19th World Congress of Soil Science

Symposium 4.5.2
Soil and Human Culture

Soil Solutions for a Changing World,

Brisbane, Australia

1 – 6 August 2010

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Blood, guts, gore and soil: decomposition processes in graves and forensic taphonomic applications

Mark Tibbett[A]

[A]Centre for Land Rehabilitation, School of Earth and Environment, Faculty of Natural and Agricultural Sciences, University of Western Australia, Australia, Email Mark.Tibbett@uwa.edu.au

Abstract
Forensic Taphonomy aims to provide information relevant to the courts in cases where cadavers have been allowed to decompose. Here I consider the cadaver's effects on the burial environment when decomposition occurs on the soil surface or belowground. Significant advances have been made in recent years that have allowed a better understanding of cadaver decomposition, its effect on the burial environment and estimate of post-mortem interval; and these are reviewed in the context of soil-based information. I will propose how established techniques in soil science can be revised for direct applications in forensic taphonomic research that will allow rapid advances in an otherwise understudied field of applied soil science.

Key Words
Cadaver, decomposition, forensic, taphonomy, gravesoil.

Introduction
While the terrestrial environment has been much studied as a decomposition environment for materials of little forensic value such as leaf litter or dead roots (Cadisch and Giller 1997) there is clearly a need for experimental forensic taphonomy to provide rigorously tested information to practitioners and the courts to better understand gravesoils. However, forensic taphonomy must deal with the problem that it is difficult to acquire human cadavers for experimental use. Also, it is impossible to replicate human cadavers. Therefore, it is necessary to conduct field and laboratory based research using human cadaver analogues while continuing to use information from human cadaver decomposition studies and case studies.

Experimental studies of the decomposition of human cadavers under controlled conditions have rarely been carried out. Field studies, occasionally using human bodies (Rodriguez and Bass 1983; Rodriguez and Bass 1985), but more commonly animal surrogates, have been undertaken (Carter *et al.* 2008; Forbes *et al.* 2005; Micozzi 1986; Payne 1965; Payne *et al.* 1968; Turner and Wiltshire 1999). However, knowledge of the decomposition processes and the influence of the environment and edaphic parameters are limited because the primary sources of information are case studies and empirical evidence (Mant 1950; Morovic-Budak 1965; Motter 1898; Spennemann and Franke 1995). As a consequence, edaphic parameters were recognized as having little influence (Mant 1950; Mant 1987; Morovic-Budak 1965) on cadaver decomposition until the early 21st century (Carter *and* Tibbett 2008; Fiedler and Graw 2003; Forbes *et al.* 2005; Tibbett and Carter 2008). Until recently there has been almost no fundamental understanding of the processes of cadaver decomposition in soils based on contrived, replicated and properly controlled laboratory and field experiments (Tibbett *and* Carter 2009); which has made the application of an experimental soils-based approach all the more important.

A soils-based approach and it benefits to forensic taphonomy
Gravesoil is a complex and dynamic system of interdependent chemical, physical and biological processes that influence, and are influenced by, the inclusion of a body and its subsequent decomposition. These can vary by the type of soil (Fitzpatrick 2008) and have a range of eclectic physical, chemical and biological characteristics (Dawson *et al.* 2008). Examples of some basic characteristics of the burial environment that might affect the rate of cadaver decomposition include

- physical texture – whether the soil is sandy, silty or clayey can profoundly affect the rate of decomposition by limiting the movement of gasses and water to and from the site of biodegradation and O_2 demand and waste gas generation (i.e. the cadaver);
- chemistry – the acidity, alkalinity, nutrients and level of contamination of a soil may affect decomposition rates profoundly;

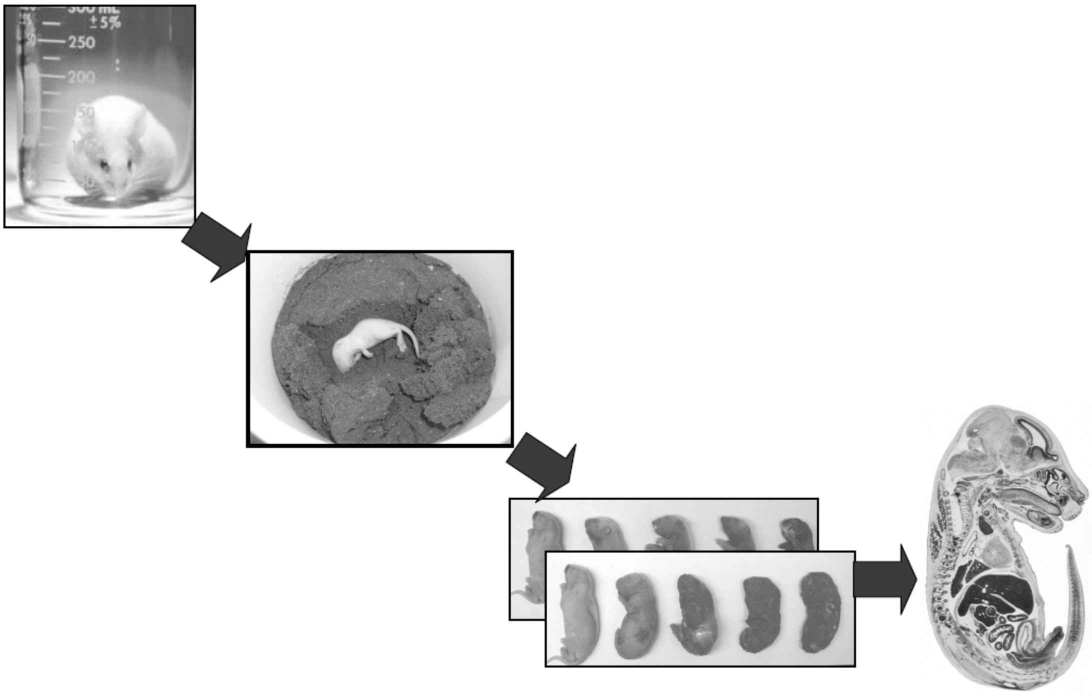

Figure 1. Idealised model for contrived soils-based studies in forensic taphonomy developed from Tibbett *et al.* (2004).

- biological activity – a soil with an active faunal population may have the capacity to decompose cadaveric tissue more quickly (Fiedler and Graw 2003) and soils exposed to cadavers (or potentially simply fertilisation with NH_4^+) previously, may have a community of bacteria and fungi adapted to cadaver decomposition (Carter and Tibbett 2008).

A more detailed understanding of gravesoil processes will likely contribute to forensic science in three primary areas: improved estimates of postmortem interval, postburial interval, and enhanced methods to locate clandestine graves and gravesoils.

Estimation of postmortem interval

An accurate estimation of postmortem interval (PMI) is one cardinal objective central to any medicolegal investigation of death, equal to victim identification and cause of death. Determination of the PMI can direct or re-orientate an investigation by serving to validate or reject an alibi or elucidate the perimortem activities of a victim. Pathology, anthropology and entomology, from oldest to recent, have developed criteria to enhance the estimation of PMI. Traditionally, in early postmortem time the pathologist best ascertained the PMI using the soft tissue indicator of rigor mortis (chemical change to muscle tissue that causes stiffening) , livor mortis (postmortem lividity or hypostasis) and algor mortis (the reduction in body temperature following death) (DiMaio and Dana 2006). As the interval lengthens to include the visual cues of numerous gross morphological attributes of decomposition (i.e., bloating, discoloration, etc.) anthropology has become increasingly astute at PMI estimation by temperature correlation (Megyesi *et al.* 2005). Most successful in estimation of the PMI, overlapping pathology and anthropology, is entomology using the developmental biology of blowflies (Higley and Haskell 2001). Blowfly larvae are at their greatest forensic value up until Advanced Decay (see Payne 1965), which can occur as soon as 10-14 days after death in warmer months. Forensic taphonomy lacks a precise method to estimate PMI once the fly larvae have begun to pupate. This time period that follows Advanced Decay, the extended PMI, is where gravesoil processes will likely have their greatest forensic impact.

