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HUMANITY'S TRANSFORMATION OF EARTH'S SOIL: PEDOLOGY'S NEW FRONTIER

Daniel deB. Richter Jr.

Pedology was born in the 18th and 19th centuries, when soil was first conceived as a natural body worthy of its own scientific investigation. For well over a century, pedology explored soil as a system developed from a complex of natural processes. By the mid-20th century, however, human activities began to affect substantial global soil changes with influence on the dynamics of the Earth's environment. Such anthropedogenesis was first defined as "metapedogenesis" by Yaalon and Yaron (1966), a definition that we propose here to be as important to the development of pedology as the natural-body concept of soil first articulated by Dokuchaev and Hilgard more than a century ago.

In this article, we distinguish between humanity's contemporary and historic influences on soil, as it is increasingly important for ecosystem analysis and management to distinguish contemporary changes that are overlain on those from the past. Although our understanding of global soil change is strikingly elementary, it is fundamental to establishing greater management control over Earth's rapidly changing ecosystems. Humanity's transformation of Earth's soil challenges scientists to develop a pedology with broad purview and decades' time scale, a pedology that supports the science and management of the environment, ecosystems, and global change. (Soil Science 2007;172:957–967)

Key words: Pedology, metapedogenesis, anthropedogenesis, Anthropocene, soil acidity, Earth system science, global change science, the Critical Zone.

FOR millennia, humanity has worked hard to domesticate "wild" soils to meet core human needs (Bouma and Hole, 1971; Hole, 1974; Buol et al., 2003). Over half of Earth's soils are currently cultivated for food crops, grazed and managed for hay, and periodically logged for wood. Increasing fractions of Earth's soil are manipulated for residential, industrial, transportation, and recreational development; altered in hydrology; chemically contaminated; and used for waste disposal. A complex history of human impact is accruing within soils, as new changes are overlain on those from the past.

Like it or not, we live in the Anthropocene age (Crutzen, 2002), an age defined by the global scale of human impacts on the environment, and most especially the soil. Geologists now consider humanity to be the Earth's primary geomorphologic agent (Hooke, 2000; Wilkinson, 2005). Global soil change (Arnold et al., 1990) is significantly altering the Earth's carbon cycle (Houghton, 2003), nitrogen cycle (Vitousek et al., 1997), and climate system (Robertson et al., 2000) and seriously degrading water quality (Schlesinger, 1997). A recent review of agricultural and urban land uses in the United States indicated about 5% of US soils were at risk of "substantial loss" or "complete extinction" (Amundson et al., 2003), an area that would be greatly enlarged if historic uses and misuses of soils were included with those of the present. Although it is easy to view the many human-driven changes of Earth's soil as degradation (e.g., Trimble, 1974), humans alter soil in positive ways as well (Craft et al., 2003). If humanity is to succeed in the coming decades, we must interact much more positively with the great diversity of Earth's soils.

Duke University, Durham, NC. E-mail: drichter@duke.edu.

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The objectives of this article are to evaluate how human activities are transforming Earth's soil and the science of pedology, and how a decades' scale pedology can greatly improve scientific understanding of soil and help establish management control over global environmental change. The growth and evolution of pedology are evaluated from its time as a basic, natural science that was narrowly focused on soil as a slowly changing natural system, to its present and future as a broadly interdisciplinary environmental science that quantifies and predicts human-affected soil and soil-environment change on decadal time scales. This article aims to encourage the pedological community to redouble and expand the work of its pioneers (e.g., Hilgard, 1860; Darwin, 1882; Dokuchaev, 1883; Jenny, 1941, 1961; Bidwell and Hole, 1965; Yaalon and Yaron, 1966), to further integrate humanity as agents of soil formation, and to quantify soil responses to human influence with small margins of error.

To organize this article, we use four historic perspectives, that of (1) the origins of pedology as a basic, natural science, (2) some subsequent misconceptions about soil's rate of change, (3) the recent acceleration of human-forced global soil change, and (4) the transformation of pedology in response to global soil change. These perspectives lead to the conclusion that pedology will make critical contributions to environmental science and management in the decades ahead, especially as it integrates humanity into its core concepts and develops a broadly based interdisciplinary approach to soils and the environment, ecosystems, and global change.

