web that presents many benefits such as diseases suppression, nutrient retention, improve soil structure, making mineral nutrients available to plants, decomposition of toxic materials, improve crop quality. Soil food web works in synergy with plants and helps crops to overcome more easily drought or floods.

The primary goal of this technology is to grow healthy plants on a worldwide scale. Healthy plants achieve synergies with the soil and improve its health, recover carbon in the soil, increase water retention, and improve soil structure and nutritional status. Drought years will be more profitable for farmers using regenerative agriculture technology, since organically grown cereal prices will be higher, resulting in greater average yields. In a short period of time, farmers using regenerative agriculture technology will spend less money, yields will grow, profitability will increase, soils will regenerate, and drought years will become less risky.

Author details

Eugen Popescu, Florin Nenciu* and Valentin Nicolae Vladut
INMA Bucharest—National Institute for Research-Development of Machines and Installations Designed for Agriculture and Food Industry, Bucharest, Romania

*Address all correspondence to: florin.nenciu@inma.ro

References

[1] Gomiero T. Soil degradation, land scarcity and food security: Reviewing a complex challenge. Sustainability. 2016;**8**:281. DOI: 10.3390/su8030281

[2] Crawford E. 3 basic tenets of regenerative farming could improve soil health, food production and bottom line. Food navigator-usa.com. 2018. Available from: https://www.foodnavigator-usa.com/Article/2018/08/17/3-basic-tenets-of-regenerative-farming-could-improve-soil-health-food-production-and-bottom-lines

[3] Coursework Stanford University. Topsoil Erosion 2015. un report 2015 humanity is losing 0.3% of food per year. Available from: http://large.stanford.edu/courses/2015/ph240/verso2/

[4] Hornbeck R. The enduring impact of the American Dust Bowl: Short- and long-run adjustments to environmental catastrophe. American Economic Review. 2012;**102**:1477-1507

[5] Gretton P, Salma U. Land degradation and the Australian agricultural industry, Staff information paper, Industry Commission. GPO Box 84, Canberra ACT 2601: Commonwealth of Australia, Australian Government Publishing Service, AGPS; 1996. Available from: https://www.pc.gov.au/research/supporting/land-degradation/landdegr.pdf

[6] Lal R, Hall GF, Miller FP. Soil degradation: I. Basic processes. LDD Land Degradation & Development. 1989;**1**:51-69. DOI: 10.1002/ldr.3400010106

[7] Oldeman RL. Global Extend of soil Degradation. Bi-Annual Report. ISRIC Bi-Annual Report. 1992. pp. 19-36. Available from: https://library.wur.nl/WebQuery/wurpubs/fulltext/299739

[8] Butzer KW. Environmental history in the Mediterranean world: Cross-disciplinary investigation of cause-and-effect for degradation and soil erosion. Journal of Arheological Science. 2005;**32**:1773-1800. DOI: 10.1016/j.jas.2005.06.001

[9] McGarry D. Tillage and Soil Compaction. Conservation Agriculture2003. pp. 307-316. Available from: https://link.springer.com/chapter/10.1007/978-94-017-1143-2_37

[10] Savci S. Investigation of effect of chemical fertilizers on environment. APCBEE Procedia. 2012;**1**:287-292. DOI: 10.1016/j.apcbee.2012.03.047

[11] Romig DE, Garlynd MJ, Garris MF, Mc Sweeney K. How farmers assess soil health and quality. Journal of Soil and Water Conservation. 2012;**1**:287-292. DOI: 10.1016/j.apcbee.2012.03.047

[12] Haney RL, Haney EB, Smith R, et al. The soil health tool—Theory and initial broad-scale. Applied Soil Ecology. 2018;**125**:162-168

[13] Shiva V. Monocultures of the Mind: Perspectives on Biodiversity and Biotechnology. Available from: https://books.google.ro/books?hl=en&lr=&id=QcstWYIcbHkC&oi=fnd&pg=PA5&dq=shiva+monocultures+of+the+mind&ots=vBJ6J4d6sM&sig=Z

[14] Habib U, Eroglu G, et al. Using high resolution images and elevation data in classifying erosion risks of bare soil areas in the Hatila Valley Natural Protected Area, Turkey. Stochastic Environmental Research and Risk Assessment. 2010;**24**:699-704 Available from: https://link.springer.com/article/10.1007/s00477-009-0356-5