Gravesoil research holds promise as it may provide a rapid and reliable technique to estimate PMI and help control for the increasing time error that accompanies extended decomposition stages (Tibbett and Carter 2008; Tibbett and Carter 2009). This is a particular problem in rural areas where bodies can go undetected for several months following death. At present, only the technique developed by Vass *et al.* (2002) can be used to estimate PMI directly following the migration fly larvae. Thus, a great need exists to develop rapid,

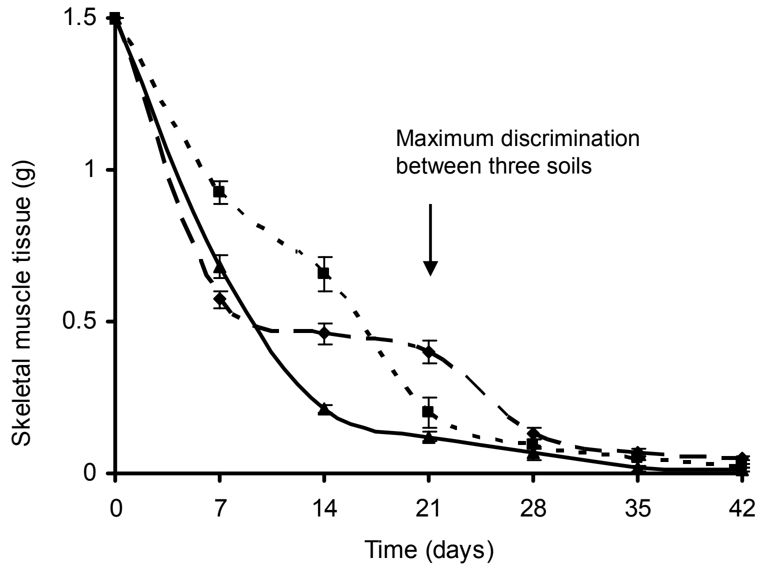

Figure 2. Decomposition of skeletal muscle tissue (1.5 g) as measured by mass loss for three soils over a six week laboratory incubation. Soils were: (i) acidic Podsol (solid line with triangles), (ii) neutral Cambisol (Brown Earth) (dotted line with squares), (iii) alkaline Rendzina (dashed line with diamonds). Note the contrasting decomposition for each soil type after two weeks incubation. Bars equal standard error of the mean, n = 6. Adapted from Haslam and Tibbett (2009).

reliable, and inexpensive techniques that use the biology and chemistry of gravesoil as a basis to estimate postmortem interval (Tibbett and Carter 2008; Tibbett and Carter 2009). For this, I propose the use of contrived soils-based studies in forensic taphonomy (Figure 1). From such studies we are now able to reliably quantify for the first time the effect of environmental and edaphic parameters on cadaver decomposition, and these include soil temperature, moisture, pH and the effect of freezing (Carter *et al.* 2006; Carter *et al.* 2008; Haslam and Tibbett 2009; Stokes *et al.* 2009)(e.g. Figure 2).

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More than dirt: a new view of *Soil and Culture*

Edward R. Landa[A] and Christian Feller[B]

[A]U.S. Geological Survey, 430 National Center, Reston Virginia 20192, USA; Email erlanda@usgs.gov
[B]Institut de Recherche pour le Développement (IRD), Montpellier, France; Email christian.feller@ird.fr

Abstract
Soil and Culture [Landa and Feller (2009)] is the capstone project of the International Union of Soil Sciences' Commission on the History, Philosophy, and Sociology of Soil Science for 2006-2010. This paper will provide an overview of the book, and how it fits into strategies aimed at raising the public awareness of soils and soil science.

Key Words
Soil, culture, art, literature, philosophy, environment.

Enigma

SOIL –beneath our feet
–food and fiber
–ashes to ashes, dust to dust
–dirt

As reflected in a special issue of Science (2004), soil is the final frontier of environmental research. The critical role of soil in biogeochemical processes is linked to its properties and place–porous, structured, and spatially variable, it serves as a conduit, buffer, and transformer of water, solutes and gases. Yet what is complex, life-giving, and sacred to some, is ordinary, even ugly, to others. This is the enigma that is soil.

A cultural history

It has been said "scientific advances do not truly become the possession of a culture until these discoveries are expressed through that culture's art and poetry" (Frodeman 2003). For soils, no such cultural history has been written–that was our goal in *Soil and Culture* (Landa and Feller 2009). The view of "culture" in our book is, however, more expansive, both temporally and topically, spanning to antiquity and beyond just art and poetry. As soil is a key consideration in the everyday life of many, rather than an abstract scientific concept to a few, *Soil and Culture* explores the perception of soil in ancient, traditional, and modern societies. It looks at the visual arts (painting, textiles, sculpture, architecture, film and comics), literary arts (prose, and poetry), religion, philosophy, anthropology, archaeology, stamp-design and wine production. Like soils, humans dwell in the dark, as well as the light. Thus, we have extended the reach to topics such as disease and warfare.

Soil and Culture explores high culture and popular culture–from the paintings of Hieronymus Bosch to the films of Steve McQueen. It looks at the work of ancient societies and contemporary artists. Our contributors delve into the mind of Carl Jung and the bellies of soil eaters. They examine Chinese paintings, African mud cloths, Mayan rituals, Japanese films, French comic strips, and Russian poetry. Like the biodiversity that characterizes soils, we have gathered a diverse pool of contributors– poets, studio artists, gallery owners, farmers, philosophers, historians, geographers, geologists, as well as our soil science colleagues.

Perspectives

Our profession has a big tent, and as well as our specialization, most of us have enjoyed exploring the territories within that tent that are less familiar, as well as the surrounding biological, physical and earth science-realms beyond those tent walls. With *Soil and Culture*, we are now going further from familiar grounds–not on a path of dilution, but rather one of enrichment and new perspectives–to see the realm that we study through other people's eyes. We hope that our readership will include our professional kin and neighbors in science. But we also hope to attract others beyond the neighborhood, and to further the possibilities of dialog beyond those boundaries in the future–soil scientists talking with and working with sculptors, philosophers, painters and environmental historians. The list of human endeavors touched by the soil is immense, and such non-traditional linkages would seem to be fertile grounds indeed.

Our authors delve into the complexity of physical-, chemical- and biological-processes operating in soils, and how soils touch people's lives on a variety of levels–from the intellectual, to the pragmatic, to the spiritual. As Benno Warkentin (1994) has observed: "Because of the importance of soil to life on earth, soil has been viewed subjectively as well as objectively, emotionally as well as rationally." While scientists investigating soils can measure water infiltration pathways and rates, and use gas chromatography to investigate the release of volatile organic compounds, there is also a human component to such processes:

"To dig out the earth was to discover unusual treasures like pieces of colored glass, snail shells, and shard of pottery. To water the earth and see how it absorbs the water we provide is also a unique experience. To walk on the earth after a rainstorm is to be in touch with absolute fulfillment: the earth, satisfied, floods us with its well-being, while its many aromas saturate the air and fill us with life-creating impulses." Reinaldo Arenas (1993)

It is this interface, of soil science and the soil underfoot us all, that our authors explore in *Soil and Culture*.

Outreach

Outreach has become an increasingly important concern to scientific societies and funding agencies. For the environmental sciences, the point is succinctly put by Harrison et al. (2009): "Because of the important role science plays in peoples' lives and the significant (and increasing) impact of humans on the environment, there is a great and growing need to improve links between scientists and society."

