ANNUAL REPORT 1989

International Soil Reference and Information Centre
Wageningen - The Netherlands

ISRIC was born out of an initiative of the International Society of Soil Science, and was adopted by Unesco as one of its activities in the field of earth sciences. It was formally founded on 1st January 1966 by the Government of The Netherlands, upon assignment by the General Conference of Unesco in 1964.

Most of the working funds are provided by the Dutch Ministry of Education and Sciences, and are accountable to the Directorate-General for International Cooperation (DGIS) of the Ministry of Foreign Affairs.

The constituent members of the Board of ISRIC are the International Institute for Aerospace Survey and Earth Sciences (ITC) in Enschede, the Wageningen Agricultural University (WAU) and the Government Service for Agricultural Research (DLO).

Advice on the programmes and activities of ISRIC is given by a Unesco-FAO appointed International Advisory Panel (IAP) and by a Netherlands Advisory Council (NAC).

The financial-administrative responsibility for the working funds and for the permanent staff of ISRIC rest formally with the Board of ITC.

Up to 31 December 1983 the name was International Soil Museum (ISM).

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1 THE ORGANIZATION AND ITS DEVELOPMENTS

1.1 ORGANIZATION

The organisational structure outlined in previous Annual Reports remained essentially the same. The longer-term activities, for which funds for a fixed-term have been secured, were also prominent in 1989. A re-structuring of the organization is foreseen and will possibly be implemented next year.

ISRIC's activities consists of six sections, three programmes, and consulting and miscellaneous projects.

Sections

Soil monolith collection
This section deals with the building up of ISRIC's world collection of monoliths and encompasses all work from selecting and taking of the soil profile to the final monolith being placed in the exhibition room or reference store ("pedonarium"). The work is related to the National Soil Reference Collection Programme (NASREC) and to the Collection of Reference Laterite Profiles (CORLAT).

Laboratory
Besides routine analytical work for the monolith collection, this section carries out a number of ad-hoc analyses, particularly for reference purposes. This activity is connected with the Laboratory Methods and Data Exchange Programme (LABEX).

Micromorphology
The work includes the preparation and description of the thin sections belonging to the soils of the collection. Like the laboratory, the micromorphology section is involved in a number of other activities as well.

Documentation
This section deals with the development of ISRIC's Soil Information System (ISIS), with the library, and with the map collection.

Soil classification, correlation and mapping
Activities in this section are mainly related to the development of a Revised Legend for the FAO-Unesco Soil Map of the World, to some International Committees for the improvement of the USDA Soil Taxonomy, and to the development of an International Reference Base for national soil classification systems (IRB). Preparatory work is being carried out for updating the FAO-

Unesco soil map at 1:5 million scale, and a related activity is the establishment of a World Soils and Terrain Digital Database at 1:1 million scale (SOTER).

Transfer of knowledge
This section deals with the Course on the Establishment and Use of National Soil Reference Collections and Databases, with receiving visitors, lecturing, and with supplying written and oral information.

Programmes
These are longer term activities, for which however only fixed-term extra funds have been secured.

National Soil Reference Collections Programme (NASREC)
This programme encompasses support for the building up of a number of national soil reference collections in selected countries of Africa, South America and Asia.

Laboratory Methods and Data Exchange Programme (LABEX)
This soil sample exchange programme between about 100 laboratories aims to improve the quality of soil analytical data by providing external references and standard procedures to the participants.

Preparation of a World Soils and Terrain Digital Database (SOTER)
This is a programme to support the establishment of a geographic information system on the soils of the world at scale 1:1 million, an ISSS initiative that is a sequel to the FAO-Unesco Soil Map of the World project of the sixties.
The United Nations Environment Programme (UNEP) in Nairobi awarded a major contract for the global assessment of soil degradation (GLASOD project) to be accompanied by quantification of status and hazards of the various forms of soil and land degradation in at least one pilot area - the latter based on the ISSS-initiated methodology for the establishment of a World Soils and Terrain Digital Database (SOTER).

Consulting and Projects
This embraces not only missions of ISRIC staff members, but also the employment of extra personnel at ISRIC to carry out specific projects. A prominent project is the 'Soils and the Greenhouse Effect' activity (ISEC).

1.2 INSTITUTIONAL DEVELOPMENTS

Continuing attention was given to the building-up of the world collection of soil profiles, in the form of monoliths, to the accompanying computerised database (ISIS) and to the collection of maps and reports on the geography of soils and related natural resources, with emphasis on Third World countries.

The uniqueness of this database was recognised by the formal acceptance, in the course of the year, of ISRIC as a World Data Centre for Soil Geography and Classification within the WDC system of the International Council of Scientific Unions (ICSU). This strengthened the need for effective and user-friendly computerised database systems for all information available at ISRIC, and a number of hard- and software material was acquired for the purpose.

Ad-hoc financing, by the Dutch Directorate-General for Development Cooperation (DGIS), allowed the continuation of the Laboratory Methods and Data Exchange Programme (LABEX), be it at a somewhat reduced level. Contacts were established to merge the routine part of sample exchange with the plant- and soil sample exchange programme of the Wageningen University, in the view that ISRIC will henceforward give more attention to the development of guidelines for Good Laboratory Practice and on-the-spot advice to the establishment and output quality control of Third-World soil laboratories.

The programme for the establishment of national soil reference collections and associated databases (NASREC) had a temporary lapse in financing, but towards the end of the year agreement was reached for a three-years additional DGIS funding through UNEP's Clearing House Facility. DGIS and Unesco's Division of Ecological Sciences provided finances for yet another two-months central training course, in September-October 1989, on the establishment of such national reference collections. It is the aim that in the future this service can be replaced by regional courses in some Third-World countries that already have a fully operational national collection and database through the activities of the NASREC programme.

For lack of funds or volunteer staff for the subject, no substantial progress was made at the establishment of a reference collection of whole laterite profiles for interdisciplinary use and the compilation of a compendium *cum* wallchart on lateritic materials (CORLAT) - even though awareness is growing that the current confusion on terminology, methods of description and analysis of the processes of lateritization/bauxitization/plinthization and its products warrants urgent attention.

Temporary staff devoted much time to three main projects. The first one was the organization of an international conference on "Soils and the Greenhouse Effect", at the request of the Dutch Ministry of Housing, Physical Planning and the Environment. It took place in August 1989 and attracted much attention in the context of the preparations for ICSU's International Geosphere-Biosphere Programme (IGBP). The conclusions and recommendations of the conference, the invited and voluntary papers, and the background documentation will be published in book form early 1990 by John Wiley & Sons. One of the outcomes of the conference will be more attention by the Centre to soil in their geographic context as sources and sinks of greenhouse gases and as filters for pollutants (see also lead article).