[15] Teasdale JR, Daughtry CST. Weed Suppression by Live and Desiccated Hairy Vetch (*Vicia villosa*). Cambridge: Cambridge University Press; 2017. Available from: https://www.cambridge.org/core/journals/weed-science/article/abs/weed-suppression-by-live-and-desiccated-hairy-vetch-vicia-villosa/91

[16] Baumhardt L. Dust Bowl Era. Encyclopedia of Water Science 2003. Available from: https://www.baymeadowscharter.org/ourpages/auto/2019/9/16/54520179/Lithosphere%20KQ4_%20Dust%20Bowl%20Case%20Study.pdf

[17] Chen Y, Cavers C, Tessier S, Monero F, Lobb D. Short-term tillage effects on soil cone index and plant development in a poorly drained, heavy clay soil. Soil and Tillage Research. 2004;**82**:161-171

[18] Tsubo M, Fukai S, Basnayake J. Effects of soil clay content on water balance and productivity in Rainfed Lowland Rice Ecosystem in Northeast Thailand. Plant Production Science. 2007;**2007**:10. Available from: https://www.tandfonline.com/doi/abs/10.1626/pps.10.2

[19] Tripath S, Srivasta P, Devi RS. Chapter 2—Influence of synthetic fertilizers and pesticides on soil health and soil microbiology. In: Agrochemicals Detection, Treatment and Remediation. 2020. pp. 25-54. DOI: 10.1016/B978-0-08-103017-2.00002-7

[20] Power JF, Scheper S. Nitrate contamination of groundwater in North America Agriculture. Ecosystems & Environment. 1989;**26**:165-187

[21] Andensen A. Science in Agriculture. ISBN-13: 978-0911311358. Available from: https://www.amazon.com/Science-Agriculture-Advanced-Methods-Sustainable/dp/0911311351

[22] Fageria VD. Nutrient interactions in crop plants. Journal of Plant Nutrition. 2006;**24**:1269-1290. DOI: 10.1081/PLN-100106981

[23] Novoa R, Loomis RS. Nitrogen and plant production. Plant and Soil. 1981;**58**:177-204. Available from: https://link.springer.com/article/10.1007/BF02180053

[24] Goyal SS, Huffaker RC. Chapter 6. Field lab earth podcast. In: Nitrogen Toxicity. 2001. DOI: 10.2134/1990.nitrogenincropproduction.c6

[25] Shiva V. Monocultures of the Mind. Perspectives on Biodiversity and Biotechnology. 1993. Available from: https://books.google.ro/books?hl=en&lr=&id=QcstWYIcbHkC&oi=fnd&pg=PA5&dq=shiva+monocultures+of+the+mind&ots=vBJ6K1l6sK&sig=o4EjfW2z7L3oW2zxP9xMP0YTgMw&redir_esc=y#v=onepage&q=shiva%20monocultures%20of%20the%20mind&f=false

[26] Ewel JJ, Mazzarino MJ, Berish CW. Tropical soil fertility changes under monocultures and successional communities of different structure. Ecological Aplication. 1991;**11991**:289-302. DOI: 10.2307/1941758

[27] Zektser S, Loáiciga HA, Wolf JT. Environmental impacts of groundwater overdraft: Selected case studies in the southwestern United States. Environmental Geology. 2004;**47**:396-404. Available from: https://link.springer.com/article/10.1007/s00254-004-1164-3

[28] Collins W, Qualset CO. Biodiversity in Agroecosystems. West Palm Beach, FL: CRL Press LLC; 1999

[29] Malakouti MJ. The effect of micronutrients in ensuring efficient use of macronutrients. Turkish Journal of

Agriculture and Forestry. 2008;**32**:215-220. Available from: https://journals.tubitak.gov.tr/agriculture/abstract.htm?id=9548

[30] Römheld V. Marschner H. Function of Micronutrients in Plants FIELD, LAB, EARTH PODCAST. 1991. Chapter 9. doi:10.2136/sssabookser4.2ed.c9