Outreach from the soil science community can take many forms. The future of soil science is something we discuss a lot (*e.g.*, Hartemink 2006). Among the recent suggestions on how to better communicate our message of the importance of soils, soil stewardship, and soil science have been greater efforts at attracting liberal arts students to take soil science classes (Peterson 2008), and using the arts and humanities as bridges to greater appreciation of soil and soil processes (*e.g.*, Wessolek 2009; Sauer *et al*. 2009). In addition, a recent (U.S.) National Academy of Sciences report (Steering Committee for Frontiers in Soil Science Research, 2009) notes:

- There is a need to inspire the public about the value of soils.
- Soil science is an undervalued science and soil is an undervalued resource. It is important to raise public awareness of what we do and how soil science can resolve regional and world problems.
- Ecosystem services provided by soil include cultural aspects (aesthetic, spiritual, etc.), as well more traditionally recognized roles (providing food/fiber, water-quality regulation, nutrient cycling, etc.)

We hope that *Soil and Culture* and similar future efforts will aid in continuing efforts to encourage outreach to the broader community, and thinking about soils on various planes of abstraction.

Acknowledgements

Soil and Culture was neither conceived nor developed in a vacuum. It grew from a rich seedbed of interest in the heritage of soil science and the cultural importance of soil to society initiated in International Union of Soil Sciences (IUSS) Commission 4.5 by Dan Yaalon and Benno Warkentin. Their books (Yaalon and Berkowicz 1997; Warkentin 2006) continue to provide us guidance, and are indeed, lasting footprints in the soil. We gratefully acknowledge the support of IUSS Division 4 (Chairperson: Lyn Abbott), and the Division of History of Science and Technology of the International Union of History and Philosophy of Science (Secretary General Efthymios Nicolaidis, and Treasurer Ida Stamhuis).

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Soil art: bridging the communication gap

Alexandra R. Toland[A] and Gerd Wessolek[B]

[A]Institute for Ecology, Dept. of Soil Protection, Technical University of Berlin, Germany, Email alex.toland@fertileground.de
[B]Institute for Ecology, Dept. of Soil Protection, Technical University of Berlin, Germany, Email gerd.wessolek@tu-berlin.de

Abstract
The rise of industrial agriculture paired with a global demographic shift of populations from rural to urban settings has diminished everyday interaction with soil for most members of society. This has led to a deterioration of the aesthetic image and cultural value of soil. Among other efforts to increase soil awareness, concerned artists have been reclaiming the image of soil as a culturally, aesthetically and ecologically invaluable common good. From the early environmental art of the 60s and 70s to more recent artworks on urban and industrial brownfields, soil functions such as growth medium and habitat, archive and contamination filter have become subject matter for artistic expression and public discourse. In the following paper we present soil in the context of the environmental arts movement as well as art in the context soil science. How can art contribute to soil conservation – both with the aim of generating greater public understanding and promoting cultural values, but also by developing creative methods to directly confront problems such as contamination, erosion, or humus loss? Based on a brief review of well-known artworks, a survey of soil scientists, interviews with artists, and our own creative field experiments, we address the use of art in bridging communication gaps between soil conservation and the general public.

Key Words
Soil Art, soil communication, reclamation aesthetics, creative collaboration, interdisciplinary research.

Introduction
Cultural utilization of soil as expressive media, e.g. as pigment (see Ugolini 2010), sculptural or structural material, predates its appropriation for agriculture. While aesthetic uses of soil may be identified throughout human history, the rise of industrial agriculture paired with a global demographic shift of populations from rural to urban settings has diminished everyday interaction with soil for most members of modern society. In the absence of aboriginal or agricultural relationships with the earth, the aesthetic value and cultural context of soil deteriorates and the psychological gap between human populations and the earth widens. The image and identity of soil is reduced to dirt.

Despite this lack of appreciation, current soil conservation relies almost exclusively on soil scientific principles. In so doing, it neglects cultural values and strategies, which could improve human perception and also ideally human treatment of soil. In recent years several publications have addressed this issue by encouraging stronger integration of soil science in education from kindergarten through university (Herrmann 2006; Smiles *et al.* 2000), better public reference tools (Van Baren *et al.* 1998), consideration of social and cultural research (Greenland 1991; Minami 2009; Winiwarter 2006) and the introduction of art as a tool of environmental communication and consciousness-raising (Feller, Lardy and Ugolini 2010; Van Breemen 2010; Toland and Wessolek 2010). This last point is the focus of our present inquiry.

While scientific research provides lawmakers and public stakeholders with numerical analyses and expert prognoses, art plays a vital role in communicating environmental issues to the greater public. Because art is a free, experimental format where ideas can be independently and critically tested before ending up in mainstream media, art can be seen as an *indicator* of shifts in cultural values or norms. If we consider art not only as cultural indicator but also as *instrument*, which can be planned and integrated into public space and urban culture, we can regard art as a resource or *service* of environmental communication and conservation. The significance of art in scientific fields such as information and communications technology, robotics, and materials science is reflected at art festivals such as the Ars Electronica in Linz, Austria and the Transmediale in Berlin, Germany. However, an information gap seems to persist between environmental art and environmental science. Wilson (2002*a*) has suggested that art and science operate as intersecting cultural duties. "Bridging the communication gap" is therefore seen as a cultural duty of both scientists and artists working with soil, in order to improve public awareness and achieve a broader approach to soil conservation. Bouma and Hartemink (2002) have emphasized the need for interdisciplinary research programs to support communication between soil scientists, planers, politicians, and other stakeholders. Yaalon (1996) has similarly suggested the need for soil technology transfer between societies of industrial and developing nations. The cultivation of professional research partnerships is also necessary for accurate knowledge transfer between scientific and artistic disciplines. Organizations such as the Leonardo International Society for the Arts, Sciences and Technology (ISAST), the Art and Science Collaborations Inc. (ASCI), and the Arts and Ecology Program of the Royal Society for the Arts attempt to bridge this divide. International projects such as Cape Farewell and the 350.org campaign have brought together artists, scientists and educators to raise awareness about climate change. Despite many individual examples, no equivalent interdisciplinary program yet exists to address soil conservation issues on a larger cultural scale.

By communicating examples of soil art to a mostly scientific audience, this presentation functions as one step in such a knowledge transfer process. Conversely, we are interested in the creative aspects of scientific research, and how these might inform and enrich artistic practice. Our larger goal is to encourage creative science-art collaboration. Based on a brief review of artworks, a survey of soil scientists, interviews with artists, and our own creative field experiments, we explore opportunities of collaboration, both with the aim of generating greater public understanding, but also by combining methodological expertise to confront problems such as contamination, erosion and stronger legal conservation.

Art-historical context: soil as subject matter

Depictions of soil and geologic forms may be identified in almost all major artistic genres. However, artwork explicitly dealing with soil and soil conservation issues is characteristic to the environmental arts movement spanning over the last 50 years. From the Land Art of the 60s and 70s to more recent environmental art projects, it is important to distinguish between artworks that utilize a symbolic reference to "earth," and those that contextualize "soil" as a geophysical and biochemical body. We introduce soil art as: *art consciously in or with soil or about soil conservation issues, expressed via a wide range of artistic disciplines, resulting in a multisensory aesthetic experience* (Toland and Wessolek 2010*a*).