ORIGINS OF PEDOLOGY AS A BASIC, NATURAL SCIENCE

Pedology is deeply rooted in the 18th and 19th centuries, and its birth as a science was marked by soil's conception as an "independent natural body" worthy of its own scientific investigation (Jenny, 1961). Many persons helped originate this natural-body concept of soil (Tandarich et al., 2002), including F.A. Fallou (1862) and C. Darwin (1882), but it was the prolific American and Russian scientists, E.W. Hilgard (1860) and V.V. Dokuchaev (1883), who most spurred the development of the young science (Jenny 1961). Hilgard (1860) opens the second half of his famous report on Mississippi soils with the question, "What is soil?" and replies that he is mainly interested in the natural processes that have created *virgin soils* [Hilgard's italics]. Similarly, Dokuchaev's ideas are evident even today including the five natural soil fashioners: geologic material, climate, organisms, geomorphology, and time (Jenny, 1941, 1980; Brady and Weil, 2002; Buol et al., 2003; Evtuhov, 2006).

Ironically, throughout pedology's development as a basic, natural science, it has been supported by one of the most applied of sciences, that of agronomy. Dokuchaev, for example, mapped large areas of Chernozems on the Russian steppe for agricultural land valuation and taxation and by so doing formulated his classical ideas about how the natural environment creates soil (Evtuhov, 2006). Similarly, Hilgard became expert on the agricultural potential of the United States' soils across the old cotton belt from the Carolinas to California. Even still, what endures most about Hilgard is his articulation of soil as "a distinct segment of nature, possessing its own internal organization, genesis, and dynamics, and deserving scientific inquiry and classification" (Jenny, 1961).

That pedology developed as a basic science over most of its lifetime is documented well by textbooks. From 1937 through 1990, for example, eight editions of the popular soils text authored by Lyon, Buckman, Brady, and Weil, promoted pedology as a basic science. In the 1946 edition by Lyon and Buckman, pedology was defined as "soil science in its most restricted form," a science that aims to "consider the soil purely as a natural body…with little regard for practical utilization." In fact, until well into the 20th century, nearly all pedology articles and texts mentioned little or nothing about the human role in soil formation (e.g., Byers et al., 1938). Viewed from today's perspective, pedology overemphasized the natural environment to the exclusion of humanity's influence (Dudal et al., 2002; Ibáñez and Boixadera, 2002).

Yet the emphasis on the natural environment was understandable, given how daunting the tasks for pedology have proven (e.g., Richter and Babbar, 1991; Lal and Sanchez, 1992). Natural soil-forming factors range so widely that Earth's potential spectrum of soils seems virtually infinite. Pedology's task according to some is to explain and predict "the most complex biomaterial on the planet" (Young and Crawford, 2004). Pedologists throughout history have found soils to be extremely diverse and heterogeneous on local to global scales, "the most complex and unparsimonious of all natural science entities," according to Johnson (2005). To modify a quote attributed to the biologist, J. B. S. Haldane, the extreme diversity of beetles *and* soils suggests that the Creator has inordinate fondness for both.

Making pedology's task more challenging still are the time scales over which soils function. Soils can be destroyed and reinitiated in a moment's passing, due to the abruptness of floods, mudflows, wind storms, volcanic ejecta, or tectonics, and yet soil formation also plays out over incredibly long sweeps of time. Youthful soils are found on stream terraces stable for a few decades or even on 10,000-year-old glacial deposits. Ancient soils are distinguished if they develop and survive for millions of years on geomorphically stable landforms. With soils ranging so widely across space and time, it is entirely understandable why early pedologists focused on natural soils and soil-forming factors and considered humanity to be more an interruption than a part of the process of soil formation.