[31] Allowey BJ. Micronutrient Deficiecies in Global Crop Production. United Kingdom: Springer; 2008. pp. 1-39 https://books.google.ro/books?hl=en&lr=&id=_55yK0hj67IC&oi=fnd&pg=PR2&dq=brian+micronutrients+deficiencies&ots=WuW6zive7_&sig

[32] Douglas E, Romig M, Garlynd J, Harris RF, McSweeney K. How farmers assess soil health and quality. Journal of Soil and Water Conservation. 1995;**50**:229-236

[33] Rodale Institute blog. Available from: https://rodaleinstitute.org/why-organic/organic-basics/regenerative-organic-agriculture/

[34] Rhodes CJ. The imperative for regenerative agriculture. Research Progress. 2017. DOI: 10.3184/003685017X14876775256165

[35] Dougherty B. Regenerative Agriculture: The Path to Healing Agroecosystems and Feeding the World in the 21st Century Nuffield International. 2019. Available from: https://www.nuffieldscholar.org/sites/default/files/reports/2018_US_Brian-Dougherty_Regenerative-Agriculture-The-Path-To-Healing-Agroecos

[36] Galston AW. Photosynthesis as a basis for life support on earth and in space. BioScience. 1992;**42**:490-493. Available from: https://www.jstor.org/stable/1311878

[37] Jensen PJD, Lambreva MD, Plumere N. Photosynthesis at the forefront of a sustainable life. Crop Biology and Sustenability. 2014;**2**. DOI: 10.3389/fchem.2014.00036

[38] Ashraf M. Inducing drought tolerance in plants. Biotechnology Advances. 2010;**28**:169-183

[39] Brown G. Dirt to Soil. Vol. 7. ISBN13 (EAN): 9781603587631

[40] Nunes MR, Karlen DL, Moorman TB. Tillage intensity effects on soil structure indicators—A US meta-analysis. US Sustainability. 2020;**12**. DOI: 10.3390/su12052071

[41] Griffiths BS, Philippot L. Insights into the resistance and resilience of the soil microbial community. FEMS Microbiology Reviews. 2013;**37**:112-129

[42] Cammeraat LHA, Cimeson A. Deriving indicators of soil degradation from soil aggregation studies in southeastern Spain and southern France. Geomorphology. 1998;**23**:307-321

[43] Tilman D, Isbell F, Cowles JM. Biodiversity and ecosystem functioning. Annual Review of Ecology, Evolution, and Systematics. 2014;**45**:471-493. DOI: 10.1146/annurev-ecolsys-120213-091917

[44] Cheng W, Coleman DC. Effect of living roots on soil organic matter decomposition. Soil Biology and Bichemistry. 1990;**22**:781-787. DOI: 10.1016/0038-0717(90)90157-U

[45] Francis CA, Harwood RR, Parr JF. The Potential for Regenerative Agriculture in the Developing World. Cambridge University Press; 2009. Available from: https://www.cambridge.org/core/journals/american-journal-of-alternative-agriculture/article/abs/potential-for-regenerative-agriculture

[46] Franzluebbers AJ, Hons FM, Zuberer DA. Tillage and crop effects on seasonal dynamics of soil CO_2 evolution, water content, temperature, and bulk density. Applied Soil Ecology. 1995;**2**:95-109

[47] Andersen A. Science in Agriculture. 2nd ed. Vol. 12. Greeley, CO, USA: ACRES USA; pp. 189-203

[48] Walters C. Weeds Control without Poison. Greeley, Colorado, USA: ACRES USA; 1999

[49] Anderson A. The Anatomy of Life & Energy. Vol. 4. Greeley, CO, USA: ACRES USA; p. 51

[50] Gerard CJ, Bloodworth ME, Burleson CA, Cowley WR. Hardpan formation as affected by soil moisture loss. Soil Science Society Journal. 1961;**25**:460-463. DOI: 10.2136/sssaj1961.03615995002500060013x

[51] Chen Y, Cavers C, Tessier S. Short-term tillage effects on soil cone index and plant development in a poorly drained, heavy clay soil. Soil and Tillage Research. 2005;**82**(2):161-171. DOI: 10.1016/j.still.2004.06.006

[52] Anghelova VR, Akovai VI, Artinova NS, Ivanov KI. The effect of organic amendments on soil. Bulgarian Journal of Agricultural Science. 2013:958-971