Two main approaches to soil art should be articulated: artwork that is primarily concerned with the formal aesthetic properties of soils, and artwork that is ecologically restorative and thus "functional." Barbara Matilsky (1992 p. 56) makes a similar distinction between artists who have "proposed or created ecological artworks that provide solutions to the problems facing natural and urban ecosystems," and artists who hone their skills to attract attention or create awareness of environmental issues by "framing the problems through a variety of media…" The early Land Artists, for example, were mainly occupied with aesthetic form, embedding visual symbols from the minimalist and post-modern movements into remote natural settings. Artists such as Michael Heizer, Walter de Maria, Robert Morris, and Robert Smithson provoked new ways of perceiving the environment by bulldozing monumental shapes into the landscape and exhibiting piles of soil and rocks as sculptural works. Around the same time period a more reactionary group of environmental artists, including e.g. Alan Sonfist, Newton and Helen Mayer Harrison, Agnes Denes, and Joseph Beuys, concentrated their artistic efforts on repairing and restoring urban ecosystems.

Art facilitates dialog, afterthought and the transference of new ideas. It has the ability to reach unexpected audiences and provide new perspectives on the environment and our relation to it. While it might be difficult to literally transform equations for preferential flow into meaningful artwork, we may link different *artistic motifs* to specific *soil functions* that most everyone can relate to and understand. In this sense, we may associate human fertility with soil fertility in the works of Charles Simonds, Ana Mendieta or Shai Zakai, or learn to appreciate the archival function of soils in the survey and documentation projects of Betty Beier, Daro Montag, and Marianne Greve.

Despite "a profusion of terms" (Bower 2009), including Land Art, earth art, environmental art, and now soil art, the term *eco-art* historically refers to art *with* and *for* nature as opposed to art simply *about* or *in* nature (Aagerstoun 2007). In areas with weak mitigation policies, eco-art has come to fill a planning void in degenerate landscapes. Land remediation and mitigation is disguised as sculpture and performance art. Some interdisciplinary projects are unique in that they are either initiated by or include artists in solving local and regional environmental problems. For example, the Acid Mine Drainage and Art project (1994 – 2005) in Vintondale, Pennsylvania is a tribute to the cultural and environmental heritage of the mining region. Artist Stacy Levy designed a passive water treatment system, or "Litmus Garden," to help communicate soil processes of buffering and filtration. Initiated by art professors Tim Collins, Reiko Goto and Bob Bingham of the Carnegie Mellon Studio for Creative Inquiry, the *Nine Mile Run* greenway restoration project in Pittsburg, Pennsylvania also addresses complex soil remediation processes. On a smaller scale, artist Georg Dietzler has confronted soil contamination issues by using mycoremediation (*i.e.*, remediation facilitated by fungi) in his long-term installation projects. In works such as *Self-Decomposing Laboratory* (1999) and *Moveable Oyster Mushroom Patch* (1996-1997), Dietzler makes use of the edible oyster mushroom (*Pleurotus ostreatus*) to break down organic pollutants such as PCBs (polychlorinated biphenyls). In a similar bioremediation project, the "Revival Field" (1990 – 1993), artist Mel Chin planted a field of heavy metal absorbing "hypo-accumulators" at the Pig's Eye Landfill in Minnesota. In his most recent project, "Paydirt," Chin launched a public awareness campaign about the high lead content in New Orleans' soils, a problem that has increased long after the floodwaters of Hurricane Katrina receded.

Soil science context: art as vehicle

The examples given above are icons of eco-art. They challenge traditional art forms with the development of a new visual vocabulary, *reclamation aesthetics* (Spaid 2002, p. 109; Toland and Wessolek 2010*b*). As soil resources become scarcer and scientists look for new approaches to soil protection, eco-art and its derivative soil-art might be considered new cultural allies. While relatively more people are involved in the arts than have access to the complicated topics of soil science, a combination of soil science and art could offer soil a new public image (Wessolek 2002). Art may be seen as a "vehicle" to spark interest and promote a wider understanding of the hidden resource beneath our feet. Artistic involvement, however, need not always result in a conventional object or exhibition, but can be seen as a creative phase in conservation, education and public awareness programs. Because cities boast a concentration of cultural and artistic activity as well as acclaimed research and academic institutions, urban soils can be considered a natural starting point for interdisciplinary collaboration. This is reflected in the selection of artworks above, many of which were created in urban and industrial areas. While the field of soil science has traditionally focused on optimizing soil as a resource for the production of food and fuel, city soils have historically been evaluated on different terms – that is, as medium for buildings and infrastructure. An increase in urban ecological research has led to new forms of perception and environmental protection objectives in cities. For example, urban soils offer a unique perspective into history. An archive of war, peace, cultural, and environmental change is preserved beneath our backyards and sidewalks. Urban agriculture and on-site rainwater harvesting have also become important topics for subsistence farmers in developing nations as well as slow-food activists in industrialized nations. The diversity, dynamics and vulnerability of urban soils demand a need for awareness, acceptance and education and thus provide creative stimulus for artistic involvement.

The Department of Soil Protection at the TU-Berlin has been investigating several approaches to art-pedology in recent years. Our own attempts of cultivating art as a vehicle of communication include: a soil and art group that was founded in 2000, the organization of several soil-art exhibitions, and a permanent collection of soil-art on display in the Gorbatschow Building of the TU Campus. In 2007 and 2008, we led a series of creative field exercises in an overgrown urban lot near the TU campus. Landscape planning and environmental engineering students and staff were encouraged to paint their impressions of the site with materials found on or buried in the soil. Since 2002, several thesis papers and three semester-long student projects have also dealt with the topic of soil and art. For example, Andreas Vetter created plans for an urban soil park and Hardy Buhl installed a giant "soil cake" sculpture to demonstrate the remediation of a former wastewater-leaching field. In another example Fritz Kleinschroth and the student project group *Soil Art on Urban Brownfields* created an oversized "ecological footprint" made of onion peels and other kitchen scraps from a city homeless shelter (Figure 1). The footprint was "stamped" on the "Gleisdreieck," a former goods depot in Berlin. A time-lapse video of the disappearing footprint was made to illustrate processes of humification and mineralization. More student films can be found on youtube under: *media, soil, tu-berlin*.

Figure 1. "Ecological Footprint" by Fritz Kleinschroth and the student project group "Soil Art on Urban Brownfields." Time Lapse Documentation of 20 m^2 of food scraps and carrot peels, Gleisdreieck Berlin, 2007.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Bridging the gap: creative collaboration, opportunities, and challenges
To address the idea of creative collaboration between soil scientists and soil artists, we have been gathering opinions from both fields. In 2007, we drafted a questionnaire on soil science, aesthetics and art, which was distributed at the German Soil Science Society's annual conference at a session on soil science, society and education and subsequently carried out at conferences in Australia, New Zealand and China. We asked members to share their opinions about the aesthetic properties of soil and their potential willingness to collaborate with artists. 85% answered that they would be personally willing to cooperate with an artist, while about 64% regarded the interdisciplinary direction of "soil art" as important. The results of this inquiry are included in our contribution to the book *Soil and Culture* (Landa and Feller 2010).

In January 2010 we carried out fifteen in-depth interviews with ecological artists who have worked with soil or soil conservation issues. Artistic formats included sculpture, ceramics, installation, illustration, painting, performance, video, graphic design, interactive or participatory interventions, educational events, and landscape design. Environmental themes included moor degradation, acid mine drainage, rainwater harvesting, urban agriculture, pedodiversity, and coastal reforestation. Given this wide range of soil issues and artistic approaches, the topics of didactic aesthetics and restoration aesthetics came up in almost all interviews. Although most of the artists answered that they thought about content first and then form, about half of the artists felt that art should inspire through innovative form, rather rely too heavily on informative texts or educational props. One artist described her art as a form of subservience – a service to community and environment. Other artists spoke of their work as an ethical or spiritual duty to nature. All but one artist described instances of collaboration, which differed when working with other artists, scientists, city planners and educators. All artists described an interdisciplinary nature to their work and expressed interest in collaborating with scientists, although most had already worked together with scientists and engineers.

