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# Soil -

## *Earth's living skin*

*Earth sciences for society*

*www.yearofplanetearth.org*

Prospectus for a key theme of the International Year of Planet Earth

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## What is this brochure for?

This brochure is a prospectus for one of the main scientific themes of the International Year of Planet Earth.

It describes, in accessible terms, why this particular theme has been chosen - why the research that the Year hopes to support under this theme is of such vital importance to our understanding of the Earth System, and to society at large.

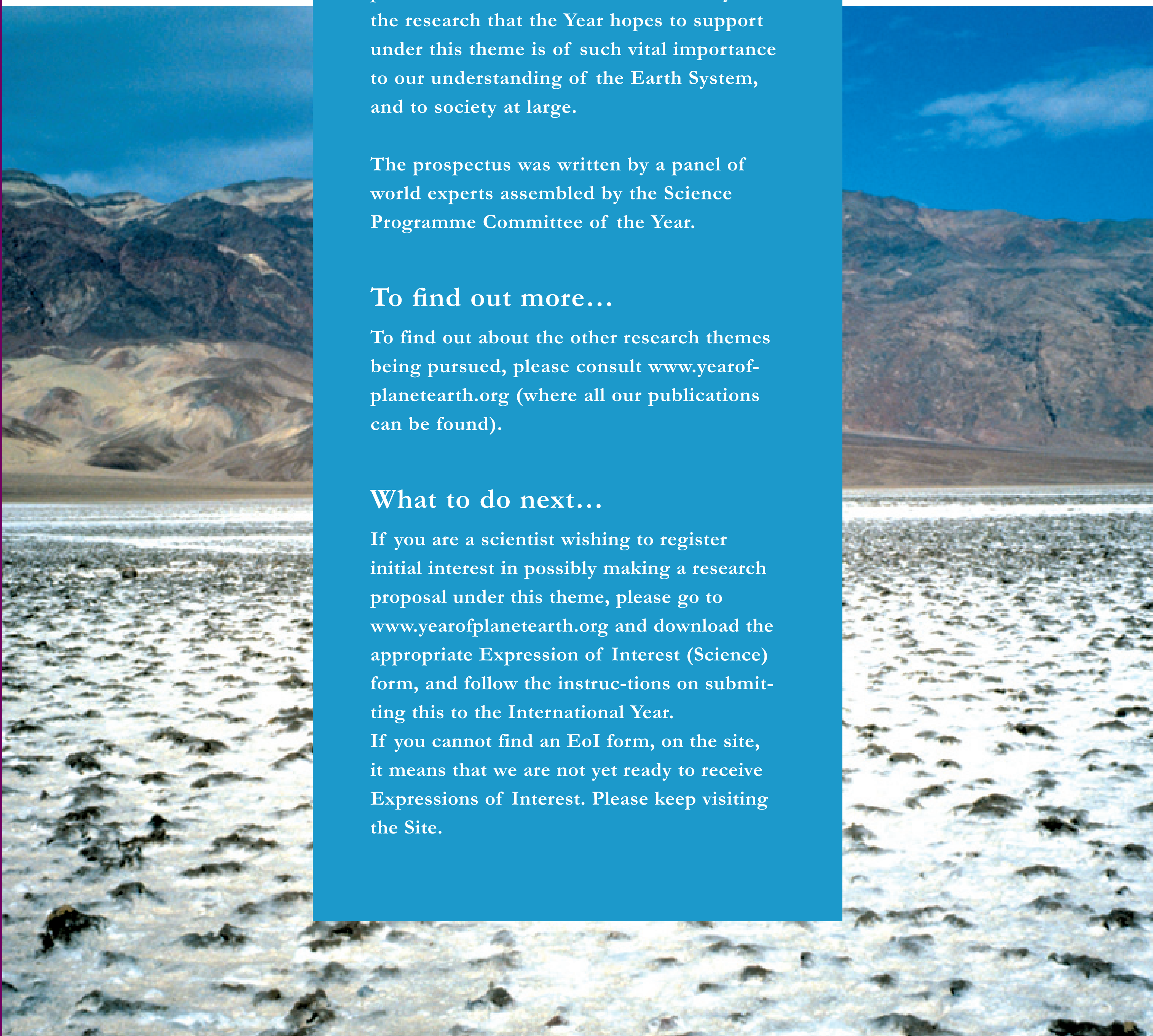
The prospectus was written by a panel of world experts assembled by the Science Programme Committee of the Year.

