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Review

Alternative Land Management Strategies and Their Impact on Soil Conservation

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Abstract: Soil conservation is threatened by a number of factors, namely the effects of intensive agricultural practices, the increasing pressure for food production linked to the increasing human population, the consumption patterns in developed and emerging economies, and the conversion of agriculture from the production of commodities (which is itself a goal in need of discussion) to the production of biofuels. The extent of human pressure and the effects of conflicting land use systems need to be addressed. Alternative and conservative agricultural practices need to be explored and widely adopted in order to preserve the soil fertility, assessing their pros and cons. In this paper, the main potential alternative practices are reviewed, focusing in particular on organic farming. It is also argued that in order to better plan to preserve soil health a strategy considering the whole food system is required.

Keywords: soil conservation practices; organic farming; low-input farming; land use change; farming system analysis

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1. Introduction

In the early 1970s, with the “green revolution” led by Norman Borlaug (1914–2009, Nobel Peace Prize in 1970), agricultural productivity experienced an incredible leap forward. The productivity of the new high-yielding grain varieties (HYVs, termed also high-response varieties), on average, more than doubled and for some cereals it improved by a staggering 4–5 times [1–3]. This helped to meet world food demand and saving hundreds of millions from starvation. Asia, for example, which was threatened by hunger and mass starvation as late as the mid-1960s, became self-sufficient in staple foods within 20 years, even though its population more than doubled [4]. The green revolution relied on cheap fossil fuels, which allowed the industrial production of chemical fertilizers and pesticides, the mechanization of agriculture and the massive use of irrigation [1,5]. Along with those tangible benefits, the new intensive agriculture had to face also some problems. Crops were more prone to pests and diseases and newly developed synthetic pesticides were necessary to keep pests out of the crops. The environmental impact of agricultural activity increased too, and the overall efficiency (as output/input) declined sharply [2–4,6,7]. Decades of agricultural intensification, then, exacerbated the demand for water use and affected soil fertility, threatening long-term crop productivity by increasing soil degradation and causing water shortages [7–10].

It has been widely reported that intensive farming exacerbates soil erosion and loss of Soil Organic Matter (SOM), threatening the long-term sustainability of crop production, especially under extreme climatic events such as droughts [9,11–16].

About 40% of global croplands may be experiencing some degree of soil erosion, reduced fertility, or overgrazing [9,11,17,18]. Soil erosion has been estimated to reduce yields on about 16% of agricultural land, especially cropland in Africa and Central America and pastures in Africa [17]. At present, the accelerated rates of erosion experienced are causing major modifications to carbon, nitrogen and phosphorus biogeochemical cycles [10,19]. Resistance of soils to erosion is closely linked to the stabilizing influence of organic matter and vegetation cover. In regions such as Asia and Africa, where soil erosion is associated with reduced vegetation cover, the loss of soil carbon can trigger catastrophic shifts to severely degraded landscapes [10,20].

Most SOM is found in the topsoil (15–25 cm of the A horizon) in the form of above- and belowground plant residues. SOM is of key importance for soil fertility [11,14,21–24]. The Soil Organic Carbon pool to 1 m depth ranges from 30 tons ha^{-1} in arid climates to 800 tons ha^{-1} in organic soils in cold regions, and a predominant range of 50 to 150 tons ha^{-1} [14]. Fertile agricultural soils can contain up to 100 tons of organic matter per hectare (or 4% of the total soil weight) and, in the case of most agricultural soils, SOM represents 1%–5% of topsoil [25]. Conventional agricultural practices that tend to leave soil uncovered for long periods of the year are responsible for topsoil erosion and reduction of its SOM content. Soil removed by either wind or water erosion is 1.3–5.0 times richer in organic matter than the soil left behind [14,15,21,26]. About 95% of soil nitrogen and 25%–50% of soil phosphorus are contained in the SOM-containing topsoil layer [15,21], the importance of which is such that in one study it was estimated that the reduction of SOM from 1.4% to 0.9% lowered the grain yield potential by 50% [27].

Agricultural practices such as no-till agriculture or minimum tillage, and organic farming can help to reduce soil loss and restore soil fertility [15,16,28–31]. Although permanent grasslands respond slower and probably weaker to organic management than crop fields do, it seems that organic practice may benefits grassland too [32].