The second major project was the preparation, on behalf of UNEP, of a map on the Global Assessment of human-induced Soil Degradation (GLASOD). A methodology was established and contributions from a network of regional correlators and national soil resources institutions flowed-in throughout the year. Much compilation work was carried out, with kind assistance from the soils department of the Winand Staring Centre in Wageningen. The printed final product will be available in the course of 1990.

Also supported by UNEP was the preparation of a soil and terrain database (SOTER) for a pilot area in Latin America (parts of Argentina, Brazil and Uruguay), in the framework of the programme for the establishment of a world soil and terrain digital database of the International Society of Soil Science (ISSS). The pilot area is also serving as a "window" for the establishment of both the status and hazard of soil degradation in a quantitative and geo-referenced form. Project proposals for similar pilot areas in West Africa, Central America and other regions, with associated training programmes, were prepared and submitted to several funding agencies. The technical manual for SOTER activities was revised by an international panel of experts, incorporating the first experiences.

The outlook for a somewhat enlarged long-term financing of core activities of the Centre improved. Towards the end of the year definite confirmation was obtained that core funding by the Dutch Government's Ministry of Education and Science - chargeable to the financial ceiling of international development cooperation - will increase as from the financial year 1990 by NLG 185,000. These extra funds will be used for much-needed equipment and upkeep of the Centre, and for the strengthening of the educational facilities - the latter to serve better the ever-increasing number of study visits of groups of European students, and individual soil scientists from all over the world.

The Dutch Directorate-General for Development Cooperation DGIS held out a prospect for a one-time contribution of NLG 300,000 to enable the refurbishing of an empty university building nextdoors to the Centre (a hundred-years old monument, originally used for agricultural engineering teaching), to be matched by co-financing from the Wageningen University to the tune of NLG 150,000. This much needed extra space will be used as working room for soil monolith preparation and training therein, as collection depot, and for some project office space. It is expected that this annex will be effectively occupied towards the end of 1990.

No decision was yet been reached on the formal status of ISRIC within the system of development-oriented Dutch education and research, and in relation to the funding fathers of the Centre, i.e. ISSS and Unesco.

Visit of H.R.H. Princess Maha Chakri Sirindhorn of the Kingdom of Thailand. ISRIC's Director Dr. Sombroek presents samples of Thai soils from the Centre's collection.

2 ARTICLE

POLLUTED AND CONTAMINATED SOILS

E.M. Bridges[1]

Air, water and soil are three basic necessities for life on earth and all three are closely associated in the terrestrial environment. The need to protect the atmosphere and water supplies from pollution has been understood for well over a century, but it is only within the last decade that policies to safeguard soils have emerged. Few national governments have policy statements on this subject and it is as recent as 1981 that Resolution 8/81, the World Soil Charter, was passed by FAO, and this only included a brief mention of the problem of soil pollution. As soil pollution can be a hazard to health and the purity of water supplies, the need to protect soils is clear.

Polluted soils are those which contain alien substances that are likely to cause harm, directly or indirectly, to man, to the environment, and occasionally other targets. Many substances are present in small amounts or low concentrations in soils; these are not necessarily harmful, but may be regarded as contaminants. Thus a distinction can be drawn between polluted and contaminated soils, but the conventional usage of the term *contaminated soils* ignores this scientific distinction. In order to make the position clear, the definition of contaminated soils has a corollory that to be hazardous, pollutant substances must be present in quantities and concentrations above background levels normally experienced in soils (Fisk, 1990; Smith, 1985).

Soil pollution

Throughout the 1980s numerous horrific accounts of soil pollution were published, usually associated with specific industrial sites or chemical waste buried in landfills. Mostly, these were in industrial countries - USA, Canada, United Kingdom, France, Germany, the Netherlands, Germany, Poland - but attempts have been made by unscrupulous companies to dump toxic wastes in developing countries in return for hard currency, so spreading dangerous pollution to areas hitherto free of serious soil pollution. In many countries the lack of pollution controls in the past has allowed irresponsible dumping of toxic chemicals in holes in the ground, which when filled

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have been covered and forgotten. Eventually, the containers decompose and the toxic materials are released and migrate into the surrounding environment where they enter terrestrial and fluvial ecosystems and are passed along the food chain with disasterous results. Often confined to relatively small areas, these sites are numerous and widespread. A recent survey in five European countries revealed 8900 polluted sites which require immediate treatment with another 13,800 sites requiring further investigation. Altogether, it is estimated that approximately 185,000 ha are affected. Of the countries surveyed, Germany has the greatest number of polluted sites, followed in turn by the United Kingdom, the Netherlands, Denmark and France (Haines, 1988). Even in a small country like Wales, over 746 potentially dangerous sites with polluted soils covering 4079 ha have been identified, and this number does not include sites of less than 0.5 ha (Welsh Office, 1984).

Diffuse contamination

It has been pointed out that diffuse contamination of soils may be a more important problem at the international and national level than the grossly polluted sites mentioned previously. Diffuse contamination arises from acid deposition, radionuclides and the dusts of the urban-industrial society. Acid deposition is a widespread phenomenon especially in the uplands of western and northern Europe. Observation and experimentation have shown that as the soil solution is acidified, leaching of many elements is increased and the soil biological activity is decreased. The rate of organic decomposition and mineralization falls and nitrification is inhibited. These effects are more marked under woodland (Longhurst, 1989). Soils have received radioactive fallout as a result of weapons testing and accidental discharges from nuclear installations since World War Two. Although soils are capable of immobilizing radionuclides by ion exchange, precipitation and complexing, the same exchange mechanism which enables plants to obtain their nutrients allows them to take-up the radionuclides. Once in plants, caesium, plutonium, strontium and ruthenium may enter the human food chain through the activity of grazing animals (Livens and Rimmer, 1988). In addition to the acid deposition problem, the burning of fossil fuels and general industrial activity leads to the widespread deposition of dust containing toxic metals upon soils. The problem is most acute in urban areas where coal fires and motor cars have released significant quantities of metals. A worldwide assessment of soil contamination by metals is reported by Nriagu and Pacyna (1988).

Agricultural activities are responsible for the addition of small, repeated amounts of contaminants to soils over large areas and so may be considered in this context. For many years copper sulphate solution (Bordeaux mixture) has been used as a fungicide in vineyards as well as on bananas, citrus and other orchard crops. This has resulted in raising Cu concentrations to 1100-1500 mg/kg from background values of 20-30 mg/kg. Phosphatic fertilizers are responsible for additions of Cd and mercuric seed dressings could be responsible for the introduction of between 100-200 $mg/m^2/yr$ Hg. Traditionally farm-yard manure has been returned to the land for the benefit of its organic content and the plant nutrients it contains. However, modern pig and poultry feed has copper sulphate additives and arsenic is also added to poultry feed; both elements subsequently appear in the droppings. Disposal of sewage sludge to farm land is similarly limited by the presence of enhanced toxic metal concentrations including Cd, Cu, Ni, Pb and Zn. The impact of toxic metals on individual soils is influenced by the soil pH, particle-size distribution and organic matter content. Guidelines for the disposal of sewage sludge are available in many countries (Alloway, 1990).