## To find out more…

To find out about the other research themes being pursued, please consult www.yearof-planetearth.org (where all our publications can be found).

## What to do next…

If you are a scientist wishing to register initial interest in possibly making a research proposal under this theme, please go to www.yearofplanetearth.org and download the appropriate Expression of Interest (Science) form, and follow the instruc-tions on submit-ting this to the International Year.
If you cannot find an EoI form, on the site, it means that we are not yet ready to receive Expressions of Interest. Please keep visiting the Site.



**Without soils, Earth's landscape would be as barren as Mars**

## Earth's living skin

***Soils are truly wonderful. They are major support systems of human life and welfare. They provide anchorage for roots, hold water long enough for plants to make use of it, and hold nutrients that sustain life – otherwise the Earth's landscape would be as barren as Mars. Soils are home to myriad micro-organisms that accomplish a suite of biochemical transformations - from fixing atmospheric nitrogen to the decomposition of organic matter - and to armies of microscopic animals as well as the familiar earthworms, ants and termites. In fact, most of the land's bio-diversity lives in the soil, not above ground.***

We build on soil, as well as in it and with it. And it's not all the same out there!. The abundance of life, habitats, and opportunities for human occupation mirror the tremendous variety of soils that are the Earth's living skin.

## Who is behind the International Year?

**Initiated by the International Union of Geological Sciences (IUGS) in 2001, the proposed International Year of Planet Earth was immediately endorsed by UNESCO's Earth Science Division, and later by the joint UNESCO-IUGS International Geoscience Programme (IGCP).**

**The main aim of the International Year - to demonstrate the great potential of the Earth sciences to lay the foundations of a safer, healthier and wealthier society - explains the Year's subtitle: Earth sciences for society.**

*Thick, fertile soil on a stable site; resilient structure, rich in organic matter, good nutrient status and water holding capacity; supports intensive farming*

## It's not all the same out there!

Different kinds of soil are spread across different landscapes – not randomly but in predictable patterns first identified 125 years ago by pioneering Russian pedologist Vasiliy Dokuchaev (1846-1903) as functions of parent material, climate, relief and living organisms acting over time - or, as he put it, the "age of the landscape".

People are part of the equation too; soils, like landscapes, are often man-made. Farmers make agricultural soils which, if they are successful, support sustainable farming systems; sometimes, a farmer fails to make such a soil but all the operations of good soil management are directed towards this goal. Our footprint is stamped even more firmly on urban development that makes different and very special demands on soils; by land use changes that distort infiltration and drainage, and in climatic change, against which soil provides the only buffer that we know how to manage.

Different soil landscapes respond to management (and mismanagement) in various ways. For this reason, particular kinds of production or construction are favoured in some places and not in others. Soil surveys identify and characterise soil landscapes; other branches of soil science are then applied to maximise the natural advantages or avoid the difficulties, e.g. by irrigating the dry, draining the wet, fertilizing the poor, and devising strong foundations in weak soils.