In this paper, I will review some key issues concerning the environmental impact of current agricultural practices and present some potential alternative agricultural practices that may be adopted to make agriculture less environmentally damaging, reducing the use of natural resources and preserving soil fertility and biodiversity. Finally, I will discuss the need to adopt a complex approach when planning for land use and soil management.

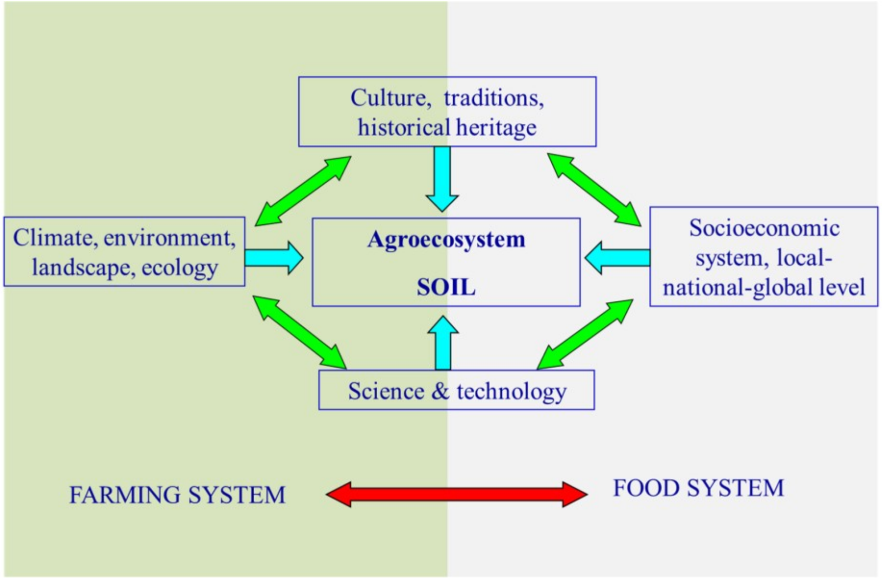
2. Soil in Context: Socioeconomic Pressure and Impact of Current Agricultural Practices

Agriculture should also aim at guarantying food security for people. As stated by [33], food security is defined as a state when "*all people, at all times, have physical and economic access to sufficient, safe and nutritious food for a healthy and active life*".

Agricultural systems are agroecosystems and agricultural science can be referred to as agroecology [22,34,35]. To this regard Miguel Altieri, one of the pioneer in agroecology science [22,36] provides the following definitions: "***Agroecosystems** are communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fiber, fuel and other products for human consumption and processing. **Agroecology** is the holistic study of agroecosystems including all the environmental and human elements. It focuses on the form, dynamics and functions of their interrelationship and the processes in which they are involved.*" (p. 8 in [36]).

Agroecosystems can effectively be understood as made up of many different component,s which can only be defined after adopting different perceptions/descriptions referring to different levels and scales. When adopting a *biophysical view* we can move from the scale of the soil, and its fauna, to arrive at the scale of crop species. When adopting a *socioeconomic view* we can start from the scale of the farmer, and moving up to that of the household of the rural community in which the household lives, to arrive at the scale of local, regional and national socio-economic systems. Using an *ecological view* we can have: the scale of the micro-ecosystems in the soil, local agroecosystems, then the scale of landscape and the watershed, up to the natural mechanisms generating biogeochemical cycles of water and nutrients that are required to stabilize and constrain the boundary conditions of the farming activity [37,38]. Agriculture is dynamic and evolving in the sense that it reflects both the changes occurring in: (i) external constraints, posed by the environmental system (e.g., biodiversity, landscape, and climate) and the socioeconomic systems (e.g., demography, cost of labor, and technological innovation), and (ii) internal characteristics reflecting cultural, social and technical innovations (Figure 1).

Figure 1. Soil and agroecosystems are complexly interwoven with the environmental, ecological and socioeconomic domains, at different hierarchical scales.



