Scientific registration n° : 75
Symposium n° : 45
Presentation : poster

Soil Preservation and the Future of Pedology
La Conservation des Sols et le Futur de la Pédologie

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Soil care is integral to the existence of the Soil Sciences. Over the past century, most of the emphasis on soil care has been toward the wise use and maintenance of soils for agriculture and pastoralism, activities that can broadly be categorized as *soil conservation*. Yet, another role of the Soil Sciences is to derive an understanding of natural soil processes in non-agricultural landscapes. These two activities are, in my estimation, coming into conflict as agricultural and urban expansion (partially fueled by improved science and technology) are rapidly diminishing many undisturbed soils around the world. I suggest that there is a critical need for the Soil Sciences to adopt *soil preservation* - preservation of soilscapes (both undisturbed and agricultural) - as a new, and intensive, soil care effort - an effort critical to the future our Science. In this paper, I present a scientific rationale for soil preservation, and review current literature related to rates of soil loss, and discuss issues pertinent to soil preservation.

Nature of Pedology

Pedology, in the American usage of the word, can be viewed as the study of soil properties and processes *in situ* on the landscape. It is but one of the several recognized branches of the Soil Sciences (e.g. soil chemistry, soil physics, etc.) but it is arguably the only one whose very existence depends on the availability of undisturbed soils for study. Stated differently, Pedology is largely a historical, and observational, science. While there are certainly great experimental research opportunities in Pedology, and also many pressing opportunities for research in disturbed landscapes, it is the "natural" soils (i.e. non-human disturbed landscapes) that provide the theoretical framework on which the science exists.

Soils, the objects of study in Pedology, are historical objects, representing the end result of natural experiments that have been on-going for thousands to millions of years. The age and events - i.e. the historical contingencies (Phillips, 1998) - that shape this mantle vary greatly from place to place, producing an almost infinite array of soils. It is possible that the set of factors that form any soil are unique and singular, and that exact examples of any modern soil have not occurred in the past nor can they be repeated again in the future. While soils are defined in numerous ways in our textbooks, their historical nature continues to be poorly emphasized. The recognition of these qualities is critical in efforts to develop conservation and preservation strategies.

The paradigm of Pedology (e.g. Jenny, 1941) states that any change in one of the factors of soil formation inevitably leads to a new, or at least different, soil. The scientific literature is filled with case studies of changes in soil properties (organic matter, structure, hydraulic properties, etc.) brought about by cultivation, pastoralism, industry, and urbanization. The changes brought by these activities greatly change the ability of the soil to be used to understand any number of natural processes or the relationship of the soil with its natural environment. Jenny (1984) referred to agricultural soils as "domesticated soils", a term that allows us to split soils into two great classes (domesticated and undomesticated) and to view soils in an analogous manner to living organisms.

The issue critical to the future of Pedology is the diversity, and areal extents, of the earth's soils in both domesticated and undomesticated states. Today, a primary factor determining the extent and future of domesticated soils is global urbanization. For undomesticated soils, urbanization, combined with continued agricultural expansion, are major processes which control the quantity of remaining undisturbed soils. Quantitative information on the rates of loss of each of these soil types is only partially available, the greatest amount of information being available on urbanization of agricultural soils. The issue of loss of remaining undisturbed soils is only beginning to receive attention, and I will address this issue with a few qualitative examples. However, before we proceed into these issues, the concept of soil diversity must be addressed, and the means by which it is quantified in various regions must be discussed.

Soil Diversity

Conceptually, it is well accepted that soil forms a continuum at the earth's surface . Although soils vary greatly from one location to another, the spatial changes may occur either abruptly, or nearly imperceptibly, along these gradients. Soil surveys worldwide have attempted to break this continuum of soils into defined classes based on soil profile characteristics using various soil classification schemes. As a result, the concept of what constitutes an individual soil type varies somewhat from one country or agency to another, and from one soil map scale to another.

Despite sometimes significant differences between approaches, there is an international commonalty of views as to what constitutes significant differences between soil types. This shared vision provides a basis for quantifying both the total areal extents of various soil types world wide, and the percentages of each soil type in natural states, and in cultivated, urban, and other land uses.