SOIL'S RATE OF CHANGE

The tendency for many soil properties to persist over long sweeps of time is significant to humanity. The long-lasting fertility of some soils is well documented in long-term soil experiments, perhaps nowhere better than in the Magruder Plots in Oklahoma, where following conversion from native prairie to cultivated crops, high crop yields were maintained by net mineralization of organic N for 65 years without N fertilization (Webb et al., 1980). At Rothamsted in southern England, in the world's longest running soil experiments, soils have supported continuous crops with increasing yields from the 1840s to the present (Poulton, 2006). In fact, humanity has used soil for agricultural and engineering objectives and relied upon the decade-to-decade and even century-to-century continuity found in the soil as a productive system.

Traditional pedology has mainly emphasized the slow rate of change (Norfleet et al., 2003), as an array of soil components are conceived to be use-invariant or to be fixed, inert, recalcitrant, resistant, refractory, unavailable, nonactive, occluded, passive, or simply nonlabile, all labels that emphasize stability and marginalize the dynamics of large fractions of the soil system. As land uses intensify and data from long-term soil experiments accumulate (Richter et al., 2007a), the rate dependence of changes in soil properties is being directly observed, and much of what has previously been conceived as being slow to change is in fact relatively dynamic from decade to decade. On time scales of decades, anthropedogenesis can rapidly alter acidification and salinization; organic matter dynamics; translocations of solutes, colloids of silicate clay, organic matter, and Fe and Al oxides; and redoximorphic features, surface charge properties, aggregation, porosity, gas and water relations, and even rooting depth and texture (Table 1). Expanded, more coordinated use of long-term experiments can greatly help quantify human forcing of soil properties and process (Richter and Markewitz, 2001).

Recognition that soils are dynamic components of ecosystems has been slow in coming (Binkley, 2006). In part, this is due to soil's difficulty in sampling, extreme heterogeneity, and notable absence of many research sites that study the same soil for more than a few years at a time (Stone, 1975; Richter and Markewitz, 2001). Soil dynamics are also masked by soil's large mass, buffering, and thresholds (Chadwick and Chorover, 2001), and soils' remarkable redundancy of biotic species and nearly unimaginable biogeocomplexity. Nevertheless, in recent years, many soil properties and processes are being documented to be dynamic on time scales of decades, and no longer can soils be taken to be mainly static in their organization and processes. A number of long-term soil experiments (Gerzabek et al., 2001; Richter et al., 2007a) and repeated soil surveys (Bellamy et al., 2005) provide evidence for soil change on relatively short (i.e., human) time scales (Table 1). Given that some of society's most important scientific questions concern the future of soil, for example, whether soil productivity for crops can be doubled in the next 50 years, or whether soil-management control can be established to minimize adverse effects on the atmosphere and water far greater attention needs to be paid to quantifying how Earth's soils are changing over time scales of decades (Table 1).

GLOBAL SOIL CHANGE

Revisiting classical conceptual models of soil systems, such as those of Simonson (1959) or Yaalon (1971), makes clear how humanity is simultaneously altering inputs, translocations, transformations, and removals, the result of which is anthropedogenesis (Fig. 1). Soil is an

TABLE 1

Soil properties grouped qualitatively according to rate of change in response to human forcings such as common agricultural and forestry practices, regional air pollution, alterations of hydrology, or climate change. Three patterns are evident: soil properties that are *dynamic*, i.e., that may change significantly in response to human forcings over time scales of decades; *slowly dynamic*, i.e., that may change significantly over centuries; and *persistent*, i.e., that may change only over multimillennia

Dynamic, 10 y	Slowly dynamic, 10^2 years	Persistent, $>10^3$ y
Organic carbon (Smith et al., 1997)	Fe/Al oxides	Non-pH–dependent charge
Acidity and salinity (Markewitz et al., 1998)	Stabilized humic substances	Texture
pH-dependent surface charge (Sollins et al., 1998)	Illuvial clay	Rock volume
Bulk density and porosity (Rachman et al., 2003)	Occluded fractions of C, N, P, etc.	Duripans and Plinthite
Bioavailability of macronutrients, trace elements, and contaminants (Bradbury et al., 1993)		
Aggregation (Six et al., 2004)		
Redoximorphic features (Richter et al., 2007b)		
Infiltration and hydraulic conductivity		
Rooting depth and volume		

open thermodynamic system, and humanity is increasingly subjecting soil to a wide range of forcings, all with poorly quantified results. We have a too elementary understanding about rates and trajectories of soil change in this new Anthropocene age (Grossman et al., 2001).