However, this complex nature of agroecosystem has been neglected. As pointed out by Foley *et al.* (pp. 570–571 in [39]) "In short, modern agricultural land use practices may be trading short-term increases in food production for long-term losses, in ecosystem services, including many that are important to agriculture". In order to work for a more sustainable agriculture we have to acknowledge: (1) the multifunctional nature of agriculture, that is not only producing commodities but also preserving the health of ecosystems, and quality of life for consumers and rural communities; and (2) the multi-scale nature of the complex network of relations among ecosystems and socioeconomic systems, that requires considering simultaneously different but relevant dynamics operating at different hierarchical levels [37–42].

Soil is the keystone of the agroecosystem, and preserving its health and fertility is a must. In order to work toward better soil management, many different issues must be tracked and dealt with: from adopting healthier management practices, to dealing with socioeconomic problems (e.g., population pressure, income distribution, market structure, subsidies mechanism), up to changing some of our paradigms and "values" concerning what agriculture is for (e.g., commodity production *vs.* food security) and how it should be cared for (e.g., massive exploitation *vs.* long term preservation of our "living support system"). Some key challenges ahead concern, for example:

(1) Population: Human population is rising by about 75 million (1.1%) per year, and will reach the staggering figures of 8.3 billion by the 2030 and of 9.2 billion by the 2050 [43–45]. At the same time (i) crop productivity stagnates and the yearly supply of grain per capita is decreasing [46–48], (ii) about 2 billion ha of the world's agricultural land have been degraded [9,23,39,47], and (iii) the Human Appropriation of Net Primary Productivity (HANPP) reached 50% leaving less and less room and resources to biodiversity and ecosystems, thus compromising the existence of many species and the proper functioning of ecosystems [49–51].

(2) Land: Recent studies suggest that by 2050 the world will need 60% [45], up to 70 more food [52]. By 2030, worldwide, an additional 120 million ha—an area twice the size of France—will be needed to support food production [53], while built-up area/cropland area—estimated 3.5% in 2000—will reach 5.1% (then 7% in 2050) [47]. The Millennium Ecosystem Assessment [7] estimated that, roughly, 10%–20% (low to medium certainty) of current grassland and forestland is projected to be converted to other uses between now and 2050, mainly due to the expansion of agriculture and, second, due to the expansion of cities and infrastructure. So a new challenge lies ahead—how to feed 9 billion with less land, water and energy [54,55]?

(3) Land for food* vs. *land for energy: Biofuels have lately been indicated as a promising source of cheap and sustainable energy. However, large scale conversion of crops, grasslands, natural and semi-natural ecosystems may have detrimental social (e.g., food security, land, grabbing) and ecological consequences (e.g. deforestation, loss of biodiversity, soil erosion) [56,57]. Further to that the power density (W/m^2) of biomass is simply too low to fuel our energivorous society [5,55,58]. Such low power density makes biofuels a highly labor-intensive energy source, resulting in the displacement of a high fraction of society labor force to energy production and so an increase of the price of energy [5,55,59].

(4) Water: Currently, on a global scale, 70% of the 3800 km^3 of water that humans use is directed towards agriculture, 20% towards industry and 10% towards urbanized areas [8]. By 2050, agricultural water use is expected to increase by 13% [8]. The production of common crops in many parts of the world requires a great amount of water, from a few hundreds to a few thousand times the final crop mass [1,3,8,60,61].

(5) Biodiversity: Agricultural expansion has a direct impact on local biodiversity through landscape modification which, in turn, results in displacement of local populations and loss of ecosystem services. The loss of native habitats and agricultural intensification, which displaces traditional varieties of seeds with modern high-yielding, but genetically uniform crops, are threatening biodiversity (both wild and domesticated) all over the globe [7,39,62–66]. Farming, including land conversion to farmland, for instance, accounts for 37% of threats to bird species listed as threatened species [65]. Extensive industrialized agriculture also greatly contributes to impoverishing crop biodiversity, with the loss of a large number of agricultural species and varieties [67].