We are continuing our inquiry into collaborative science-art research with an extended questionnaire to be distributed in 2010 and 2011 at academic conferences and online venues. Further interviews as well as a more comprehensive analysis of completed interviews are also planned. A list of other projects, organizations, and artists, can be found on our soil arts website, as well online platforms such as the green museum, eco art space and arts and ecology website (see references below). In a contemporary integration of art and science, we must constantly examine the parallels that arise between an ever converging critical art-world and a culturally literate scientific community. This is necessary for any attempt to combine soil science and art. Both fields must inform themselves of the others' developments if they are to take part in constructive dialogue. Conscious cross-referencing and frequent communication is needed. This is not an observation, but a call to action. Professional artists and cultural theorists should be invited more often to academic conferences, into laboratories, and to contribute to engineering and agricultural research, while soil scientists might offer their expertise at environmental art symposiums, exhibitions and seminars.

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Soil in comics

Anne Richer de Forges[A], Frank Verheijen[B], Dominique Arrouays[A], Eric Blanchart[C] and Martial Bernoux[C]

[A]INRA, US 1106, InfoSol Unit, Research Centre of Orléans, 2163 av. de la Pomme de Pin, CS 40001 Ardon, 45075, Orléans cedex 2, France.
[B]National Soil Resources Institute, Cranfield University, Cranfield, United Kingdom.
[C]IRD UMR 210 Eco&Sols, Montpellier SupAgro-INRA-IRD, Bâtiment 12, 2 place Viala, 34060 Montpellier cedex 1, France.

Abstract
Comic strips and cartoons progressively became a respected art form, providing powerful imagery, expression of universal themes, and timely commentary on society. Thus, it is quite natural that the soil appears in comic strips and cartoons. In this paper, we review the various representations of the soil in comic strips and cartoons, structured around the soil functions scheme.

Key Words
Soil, comics, cartoons.

Introduction
From an anthropocentric viewpoint, soil functions can be defined as "the capacity of soil processes and components to provide goods and services that satisfy human needs, directly or indirectly" (after De Groot *et al.* 2002). Despite the use different terminologies, and to a lesser extent, different emphases and subdivisions, soil scientists generally agree on the main, or primary, soil functions. In this paper we investigate how the individual soil functions are portrayed in comic strips and cartoons, before discussing general themes and relative importance.

Soil habitat function
That soil is a habitat is often recognised in comic strips; however, only a small part of this remarkable soil biodiversity appears in comic strips. Most of the characters are macrofauna (mainly earthworms), but other animals, partly dependent on soil for their habitat, also appear (*e.g.*, rabbit, mole, badger, ant, platypus). In addition, numerous imaginary creatures populate the soils in comic strips. Soil, as all natural media, provided a source of inspiration for imaginary creatures and worlds. The fact that the soil is still largely unknown by almost everybody certainly enhances its fantasy potential.

Information function
Most material that primarily concerns the information function of soil can be subdivided into i) archaeology-related stories, *e.g.*, treasure hunting, and ii) comic strips that teach about soil processes or properties. A vast volume of educational comic strips in soil have been produced. Comic strips that primarily aim to entertain (*i.e.*, mainstream comic strips), rather than educate, reach a large proportion of the public. When soil is the topic of a mainstream comic strip, as for example in some Donald Duck stories, awareness of soil is raised with a large part of an age group outside of a school setting. Although more limited in its depth of soil information, this kind of soil information is a valuable aid in raising the profile of soil.

Production function
That the food we eat was grown in soil is something that all of us should be aware of. However, in most cases, cartoons and comic strips that feature the growing of arable crops do not link this to the soil. Tools for soil tillage are sometimes present, the most common of which is the spade. In the few cases where the link between food and soil was made, the soil was treated as a 'black box', *i.e.*, crops grow better in one soil than the other, but the reasons for this remain unclear, sometimes with an almost mystical element to it. Gardening was, by far, the most frequently encountered topic in soil-related comic strips. This is probably explained by the fact that more of us do small-scale gardening than large-scale farming. Of course, all of us eat food produced by, in, or on soil; but being one step removed from the process appears to have resulted in a limited personal association with soil, and, therefore limited coverage in comic strips.

Engineering function
Situations where soil properties and processes are not considered carefully enough, and lead to disaster, are

common topics in satirical cartoons. It is simply assumed that the soil will provide a good quality, stable platform for us and our structures. However, when the performance of the soil is not in check with the structures we have placed upon it, the soil is easily blamed, although in nearly all circumstances, faulty human planning was to blame.

Regulation function

The regulation function was the least encountered soil function in the investigated comic strips. From an environmental point of view, as well as from a scientific position, the interaction of soil with other ecosystem components is arguably the most important soil function of all. However, examples of the regulation function of soil featuring in comic strips proved to be few and far between.

Conflicts between soil functions

In comic strips, such as in other arts, conflicts between soil functions are mainly reflected in land use clashes of interest. Classical examples come from the history of the American West (*e.g.*, extension of the railway, cattle ranchers vs. "sodbusters"). Other numerous examples of conflicts of interest relate to gardening vs. animal habitat (*e.g.*, hunting the moles), or gardening vs. animal activity.

Soil inventory and monitoring

As conflicts between soil functions must be solved, and as soil is a natural resource of common interest that is under increasing environmental pressure (CEC 2006), it is essential that soil inventory and monitoring are undertaken, in order to manage this resource properly. Soil inventory and monitoring are quite esoteric subjects, and as such, are almost never encountered in comic strips. However, from the soil scientist community (newsletters, websites, educational books), comics strips illustrating soil surveyors doing fieldwork are far more numerous. Digging the soil is a very frequent activity in such comic strips and cartoons.

Conclusions

With the rise of the Internet, the use of comics seems to be a growing area, with several initiatives by government agencies and research institutes as part of their public education outreach to help raise awareness of soil as an ecosystem component and a fragile resource. In the more mainstream comic strips, aspects of the production, habitat and engineering functions of soil appear to receive most attention, whereas the regulation function seems to be underrepresented. Compared to the other two main natural media on the planet (*i.e.*, water and air) soil appears to receive relatively little attention in comic strips. For educational comic strips, however, the regulation function, with all its complex interwoven soil biological, chemical and physical processes, may be a fertile source of inspiration.

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The comic strip: a good means of communication on soil!

Anne Richer de Forges[A], Dominique Arrouays[A], Eric Blanchart[B] and Martial Bernoux[B]

[A]INRA, US 1106, InfoSol Unit, Research Centre of Orléans, 2163 av. de la Pomme de Pin, CS 40001 Ardon, 45075, Orléans cedex 2, France.
[B]IRD UMR 210 Eco&Sols, Montpellier SupAgro-INRA-IRD, Bâtiment 12, 2 place Viala, 34060 Montpellier cedex 1, France.

Abstract
Comic strips are a means of communication not much exploited in science of the soil to sensitize the general public. Compared to the other two main natural media on the planet (*i.e.*, water and air) soil appears to receive relatively little attention in comic strips (Richer de Forges *et al.* 2010). In this paper, we present an example of a comic strip focusing on characters belonging to macrofauna (the hero is an earthworm), but other animals, partly dependent on soil for their habitat, also appear (*e.g.*, mole, field mouse, ant).

Key Words
Soil, comic strips, communication, earthworm, macrofauna.

Introduction
Comic strips and cartoons progressively became a respected art form, providing powerful imagery, expression of universal themes, and timely commentary on society. According to a study by the French National Institute for Statistics and Economic Studies (INSEE), more than a quarter of the adult French population read comic strips. The young persons read more comic strips than the others (47 % of the 15-19 years old, 16 % of the 55 to 64 years old, and only 4 % of the 65 and more years old). The men read them more than the women (31% of men, 21% of women) and qualified persons more than those unqualified (52 % of those having the upper level of education and 8 % of those who have no certificate at all). This means of communication can be used to develop soil awareness. In this paper, we present an example of a comic strip focusing on characters belonging to macrofauna (the hero is an earthworm), but other animals, partly dependent on soil for their habitat, also appear (*e.g.*, mole, field mouse, ant).