The problems of assessing the significance of dispersed soil contamination are well exemplified by the presence of polynuclear aromatic hydrocarbons. Jones (1988) describes how these substances result naturally from the burning of vegetation. They also arise from the buring of fossil fuels and are constituents of domestic and industrial wastes. Soils contain residual amounts, the balance between inputs and losses through microbial breakdown. Analysis of historic soil samples taken from Broadbaulk field at Rothamsted show a five-fold increase in the past 100 years with the more complex (and difficult to break down) hydrocarbons showing proportionately larger increases.

Initially, it might be thought to be a simple task to stipulate the amounts or concentration of hazardous substances which constitute the soil or land being contaminated. However, the degree of hazard varies according to the intensity of land use and the degree of exposure of potential 'targets' to the contaminants present. Contaminants may be present as short-term highly toxic hazards which may give acute symptoms, or they may have a more insidious long-term effect producing chronic illness in human beings, animals and plants. As well as straightforward poisonous substances, the list of contaminants includes carcinogenic, teratogenic and mutagenic substances.

Nature and sources of contaminants

Contaminants affecting soils may be in the form of solids, liquids or gases. The most common toxic substances observed to pollute soils include metallic elements and their compounds, organic chemicals, oils and tars, pesticides, explosive and asphyxiant gases, radioactive materials, biologically active materials, combustible materials, asbestos and other hazardous minerals. These substances commonly arise from the disposal of toxic industrial wastes placed in designated landfills, uncontrolled dumps spillages and atmospheric fallout. Accidents resulting in spillage and leakage are commonplace in factories, in transit, at distribution facilities and at scrapyard sites where equipment is broken down for recycling. Whilst any industrial site may be contaminated to some degree, the following industrial activities will almost certainly result in pollution of soils (Smith, 1985):

Mining, smelting, refining and working of metals
Gas works
Chemical works
Pesticide manufacture
Paint and colouring manufacture
Explosives and munitions works
Oil and petroleum production and storage
Pharmaceutical works
Tanneries and wood preserving factories
Docks and railway land
Asbestos factories
Manufacture of integrated circuits and semi-conductors
Scrapyards
Sewage farms and works
Landfills and waste disposal sites.

Most of these severely polluted sites are found in urban areas, but rural locations are not exempt from contamination. Spillages, irresponsible dumping of wastes and the over-enthusiastic use of agrochemicals including insecticides, herbicides and fungicides, all spread the burden of soil pollution into the countryside.

Vulnerable targets

Contaminated soils can be a hazard in several ways and so require to be assessed accordingly. In the first place contaminants may be dangerous for *human beings*. They may be a hazard if ingested or if they come into contact with the skin, alternatively substances may be concentrated as they are passed along the food chain until they reach human beings. Gases contaminating soils may be asphyxiants or poisonous if inhaled and some gases are capable of explosion if they accumulate in confined spaces beneath buildings or in cupboards. Where methane displaces air from the pore spaces, soils become anaerobic and root growth is limited.

Animals also can suffer from soil contamination by direct ingestion and indirectly if toxic elements are taken up by plants and then consumed whilst grazing. Soil fauna and microfauna may be adversely affected by contaminants and reduced in number so limiting the biological turnover. In the case of *crops* and *ornamental plants*, contamination of the soil may result in stunted growth and low yields and in extreme conditions, death. However, many common metallic elements, boron, cobalt, copper, nickel and zinc, are plant micronutrients which are necessary at low concentrations.

Soil contamination may affect buildings in a number of ways. The danger of explosion and fire from gases has already been mentioned. If the soil is contaminated with combustible material, underground fires may produce dangerous fumes. Such fires are difficult to extinguish and burning also results in subsidence which may affect the stability of structures. Concrete can be disrupted by the growth of salt crystals, derived from sulphates, weakening the foundations of buildings. The presence of oily or tarry substances in the soil may affect service ducts. Organic pollutants are known to attack plastics, rubber and other polymeric materials used as jointing seals. Phenols for example may penetrate plastic water pipes buried in polluted soils, weakening them and tainting water supplies.

DEALING WITH THE PROBLEM

The process of site assessment is complex and may involve documentary investigations, site visits and chemical analysis of soil, water and air samples (Bridges, 1987). Once a site has been assessed as being polluted, the soil scientist is faced with several options. It is possible that the contaminated soil could be dealt with *in situ*. Some newly developed techniques are designed to process the soil without excavation, but virtually all of these are only at the experimental or developmental stage. Alternatively, the contaminated soil is excavated and dealt with on site or excavated and removed to another site. This last option is often employed, but where possible, treatment should take place on site to avoid spreading the polution elsewhere.

Any solution of the problem of contaminated soil must take into consideration the underlying geological and hydrological features of the site. The physical properties of the soil and geological materials beneath are of critical significance in determining the mobility and direction of movement of contaminants. Many examples of contamination have occurred on soils developed from Tertiary, Quaternary and Holocene deposits, especially in Germany, Denmark, the Netherlands, USA, Canada and the United Kingdom. Many of these deposits are unconsolidated and so relatively easy to excavate, but the detailed stratigraphy is often complex and variable which poses difficulties of interpretation of contaminant movement. In glacial tills, for example, impermeable layers may help to limit the downward penetration of pollution, but are often impersistent and difficult to trace laterally.

The position of the water table is also a critical factor in soil contamination. If the polluted ground extends below the water table, saturated conditions may cause anaerobic conditions which enhance the solubility and mobility of many contaminants. A water table at shallow depth allows rapid leaching of substances and contamination ensues, but where the water table is deep, noxious substances being leached may become adsorbed onto the weathered rock material and the contamination is attenuated. Soluble contaminants which reach the water table will spread in a plume following the direction of flow of the ground water. Immiscible contaminants, such as petroleum leaking from underground tanks, will come to rest on the water table which will stop further penetration. Consequently, one solution of spreading contamination is to lower the ground water beneath an area of contamination by pumping. Contamination is then drawn into the cone of depletion and can be pumped out and separated from the ground water. In other cases, knowledge of the ground water and pattern of flow is necessary before appropriate remedial action is taken, such as the insertion of diversion barriers.

If the contaminated soil is to be left *in situ*, then the simplest approach is to immobilize it or to contain it physically with barriers. If excavated, the most commonly used method of ridding soil of pollution is the use of heat to extract or decompose harmful substances, but other chemical or microbiological techniques are available or are being developed. Some physical methods of separating contaminants from soils have been proposed. These techniques of dealing with polluted soils will now be reviewed.