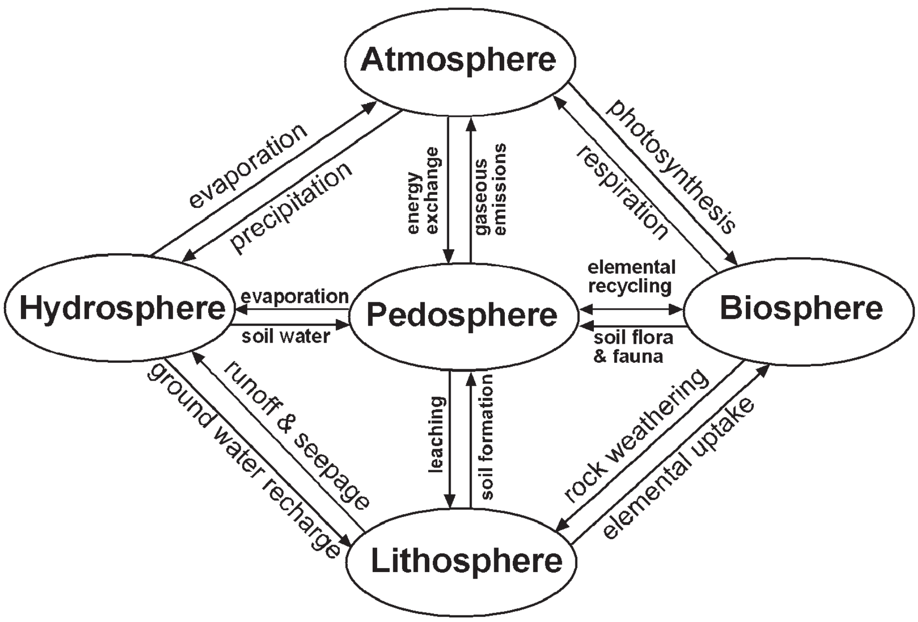
*Soil is full of life*

*Infertile soil, strongly weathered, strongly leached, acid and poor in nutrients. Costly inputs needed for sustainable farming but the soil is excellent for making bricks*

## When land use and management are well matched with soil capability, things work out as expected

*Main interactions between the pedosphere (soil), biosphere (plants, animals), lithosphere (rocks), hydrosphere (water) and atmosphere (air)*

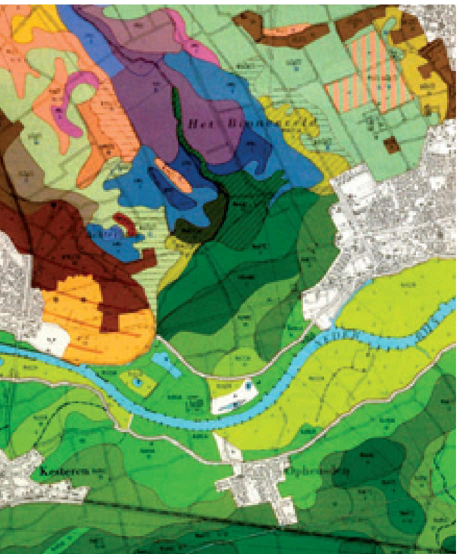
Life, soil, the atmosphere, water and landforms have all evolved together; none would be the same without all of the others. Soil connects, responds to, and shapes the land, the atmosphere and its climates, surface water and groundwater, and ecosystems.