(6) Synthetic fertilizers: Between 1960 and 1995, at a global scale, N fertilizer use on cereals increased sevenfold, whilst cereal yields more than doubled; however, N fertilizer efficiency (cereal yields divided by N fertilizer inputs) declined from over 70 to around 25 kg grain per kg N [6,68]. The overall global nitrogen use efficiency of cereals decreased from ~80% in 1960 to ~30% in 2000 [6,69]. Global data for maize, rice, and wheat indicate that only 18% to 49% of nitrogen applied as fertilizer is taken up by crops; the remainder is lost to runoff, leaching, or volatilization [68]. Nitrogen fertilizers are of key importance in intensive conventional agriculture. However, their use turns out to be a major cause of concern when it comes to environmental pollution. The primary source of N pollution comes from N-based agricultural fertilizers, whose use is forecast to double or almost triple by 2050 [6,19,70]. Synthetic fertilizers also have a direct negative impact on soil diversity and several soil processes. The use of synthetic fertilizers and herbicides applications changes relations within and between below and aboveground soil components, promoting negative impact on agriculture by reducing internal biological cycles and pest control [71].

(7) Pesticides: Widespread use of pesticides on crops has led to the emergence of many pesticide-resistant pests and pathogens [62,72–75]. People can be exposed to excessive pesticide levels while working; via food, soil, water or air; or by directly ingesting pesticide products. Pesticides are known to cause 26 million human poisonings per year and 220,000 deaths [76]. Along with other synthetic chemicals, some pesticides have a direct effect on the reproductive system of many high organisms, acting as endocrine disruptors, and inducing severe reproductive problems and modifying sexual behavior [77,78].

(8) Food waste: When it comes to the food system, it is disturbing, to say the least, to know that 30%–40% of the food produced in the field is wasted through the food system; in industrialized countries it is estimated that 15%–20% of it just passes directly from our fridge to the bin [1,54,79–82]. Food wastage clashes with the increasing costs of intensive agricultural practices. Costs are being paid in terms of loss of soil and fertility, reduction of water supply, threat to biodiversity and pollution from agrochemicals [6–8,19]. For the USA it has been estimated that the energy embedded in wasted food represents approximately 2% of annual energy consumption, which is substantial when compared to other energy conservation and production proposals [80].

(9) Diet balance: Population growth is not the only driver increasing the demand for agricultural products. Higher pressure is exerted by the increasing per capita consumption and changes in diets leading to the consumption of more livestock products by people in newly industrialized countries such as China, India and Brazil [3,45,83]. Referring to the average American diet with meat, Pimentel and Pimentel [3], and Pimentel [84] estimate that a vegetarian diet of an equivalent 2200 kcal per day (referring to The Food and Drug Administration, which recommends an average daily consumption of 2000 kcal for females and 2500 kcal per day for males), requires 33% less fossil energy, much less than the average American is consuming today. Reducing the caloric intake would significantly reduce the total energy expended for food production as well as help lessen the obesity problem [3,83].

(10) Energy: The global share of energy used in agriculture is less than 5% of all primary inputs, ranging in affluent societies from as low as 3%, in the United States, and as high as 11% in the Netherlands [5]. In contrast, direct and indirect agricultural energy uses claimed about 15% of China's total primary energy supply [5]. About 30%–50% of agriculture energy cost is accounted for fertilizers [3,5,82]. In industrialized countries, however, the energy in the production sector (agriculture) is a small fraction of the total energy cost of food, as most of the energy used by the food system being consumed by post-harvest activities (Table 1). In order to save energy and reduce CO_2 emission related to food production and consumption, it is then important to address the functioning of the whole food system. Pimentel *et al.* [85] estimated that the amount of fossil energy used in the USA food system could be reduced by about 50% with changes in production, processing, packaging, transport, and consumption.

Table 1. Energy input for a 455 g, can of sweet corn in the USA market (from [3] modified).

Energy input	Kcal	% On total
Production	450	15
Processing	316	10
Packaging	1006	33
Transport	158	5
Distribution	340	11
Shopping	311	10
Home	457	15
Total	3038	100

3. Alternative Management Practices

In this section, some promising alternative agricultural practices are reviewed concerning their benefits to preserve soil fertility and reduce the overall environmental impact of agriculture.