Stabilization

Where it is desired to restrict movement of a soil pollutant, it is possible to 'stabilize' it into a solid mass using inorganic agents such as cement, lime, gypsum, pozzolans, silicates or organic substances such as epoxy resins, polyesters, asphalt, polyethylene, polyethylene-polybutadiene and urea-formaldehyde to bind the contaminated soil.

Stabilization is a technique used to immobilize soil contaminants by reducing their solubility. Also the possibility of contamination being blown about as dust is reduced by solidification. The techniques can be carried out on site without excavating the soil, so there appear to be some advantages for this technology. Without excavation, contaminated soil may be injected with the stabilizing substance at high pressure so mobility of contaminants is greatly reduced and the bearing capacity increased. Alternatively, the polluted soil could be excavated and mixed on site before being replaced; clearly, this method ensures thorough mixing and is more satisfactory.

Commercial claims for the reliability of stabilization methods have been over-optimistic and experience in the UK and USA has found shortcomings in their effectiveness. Evaluation of most of these stabilizing compounds are being undertaken currently by the US EPA (Wiles *et al.*, 1988). Failure may be caused by incorrect mixing of constituents or as a result of the presence of organic matter or other reactive substances which inhibit the setting of the stabilizing chemicals. However, lime, cement and pozzolans and silicates are inexpensive, easily available and harmless, so although rather unreliable, they have been widely used; the use of thermoplastic resin is more reliable but involves specialized apparatus and is more expensive. Other difficulties with resins are that the soil has to be dried before mixing and the chemicals used present a danger of explosion or fire.

Fusing polluted soil into a glassy solid by passing a strong electric current through it has been developed from a process designed for isolation of radioactive wastes in the USA. It consists of placing electrodes in the soil to the required treatment depth, a starter path placed between the electrodes and the current passed through. The passage of the electricity heats the soil to over 2000°C. Non-volatile contaminants are melted and incorporated in the vitrified soil material and volatiles may be collected by placing a hood over the soil under treatment. In the USA the cost of this method, now tested at large-scale field trials is \$140-290 per m^3 (Hampel and Fitzpatrick, 1988).

Barriers

Barriers to limit the spread of soil pollutants may be constructed using well known and tested civil engineering techniques such as piling and grouting. Recent research and development of these techniques has widened the scope of materials used but insufficient time has elapsed to indicate the long-term success of many of the methods employed. Barriers may be simply to surround the contaminated area so that the amount of leachate can be controlled or they can be used to completely encapsulate the polluted soil. Where it is difficult or undesirable to excavate contaminated soil and a hazard exists to ground-water supplies barriers are the probable solution. Barriers can also be used to interrupt the movement of gas, such as methane, through the soil. However, the movement of organic liquids such as benzene and toluene may not be effectively restricted by a clay or slurry wall and in this case re-inforcing the barrier with a plastic membrane may be necessary.

Sheet steel piling is available from suppliers and can be effective to depths as great as 20 or 30 m, but in bouldery soils or where there are demolition wastes are present, there are difficulties in inserting the steel sheets. Heavy gauge and light gauge steel walling are commonly used, but their joints are not designed to be liquid or gas-tight. Their effectiveness in containing soil pollutants depends greatly on the nature of the underlying substrata and whether they can be driven into impermeable layers at depth.

A similar result can be obtained by inserting a wall of a material of low permeability around the polluted area. This may be achieved by simply excavating a

trench all around the site and backfilling it with a material of low permeability. Clay and compacted loamy soil have been used effectively where such materials are available on site, but greater uniformity is obtained with cement or sodium silicate slurry mixtures.
Insertion of these may be achieved also by vibrating a mould into the soil, when removed it leaves a vertical slot which is then infilled with a slurry mixture. Slurry mixtures composed of cement and bentonite clay have been widely used, but recent developments have used sodium silicate with cement, accelerators and other reactants to give rapid setting and decreased permeability.

A high-pressure air or water jet technique has been developed to cut a slot in the ground into which a barrier may be inserted. This method has been used in Germany and Japan to control movement of soil contaminants. The technique is to bore a line of holes into which the equipment can be lowered. A slot is then removed between the boreholes and infilled with an impermeable barrier material (Childs, 1985).

It is clearly more difficult to place a barrier beneath a polluted mass of soil, but this can be achieved by similar methods to those described in the previous paragraph. A network of boreholes is drilled to beneath the contamination, the jet equipment then lowered into the bottom of the hole and whilst in operation it is rotated so that it cuts a disc-shaped hollow around the base of each borehole intersecting with adjacent hollows. These are then filled with a slurry mixture. If this jet-cutting equipment is not available, the older technique of grouting may be employed. This is a well-tried method used by civil engineers to strengthen rock or soil and reduce permeability by injecting viscous fluids which subsequently solidify in the cracks and pores. There are obvious problems of ensuring a complete seal beneath contamination and the long-term integrity of the materials used in the presence of many contaminants is unknown.

An important part of any technique to isolate pollutants is the provision of a cover to segregate the contamination and to keep out precipitation, otherwise the percolating rainwater may leach out contaminants. The term 'cover system' is prefered as it comprises a sequence of layers, each of which has a specific function. Obviously there is a layer which forms the barrier; this may be formed of soil material or it may be a plastic membrane. Above the barrier layer it is necessary to make provision for the shedding of rainwater and below it in many cases, a permeable layer is necessary for the venting of gases. If a plastic membrane is used, it is necessary to have a layer of sand above and below it for protection, this protective layer can also be used for drainage or gas venting. An additional layer of coarse gravel may be required if it is necessary to break the capilliary rise of liquids from the contaminated ground, and where toxic metals or stongly acidic materials are concerned, a layer of limestone chippings can also act as a chemical barrier. Finally, it is desirable for amenity and practical reasons to protect the barrier layer from the elements, so subsoil and soil layers are provided in which grass can grow. It is desirable to exclude tree species as their roots may penetrate the barrier layer, particularly if it is formed from a soil material. If breached, roots may bring up toxic materials from beneath the barrier and water could gain access to the contamination beneath. Transpiration by trees may also dry out a clay barrier and crack it, so it loses its integrity.

Thermal techniques

Thermal methods of de-contaminating soil employ fixed or mobile plant. Recent developments in this field have been pioneered mainly in the Netherlands and the USA. The plant comprises either directly or indirectly heated rotary kilns, or in one pilot plant, a fluidized-bed furnace. There are at present ten companies operational in the Netherlands capable of dealing with over 500,000 tonnes of polluted soil per year (Batstra, 1988). In the USA, a mobile plant has been developed, each unit based on three heavy-duty trailers. These mobile units are capable of cleansing up to 0.9 tonnes per hour of polluted soil and have the advantage of being moved from site to site. Current air pollution legislation concerning chimney height would prohibit the use of such plants in the UK at present. Other countries are in the process of developing their own facilities, notably West Germany. Although there are now several thermal decontamination plants in operation, experience is limited and has only moved from the laboratory stage to operational plant during the last five years.