Soil in comic strip
According to Richer de Forges *et al*. (2010), the soil appears to receive relatively little attention in comic strips. However, soil, as all natural media, may provide a source of inspiration for real or imaginary creatures and worlds. The fact that the soil is still largely unknown by almost everybody certainly enhances its fantasy potential. The soil inhabitants may be a fertile source of inspiration, spokesmen for soil protection, and a means to attract young people toward a soils career.

A new comic strip: the adventures of "Childéric le lombric"
We realised a comic strip based on soil macrofauna adventures. The main message that we want to deliver is that soil is a living, amazing, exciting, entertaining, coloured… world. Nearly all the "real world" soil animal characters that feature in comic strips are earthworms. Other animals, living in burrows, often appear in comic strips. The most frequent one is the mole. Another frequently character is the badger. Most often, soil animals also appear, not as specifically personified characters, but as part of the story. We chose an earthworm as our main hero because it is the most famous animal living in soil. Other characters are soil animals unknown by the general public (*Oribatida* [beetle mites], *Symphypleona* [springtails]…). For practical reasons, we chose deliberately not to take into account real sizes of these organisms.

A Darwin's scenario
In 1838 Darwin published his first paper on earthworms, showing their importance for bioturbation and the burial of surface-lying objects, and placing him as a pioneer of soil science (Brown *et al.* 2003; Feller *et al.* 2003). In October 1881, nearly 44 years after writing his first paper, and about 6 months before his death, Darwin published his last book, "The Formation of Vegetable Mould through the Action of Worms with Observations on their Habits". In this book, Darwin relates his different experiments on earthworms in order to know if they have senses (hearing, smell, view, etc). In our comic strip, these experiments are lived by our heroes who feel like "the prisoners of Darwin". Earthworms also draw conclusions from Darwin's experiments. Their conclusions can therefore differ from Darwin's ones. In this comic strip, we also introduce soil animals that are unknown by the general public.

Conclusion

The power of comic strips to aid in the education seems substantial. Contrary to air and water (and above-ground biology), soil is a visually poor medium, certainly for above-ground dwellers like humans. Comic strips provide a means of visualising the opaque world of soil. Moreover, comic strips are not hindered by issues of scale, i.e. from macro soil fauna to microbial organisms or molecular scale processes. At the same time, the ability to visualise across spatial scales concomitantly implies a responsibility or challenge to take scale into consideration in the education process.

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The representation of soil in the Western Art: From genesis to pedogenesis

Christian Feller[A], Lydie Chapuis-Lardy[A] and Fiorenzo Ugolini[B]

[A]Institut de Recherche pour le Développement (IRD), UMR 210 Eco&Sols, SUPAGRO, Bâtiment 12, 2 Place Viala, 34060 Montpellier cedex 1, France.
[B]Universita Degli Studi, Dipartimento di Scienza del Suolo e Nutrizione della Pianta, Piazzale delle Cascine 16, Firenze, Italy.

Abstract
This communication is a chronological short history of Western art (mainly paintings) from Prehistory to the contemporary period through the word "Soil". The conclusion is that the vision of Soil (in a scientific meaning), as an independent work of art, is recent.

Key Words
Soil, landscape, Western art, paintings.

The websites allowing one to see the artworks are designated as [x] in the text; the links are provided in the references list.

Soil (capitalized) or soil in Art?
It is widely accepted that humans always have considered the natural environment a subject of great interest to art. Early pictorial examples include cave paintings done by Cro-Magnon man during the Upper Palaeolithic, about 30,000-40,000 years ago. However the vision of Soil (in a scientific meaning), as an independent work of art, is recent and still extremely rare in the world of painting. For many years, artists have depicted actual or imaginary landscapes from which the trained eye of a pedologist, agronomist or geographer can recognise a schematic view of what is commonly called soil but not Soil (as a Soil profile). This communication will: (i) show representations of Soil or soil in Western Art from the Palaeolithic to the modern era, and (ii) show some recent artworks where the Soil is considered as the main subject, and has as its goal to present Soil in art from Genesis (the Bible) to Pedogenesis (the scientific approach of the Soil formation, from the Greek word *Pedon* meaning soil) [1, 2].

When soil is depicted by chance in the landscape: the soil as a surface
In the biblical Genesis story of the World creation, the whole of humanity is "soil" as Adam–meaning "soil" in Hebrew–was created from red dust and returned back to it.

To a large extent, representation of soils, as even a single line of soil surface, is neglected in upper-Palaeolithic cave paintings.

The few extremely schematic representations inherited from the Assyrian civilisation (11th to 7th BC) depict natural scenes in which the soil surface is represented by schematic rocks and hillocks, drawn as shaped curves (Parot 1961, p. 40). In Grecian art, very few traces of soil representation have been found, except for frescoes of Aegean art coming from Santorini dating from the 5th century BC (Carli 1980, p. 21). Wall paintings were widespread in the Roman civilisation as decorative art designed in a truly realistic style that would never be seen again until the Early Renaissance. At Pompeii, Nature was represented through flowers and birds, as well as other animals. However, relatively few representations of the landscape stood the test of time (Carli 1980, pp. 12 and 24). They were probably simply lost.

From the Byzantine period of the Early Middle Ages (6th century), many mosaics depicted rocky landscapes. However, between the 5th and 12th century, the representations of soil surface or landscapes are very often strongly schematised with undulating lines or hillocks, as in religious miniatures.

The Florentine painter Giotto (1266-1337) made a decisive break with the static Byzantine style, introducing realism. His paintings of rocky landscapes were among the first that included some perspective. Other Italian painters from the contemporary Giotto's Sienese school developed a similar naturalistic style: Duccio di Buoninsegna (1260-1318), Simone Martini (1284-1344) and the Lorenzetti Brothers (1280/1285-1348).

During the Renaissance, the soil, as a surface, is generally represented in a highly realistic way, even for symbolic and/or imaginary landscapes. Such realism sometimes allows one to discern the Soil profile with different colours given to the surface soil and to deep horizons, as, for example, in the works by Hans Memling (1430-1494) of "The Last Judgment", *circa* 1470 [3] and Hieronymus Bosch with his "St John the Baptist" (*circa* 1500).

When soil is depicted by choice in the landscape: the Soil as a profile

Three reasons motivated the representation of a soil profile: to explain the resurrection of the dead, to display the roots, to show ploughing.

In the "Last Judgment" by Rogier Van der Weyden (1432) the resurrection of dead required the artist to show the Soil profile. The complete painting exhibits numerous such soil profiles.