The difficulty in using existing data of global land use to estimate decline in natural soil diversity is that, as I will discuss below, land use change is quantified by biotic type (i.e. vegetation). While it should be possible to merge soil and these biotic-based data bases, this work (to my knowledge) remains to be undertaken. Next, for the purposes of illustrating the importance of the loss of soil diversity, I review several recent compilations of the percentages of the earth now in agriculture and in urban uses.

Losses of undisturbed soils

As mentioned, compilations of natural soil loss have not been made, but ecosystem-based analyses have been undertaken as various maps and remotely sensed data are digitized and analyzed. A widely quoted (Williams, 1994; Graetz, 1994) compilation of pre-human and present-day ecosystems is that of Matthews (1983), who compiled a global land use data base using approximately 100 published sources complemented by satellite imagery (Table 1).

Table 1. Estimated changes in the areas of the major land-cover types between pre-agricultural times and the present (x 10^6 km^2)(Table 2 from Graetz (1994) derived from data from Matthews (1983)).

Land Cover Type	Pre-agricultural area	Present area	% Change
Total forest	46.8	39.3	-16.0
Woodland	9.7	7.9	-18.6
Shrubland	16.2	14.8	-8.6
Grassland	34.0	27.4	-19.4
Tundra	7.4	7.4	0
Desert	15.9	15.6	-1.9
Cultivation	0	17.6	+1760.0

As the data illustrate, certain biomes have been more preferentially utilized for cultivation than others, in particular the grasslands have been more heavily impacted, in terms of both total area and percentage of the total.

What remains is for these data bases to be over-lain on world soil maps in order to develop a sense of the loss of specific soil classes to agriculture. Qualitatively, we know that certain biomes and soil types are likely to be severely impacted. As an example, the former tall grass prairie of the Great Plains of North America has almost been completely converted to crop production, and attempts to locate undisturbed soils in these areas for scientific study are difficult. In some portions of this area, we have found that cemeteries contain the last remaining undisturbed landscape segments (Kelly et al., 1991).

Urbanization of agricultural soils

Concern over the loss of agricultural soils to urbanization is a long-standing issue. However, as Imhoff et al. (1997) note, obtaining accurate estimates on the amount of land devoted to urban use, and the rate of urban land growth, has proven to be difficult.

In the United States, the Natural Resource Conservation Service has initiated a long-term monitoring program to estimate land use changes. This data base has been used in recent compilations to emphasize the role of urbanization in the reduction of high quality farmland in the United States (Sorenson et al., 1997). Estimates of urban land globally appear varied (Douglas, 1994), due to differences in definition of urban lands and in different data bases used for comparison. Douglas (1994) estimates that 247 x 10^6 ha of the world are now in urban areas.

Imhoff et al. (1997) have developed a unique means of compiling urban land areas based on nighttime city light footprints obtained from satellite imagery. Using this data base, these authors: (1) showed that about 2.7 % of the USA is urbanized (agreeing well with independent estimates) and (2) that by overlaying the city lights data on the FAO soil map of the USA, that urbanization is preferentially concentrated on certain soil types (up to 50 to 70 % of some FOA soil types are now in urban use). This innovative GIS-based approach using satellite data and soil inventory data reveal the important concept that human alteration of the landscape is not evenly dispersed, and that many soil types are far more susceptible to change than others. The expansion of this approach to the globe is critical to both assess urbanization, as well as cultivation, effects on soil types.

Arguments for Preservation of Soil Diversity

Many of the issues relevant to soil diversity are shared by those concerned with biodiversity. Ehrlich and Wilson (1991), argue that the preservation of biodiversity is important for 4 reasons: ethical, aesthetic, economic, and earth sustainability. To these 4 reasons, all relevant to soil diversity, I will add a fifth: scientific. Below I briefly discuss these reasons for soil preservation as a means of establishing a dialogue as to why we should consider this issue as being important in the Soil Sciences.

Ethical reasons for preservation: Homo Sapiens is but one of up to 30 million animal species on Earth, but today it essentially has altered or nearly controls the many of the planet's biogeochemical cycles (Vitousek et al., 1986). Ehrlich and Wilson (1991) argue we have a moral responsibility to protect the other inhabitants of the planet, and by extension, their environments (including soils).