3.1. Low Input, No-Tillage Agriculture

Sustainable agriculture must, as defined by the U.S. Department of Agriculture in the 1990 Farm Bill: "over the long term, satisfy human needs, enhance environmental quality and natural resource base, make the most efficient use of nonrenewable resources and integrate natural biological processes, sustain economic viability, and enhance quality of life" [86]. The early idea of a sustainable agriculture was for a farming system that mimics natural ecosystems, and developed in USA in the 1980s (e.g., [87–89]).

Sustainable agriculture should aim at preserving the natural resource base, especially soil and water, relying on minimum artificial inputs from outside the farm system. It should be able to recover from the disturbances caused by cultivation and harvest while at the same time being economically and socially viable [22,34,35,88,90–96]. Sustainable agriculture aims at keeping to a minimum or not used at all agrochemicals (such as in organic agriculture), by adopting conservative practices (crop rotation, integrated pest management, natural fertilization methods, minimum tillage, biological control), which are fully integrated in farm management. Agricultural practices such as no-till agriculture, or minimum tillage, have demonstrated valuable strategy to reduce soil loss and restore soil fertility [16,28,36,91,92]. Soil fertility can be improved also in conventional tillage, by adopting proper farming practices (e.g., using cover crops, leaving residues in the field, avoiding soil compaction, reducing the use of agrochemicals).

Agricultural activities (not including forest conversion) account for approximately 5% of anthropogenic emissions of CO_2 and the 10%–12% of total global anthropogenic emissions of GHGs (5.1 to 6.1 Gt CO_2 eq. yr^{-1} in 2005), accounting for nearly all the anthropogenic methane and one to two thirds of all anthropogenic nitrous oxide emissions are due to agricultural activities [97]. In 2008, in the USA, agricultural activities were responsible for about 7% of total U.S. GHGs emissions in 2008 (with livestock as major contributors) with an increase of 10% from 1998 to 2008 [98]. Adopting conservation tillage (including no-till practices), could reduce GHGs by an important amount [14,15,99–101]. It has been estimated [102] that by adopting sustainable practices, agriculture could offset up to about 20% of total global annual CO_2 emissions. Evidence from numerous Long Term Agroecosystem Experiments indicates that returning residues to soil, rather than removing them, converts many soils from “sources” to “sinks” for atmospheric CO_2 [12,14,101,102]. According to [101], it seems possible that a mix of residues that includes legumes and more recalcitrant materials such as cereal straw or forage crops could result in the greatest stabilization of soil structure.

However, it is to be pointed out that SOM can be increased up to a certain level where it starts leveling-off. Therefore, there is a limit to how much carbon the soil can capture acting as a carbon sink and that conversion to more sustainable agriculture can only represent a temporary and partial solution to the problem of carbon dioxide emissions. Long term solutions concerning GHGs emission abatement should rely on a more general change of our development path, for instance by reducing the overall fossil fuel consumption.

3.2. Perennial Crops

From the 1980s some scholars began suggesting to move from an agriculture based on annual crops to an agriculture relying on the cultivation of perennial crops, order to reduce the detrimental effect of soil tillage; agrochemical usage could be avoided or at least greatly reduced authors. Perennial crops seem to bring a valuable number of benefits [68,87,88,103,104]: (i) with their roots exceeding depths of two meters, can improve ecosystem functions, such as water conservation, nitrogen cycling and carbon sequestration; more than 50% when compared to conventional crops, they are reported to be 50 times more effective than annual crops in maintaining topsoil, reduce N losses from 30 to 50 times, and store about 300 up to 1100 kg C/ha per year compare to 0 to 300–400 kg C/ha per year as do annual crops, and it is believed they could help restrain climate change, (ii) reduce management costs, because they do not need to be replanted every year; so they require fewer passes of farm machinery and fewer inputs of pesticides and fertilizers as well, which reduces fossil fuel use, (iii) required less harmful inputs, herbicide costs for annual crop production may be 4 to 8.5 times the herbicide costs for perennial crop production, so fewer inputs in perennial systems mean lower cash expenditures for the farmer and a greatly reduced environmental impact. Work is still needed, however, to improve yield performances and post-harvest processing technologies capable of utilizing more perennial crops [103,104].

