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Biodiversity and Sustainability

Odo Primavesi
Brazilian Agricultural Research Corporation—Embrapa, São Carlos, São Paulo, Brazil

INTRODUCTION

Currently, the discussion on sustainability and biodiversity is focused at the level of the economic, agricultural, and policy sectors. However, there are different interpretations about this discussion, depending on the point of view of the party presenting the argument. In this text, a global view is given to better understand the specificity based on the ecological principles that runs nature. These principles remain today as the source of inspiration and reference for the development of useful concepts to promote life and its quality.

BIODIVERSITY

What Is Biodiversity?

The United Nations Convention on Biological Diversity (CBD) defines biological diversity as "the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems."[1] Table 1 brings the global measured and estimated biodiversity in the world ecosystem.

Diversity is considered at different levels, between individuals, subspecies, species (most useful level), biological communities, and ecosystems. Species richness increases from colder to warmer latitudes. This is also true for the deep-sea species diversity.[2]

The biological diversity is organized in a food web, with plants as base and humans as top of the pyramid, and where the individuals act as producers or consumers, or as recyclers or decomposers.[3]

The soil is one of the most diverse habitats on earth and contains one of the most diverse assemblages of living organisms, mainly in the humid tropics. For example, a single gram of soil may contain millions of individuals and several thousand species of bacteria.[4] Table 2 brings a 100 × 30-cm-deep soil life in a pasture under temperate climate, remembering that in tropical conditions there is a greater presence of termites, ants, larvae of beetles, and flies (Table 3). But in a broader view, it is advisable to consider soil as the undissociable soil–plant interaction. This will improve the degree of soil biodiversity, including, e.g., the rooting system architectures or the so-called weeds, which are visible indicators of the degree of soil health.[5]

In both natural and agricultural ecosystems, the different groups of soil biota interacting with plants (Table 4) and their debris (Table 5) are responsible for, or strongly influence, the soil properties and optimize processes, including soil genesis, soil structure, carbon, nutrient and water cycles, agrochemical movement or breakdown, plant protection and growth, etc.[3,6] They act in processes of synthesis or production, transformation and decomposition, or consumption of organic material, affecting abiotic and biotic components, transportation, and soil engineering.

Therefore soil biodiversity is a ground stone for sustainable agriculture and it could be used as a good indicator nf agro-ecosystem or soil health. Soil biodiversity does not necessarily refer to the number of individuals or species, but to the ratio of functional groups (Table 6) and the result or the tool of their activities, such as the presence and intensity of enzymatic activity.[5]

What Is Its Importance?

In general, the arguments for biodiversity conservation and their importance are optimized environmental services (water cleaning up, recycling, biodegradation, soil permeabilizing, fertilizatioa, etc.), food supplies, natural products, materials, medicines, fertilizers, pesticides, biological control agents, warning signs, genes, model systems for science, interesting wildlife, future options.[2] Considering the process nature uses to develop a site or to recover its resting soil, it could be seen that biodiversity is the key tool used because it allows the complementary activity of individuals with different structures, needs, wastes, and functions to flourish in one of the diverse habitats created by the diverse iateraction of the abiotic and emergent biotic factors occurring in this site. Nature uses biodiversity to produce the maximum of life and biomass per square meter and the available energy unity per year. But biodiversity is also the result of this

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Table 1 Global Diversity of Species

Groups		Cataloged	Estimated	Note
Total		1.4 million	5–50 million	
Mammals		4,000	90–95%	
Reptiles and amphibians		10,848	90–95%	
Birds		9,040	94–100%	2–3 times in the tropics
Fishes		19,056	83–100%	
Plants		322,311	67–100%	
	trees	(50,000)		estimated for the tropics
Invertebrates		1,020,561	3–27%	
	beetles			40% of arthropods
	hemipterans	78,656	37.5%	10% of all insects
Microorganisms		5,760	3–27%	

(From Ref. [1].)

settlement process of nature. At the same time, nature, by developing a short food chain into a complex food net, allows for a greater food availability and diversity for the individuals on the top of the food web or food pyramid, such as the humans, and also ensures their sustainability. When biodiversity of the food web is disrupted by the establishment of a monoculture and when the environment is submitted to a degradation process, with malnourished plants and greater meso- and microclimate variability, the population outbreak of the more resistant members of the food web may occur as the so-called parasites and pathogens.[5]

The reason for the species richness of the tropics is not known. Some ideas proposed are the longer time to develop a new species, greater supply of solar energy allowing more biomass production, or more organisms per unit area.[2]