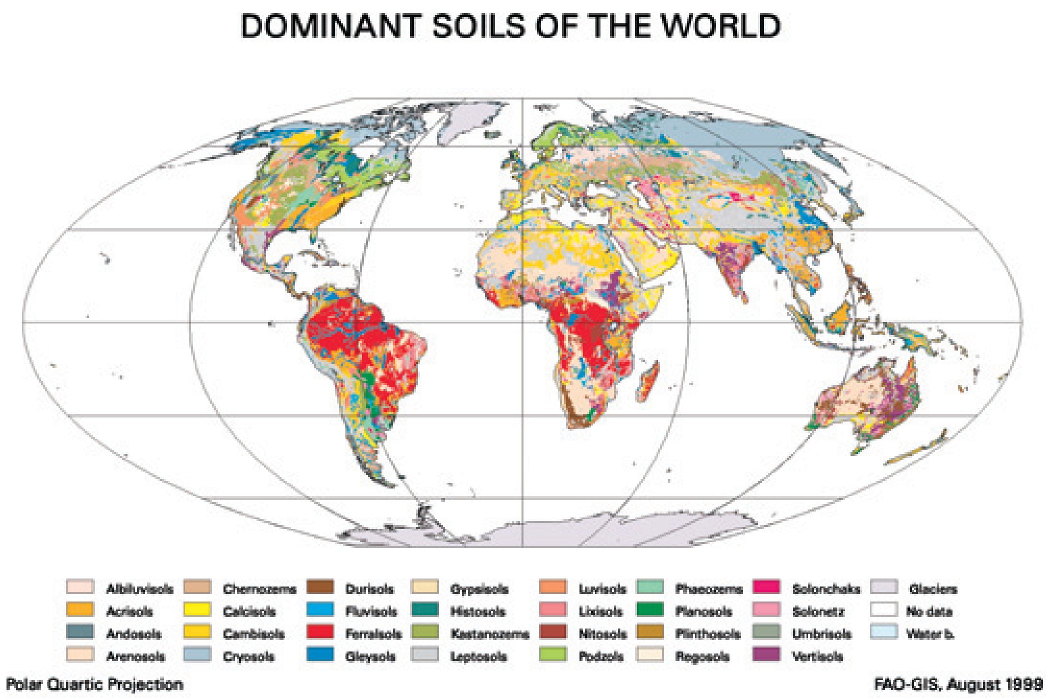



It may be ragged and thinly stretched; but soil, the vital skin of Planet Earth, is depended on by all terrestrial life. Yet we take it for granted – treat it as an apparently limitless resource to be husbanded or exploited for production, often without regard for soil quality.

Not so long ago, soil, water, fuel and mineral resources were simply that – resources. Of course, economies and societies are built upon soils and most Earth science activity is devoted to obviously useful activities that support the economy. In the case of soil science, this means supporting many different activities, including agricultural production, civil engineering, water supplies, water and air quality, sanitation and waste disposal to achieve the sustainable use of this finite and delicate system (see Box on 'Sustainable development').

*Soil maps depict different kinds of soil within the landscape, permitting a range of interpretations for practical uses*





“Sustainable development”

The term ‘sustainable development’ came from opposition between those who supported policies preserving the ‘sustainability’ of the Earth’s environment and those who advocated economic development. Environmentalists acknow-ledged that economic development was necessary (in part to avoid imposing the costs of environmental protection on those least able to afford them) but also because economic stagnation often reduces support for environmental protection efforts.

(continued...)

## Soil science and society

When land use and management are well matched with soil capability, things work out as expected. Crops and gardens flourish, livestock thrive, springs and wells yield, roads and buildings perform to specifications, investments are secure – and most people don’t even notice. Things don't work out as expected when the soil cannot meet a crop’s water and nutrient requirements. Then, crops fail and livestock sicken; in shrink-swell soils or saline seeps, roads, buildings, pipelines and cables break up; on unstable sites, structures may collapse catastrophically. In large urban areas, the sealing of the soil surface (covering the soil with concrete or asphalt) means more and faster runoff.

With far-reaching changes in soil use and management, there comes a point when the productive, hydrological and ecological functions of the landscape – functions that we take for granted - are lost. We have enjoyed great successes (e.g. through the application of fertilizers, drainage and irrigation); but there are also yawning gaps between how well soil functions are performed and how well they need to be.

The challenge for soil science is to provide intelligence, so that unsuitable sites may be avoided or appropriate precautions taken, and so that livelihoods, and essential soil functions, are maintained.

*Urban development on steep land in Hong Kong,*
*Aerial view of the same site after a landslip triggered by heavy rains.*

**We have enjoyed great successes but there are also yawning gaps between how well soil functions are performed and how well they need to be.**

A very different perspective on Planet Earth is now revealed by new technology that shows us Earth processes and systems at the scales at which they actually operate. Freed from the limitations of our physical size and our five senses, we can now see and measure from the molecular scale to the global, in time spans from nanoseconds to millennia. These observations have been built into models of Earth processes that predict the outcomes of present trends and management options. Rather than relying on trial-and-error, we now use predictive models to underpin decision- and policy-making, with the potential to improve soil quality and protect the living skin of the Earth for future generations.