Perennial crops are predicted to better adapt to temperature increases as the magnitude predicted by most climate-change models. Cassman *et al.* [68] report that increases of 3 to 8 degrees Celsius are predicted to increase yields of switchgrass (*Panicum virgatum*), a perennial forage (used as hay or grazed by cattle) and energy crop, by 5000 kg per ha, whereas for annual species yields are predicted to decline (e.g., maize—1500 kg per ha; soy-bean—800 kg per ha; sorghum—1000 kg per ha).

3.3. Organic Farming

A different alternative to conventional agriculture has been proposed and implemented by the organic agriculture movement. Organic agriculture is regulated by international and national institutional bodies, which certify organic products from production to handling and processing [105–110]. The origins of organic agriculture can be traced back to the 1920–1930 period in North Europe (mostly Germany and UK) [30,111–114], and it is now widely spread all over the world.

Preserving and enhancing soil health is at the core of organic farming. To preserve soil fertility organic agriculture relies on a number of farming practices that take fully advantage of the ecological cycles. In organic farming systems, soil fertility is enhanced by crop rotation, intercropping, polyculture, cover crops and mulching. Pest control is achieved by using appropriate cropping techniques, biological control and natural pesticides (mainly extracted from plants). Weed control, in many cases the main focal problem for organic farming, is managed by appropriate rotation, seeding timing, mechanic cultivation, mulching, transplanting, flaming, *etc.*, [15,73,112,115].

Soil characteristics are generally site-specific, but to date many studies have proven organic farming to perform better in preserving or improving soil quality with regards to both biophysical (e.g., SOM, stored nutrients) and biological (e.g., biodiversity) properties (e.g., [30,99,116–130]). It has also being reported that the combined application of organic resources and mineral fertilizers may represent a viable approach to address soil fertility decline in sub-Saharan Africa [131].

Although few in number, important long-term studies concerning SOM content and soil characteristics in organic and conventional soils have been carried out, both in USA and Europe [30,116,121,124,129]. Organic farming resulted in significant higher SOM content along with other better biochemical performance indicators and soil erosion was greatly reduced, with an erosion rate that differed up to 4 times [124].

Techniques to reduce N loss and to increase the efficiency of N uptake are widely used in organic farming, and many trials demonstrate the benefit of organic farming in reducing N leaching and increasing N uptake efficiency [99,117,132,133]. Possible drawbacks from organic fertilization have been reported by some authors (e.g., [2,134–136]): the "slow release'' of nutrients from organic compost or green manures can be difficult to control and harness and may fail to match crop demand, resulting in N losses through leaching and volatilization. Moreover, in organic systems, competition with weeds can greatly reduce N intake efficiency [135].

Sustainable agricultural practices can be effective in improving water use efficiency in particular in poor developing country affected by water scarcity [93,92]. Long-term crop yield stability and the ability to buffer yields through climatic adversity will be critical factors in agriculture's capability to support society in the future. It has been estimated that for every 1% of SOM content, the soil can hold 10.000–11.000 liters of plant-available water per ha of soil down to about 30 cm [13]. A number of studies have shown that, under drought conditions, crops in organically managed systems produce higher yields than comparable crops managed conventionally. This advantage can result in organic crops out-yielding conventional crops by 70%–90% under severe drought conditions [122,124,137–139]. The primary reason for higher yield in organic crops is thought to be due to the higher water-holding capacity of the soils under organic management, up to 100% higher in the crop root zone [13,116,122]. Others studies have shown that organically managed crop systems have lower long-term yield variability and higher cropping system stability [12,138].

A number of works [30,123,140,141], reports that organic farming is usually associated with a significantly higher level of biological activity, represented by bacteria, fungi, springtails, mites and earthworms. In a Swiss long-term experiment [119,121,127], soil ecological performance was greatly enhanced under biodynamic and organic management. Microbial biomass and activity increased under organic management, root length colonized by mycorrhizae in organic farming systems was 40% higher than in conventional systems, and biomass and abundance of earthworms were from 30% to 320% higher in the organic plots as compared with conventional. Concerning soil health, Briar *et al.* [126] conclude that transition from conventional to organic farming can increase soil microbial biomass and populations of beneficial bacterivore nematodes while simultaneously reducing the populations of predominantly plant-parasitic nematodes. Soil management is reported to affect pest response. A number of studies report pest preferring plants which have been nurtured with synthetic fertilizer rather than those growing in organically managed soil [30,142–147], and under conventional management natural enemies are also often doing worse probably due to the use of agrochemicals [148].