As the 20th century progressed, the growing awareness of the Earth as a global ecosystem (e.g., Vernadsky, 1926; Thomas, 1955; Hutchinson, 1970; Odum, 1971) motivated critical thinking about human relations with the Earth's biosphere and soil (Brantley et al., 2006; Wilding and Lin, 2006). Although Marsh (1885) raised concerns about human alteration of the Earth's soil in the 19th century, such alterations began to be quantified by the mid- and late 20th century as human-soil relations were transformed by extensive land conversions, intensified land uses, transcontinental air pollution, thermonuclear testing, and even climate change (Simonson, 1951; Hutchinson, 1970; Schlesinger, 1997).

In response to the growing recognition of global soil change, Bidwell and Hole (1965) and Yaalon and Yaron (1966) forcefully argued that pedology needed to embrace "the vast activities of man." Bidwell and Hole (1965) suggested not only that hunting, gathering, and cultivation were integral components of soil formation, but so too were watershed management and even planning. When Yaalon and Yaron (1966) used the term "metapedogenesis" to describe soil change driven by humanity, pedology became a science with direct application for all the ways that humanity and soils interact with the environment from local to global scales.

Contemporary pedologists conceive of soil differently than did Hilgard (1860) and Dokuchaev (1883) whose pedological frontiers were focused on the natural formation of *virgin soils*. In the Anthrocene age, pedologists are increasingly focused on the science and management of human-affected soils. Because of this shift of focus, Yaalon and Yaron's (1966) metapedogenesis is now seen to be as fundamentally important to the development of pedology as was the original definition of soil as a natural body that is attributed to Dokuchaev and Hilgard well over a century ago.

INTEGRATING HUMANITY INTO A DECADES' SCALE PEDOLOGY

Because the job of the pedologist has always been to provide information about the properties and processes of Earth's soil, contemporary pedologists need not only understand soil as a natural body, but as a historical and cultural body as well (Wells and Noller, 1999; Showers, 2006). The accelerating pace of global soil change challenges pedologists not only to quantify how soils are affected by humanity (Stroganova et al., 1997; Zitong et al., 1999; Schaetzl and Anderson 2005; Galbraith, 2006), but also how human-impacted soils interact with the wider environment. The job of the pedologist has expanded from one attending to Earth's soil as a natural body, to one that includes all of human relations with soils in the global environment.

In the remainder of this article, the immediate need for a decades' scale pedology is

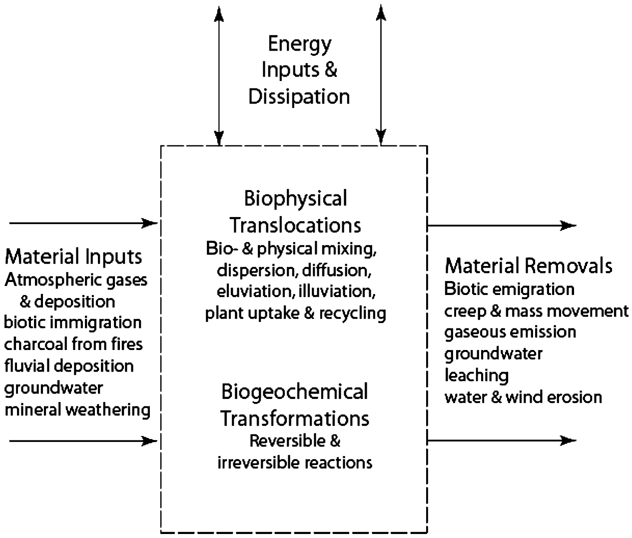

Fig. 1. Soil as an open thermodynamic system controlled by inputs, translocations, transformations, and removals, acting together over time scales ranging up to millions of years (Simonson, 1959; Yaalon, 1971; Schaetzl and Anderson, 2005). Humanity extensively alters all four sets of processes and thereby affects anthropedogenesis and soil interactions with the environment from local to global scale.