Knowing about minerals, soil fabric and living organisms at the microscopic scale, and about the mechanics of physical, chemical and biological processes, opens many exciting new possibilities for manipulating and intervening – and all without much change in the way science is carried out or decisions made. The old fashioned scientist with the microscope or retort has become today's scientist with the electron microscope or plasma spectrometer; but the decisions based on the new information remain those of individual advantage and conscience, and within the competences of nation states.
Our new knowledge of Earth systems, systems that are bigger, more powerful, and which operate over time spans so much longer than the few brief millennia of which we (as a civilization) have experience, has greater implications.

**Likewise, those who advocated economic development recognized a parallel between the protection of environmental endowments and the concept of protecting capital in a sustainable economy. A viable economy must live off its income without a net reduction in capital over time. Similarly, a population must live within the carrying capacity of its ecosystem, which represents a form of natural capital.**

**Water resources may be destroyed,**

**or increased threefold,**

**depending on how the soil is managed**

## Science programme

**A panel of 20 eminent geoscientists from all parts of the world decided on a list of ten broad science themes - Groundwater, Hazards, Earth & Health, Climate, Resources, Megacities, Deep Earth, Ocean, Life and Soils.**

**The next step is to identify substantive science topics with clear deliverables within each broad theme. A 'key-text' team has now been set up for each, tasked with working out an Action Plan. Each team will produce a text that will be published as a theme prospectus like this one.**

**A series of Implementation Groups will then be created to set the work under the ten programmes in motion. Every effort will be made to involve specialists from countries with particular interest in (and need for) these programmes.**

**For more information - www.yearofplanetearth.org**

## Water at source

The one ultimate source of all fresh water is rain. Depending on land cover and soil condition, it is either intercepted and evaporated, infiltrated into the soil - or lost as damaging runoff. Rapid runoff brings floods, erosion of fertile soil, and riverbank erosion - damaging aquatic ecosystems, and clogging reservoirs and waterways. Depending on the thickness, permeability and water-retaining capacity of the soil, the infiltrated water may be held in the soil and used by plants, or drained to recharge groundwater and stream flow.

Whether the water becomes "hazard" or "resource" depends on the way it is partitioned at the soil surface and in the soil profile. That is to say, it depends on the kind of soil, its use and management. Water resources may be destroyed, or increased threefold, depending on how the soil is managed. However, while management of water at source is carried out largely by farmers and grazers in rural areas of catchments, the beneficiaries of their work live overwhelmingly in urban areas downstream. Sustainable management of water resources, and mitigation of associated hazards requires:

- better understanding of each unique water delivery system (climate, soil, terrain, surface and groundwaters, and land use)
- management applied at the scale of a whole watershed, not just at selected points or farms
- payment by downstream beneficiaries to the upstream managers to enable them to manage both land and water more comprehensively than they do now.

### Among these global systems, soils are integral to:

- **Climate:** through mediation of the water cycle, carbon storage and emission of greenhouse gases (water vapour, $CO_2$, NOx and methane); (see *Earth & Health*, Prospectus 4 in this series)
- **Water cycle:** Soils make up a key link and buffer system within the world's hydrological cycle. About 60% of fresh water is "green" water, held in the soil and available to plants. Soils also regulate streams and groundwater flows that support wetlands, irrigation, and domestic and industrial water supplies – sometimes thousands of miles downstream (see *Planet Earth in our hands* - Brochure 1 in this series).
- **Waste and nutrient cycles:** Nutrients released by weathering, or fixed from the air, are recycled; toxins are neutralised. Disturbance of the cycle may bring about eutrophication or pollution of soils and water or, on the other hand, depletion of nutrients, threatening livelihoods across the world
- **Erosion:** Loss of soils cover can lead to the stripping of the living skin, with all its irreplaceable functions, muddying waters and dumping sediment where it is not wanted – on fertile soils elsewhere, in streams, reservoirs and harbours. Erosion is not all bad; many of our most fertile soils in deltas, alluvial and loess plains are products of past erosion, as are the nutrients in the oceans. However, when wind and water erosion is accelerated by mismanagement, it leads to alarming degradation of soils and diminished air and water quality.