Thermal destruction of soil contaminants is an energy-demanding process because soil has a low heat content. So, it is advantageous to use two kilns, the first kiln heats the soil and drives off any volatile substances and the second kiln, operating at 400-700°C, destroys any residual organic pollutants. The effluent gas is passed through a high temperature afterburner at temperatures between 900 and 1200°C to finally decompose contaminants into harmless compounds. After dust removal the gas is finally cleaned by scrubbers to remove acidic combustion products before being discharged.

According to the type of contaminant present there are three levels of treatment possible. Effluent gases containing polychlorinated biphenyls (PCBs), carcinogenic fluids which form dioxins if burnt at low temperature, or dioxins themselves require burning-off at temperatures of around 1200°C before they are rendered innocuous, but many organic substances are capable of being oxidized to harmless end-products at temperatures of 200 to 400°C. At low temperatures the flue gas containing the contaminants may be cooled and scrubbed to remove contaminants which are retained in the liquid form. Techniques such as precipitation, distillation or coagulation can be used where appropriate to separate liquid contaminants (De Leer, 1988).

Where soil contaminants are known to be water-soluble or relatively volatile, the process of steam-stripping may be used. Steam is injected into the soil and the contaminants collected by vacuum drains, condensed and the waste waters separated. Steam may also be generated from the contaminated soil by wetting before passing it into a kiln. Hydrocarbons, such as petrol, kerosene, turpentine, benzene, toluene and xylene, halogenated hydrocarbons such as perchloroethylene, trichloroethylene, methylene, trichlorobenzine and dichlorobenzene, water soluble hydrocarbons such as methanol, ethanol, iso-propanol and phenol as well as volatile inorganic substances such as ammonia and hydrogen sulphide can all be removed from soil by steam stripping. Problems are likely to occur with clay-rich soils where adsorption of contaminants onto the surface of clays covered with a water film requires a long residence time in the kiln to reduce the contaminant to a desired safe concentration. Difficulties are also experienced with clayey soils which form clods, so not all the soil is effectively exposed to the steam-stripping process.

Laboratory experiments on decontamination of soil containing aldrin and dieldrin have shown that heating to temperature of 350-450°C was needed to reduce the concentration of these substances to below the required residual concentration of 0.1 mg/kg. Production of chlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) occurred particularly at temperatures of 750-950°C which indicated the necessity of selecting the correct incineration conditions of both temperature and residence time in the after burner (De Leer, 1988). In the USA, soils contaminated by the herbicide agent orange have been de-contaminated by thermal action using a transportable rotary kiln. The soils were polluted by spillage and leakage during storage at a site in Mississippi, and contained the herbicides 2,4-D and 2,4,5-T in concentrations which ranged from a few ppb to over 200,000 ppm. Dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) was also present in amounts ranging up to 500 ppb. The apparatus reduced the contaminants by three orders of magnitude to concentration of below 1 ng/kg (parts per trillion) (Stoddart and Short, 1988).

Soils contaminated with a wide range of organic compounds have been found to occur within the curtilege of former gasworks. The pollutants contained in soil from gasworks sites may include cyanides, sulphides, polycyclic aromatic hydrocarbons, phenols, and alkylated benzenes. In the process of combustion the soil organic matter is destroyed as well as the contaminants, but the sandy soils treated in the Netherlands are more manageable than loamy or clayey soils from which much larger amounts of contaminated sludge will be produced. In the process of thermal decontamination 90-98% of soil organic pollutants can be removed from soil, 98% or more of cyanide compounds can be removed and almost complete removal (99.5%) of benzene, toluene, ethylbenzene, xylene and polycyclic aromatic compounds is achieved at a cost of between £25 and £60 per ton (Soczo *et al.*, 1987). Similar results have been obtained from a plant in Germany for removing organic contaminants. At the high temperatures attained in the incinerator, mercury is volatalized and some heavy metals are also reduced in amount during treatment. These metals are either sintered or become volatile and pass into the gas stream and when cooling occurs they precipitate onto dust particles and can be removed by cyclones (Glaser, 1988). At the end of the process the cleaned soil has few of its former pedological characteristics left: it is lifeless, organic matter has been oxidized, the structure has been destroyed but it is free from contaminants and can be used as safe fill material. Studies have begun on the rate of re-appearance of life in these cleaned soils.

Microbiological techniques

The use of microbial action to de-toxify soil has received considerable interest during the past decade. Microbes have been used to extract metal from ores, so there appeared to be an obvious parallel in their use to extract metals from polluted soils. To obtain maximum benefit from microbial techniques, conditions for the bacteria must be made as near ideal as possible with sufficient oxygen for an aerobic process and an absence of oxygen in an anaerobic process. Adequate moisture should be present as well as nutrients, especially nitrogen and phosphate. The temperature should be suitable for the chosen micro-organisms which should have adequate access to the contaminant, avoiding concentrations which would be toxic. Anaerobic processes take a longer time to act, so the aerobic processes are preferred, but despite it being a slow process, microbial detoxification has been tried in several countries.

Various methods are utilized to bring about the microbial activity. Ideally, it would be advantageous to treat contaminated soil without excavation, and this approach has been tried. The contaminated soil may be cultivated into low ridges, a technique which has been used in land farming oily wastes for many years (Concawe, 1983). The method is suitable for all biodegradable contaminants including cyanides, nitril compounds, simple aromatics such as benzene, toluene, xylene or phenol, n-alkanes, simple cycloalkanes, low chlorinated C-1 and C-2 compounds and certain pesticides. Alternatively, the soil to be treated can be placed in a rotating drum, together with the appropriate nutrients and moisture and supplied with air and kept at a suitable temperature. Landfarming consists of optimizing the conditions for biological degradation of organic substances by cultivation and through the addition of nutrients and structure improvers. Soczo *et al.* (1987) and Soczo and Staps (1988) describe beds made by first laying down a sheet of 0.5 mm PVC sheet, covering it with a layer of permeable sand for protection and then placing 40 cm of contaminated soil on the sand. Sewage sludge has been used as an inoculum and regular tillage employed with a potash-rich fertilizer applied. Heavy oil concentration in soils of different texture has been reduced from 3-8,000 mg/kg to 1000 mg/kg, kerosine from between 1000-10,000 mg/kg to 500 mg/kg and aromatic hydrocarbons from 100 mg/kg down to 3 mg/kg. More complex polycyclic aromatic compounds do not appear to be broken down by this process as rapidly as gas oil, fuel oil or cutting oils. In the USA, following a fire at a pesticide store in North Dakota, soils were polluted with a mixture of herbicides and insecticides including 2,4-D, alachlor, trifluralin, carbofuran and MPCA. After three months of landfarming treatment the concentration of 2,4-D and MPCA were reduced from 86 ppm to 5 ppm. An alternative treatment in a bioreactor was used for the most polluted soils at this site. 750 m^3 of soil with concentrations of up to 1500 ppm 2,4-D and MPCA was made into a slurry and placed into a container where temperature, dissolved oxygen and pH were optimized. Concentrations of 800 ppm in the slurry were reduced to less than 10 ppm in 13 days.