emphasized, a basic and applied pedology that includes humanity in its core and one that can quantify and predict patterns and processes of human-affected soil change. With due respect to Lyon and Buckman (1946), pedology can no longer be defined as "soil science in its most restricted form"; in fact, pedology must be defined expansively, as a basic and applied science with the highest "regard for practical utilization." Pedology has today become a broadly interdisciplinary environmental science, a science key to understanding and managing Earth's dynamic Critical Zone (Brantley et al., 2006; Wilding and Lin, 2006).

There are at least four paths for more fully understanding how humanity is altering soil and the science of pedology. Such paths are often in parallel, but a comparison of their similarities and differences may help stimulate hypothesis testing, experimentation, long-term field studies, and modeling, all required of a new decades' scale pedology.

Humanity as Part of the Biotic State Factor

Implicit in the five state-factor theory of soil formation is that humans as *Homo sapiens* are a part of the biota, organism, or organic factor. These ideas were perhaps best developed in the lifelong work of Hans Jenny (1941, 1980), and most explicitly stated in one of Jenny's last papers, "The place of humans in the state factor theory of ecosystems and their soils" (Amundson and Jenny, 1991), a landmark paper that provides a formalistic approach to elaborating human influence, all within the biotic factor of Jenny's state-factor system. As it becomes increasingly clear the many ways that the Earth is entering the Anthropocene age, confining human influence within the biotic state-factor seems to underestimate humanity's reach over ecosystems and soils worldwide. From the prospect of the Anthropocene age (Crutzen, 2002), humanity has outgrown the biotic factor of soil formation.

Humanity Integrated with Each of the Five State Factors

Because human activities are affecting each state factor, human effects can be elaborated more explicitly within each. Bidwell and Hole (1965) followed this reasoning in their consideration of human influence on soil. Humanity, for example, alters *climate* on microscales to macroscales; *biota* by rearranging, promoting, and extinguishing plants and soil biota; *parent material* and *geomorphology* by physically mixing, resorting, and rearranging enormous soil volumes in cultivated fields, wetlands, riparian zones, cities, suburbs, roadways, industrial areas, mine lands, and war zones; and *time* by greatly accelerating the pace of soil change on local to global scales.

While instructive, each of the one-way interactions is actually of much higher order. One example from Bidwell and Hole (1965) will suffice. The one-way interaction of human-climate effects is described in their Table 1 as, "Release of CO_2 to atmosphere by industrial man, with possible warming trend in climate." Viewed from a 2007 understanding of the global carbon cycle, elevated CO_2 affects soils in complex interactions involving not only soil warming (Rustad et al. 2001), but also by stimulating plant photosynthesis and above and belowground respiration (Norby et al., 2005), and CO_2-dependent weathering reactions with soil minerals (Oh and Richter, 2004). Integrating human influence into each soil-forming factor thus diminishes the complexity of human relations with soil. Even Bidwell and Hole (1965) articulated this point when they indicated that much about human influence affects soil in its entirety, in their words, "all five factors of soil formation simultaneously."

Humanity as the Sixth Soil-Forming Factor

In supporting greater recognition for humanity as a primary agent of soil formation, Dudal et al. (2002) adamantly argue that humanity be recognized as a "fully fledged" soil-forming factor. They ask very simply, "Are we a soil forming factor short?" Dudal et al. (2002) wrote that "human influence on soil formation is much more profound than originally perceived" and that human impact "occurs across all 'natural soils' not as 'deviation' but as a component part of the 'genetic soil type'." Contemporary pedologists cannot help but be impressed by what Arnold et al. (1990) call "global soil change" and to wonder about the claim of Dudal et al. that pedology may be "a soil forming factor short."