Soils make up a key link
and buffer system within
the world's hydrological cycle

## Pollution of land and water

Soils are commonly used as dumps for household and industrial wastes. In many intensively farmed areas, leaching of nutrients from manure or inorganic fertilizers and effluent from livestock or processing plants may lead to high levels of nitrate and other chemicals in the groundwater. Some soils can filter, absorb and recycle large amounts of waste; in others, toxic materials leach to streams and groundwater. Sandy soils are prone to leaching; thick clays are impermeable.

Worldwide, pollution of land and water resulting from urban and industrial development and intensive agriculture is a major research theme. For most soils, mitigation of severe pollution means excavation and costly treatment. In the European Union, North America and Australia, the requirement for preventative and remedial measures is now well anchored in law.

## Problem soils

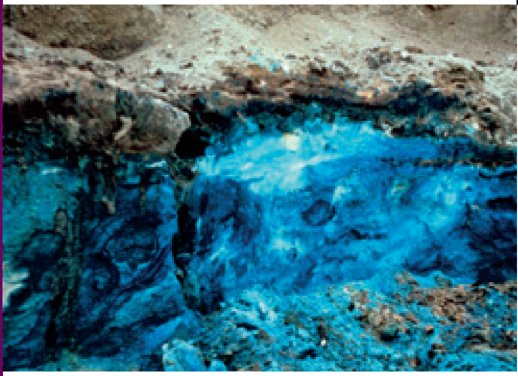
Naturally, some soils are dry when hard, very sticky when wet, poorly drained, gravelly and stony or have very low nutrient contents or toxic amounts of aluminium or salt. Ever since settled agriculture began, people have altered such soils - although some soils remain more problematical than others.

Acid sulphate soils are the nastiest soils in the world. Undisturbed, they are not a problem. If drained, they generate sulphuric acid – 10 cubic metres of sulphidic soil may generate 1.5 tonnes of sulphuric acid and release a cocktail of aluminium, heavy metals and arsenic into drainage and floodwaters. The acid corrodes steel and concrete; pollutes streams and estuaries, killing fish and causing disease. The effects of aluminium, heavy metal and arsenic in the food chain are not well understood, but are certainly unwelcome.

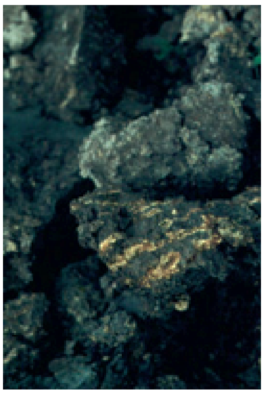
These soils occur mainly in coastal swamps, and there has always been an incentive to reclaim this land – to exploit their expected, though rarely realised fertility – or, more recently, to make way for urban and leisure development. Generations of people depending on these soils have been impoverished and poisoned by their drinking water. The engineering and environmental consequences have usually been disastrous.

Gradually, and only in some favourable cases, local people found empirical solutions. Science arrived late in the day. The process of fixing sulphates in waterlogged soils and subsequent oxidation upon drainage was elucidated by J M van Bemmelen in the 1880s, following the initial failure of the largest land reclamation project of its day, the Haarlemmermeerpolder in 1852. It took more than a century to build up a coherent body of scientific knowledge to solve practical problems and predict the occurrence and severity of these soils worldwide.

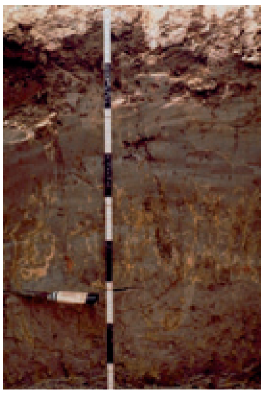
*What does the International Year's logo mean? The International Year is intended to bring together all scientists who study the Earth System. Thus, the solid Earth (lithosphere) is shown in red, the hydrosphere in dark blue, the biosphere in green and the atmosphere in light blue. The logo is based on an original designed for a similar initiative called Jahr der Geowissenschaften 2002 (Earth Sciences Year 2002) organised in Germany. The German Ministry of Education and Research presented the logo to the IUGS.*