Bewley and Theile (1988) reported that microbial treatment was £ 70,000 less expensive than conventional land restoration methods would have been on the site of a former gasworks near Blackburn, U.K. About 30,500 m^3 soil contaminated with polyaromatic hydrocarbons and phenols were treated microbially by a strain of introduced 'vanguard' organisms. When this inoculum was omited, no significant breakdown of contaminants occurred, which indicated that the appropriate bacteria were not present in the soil in sufficient numbers to respond to the challenge. Following laboratory experimentation, field trials achieved a reduction of polyaromatic hydrocarbons to less than 10,000 ppm and the total phenol concentration was brought to below 5 ppm. The most effective micro-organism resulted in a PAH reduction from 12,500 to 7600 ppm in 8 weeks. Another micro-organism was effective in reducing the concentration of fluoranthene and pyrene.

Microbial treatment of soil polluted by PCBs from a scrapyard site near Bordeaux, France is described by Goubier (1988). The operation entailed deposition of the excavated soil in a shallow pit, the bottom of which was covered by an impermeable liner. The soil under treatment was covered with peat. A mixture of water, mutant bacteria, nutrients, chalk and additives was spread twice in the autumn of 1986 and once in the spring of 1987. The soil originally contained 6.4 g/kg of PCBs which was reduced by 98% to less than 0.1 g/kg after the third treatment.

Chemical methods

Of the many possibilities available for treating contaminated soil, the chemical processes most likely to produce harmless end-products following a chemical reaction are hydrolysis, oxydation and reduction (Rulkens *et al.*, 1985). The effectiveness of chemical processes depends upon an intimate contact being made between the contaminant and the chemical applied; consequently it is usual to excavate and to make the soil into a slurry. To ensure a thorough reaction and complete detoxification, it is usual to use an excess of chemicals and the reaction can take a long time. It is necessary when the process is complete to separate the soil from the contaminant and the extractant chemical, the latter preferably to be re-used. *In situ* treatment avoids the necessity of excavation but other problems may arise if there is danger of displacement of either the contaminant or its antidote into the ground water. The success or failure of these *in situ* methods is highly dependent upon the nature of the contamination and its distribution in the soil. If the soil permeability varies greatly, pockets of contamination may remain.

In Germany, the injection of oxygen-enriched water into the ground to increase the redox potential has been proposed. The increased concentration of oxygen promotes microbiological activity which would decrease the effects of contamination in soil and ground water. In Japan, the reduction of soluble hexavalent chromium to the insoluble trivalent form has been attempted on a site contaminated with chromite residues. The site was surrounded by an in-soil barrier and ferrous sulphate used as a reducing agent. The effectiveness of the treatment has not yet been commented upon. An attempt to use precipitation is documented from Germany where arsenic concentrations in ground water near a zinc smelter were unacceptably high. The arsenic in the soil and ground water was in the trivalent form. Oxydation of the arsenic in the presence of calcium and ferrous ions would result in precipitation as the safer pentavalent form. Potassium permanganate was injected into the ground and for two years a temporary decrease in the concentration of arsenic in the ground water was observed.

Extracting agents, either acid or alkali, may be mixed with a polluted soil so that in the ensuing reaction the contaminant is transferred from the soil to the extracting agent. In theory this works well, but in practice the extracted contaminant is accompanied by clay and organic materials, forming a sludge which either requires further treatment or is difficult to dispose of. Leaching has a potential application for the separation of toxic metals, cyanides, hydrocarbons and halogenated hydrocarbons from soils. Hydrochloric, nitric and sulphuric acids can be used for the extraction of toxic metals from soils. Sodium hydroxide and sodium carbonate solutions are capable of extracting cyanides from contaminated soil as well as halogenated hydrocarbons and other substances preferentially held by the organic matter. Sometimes it is possible to utilize an alkali waste from one contaminated site to isolate or neutralize strongly acid materials on another. Jones *et al.* (1982) describe the use of alkali wastes consisting of calcium hydroxide and calcium sulphide as a chemical barrier, 50 cm thick, to neutralize the acidity and to prevent the rise of toxic metals from an area contaminated with cadmium, copper, zinc and barium. A soil layer of 15 cm was laid on top and is now grassed as a golf course.

Physical methods

Separation of contaminants from soils can be achieved by mechanical or physical methods in certain circumstances. The characters of specific gravity, particle size, settling velocity, surface properties and magnetic properties can be exploited to obtain a separation (Assink, 1988). However, as has already been observed in the chemical processes of soil decontamination, the presence of organic matter and clay-size particles make a final separation of contaminant from the sludge difficult.

If the property of specific gravity is used, the contaminated soil must first be thoroughly mixed and suspended in a suitable liquid, usually water. After treatment the contaminant is contained in the liquid and the clean soil settles to the bottom of the vessel in which the separation is taking place. The method is suitable for sandy soils contaminated with oil or other substances with a lower density which are not soluble in water.

Where it is known that the contamination is associated with a certain particle size, it is possible to utilize the method of particle- size analysis to effect a separation. Both wet and dry sieving can be used to separate particles coarser than silt-size, but sedimentation must be used to separate finer particles. An alternative procedure is to utilise the particle size to achieve a separation in an upward-flowing column of liquid or gas to effect a 'classification' as it is referred to in engineering terms. In both sieving and sedimentation methods it is important to ensure that the soil is adequately disaggregated and effectively dispersed in the liquid before separation commences. The use of magnetic properties is also a possibility but in practice it probably has limited application as the contaminant would have to be associated with an element or substances with magnetic properties in the soil. Equipment is available commercially for these processes.

Flotation is a widely used physical technique for separation of metallic ores from the country rock in which they are contained. In the treatment the polluted soil would need to be suspended in water to which flotation agents are added. The suspension is then aerated and the small bubbles carry the contaminant away in foam. The contaminants have to be small enough in size and capable of forming an emulsion. Theoretically, many contaminants should be capable of treatment in this manner including halogenated organic substances, oil and metal particles. In practice, the selectivity needed for soil decontamination is not good enough and the problems of organic and clay content in soils render the method of limited application.