However, it has to be pointed out that local specificity plays an important role in determining the performance of a farming system (and hold true for management systems in general): what is sustainable for one region may not be for another region or area [138,149]. This is relevant to understand both the unifying principles of soil response over large scale [150], and across different land-use types [71]. For example, in highly densely populated areas of Asia it may be difficult to give up chemical fertilizers without posing a risk to food security. Still sound techniques could be employed to limit the use of harmful (and costly) pesticides, prevent soil erosion and protecting biodiversity [36,73,151–154].

The benefits associated with the adoption of organic farming practices have been questioned by many authors to different degrees; I refer to Gomiero *et al.* [30] for a review of the discussion. Although yield in organic agriculture is generally lower (20% or more) than that from conventional farming [30,155,156] (but there are long term studies which prove that the yield can be comparable (e.g., [124]), still it is important to conduct more research in that direction in view of the foreseen higher cost of agricultural inputs (along with the increasing cost of energy), and the need to preserve the fertility of the soil. It has also to be pointed out that the assessment of agriculture cannot be limited to yield or commodities production, or account only for farm investment and revenue [30,149]. Other key issues have to be accounted for, which are generally missed such as: water consumption, biodiversity preservation, reduction in the use of agrochemicals, energy consumption and GHGs emission.

4. Conclusions

Intensive farming tends to exacerbate soil erosion and loss of soil organic matter, posing a threat to the long term sustainability of agriculture, especially under extreme climatic events such as droughts.

Work is urgently needed to improve the overall efficiency of the agricultural and food system, in a way that reduces the pressure exerted on the environment and on the soil. For that we have to simultaneously deal with a number of different and complex problems of widely different nature: environmental, social, economic, technical, cultural, educational, *etc.* We cannot think to save our soil if we keep treating it as a factory, sticking to a "fuel in–food out" model. Soil is not a machine, it is a living being of astonishing, and still largely unexplored, complexity. To seriously address the soil issue, we should agree that it is necessary to rethink the structure and functioning of the whole food system to start with. Social policies (e.g., education, women empowerment, microcredit, participative extension and health programs) should be undertaken in order to improve the livelihood conditions of those affected by poverty and high demographic growth.

Farming techniques able to effectively reduce soil erosion, while preserving and enhancing fertility, have been developed and are adopted by farmers in many different regions. Reduced tillage and organic farming, along with a shift to perennial crops are providing promising results and should be further explored and researched, particularly concerning weeds and pest control. To date many studies have proved organic farming to perform better than conventional in improving soil quality regarding to both biophysical (e.g., SOM, stored nutrients) and biological (e.g., biodiversity) properties. Critics may be right in pointing out some inherent limits of organic agriculture (e.g., lower yield). The sustainability of the food system, however, has to be addressed from many different perspectives, in a holistic way, and with a long term perspective in mind. Given the crucial role that food production (and then agriculture) plays in our life, our major concern should be to secure that farming practice guarantees the resilience of our food production system ("*The ability of a system to maintain productivity in spite of a major disturbance, such as caused by intensive stress or a large perturbation*" [157], p. 723). More work has to be done to acquire knowledge about the comparative sustainability of different farming systems. Adaptive measures to cope with climate change should treasure knowledge gained from organic and other alternative farming practices. Extensive experimentation should be conducted to gain better understanding of the complex interaction among farming practices, environmental characteristics and agroecosystem resilience.

Eventually we should be willing to reconsider our relation with the land and rethink the structure of our food system in view of increasing its sustainability. That implies to work in parallel also on the social, economic and political dimensions of our society. I wish to conclude with the words of Aldo Leopold (p. 226 in [158]) "*Perhaps the most serious obstacle impeding the evolution of a land ethic is the fact that our educational and economic system is headed away from, rather than toward, an intense consciousness of land*". It is time to go back to the foundation.

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Conflicts of Interest

The author declares that there are no conflict of interest.

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