*Severely polluted soils in the Netherlands for which excavation is essential*



*Electronmicrograph of pyrite in a sulphidic soil the result of bacterial reduction of sulphate in waterlogged conditions, the growing crystals also scavenge heavy metals and arsenic from the environment*



*Acid sulphate soil: the characteristic yellow mineral is jarosite which forms under the severely acid conditions produced by oxidation of pyrite*

**Soil science has greatly contributed to the exponential increase in agricultural production**

## Quick, accurate survey of regional and global systems

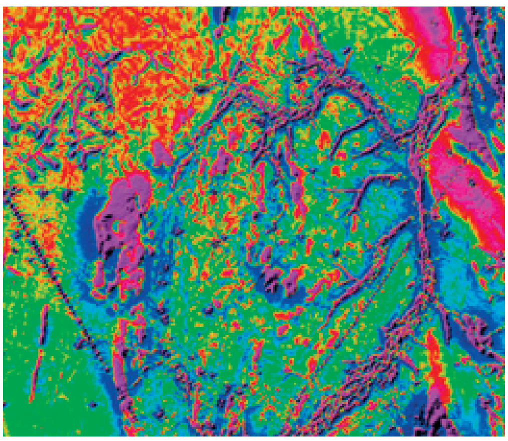
New knowledge of regional and global systems is coming from airborne and space-borne sensors. Analysis of the data, made possible through a dramatic increase in computing power, reveals the size, complexity and time scales of these systems and indicates how they may be interrelated. Detailed and reliable information is essential for sound policymaking. Scientists have to carry this information to the point of decision and become involved in policy development.

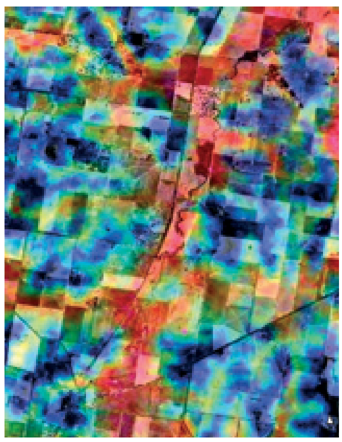
There is a wealth of information on soils but much is dated, inaccurate, unavailable at appropriate scales, or relatively inaccessible. New airborne and space-borne sensors offer unprecedented detail, accuracy, rapid regional or global coverage and, in the case of magnetics and electromagnetics, also provide information from deep below the surface. Satellite data, in particular, provide a monitoring capability at very low marginal cost. However, field calibration and skilled interpretation remain crucial.

The new information is being used in climate models, agricultural and forest production estimates, assessment of land degradation and improvement, water resources management, and estimation of erosion and sedimentation. Good intelligence can support interventions to arrest salinity, identify shallow groundwater resources, design water storages and other engineering works, and assess land suitability for particular uses.

*Aerial photo overlaid on electromagnetic conductivity image from 30-40m below surface. Red indicates conductive, saline groundwater in prior stream channels, blue indicates resistive, non-saline materials.*

*Airborne magnetic image. Magenta picks out magnetic gravels that may be conduits for groundwater flow.*





## Soil – system within a system

English scientist James Lovelock has pointed out that Planet Earth appears to behave as a self-regulating system; he called it Gaia. If this is true, the implications profound – for Earth sciences and for the way societies make decisions.

- Understanding global systems requires collaboration - interdisciplinary, inter-institutional, and international.
- Global systems transcend private property, local and national jurisdictions and competences.
- They operate over decades and centuries. Unwelcome changes may be slow to materialize but, equally, will be hard to halt or reverse.
- Global systems underpin all economies and societies but their benefits are claimed either as private property or as free, open-access resources.

Therefore, the scientific and outreach programs of the International Year of Planet Earth will focus on the global and regional systems that underpin our familiar lives, our future as a species, and the trajectory of our planet's evolution.