Aesthetic reasons for preservation: Aesthetic arguments for preservation would seem to ring true primarily for plants and animals, those components within our field of vision and comparable in size to human beings. However, solid scholarly arguments have been advanced for aesthetic value of soils (Jenny, 1968; Jenny and Stuart, 1984). With respect to soil aesthetics, Jenny (Jenny and Stuart, 1984) said: "Well, soil appeals to my senses...As yet, neither touch nor smell sensations have been accorded aesthetic recognition, but colors delight painters, photographers, and writers...Warm brownish colors characterize fields and roofs in Cézanne's landscape paintings of southern France, and radiant red soils of the tropics dominate the canvases of Gauguin and Portinari...I have seen so many delicate shapes, forms, and colors in soil profiles that, to me, soils are beautiful. Whenever I offer this reaction to an audience, I notice smiles and curiosity, but when I follow up with slides that depict the ebony black Mollisols of Canada, titian-red Oxisols of Hawaii, and gorgeous soil profile paintings by such famous artists as Grant

Wood of Iowa, Dubuffet of France, and Schmidt-Rotluff of Germany, the hesitancy turns into applause."

Economic reasons for preservation: There can be no argument that the preservation of our presently cultivated (domesticated) soils is of utmost importance to the preservation of our species. We are an increasingly urban species which relies on the growing and uninterrupted flow of food from agriculture. The economic-based arguments for natural soil preservation have not received as much thought or analysis. Several economic arguments can be advanced here. First, there is a growing recognition that new generations of medicines and chemicals may be derived from here-to-fore unsuspected plant species. Large expanses of natural landscapes are needed to preserve the biodiversity required to sustain a stock for these products, and these landscapes by default also include the soils. However, one might even extend this argument to the soil itself. We know almost nothing about the geographical distribution of soil microorganisms and their metabolic abilities. Yet it is from the soil that some of our greatest antibiotic success stories - streptomycin for example - have come (Logan, 1995). The number of other useful products derived from the soil microflora and fauna, as just an example, are entirely unknown and may hold enormous potential in future medical and agricultural research.

Earth sustainability reasons for preservation: Complete undisturbed ecosystems (soils, plants, animals) are part of the great biogeochemical fluxes that have made, and continue to make, the Earth habitable for humans. The general importance of soils in these cycles is well recognized, but the quantitative role is at best poorly known as Soil Science research slowly shifts from agricultural applications to global geochemistry. Through soils pass many of the trace gases of our atmosphere - particularly CO_2 (Amundson et al., 1997), and changes in the proportion of undisturbed soils have had, and continue to have, and profound effect on the CO_2 concentrations of the atmosphere (Sundquist, 1993). Weathering processes and exchange reactions in soils likely have the major control on the chemical composition of the streams and rivers of the world, ultimately affecting the chemistry to the ocean. While numerous cases studies from today's scientific literature will support the view that soils are major components in global water chemistry , the importance of this function may have been best summarized by DaVinci, nearly 500 years ago (Richter, 1970): "It has been said that the saltiness of the sea is the sweat of the earth".

Scientific reasons for soil preservation: From a purely self-serving perspective as a scientist, I argue that study of undisturbed soils and soil processes constitutes the "raison d'être" of pedology. Undisturbed soils are needed for Pedology to function as a science in order to (1) understand the type and rate of natural soil forming processes and (2) to provide a benchmark for human alteration of the environment. As we continue to reduce many of the soil types of the world, or eliminate them completely, we leave a diminished set of natural experiments for ourselves and our scientific progeny. We have much, or nearly everything, to learn about soil processes and properties and how they control the world we live in and how they can tell us about our past and help us evaluate our future.

Conclusions

In this paper, I have advanced the argument that as pedologists we live in perilous times. We can rightly make the claim, now that we are beginning our second century, that we are a bona fide branch of the natural sciences with a certain degree of maturity. Yet, despite our growing legitimacy as a science, the very objects of our study (soils) are disappearing at an alarming rate. Stemming the rate of this loss will only occur from support initiated by the scientific community, support that will require both education and political action.

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Keywords: preservation, biodiversity, pedology, anthropic soils
Mots clés : conservation des sols, biodiversité, pédologie, anthropisation des sols