Humanity as Transformer of Soil Formation

The previous three discussions emphasize how thoroughly the Earth's soil is being modified by humanity. Yaalon and Yaron (1966) propose that human influence creates a new reference system for soil formation, a new pedogenesis altogether, and in the technical jargon of pedologists, "a new t_0 from which a new wave of polygenesis has begun." They suggest that the natural soil body operates as the parent material upon which human-affected changes operate. One appealing aspect of this approach is the forcefulness with which it brings humanity into the core of soil formation, and its emphasis on the many research and education opportunities created by a decades' scale pedology.

SOIL TRANSFORMED FROM NATURAL TO HISTORICAL-CULTURAL BODY

Hans Jenny's (1941) *Factors of Soil Formation* does not separate human activity as a major soil-forming factor. Even still, Jenny is eloquent when describing historic legacies of human influence. Jenny's (1941) drawings and data of the weathering of stones from ancient and long-abandoned castles are particularly moving, and these descriptions contain the beginnings of the concept that soil is a historic body.

The accrual of historical impacts is transforming soil globally from a natural to a historic and cultural body (Bridges, 1978; Showers, 2006). A framework for this transformation is illustrated in Figure 2 and includes three telescoping time scales of soil formation: the multimillennial pedogenesis of traditional pedology, the legacies of human history, and the active human impacts in the contemporary ecosystem. The framework subdivides anthropedogenesis into historic and contemporary dimensions so as to increase pedology's ability to address questions about environmental and global change. One important objective for anthropedogenesis is to explicitly reach out not only to the fields of history and anthropology, but also to all disciplines of the natural and social sciences and humanities with potential interests in the Earth's soil.

The general applicability of Figure 2 is specifically demonstrated with soil changes observed at the long-term Calhoun soil-ecosystem study in the Piedmont of South Carolina. The Calhoun study illustrates how soil has been transformed from natural to historic and cultural body and why the three pedologic time scales in Figure 2 are needed for understanding anthropedogenesis and environmental change. The Calhoun study directly observes biogeochemical changes in soils over 50 years, includes soil sampling and archiving on eight occasions, and documents substantial alterations in soil C, N, P, macro-cations (Ca, Mg, and K) and trace elements (B, Mn, Fe, Zn, and Cu) and in soil acidity and surface charge. The observed soil changes have much to tell us about soil fertility, biogeochemistry, and sustained productivity and about soil's off-site effects on the atmosphere and water quality. The Calhoun experiment also demonstrates how anthropedology requires

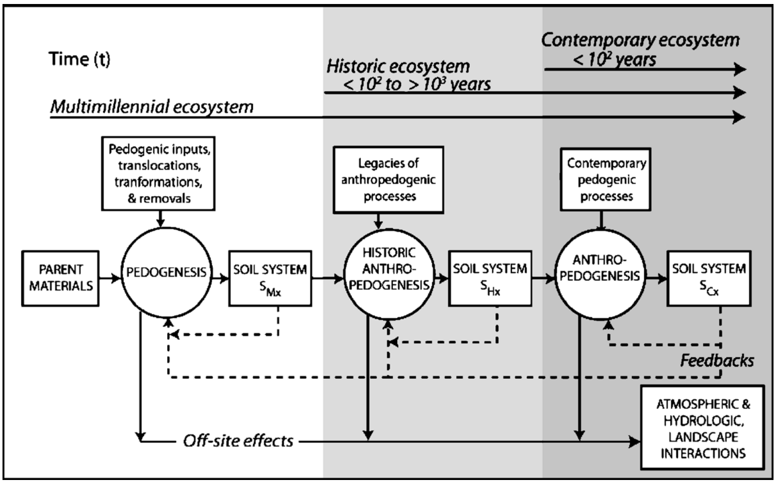

Fig. 2. Framework for understanding contemporary soil change and effects on the wider environment, organized by three ecosystems with telescoping time scales: the contemporary human-affected ecosystem, the historic ecosystem as affected by legacies of human impact, and the multimillennial natural ecosystem. The three time scales suggest nothing about steady state; in fact, the soils for each ecosystem, S_{Mx}, S_{Hx}, and S_{Cx}, are labeled with "x" to suggest soil dynamics in time and heterogeneity across the landscape. The framework recognizes the positive interaction that can be gained between pedology and fields such as history, archeology, anthropology, and many other natural and social sciences and humanities. The framework also illustrates Beckmann's (1984) point that soils are systems with a heritage more than an origin.