In the paintings of the Renaissance, the representation of a ditch or a soil cut in a painting served very often as an excuse to picture roots. In the "St John the Baptist" by Hieronymus Bosch (1450-1516) the figure of St John leans towards a sharp vertical exposure of soil which includes a strange large root [4]. A large root also appears in "The Tempest" painted by Giorgione (1477/78-1510) [5] and in "The Fall of Icarus" by Peter Brueghel the Elder (1525-1569), just at right and behind the ploughman. These works were just some examples of paintings in which large forked roots were made evident. The representation of roots was not due to chance, but chosen for its symbolic value and refers the mandragora as suggested by Marjnissen and Ruyffelaere (1987). The perception of mandragora as the subject of superstitions is presented in the "Encyclopédie des Symboles" (1996) through the following comments:

> *Mandragora is a plant with a high symbolic value, inspiring both fear and fascination. Its forked root which crudely resembles the human form has been credited since ancient times with a divine origin. It is considered as a universal medicine. The mandrake grows only at night, releasing some toxins (hyoscyamin, atropin, scolopolamin) with a narcotic effect. For this reason, the root was used by medieval witches to concoct potions, and it played a remarkable role in the occult practices. According to the legend, the root grew only beneath gallows trees as it was believed to be produced from the semen involuntarily ejaculated by a hanged man. It has to be gathered with high caution, and it was said that the mandrake gave forth an extremely piercing and fatal cry. It was uprooted, therefore, by a dog that died immediately after. During Antiquity, the mandrake was considered as one of the attributes of the sorceress Circe. The root was used by the Jews to overcome infertility. In general, mandrake was associated with black and supernatural forces that man would approach with many precautions.*

From the 14th and during the 15th century, especially in the "Très Riches Heures" and the "Calendriers" (calendars), we see representations of agricultural tasks and toils. Here, the soil is depicted with a clear concern of realism and technical specificity, including the tilling of the soil. In addition to this example, Peter Brueghel the Elder (1525/30-1569) might be newly cited for "The Fall of Icarus". Icarus is the tiny figure at the bottom on the right-hand corner, with only his legs visible, while in forefront of the canvas, attention is centered on the good Flemish ploughman tilling furrows. That was the triumph of daily working life over Utopia ("falling from the sky").

The soil by Hieronymus Bosch and his disciples

The work of Hieronymus Bosch (*circa* 1450-1516) abounds in "earth" and "bare soil" representations as it can be seen in the "The Temptation of St Anthony". The soil in Bosch's work was not only represented as a surface, but often either as a Soil profile in a slope cut (see above), or in adobes that are associated with thatched roofs. Here he emphasized the decomposition and decay of the sides of huts, in the same way that plant debris is decomposing on the top of the soil. The whole of Bosch's work is influenced by "decomposition" and soil depiction contributes to this process. The work of Bosch would deserve an independent study of his "soil", or "Soil" vision.

As Hieronymus Bosch is said to have been an inspiration for the surrealist movement of the twentieth century, some Surrealists might be considered as his disciples throughout their vision of soil or earth's uses:

- Salvador Dalí with "Soft Construction with Boiled Beans: Premonition of Civil War" (1936. Oil on canvas. Museum of Art, Philadelphia [6], "The Spectre of Sex-Appeal" (1934. Oil on canvas. Gala-Salvador Dali Foundation, Figueras, Spain [7], or the "Metamorphosis_of_Narcissus" [8];
- Yves Tanguy with the "Extinction of Useless Lights" ("Extinction des lumières inutiles") by (1927. Oil on canvas);
- Jean Dubuffet with "The Magician" by (1954. Slag and roots, including slag base), both on view at The

Museum of Modern Art, New York [9].

The soil, yesterday and today

Paintings during the 16th, 17th and 18th centuries reached realistic excellence in representing the soil surface that could never be equaled. During this period and until the 20th century, artists have not considered the Soil as a chief subject, not even the Impressionists who have rendered it only as a landscape component.

During the 20th century, the soil surface was well represented in the Land Art movement.
Today, soil is depicted as an object *per se* especially by some naturalists, agronomists, pedologists and others who have developed a substantial artistic talent besides their scientist's profession. Many works of contemporary artists–paintings, sculptures, performances, or art installations–centered on the Soil can be seen at Wessolek's website [1].

Conclusion

Our look at soil or Soil in art confirmed that in Western culture, most artists did not view soil as the complex and subtly beautiful medium that holds the interest of agronomists or pedologists. It was usually only considered as a surface. The below-ground layers were generally not represented, while rocks and other natural objects fascinated artists. However, as underlined by Jenny (1968) in his paper's conclusion: *"Whoever said that soils lack beauty is behind the times. Soil in art has arrived. It is an enrichment of art that is here to stay"*.

Finally, it is predicted that we will increasingly see more artists and soil scientists interacting at the interface of their expertise and consciousness, to produce images and objects that will capture the attention of audiences. If a successful exhibition on "The Soil" could be hosted by the Grand Palais in Paris, or the Museum of Modern Art in New York, the soil science texts would surely become best-sellers the day after the opening reception!
Never stop dreaming…

Acknowledgments

The authors thank Edward Landa for his assistance in the English language review and editing of this manuscript.

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[4] http://en.wikipedia.org/wiki/St._John_the_Baptist_in_the_Wilderness.
[5] http://en.wikipedia.org/wiki/The_Tempest_(painting)
[6] http://www.philamuseum.org/collections/permanent/51315.html
[7] http://www.salvador-dali.org/eng/cat1104-2/finici.htm)
[8] http://upload.wikimedia.org/wikipedia/en/2/21/Metamorphosis_of_Narcissus.jpg
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The use of scientific and indigenous knowledge in agricultural land evaluation and soil fertility studies of two villages in KwaZulu-Natal, South Africa

Nkosinomusa Buthelezi[A], Jeffrey Hughes[A] and Albert Modi[B]

[A] Soil Science, School of Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa, Email 204511707@ukzn.ac.za; HughesJ@ukzn.ac.za
[B] Crop Science, School of Agriculture and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg, South Africa, Email ModiAT@ukzn.ac.za.

Abstract
Local people and small-scale farmers have knowledge of their lands based on soil and land characteristics that remain largely unknown to the scientific community. It is therefore important for researchers to understand farmers' knowledge of soil classification and management. To address this, indigenous knowledge was elicited by questionnaires from 59 households in two villages (Ezigeni and Ogagwini), near Durban in KwaZulu-Natal. Farmer vernacular suitability evaluation was compared to scientifically surveyed land suitability maps. Yield was used as a quantifiable indicator to test the effect of fertility management practices. It was found that farmers' soil classification was based mainly on topsoil colour and texture. Slope position was the main factor determining land suitability. Crop yield, crop appearance, natural vegetation, soil colour and texture, and mesofauna were used to estimate soil fertility. Their fertility assessment was found to be more holistic than that of researchers. Despite this, there was a correlation between farmers' indigenous evaluation and scientific evaluation implying that there are similarities between the two approaches.

Key Words
Local knowledge, scientific knowledge, soil properties, crop indicators; organic farming.

Introduction
To secure agricultural sustainability in both subsistence and commercial farming, there is a need to reassess our land evaluation systems that have often failed to improve land use, especially in rural areas where knowledge of scientific logic is lacking. The challenge for scientists is to integrate indigenous knowledge into the scientific approach to achieve high production without compromising resources. The integrated approach will enable farming practices that will not only improve soil fertility but also ensure sustainability to prevent resource base degradation. Although many studies have investigated the potential of integrating indigenous knowledge with the scientific system to improve agricultural sustainability (e.g. Oudwater and Martin 2003; Gowing *et al.* 2004; Cervantes-Gutiérrez *et al.* 2005) there is almost no literature referring to indigenous knowledge of soils in South Africa. The main objectives of this study were therefore to (a) explore indigenous and scientific knowledge systems in terms of land evaluation; (b) compare indigenous and scientific land evaluation; and (c) test farmer soil fertility management and assessment systems using scientific methods.

Study site
The study was conducted in two villages (Ezigeni and Ogagwini) of the uMbumbulu area (KwaZulu-Natal). The area is located inland from Durban at 29° 59' 0" South, 30° 42' 0" East between 394 and 779 m a.s.l. Members of the Ezemvelo Farmers Organization form part of the population of both Ezigeni and Ogagwini villages. This group of farmers was the first subsistence farmer's organization certified to supply organic vegetables to supermarkets. Farmers rely on crop rotation, crop residues and animal manure for soil fertility management. Primary cash crops grown are amadumbe (taro), sweet potatoes and potatoes.