Dealing with gases

When the atmosphere in the soil pores becomes replaced with toxic or asphyxiating gases, a state of contamination equally as problematic as with solid or liquid pollutants exists. Gaseous contamination can be observed by the presence of odours and by the vegetation showing signs of stress or dying as the effect of the gas is to produce anaerobic conditions in an otherwise freely drained soil. Methane, carbon monoxide, carbon dioxide and nitrous oxide are produced naturally in soils (Bouwman, 1990) but gases and other volatile organic substances can often be traced to landfill sites or polluted soils. These volatile organic chemicals include benzene, toluene, phenols, ethylbenzene, naphthalene, vinyl chloride, methylene chloride, chloroethane, trichloroethylene, tetrachloroethane, chlorobenzene, xylene, trichloroethane, chloroform, coal tar residues, tetrachloroethene, vinylidene chloride, 1,2-dichloroethane, trans-1,2-dichloroethene, and pesticides (James *et al.*, 1985).

The problems of gas pollution in soil is best solved by tackling the source of the gas. Emissions of gases from landfill sites can be controlled by barrier and cover systems with a collection system which allows the gas to be burnt or utilized for heat. In-soil barriers or cut-off trenches may be used to intercept the flow of gas through the soil. Where these methods are impracticable, modification of the hydrological state of the site might be attempted by pumping to lower the water table and to introduce aerobic conditions into the polluted land. Buildings on land where gases are a problem should be adequately ventilated to prevent an accumulation of gas as methane becomes explosive in concentrations of between 5 to 15% with air (Carpenter, 1986).

Criteria for contamination

During the past decade the number of instances of gross soil pollution in all the industrial countries has been increasing. Often, but not always, these polluted sites are associated with derelict land, formerly occupied by the industries listed previously. As soil pollution presents a hazard to water supplies and health, there has been a need to develop criteria for assessing soil contamination and the technology to deal with the contaminants.

Soils are composed of a range of mineral and organic constituents and these vary in amount and content geographically as well as vertically in the soil profile. It is therefore difficult to establish a minimum concentration below which a soil may be considered uncontaminated for any particular pollutant. Average amounts of several metallic contaminants found in un-contaminated soils are given in Table 1. Moreover, the influence of texture, organic matter content, state of oxidation- reduction and pH are all relevant to the mobility or availability of many contaminants. In the Netherlands and Britain attempts have been made to determine thresholds below which a soil may be regarded as uncontaminated, or above which it is contaminated. Between these two figures lies a range of concentrations where interpretation is required before the land is re-developed or otherwise used again.

Table 1 Range of metallic elements in uncontaminated soils

Element	Concentration range mg/kg
Arsenic	0.1-40
Cadmium	0.01-1.0
Chromium	5-500
Copper	2-100
Lead	2-200
Mercury	0.1-0.5
Nickel	5-500
Zinc	10-300

Many years ago the agricultural advisory service in Britain was concerned about the amount of toxic metals added to soils through disposal of sewage sludges on agricultural land (Chumbley, 1971). More recently, the Inter-departmental Committee for the Restoration of Derelict Land of the Department of the Environment issued *Guidelines on the Assessment and Redevelopment of Contaminated Land* which proposed 'trigger concentrations' or threshold values for a range of metals and other contaminants, particularly those associated with gasworks sites (ICRCL, 1987). However, the relationship of soil contaminant concentration to an effect upon human beings or the environment generally is difficult to assess. Morgan and Simms (1988) have addressed this problem in a consideration of blood metal concentration, the pathways to the population at risk and any significant changes in numbers that are at risk in order to arrive at a valid and relevant threshold concentration for cadmium, lead and mercury.

In the Netherlands, the Government passed a Soil Protection Act in 1987, following experience gained under the provisions of the Soil Clean Up (Interim) Act of 1983. Accompanying this legislation, threshold values have been determined for three concentrations of contaminants: an uncontaminated 'reference' value, a figure which indicates further investigation is required and a third figure above which a clean-up is necessary (Table 2) (Moen *et al.*, 1986). In the past three years, an increased awareness of the significance of the natural variation of soil particle-size, organic matter content and pH has led to an appreciation of these criteria in controlling in the accumulation and/or mobility of soil contaminants. Moen (1988) has introduced factors for organic matter content and the amount of clay-sized material (less than 0.2 μm) present in soils to help determine a reference value which defines the threshold value below which soils are considered to be uncontaminated.

In Germany, Finnecy (1987) reports that Hecht (1986) had proceeded on similar lines to determine a U value below which a soil may be considered uncontaminated and a S value above which treatment is necessary. Kloke (1986) had prescribed a no effect level (NOEL) below which soil may be considered uncontaminated. Work has proceded along similar lines in the USA where considerable effort has also been expended upon the toxicology and on assessing the acceptable daily intake (ADI) of many potential soil contaminants. The toxicology of these materials has been assessed in terms of their acute, sub acute and chronic toxicity together with the mutagenic, teratogenic and carcinogenic properties where these are significant.

The complexities of diffuse soil contamination have necessitated an approach through modelling. Conceptual models have been developed by many investigators to explain the phenomenon of acid deposition. More recently the significance of the soil has been realized and it has now been included. For example, one of the most sophisticated models, RAINS simulates the effects of different atmospheric pollutants on the environment in Europe; SMART is a simulation model for acidification and regional trends, while other models have been developed which take into consideration nutrient cycling, foliar exudation, litter fall, mineralization of organic matter and root uptake. Models can also help us to understand the geographical distribution of radionuclides, but further research into their behaviour once in the soil is urgently needed, especially around Chernobyl and the other affected areas. Conversely, it is possible to compile maps of soil vulnerability which indicate the soil parameters which are known to influence strongly soil acidification. Many of these maps of soil parameters are now being incorporated into geographical information systems.

Table 2 Standards adopted in the Netherlands for soil contaminants A, reference value; B, value above which there is need for further investigation; C, value above which a clean-up is indicated (Moen *et al.*, 1986)

Substance	Concentration in					
	Soil (mg/kg dry weight)			Ground water (μg/l)		
	A	B	C	A	B	C
Metals						
Cr	100	250	800	20	50	200
Co	20	50	300	20	50	200
Ni	50	100	500	20	50	500
Cu	50	100	500	20	50	200
Zn	200	500	3000	50	200	800
As	20	30	50	10	30	100
Mo	10	40	200	5	20	100
Cd	1	5	20	1	2.5	10
Sn	20	50	300	10	30	150
Ba	200	400	2000	50	100	500
Hg	0.5	2	10	0.2	0.5	2
Pb	50	150	600	20	50	200
Inorganic pollutants						
NH (as N)	-	-	-	200	1000	3000
F (total)	200	400	2000	300	1200	4000
CN (total free)	1	10	100	5	30	100
CN (total complete)	5	50	500	10	50	200
S (total)	2	20	200	10	100	300
Br (total)	20	50	300	100	500	2000
PO (as P)	-	-	-	50	200	700
Aromatic compounds						
Benzene	0.01	0.5	5	0.2	1	5
Ethylbenzene	0.05	5	50	0.5	20	60
Toluene	0.05	3	30	0.5	15	50
Xylene	0.05	5	50	0.5	20	60
Phenols	0.02	1	10	0.5	15	50
Aromatics (total)	0.1	7	70	1	30	100
Polycyclic aromatic compounds (PCAs)						
Naphthalene	0.1	5	50	0.2	7	30
Anthracene	0.1	10	100	0.1	2	10
Phenanthrene	0.1	10	100	0.1	2	10
Fluoranthene	0.1	10	100	0.02	1	5
Pyrene	0.1	10	100	0.02	1	5
Benzo(a)pyrene	0.05	1	10	0.01	0.2	1
Total PCAs	1	20	200	0.2	10	40