information from across three pedologic time scales. The case of Calhoun's recent five decades of acidification is used for illustration of this latter point (Richter et al., 1994; Markewitz et al., 1998):

Contemporary ecosystem acidification: Acidification over the latter five decades of the 20th century is well documented at the Calhoun study by significant decreases in soil pH and base saturation and increases in KCl-exchangeable acidity, $BaCl_2$-TEA acidity, and oxalate-extractable Al (Fig. 3). Acidification has affected the profile deeply, observed throughout the upper 60-cm sampling depths, but is a process that probably extends much more deeply still. These rapid (50 year) biogeochemical changes are driven mainly by the nutritional demands of the growing forest, the soil inputs of acidic pine organic matter, and the nearly 50 years of soil leaching by natural and air-pollutant acids (Reuss and Johnson, 1986, Richter et al., 1994, Markewitz et al., 1998). For example, up to 40% of the increase in exchangeable acidity in the upper 60 cm of mineral soil was attributed by Markewitz et al. (1998) to acid atmospheric deposition, mainly atmospheric deposition of sulfur.

Legacies of agricultural history: The rapid pace of 50-year acidification is however strongly conditioned by the soil's history of agricultural inputs, specifically lime and fertilizers added to grow crops of cotton, corn, and wheat from as early as about 1800 to the mid-1950s. Several lines of evidence indicate that long-term agronomic liming substantially increased soil-exchangeable Ca^{2+} throughout 2 to 3 m of these otherwise acidic Ultisols (Richter and Markewitz, 2001). The development of the 50-year-old pine forest without continued liming consumed the soil's acid-neutralizing capacity, much of which was a historic legacy of cotton management.

Pedogenesis over multimillennia: The acidification of the Calhoun ecosystem is also conditioned by the kaolin-iron oxide mineralogy of this Kanhapludult derived from granitic gneiss. The soil is ancient and is extremely weathered with few weatherable primary minerals within at least the upper 8 m of the surface. During the 50 years of forest growth, removals of soil-exchangeable Ca^{2+} were commensurate with observed soil depletions, and thus Ca removals have readily outpaced resupplies from primary mineral weathering and deep-root uptake (Richter et al., 1994; Markewitz et al., 1998). In an important sense, the recent 50-year trajectory of soil acidification is part of a re-establishment of the Ultisol's deep-seated native acidity (Richter and Markewitz, 2001).

THE FUTURE: PEDOLOGY AS AN EARTH AND ENVIRONMENTAL SCIENCE

About half of the approximately 13 billion hectares of Earth's soil are now converted to human use: cultivated for crops; managed for pastures and hayfields; logged for wood; disturbed by mining; developed for urban, suburban, transportation, industrial, and recreational projects; and used to process burgeoning streams of human and animal wastes (FAO-STAT, 2005). In addition, important areas are contaminated by chemical compounds and materials, and large areas lie in wait of conversion for use or re-use in the coming decades. All of these soils are also being affected by changing climates and increasing concentrations of atmospheric CO_2. The age of pedogenesis has given way to the age of anthropedogenesis.