Furthermore, the shallower soils in temperate climates show a greater chemical fertility, water-hold capacity, and clay activity, and the cold switch off of biological activity will control it. In tropical conditions, the deep soils with low fertility, low water-hold capacity, low clay activity, and the higher temperatures throughout the year, will result in a greater number of interactions of water/drought × water table depth × nutrient × temperature × strong rains × wind × fire × photoperiod × oxygen (because of faster respiration rates); therefore habitat variability occurs, with specificities settled in by the different plant species, the first component of the food web. The diversity of litter, defense substances, and root exudates produced by these different plant species and correlated fauna need to be recycled by a greater number of invertebrates and microorganisms in soil, because of their specificity in producing from 1 (bacteria) to 4 (fungi, insects) degradation enzymes. The high recycling activity in soil need to be considered because of the great importance of organic material (50–90%) as nutrient source for higher plants, besides the microbial activity of rock solubilizers, N-fixing bacteria, or root surface expanding fungi (Mycorrhizae): biological fertility. In the tropics, with the great variability of habitats, the biodiversity of species and genes is the keystone for high biomass yield per high variable unit area, making the food net of an ecosystem very complex.

Table 2 Soil Fauna Number and Weight Under a Pasture in Temperate Climate

Groups	Minimum	Maximum	Optimum	Weight (g) of the optimum
Protozoa	–	–	1,551,000,000	10
Nematoda	1,800,000	120,000,000	21,000,000	40
Acarina	20,000	400,000	100,000	10
Collembola	10,000	440,000	50,000	20
Formicidae	200	500	–	–
Oligochaeta	600	2,000	800	400
Enchytraides	10,000	200,000	200,000	26
Mollusca	20	1,000	50	30

(Dunger, 1964; Kevan, 1965; from Ref. [5].)

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Table 3 Soil Macroinvertebrates (number/m^2) in Tropical Environment, at the First 10-cm Layer, Under the Litter

Groups	Semideciduous forest		*Brachiaria* pasture	
	Dry season	Rainy season	Dry season	Rainy season
Isoptera (termites)	0	746	4,344	362
Formicidae (ants)	1,091	99	1,059	48
Annelida (rainworms)	48	51	174	253
Coleoptera (beetles)	35	32	123	11
Coleoptera larvae	29	32	22	16
Diplopoda	96	35	21	45
Chilopoda	74	0	16	3
Arachnidea (spiders)	29	35	19	10
Hemiptera	0	0	54	14
Mollusca (snails)	70	80	3	0
Thysanura	23	0	17	0
Crustacea	3	0	8	8
Lepidoptera larvae	10	0	2	0
Blattodea	3	0	3	0
Dermaptera	0	0	0	2

(From Ref. [7].)

° Biodiversity reaches the maximum level when the environment offers enough water and energy and low-to-medium level of nutrients, such as nitrogen and phosphorus, avoiding the very hard inter- and intraspecific competition from some more responsive or demanding species, occurring in high-fertility and very high fertility soils, or the growth-restrictive conditions in very low fertility soils, such as soils with high aluminum content.

Table 4 Effect of Wheat Rhizosphere on Microbial Population in Soil, Under Temperate Climate

Microorganism	Number	
	Soil far from root	Soil next to root surface
Total	57,700,000	1,121,000,000
Fungi	120,000	1,160,000
Protozoa	990	2,410
Algae	26,900	4,500
Nitrifier	100,000	100,000
Denitrifier	140,000	12,650,000
Ammonifier	1,800,000	100,000,000
Sporogenic bacteria	575,000	927,000
Aerobic cellulolytic bacteria	2,700	720,000
Anaerobic cellulolytic bacteria	1,800,000	9,100

(Katznelson, 1948; from Ref. [5].)

SUSTAINABILITY

What Is Sustainability?

In 1987, the World Commission on Environment and Development established a definition of sustainability, known as the Brundtland Report. It stated that sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs. Although this definition has become widely publicized, the term sustainability is not limited to one precise definition.[8]

Several authors have discussed the real meaning of sustainability and sustainable development.[6,9] Munoz[10] has presented a theoretical model of true sustainability or sustainable development ideas with global to local implications based on the need to balance social, economic, and environmental goals; stakeholders's interests; issues to induce or determine fairer or more appropriate development solutions, options, and actions. However, the social component can be seen as part of the environmental component, and the interaction of both will generate the economic component. So the environmental component is the keystone, and only its improvement and quality will allow us to reach a stable social welfare and sustainable economic profit.

What Is Nature Teaching Us?