[53] Barker AV, Pilbeam DJ. Handbook of Plant Nutrition. Boca Raton, Florida, USA: CRC Press; 2015

[54] Jones C. Jacobsen J. Plant Nutrition and Soil Fertility. Nutrient Management Module nr.2. Available from: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.576.5603&rep=rep1&type=pdf

[55] René P, Rietra J, Heinen M. Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency communications in soil science and plant analysis. 2017;**48**:1895-1920. DOI: 10.1080/00103624.2017.1407429

[56] El-Yazied AA, Selim SM. Effect of reducing n, p mineral fertilization levels combined with biofertilizer on growth, yield and tuber quality of potato plants. Journal of Plant Production. 2007;**32**:2957-2982

[57] Zainuddin N, Keni MF, Ibrahim SAS, Masri MMM. Effect of integrated biofertilizers with chemical fertilizers on the oil palm growth and soil microbial diversity. Biocatalysis and Agricultural Biotechnology. 2022;**39**. DOI: 10.1016/j.bcab.2021.102237

[58] Hartman G, Khadka R, Uphoff N. Benefits to plant health and productivity from enhancing plant microbial symbionts the plant holobiont Volume II: Impacts of the rhizosphere on plant health. Frontiers in Plant Science. 2021;**11**:1-21. DOI: 10.3389/fpls.2020.610065

[59] Mao W, Lewis JA, Hebbar PK, Lumsden RD. Seed Treatment with a Fungal or a Bacterial Antagonist for Reducing Corn Damping-off Caused by Species of *Pythium* and *Fusarium*. APS Publications. 2007;**81**(5):450-454. DOI: 10.1094/PDIS.1997.81.5.450

[60] Bressan W. Biological control of maize seed pathogenic fungi by use of actinomycetes. Bio-Control. 2003;**48**:233-240. Available from: https://link.springer.com/article/10.1023/A:1022673226324

[61] Bennett MA. The Use of Biologicals to Enhance Vegetable Seed Quality: Seed Technology. Vol. 20. Association of Official Seed Analysts; 1998. pp. 198-208. Available from: https://www.jstor.org/stable/23433023

[62] Gomez SC, Fonseca CR, Giachini SE. Yield increase of corn inoculated with a commercial arbuscular mycorrhizal inoculant in Brazil. Santa Maria RS Brazil, Centro de Ciências Rurais:Crop Production. 2020. DOI: 10.1590/0103-8478cr20200109

[63] Lowenfels J, Lewis W. Teaming with microbes. Portland, Oregon: Timber Press; 2010

[64] Finney DM, White CM, Kaye JP. Biomass production and carbon/nitrogen ratio influence ecosystem services from cover crop mixtures. Agronomy Journal. 2016. DOI: 10.2134/agronj15.0182

[65] Mitchall JP, Shrestha A, Mathesius K. Cover cropping and no-tillage improve soil health in an arid irrigated cropping system in California's San Joaquin Valley, USA. Soil and Tillage Research. 2017;**165**:325-335. DOI: 10.1016/j.still.2016.09.001

[66] Otero M, Kepa IS, Gonzales-Murua C. Dunabeitia quality assessment of Pinus radiata production under sustainable nursery management based on compost tea. Journal of Plant Nutrition and Soil Science. 2019. DOI: 10.1002/jpln.201800309

[67] Esteves E, Locatelli G. Sap analysis: A powerful tool for monitoring plant nutrition. Horticulturae. 2021;**7**(11):426. DOI: 10.3390/horticulturae7110426

[68] Bauder TA, Waskom RM, Sutherland PL, Davis JG. Irrigation Water Quality Criteria. Colorado State University, U.S., Department of Agriculture and Colorado counties cooperating; 2011

[69] Ferguson J. The role of organic materials in gardening. Lone Star Regional Native Plant Conference 2003. Chireno. Available from: https://d1wqtxts1xzle7.cloudfront.net/68954321/viewcontent.pdf?1630356850=&response-content-disposition=inline%253B+filename%253D2nd_Lo

[70] Ingham ER. The compost tea brewing manual. Soil Food International.; 2022. Available from: https://www.soilfoodweb.com.au/shop/manuals/manuals/compost-tea-brewing-manual-5th-edition-detail