Our quantitative understanding of how soils are changing over decades' time can only be described as elementary (Richter and Markewitz, 2001, Tugel et al. 2005). External driving forces affected by human impacts alter a wide range of soil properties, and Table 1 demonstrates soil's decadal dynamism. Pedology's scientific frontier

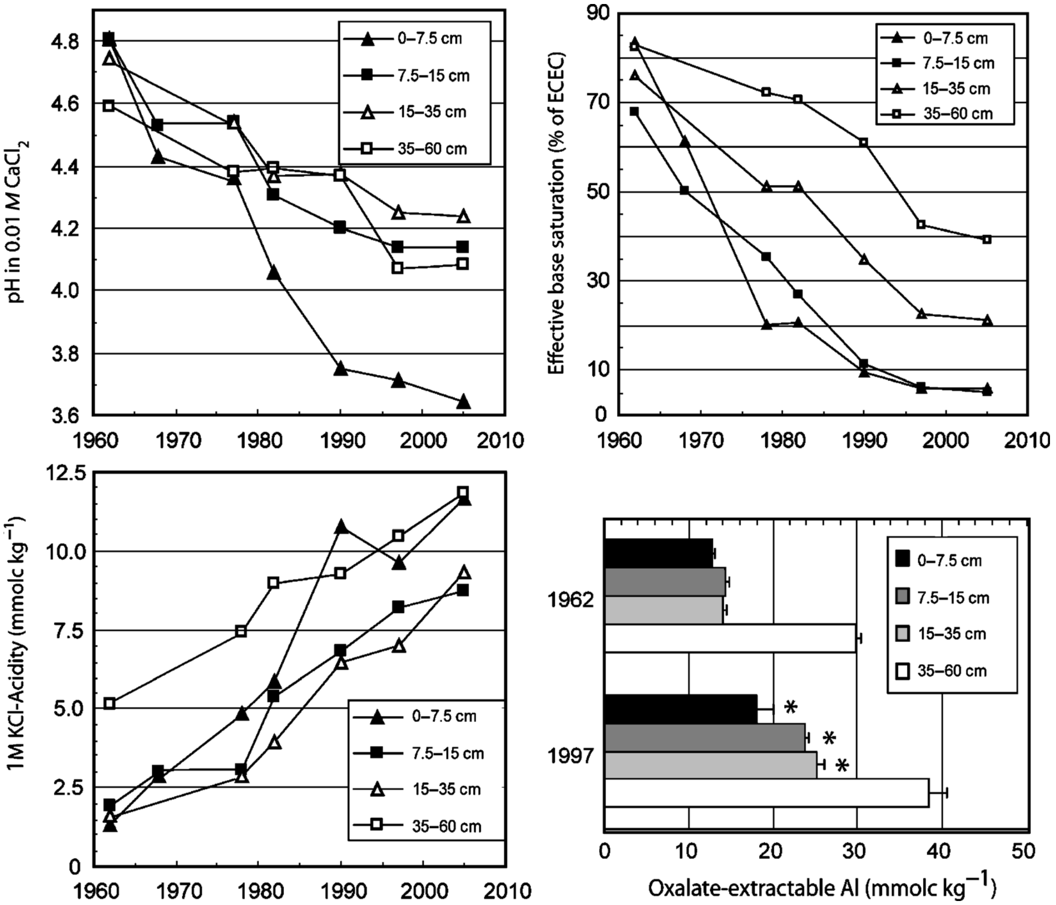

Fig. 3. Five-decade record of soil acidification at the Calhoun Experimental Forest, South Carolina, during the growth and development of a pine forest, 1957 to present. Prior to the pine forest, the soil was periodically cultivated mainly for cotton since about 1800, before which it was under oak-hickory hardwood forest. Properties and processes across all three time scales are required to understand this rapid acidification under secondary pine forest.

lies as much in corn and rice fields, mine reclamation sites, and city parks, as in remote landscapes with *virgin soils* that have had minimal human influence.

Soilscapes with minimal human influence have great intrinsic value for aesthetic reasons and biodiversity and as reference sites for comparison with human-altered landscapes. Contemporary pedologists need to become more greatly involved in land conservation. But with about 10 billion persons dependent on the Earth's soil by 2050 (Bongaarts, 1995), it is more important than ever to shore up our long-term soils-research base that can quantify decadal responses of soils to human influence. Humanity's transformation of Earth's soil challenges scientists to develop a pedology with broad purview and decades' time scale, a pedology that supports the science and management of the environment, ecosystems, and global change.

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