Methods

Indigenous land evaluation
A total of 59 farmers from both villages were interviewed to gain a general background of indigenous agricultural land evaluation and management. A questionnaire focused on local soil classification and its importance in land evaluation. Another questionnaire was produced to gather more detailed information on indigenous soil management from each farmer. The information gathered from both sets of interviews was recorded and analyzed using SPSS version 15.

Scientific land evaluation
A general purpose free survey was conducted at a scale of 1:10 000. Soil forms and families were classified according to the Soil Classification Working Group (1991). Soils were classified for land suitability and capability based on soil form, depth and drainage (Davidson 1992).

Comparison methodology
Scientific and indigenous evaluation systems were compared based on the land suitability classification. The information provided by the scientific suitability maps was compared to the vernacular suitability evaluation provided by farmers. Farmers' fertility assessment was also compared with the scientific perception. Yield was used as a quantifiable indicator to test the effect of fertility management practices implemented by Ezigeni and Ogagwini farmers. This was measured in terms of total biomass of the dominant available crops including maize, amadumbe and dry beans.

Results and discussion
Farmers' indigenous knowledge
There was no significant effect of age and education on the knowledge elicited showing that these farmers provide a platform for efficient and easy transmission of knowledge from old to young people. Farmers in both villages, with a few exceptions, own livestock and practice mixed cropping and rotation systems (below-ground followed by above-ground type of crop) for fertility management. Respondents recommended frequent rotation in taro plots especially when planted in dark soils to avoid reduction in yield. Farmers use kraal manure, stubble mulch and fallowing to replenish depleted nutrients.

Famers' soil classification
Farmers recognized 10 soil types (Table 1).

Table 1. Local soil taxonomy used by farmers of Ezigeni and Ogagwini villages.

Local name	Texture	Colour	Location	Uses
Ugadenzima	Clayey (*ubumba*)	Reddish black	Midslope	Agriculture
Idudusi	Loam (*uthambile*)	Black	Lower slope	Agriculture
Isibomvu	Clayey (*ubumba*)	Dark red	Upslope	Agriculture
Udongwe	Clayey (*ubumba*)	Grey	Footslope	Agriculture
Umgogodi	Clayey (*ubumba*)	Grey	Footslope	Plastering
Isdaka	Clayey (*ubumba*)	Black	Footslope	Agriculture
Umgubane	Gravelly (*ungamatshe)*	Black or Red	Upslope	Construction
Ugwadule	Clayey (*ubumba*)	Black or Red	Upslope	NS*
Isduli	Clayey (*ubumba*)	Black	Footslope	Agriculture
Ugedle	Sandy (*isihlabathi*)	Red	Upslope	Agriculture

* NS – not specified

Farmers were only concerned with the topsoil as they use this part of the profile for their agricultural activities. This follows a trend observed for other local classification systems (Sillitoe 1998). The farmers' classification was based on different soil morphological attributes but soil colour and texture were key properties recognized by over 80% of the farmers.

Farmers' land suitability assessment
In common with scientific evaluation, farmers recognized drainage status and soil depth (referred to as the amount of topsoil) as limiting factors for land use. However, slope was also considered an essential factor affecting land suitability (indicated by 60% of farmers). Farmers preferred footslope soils for agriculture as these are regarded as more fertile compared to upslope and midslope soils. They attributed this difference in fertility to the removal of soil from upslope and deposition downslope resulting in higher nutrient levels in footslope soils.

Twenty percent of farmers used natural vegetation focusing mainly on vegetative growth and species diversity. Consistent with a healthy soil ecosystem, farmers in these villages associated agriculturally suitable land with high species diversity (Mäder *et al.* 2002). Some farmers' land suitability evaluation was based on the differences they observed between the soils in both villages, and hence they used 'villages' as a classification criterion.

Farmers had an understanding of the effect of soil type on land suitability for different crops (Table 2). Farmers have observed the effect of soil type on yield differences between the two villages with higher yields from Ogagwini. Farmers thus regard Ogagwini soils as more fertile because they do not demand high supplementary fertilizer inputs.

Table 2. Crop suitability according to Ezigeni and Ogagwini farmers.

Local name	Fertility status	Principal crops
Ugadenzima	Low to moderate	Potatoes, maize, beans
Idudusi	High	Maize, taro, beans
Isibomvu	Moderate to high	Sweet potatoes, maize, beans
Udongwe	Moderate	Beans, taro
Isdaka	Moderate to high	Spinach, taro
Isduli	Low to moderate	Taro, maize, beans
Ugedle	Low	Potatoes, sweet potatoes

Scientific land evaluation
Soil types mapped ranged from highly suitable, deep, well drained soils to the least suitable, shallow soils. Similar to the indigenous evaluation, scientific evaluation showed that the limited suitability of Ezigeni soils was mainly due to constraints which were rarely observed for the other village. These included soil depth, poor drainage and stoniness. Despite deep soils (> 120 cm), many at Ezigeni had a duplex character. Despite these differences between the villages, Table 2 shows that the soils in both villages are generally suitable for crop production. Moreover, land suitability maps showed higher agricultural potential for the Ogagwini than Ezigeni soils. This correlation between indigenous and scientific approaches shows that there are similarities between the farmers' decisions on land use and those obtained by scientific evaluation and that the two systems share common principles and goals.

Soil fertility indicators
Farmers used a combination of indicators to rate the land as either 'good' or 'bad'. In scientific terms these lands will be either fertile or infertile, respectively. Soil colour and texture were used by 48% of farmers with dark soils indicating higher fertility than lighter soils. The abundance of mesofauna was used by 51% of farmers. Natural vegetation (18%), especially weed growth and diversity observed before planting, also gave a statement about soil fertility. However, the presence of weeds did not always reflect fertile soil conditions and led to errors by some farmers in their fertility assessment. Crop production factors are considered most reliable as they are said to clearly reflect soil fertility differences. These include crop colour and firmness (32%) during the establishment stages and crop yield (70%). This shows that crop yield forms a benchmark for soil quality in the indigenous approach (Gruver and Weil 2006). It is clear that farmer fertility assessment is mainly concerned with food security which is highly dependent on land productivity. Results showed that farmers' fertility perceptions are more holistic than those of researchers.

Yield
Both scientific and farmer suitability evaluation found Ogagwini village to be more highly suitable than Ezigeni. This was further confirmed by yield measurements taken for beans, maize and taro. There was a significant difference ($p< 0.05$) in yield between homesteads. Considering that most of the differences in soils in both villages are inherent, it is possible that yield is more a reflection of management factors. These may include time of planting, weeding, availability of organic amendments, etc. For example, although kraal manure was widely used in both villages not all homesteads own a herd of cattle. There was only one tractor to assist farmers to till their soils at the beginning of the season. This sometimes led to delays in planting as farmers have to wait their turn and for the tractor driver to be available.

Conclusion
Farmers' soil indigenous knowledge is rather abstract when compared to the more commonly obtained scientific knowledge. This is evident in farmers' soil classification which only takes into account the topsoil and extends to the way farmers perceive and assess soil fertility. Farmers' fertility indicators and soil taxonomy are based only on visible soil and crop properties and shows that farmers are more concerned with soil productivity and food security. The farmers' approach is thus more holistic than the approach of scientists. Despite many differences between the scientific and indigenous approaches, results showed that there are many links between these two systems in terms of land evaluation ranging from determination of land use to management issues which are critical components of sustainable agriculture. The farmers' soil

classification and suitability evaluation as well as their fertility assessment correlates with the scientific evaluation. These significant agreements between the approaches imply that there are fundamental similarities between them. The inclusion of indigenous knowledge into scientific approaches will hence lead to the development of land use plans that are more relevant for small-scale farmers.

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