## Four key questions

### 1. Where should we expand our knowledge base for the greatest benefit to society and the environment?

Soil science has greatly contributed to the exponential increase in agricultural production and, as a result, to feeding, housing, and clothing the people of the world. Supporting agriculture remains an important research thrust but, nowadays, soil science includes precision agriculture, organic farming and carbon sequestration (by forested and agricultural systems) as well as grappling with restoring degraded land and issues of sustainability.

Since the 1970s, soil science has been integral to environmental research issues like soil pollution, climate change, the maintenance of effective hydrological cycles, the role of soils in urban areas, and sustaining biodiversity. There are great challenges ahead for soil science as burgeoning human population and aspirations increase pressures on land and water. Both the spatial and temporal characterisation of soils, and their functioning within ecosystems, are vital for our understanding of the Earth as a global system. Wise use of natural resources requires an expanding knowledge base that accommodates the dynamics of a rapidly changing world; where to focus is a big question.

### 2. How can we link the soil science knowledge base with the diverse disciplines of the Earth sciences?

In the past, environmental data have been collected by various disciplines including geology, geomorphology, soil science, hydrology and ecology. Interdisciplinary teams increasingly use specialists' data, for example to unravel environmental changes or develop future scenarios in global modelling studies. Great benefits can be expected with a further integration of these databases and from population of the "no-man's land" between traditional fields: e.g. the regolith between soils and solid geology, and the influence of land-use and management on soil characteristics across a range of spatial scales. The pedosphere is the link between the atmosphere and the other ground-based spheres, and we need to increase the interaction between the many different groups and show that soils are important to all the others. Substantial new work is needed to bridge these gaps. The crux is how this can be done most effectively.

### 3. How can we communicate better with society?

The research maxim used to be: "If research isn't published, it hasn't happened". But publication of research results in peer-reviewed journals rarely reaches our stakeholders or society at large and does not directly influence policy and practice. Improved communication is increasingly demanded by donors and funding agencies. Relevant, science-based information is needed so that informed decisions can be made. This means more effective interaction with policy makers, but this has to be a two-way process and both parties have much to learn. We are also looking for radio and TV programmes, plays, pictures, press and Internet ventures to reach at the people at large. Better communication should also attract students on whom the future of soil science will depend.

### 4. How can we maximise use of indigenous soil knowledge?

Land users and societies have different kinds of knowledge about soils. Theirs is the distillation of generations of experience and observation; it is practical, yield-oriented and site-specific. So far, indigenous soil knowledge has only been marginally used in formal scientific investigations; but it should be a vast resource. Tapping and integrating it with formal information is not so easy.

(For how to propose outreach ideas, please see Brochure 11 in this series, *Outreach: Bringing the Earth sciences to everyone*).

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## Outreach Programme

The Outreach Programme of the International Year is faced with a particular challenge of scale. With a potential $10m to spend, it is inconceivable that it could operate in a prescriptive way. No individual or committee can think of enough wise ways of spending such a sum globally. So the Outreach Programme will, like the Science Programme, operate as a funding body, receiving bids for financial support - for anything from web-based educational resources to commissioning works of art that will help reinforce to the general public the central message of the year. It will enable things to happen locally under the umbrella of an international scheme, lending profile and coherence.

A special Outreach Prospectus in this series (number 11) is available for those who are interested in applying for support.

## Writing team

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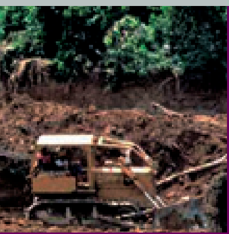

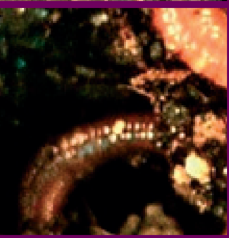

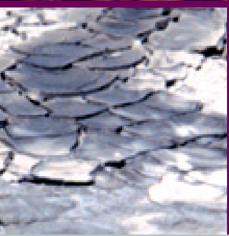

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