Nature teaches us that the development of a natural primary environment (rocky) or degraded (soil in rest for

Table 5 Physiologic Groups of Microbes in Soil, Incubated With And Without Composted Rice Straw, Fertilized With Ammonium Sulfate

	Number per gram of incubated soil			
	Straight after mixture		Four-month incubation	
Microorganism	**Without straw**	**With straw**	**Without straw**	**With straw**
Total bacteria	800,000	500,000	250,000	800,000
Total fungi	750,000	1,400,000	750,000	900,000
Aerobic N fixing	0	0	25	13
Anaerobic N fixing	7,500	45,000	2,500	95,000
Nitrifiers	450	450	110	16
Nitritefiers	45	95	600	2,500
Ammonifiers	4,500,000,000	9,500,000,000	5,000,000,000	4,500,000,000
Aerobic cellulolytic	300	1,500	2,500	2,500
Anaerobic cellulolytic	115	950	250	2,500
Reducing sulfobacteria	250	1,500	250	2,500
Oxidizing sulfobacteria	2,500	2,500	250	950
Organic S mineralizers	0	0	9	0

(Inamatsu, 1974; from Ref. [5].)

some years to restore its productive potential) area, to an on-soil-based natural climax environment (mainly forest), with a high production potential, occurs with the development or restoration of a permeahle soil, protected by a diversified vegetation with an active rooting system, and the return to soil of diversified organic material, the energy source for the diversified and active soil life. The soil vegetation and associated biodiversity interaction could improve the available resident water of a site and a longer water cycle. The more resident water, the more vegetation and the more permeable the soil. With more available resident water-permeable soil-diversified vegetation and soil life (WSB), there is an increase of relative air humidity and a decrease of the maximum temperature and the thermal amplitude, characteristic for desert environments. This friendlier mesoclimate helps more sensible plant and animal species to establish, and improves biodiversity, with their additive and emergent characteristics.

Table 6 Soil Fauna Ratio Changes with Soil Degradation in the Tropics

	Acarina		Collembola		
Biotype	**Number**	**%**	**Number**	**%**	**Ratio**
Ripparian forest	57,242	79.5	10,123	14.1	5.65
Dryland forest	49,749	78.1	11,509	18.1	4.32
Brachiaria pasture	56,144	63.7	26,973	30.6	2.08
Sunflower field	23,144	55.5	15,485	37.1	1.49

(Maldague, 1961; from Ref. [5].)

Ecology considers desert ecosystems sometimes as sustainable as tropical forest ecosystems. So what level of environmental sustainability is desirable? The biological carrying capacity (BCC) is considered as the representative of this level. It represents the concept of primary productivity of an ecosystem, or the rate in which energy is stored by photosynthetic or chemosynthetic activity of the producer organisms as organic substances, food for the food web.[3] The biological carrying capacity considers also, e.g., the feeding capacity of grazing animals (0.5 or 6 animal units of 450 kg live weight/ha yr) or grain-equivalent available for humans (4 or 16 persons/ha yr, with a minimum need of 1000 cal/day), calculated as available digestive energy or calories per surface unit and year. The biological carrying capacity depends on the recovering capacity of a site to produce biomass, after yield, extraction, degradation, or pollution activities. Considering the exuberant flora and biomass production by the Amazonian forest, the question arises: Which is the BCC of the mostly sandy soils in the Amazonian basin without that vegetation and the aggregated or dependent mesoclimate? Something similar to the Sahara? This examples show that the BCC may be managed in a certain range and sustainability improving the tripod WSB. Considering that the main objective of all human activity, from global to local scale, is to promote life and its quality, mainly the human one, the key tool in the economic system, as producer and consumer, the environmental sustainability will be reached when the BCC is adequate to supply the minimal health life requirements of a given

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human population. The increase of the BCC level will allow a rise in the human population density. What is currently occurring is the destruction of the main natural resources—WSB, the decrease of the BCC with an increase of the human population density. If nothing is carried out to revert and/or prevent such destruction, then a global disaster with acute local consequences is possible.

CONCLUSION

Looking for the macroscale procedures nature uses to develop the BCC of a sustainable site and its sustainability implications, it could be seen that the increase of resident water, the production or restoration of a surface-protected permeable soil, and the development of a diversified flora and fauna is reflected on the whole biodiversity of the soil macro-, meso- and microlife and the soil–plant complex. These procedures, based on ecological principles, need to be globally forwarded/passed to the whole human population through formal and informal environmental education programs, to increase the awareness of their vital tie to the environment and to the need to improve or maintain its health to guarantee life and its quality for the current and future generations.

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