Chlorinated organic compounds						
Aliphatic chlor.comp. (indiv.)	0.1	5	50	1	10	50
Aliphatic chlor.comp. (total)	0.1	7	70	1	15	70
Cholobenzenes (indiv.)	0.05	1	10	0.02	0.5	2
Cholobenzenes (total)	0.05	2	20	0.02	1	5
Chlorophenols (indiv.)	0.01	0.5	5	0.01	0.3	1.5
Chlorophenols (total)	0.01	1	10	0.01	0.5	2
Chlorinated PCA (total)	0.05	1	10	0.01	0.2	1
PCB (total)	0.05	1	10	0.01	0.2	1
EOCI (total)	0.1	8	80	1	15	70
Pesticides						
Organic chlorinated (indiv.)	0.1	0.5	5	0.05	0.2	1
Organic chlorinated (total)	0.1	1	10	0.1	0.5	2
Pesticides (total)	0.1	2	20	0.1	1	5
Other pollutants						
Tetrahydrofuran	0.1	4	40	0.5	20	60
Pyridine	0.1	2	20	0.5	10	30
Tetrahydrothiophene	0.1	5	50	0.5	20	60
Cyclohexanone	0.1	6	60	0.5	15	50
Styrene	0.1	5	50	0.5	20	60
Fuel	20	100	800	10	40	150
Mineral oil	100	1000	5000	20	200	600

CONCLUSIONS

One of the biggest problems of dealing with polluted soil is to answer the question 'How clean is clean?' At present the point at which it becomes necessary to carry out remedial action varies from country to country. As the European states form a closer association it will be necessary to agree upon the standards to be used. In the Netherlands a policy of *multifunctionality* has been adopted which aims to restore the polluted land to a sufficiently high standard for it effectively to be declared uncontaminated and ready for a wide range of future uses. This policy stems from the specific conditions in the Netherlands where high ground-water levels are common so pollution may rapidly affect water supplies. Removal of polluted soil is usually possible; however the excavated material must be dumped somewhere else and this simply spreads the pollution. Alternatively it must be made innocuous and this has helped to encourage the development of soil cleaning technology in the Netherlands.

In many other countries including the UK a different approach is taken. The solution of the problem of polluted soils takes into consideration the final land use envisaged. In practice this means that a flexible approach to land use planning may be used on formerly polluted sites. Grossly polluted soils must be dealt with but residual contamination may be sealed beneath low intensity land uses such as car parks where a bitumin or concrete cover can effectively isolate the polluted soil from human beings and the environment. Where the future land use is houses and gardens where children play or allotments from which significant quantities of vegetables are eaten, a more stringent standard is applied. Using this flexible approach, unnecessarily high standards need not be applied where pollution poses little or no danger. It also enables the available funds to be spread more widely as a policy of complete clean-up is extremely expensive.

The presence of contaminants in soil clearly influences its quality for many uses. For this reason soil quality has become the focus of interest of a Technical Committee of the International Standards Organization where 10 participating and 26 observing countries are attempting to agree on standards for soil quality similar to those already established for air and water. The ISO Technical Committee is concerned with the standardization of terminology, sampling methods and analytical techniques for measurement of chemical physical and biological characteristics of soils. The work of this committee is supported by affiliation with FAO, the International Society of Soil Science, the International Commission for Irrigation and Drainage and the UN Environmental Programme and several other international organizations representing engineers, chemists, hydrologists, meteorologists and the World Health Organization. In individual countries, such as the Netherlands, Federal German Republic, France and the UK, national committees have been set up to reach agreed standards of soil quality within national boundaries.

ISRIC has a valuable role to play in gathering and disseminating information about how to overcome the problems of polluted and contaminated soils. One of the aims of the UNEP World Soil Policy is to develop methodologies for global soil monitoring. Soil degradation generally is of world-wide concern and specifically GLASOD is one of the current major projects at ISRIC. Evidence of soil degradation including that caused by pollution and contamination is being gathered. When assembled together with information on the soil pattern in a geographical information system it will be the basis for the establishment of global priorities and action programmes.

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Participants 1989 course on the establishment of National Soil Reference Collections and Databases.

A group of students and staff members of the Swedish University of Agricultural Sciences, Uppsala, visiting ISRIC.

3 REGULAR ACTIVITIES BY THE SECTIONS

3.1 SOIL MONOLITH COLLECTION

During the reporting period the number of soil monoliths remained at 785 (see table below).

Monolith collection, December 1989

Australia	39
Belgium	4
Botswana	7
Brazil	29
Cameroon	1
Canada	21
People's Rep. of China	15
Colombia	19
Czechoslovakia	8
Denmark (Greenland)	6
Ecuador	20
Finland	5
France	12
Fed. Rep. of Germany	17
Ghana	4
Gabon	6
Greece	15
Hungary	20
India	30
Indonesia	25
Ireland	11
Italy	17
Ivory Coast	7
Jamaica	3
Japan	4
Kenya	65
Malawi	1
Malaysia (East)	11
(West)	7
Mali	9
Mozambique	8
Namibia	11
Netherlands	24
New Zealand	5
Nigeria	14
Norway	3
Oman	4
Pakistan	6
Peru	1
Philippines	6
Poland	14
Romania	11
Rwanda	10
Rep. of South Africa	20
Spain	20
Sri Lanka	4
Sweden	17
Switzerland	1
Syria	4
Thailand	13
Turkey	13
United Kingdom	11
U.S.A.	25
U.S.S.R.	62
Uruguay	10
West Samoa	5
Yugoslavia	3
Zaire	2
Zambia	11
Total	785

General

An unfortunate incident, caused by a leaking water de-ionizing unit, resulted in a complete loss of about 20 monoliths and a partial, hopefully partly reparable, loss of about 35 monoltihs. A complete inventory will be made in 1990. In the meantime, a programme for reclaiming the lost profiles has been made and it is expected that the Ministry of Education and Sciences will cover the extra costs.

During the year about 15 profiles have been impregnated. This work is seriously hampered by not having a full-time technician.

3.2 LABORATORY

At the end of this decade of automation and digitalization also the relatively small research laboratory of ISRIC seems to have been conquered by the computers. The old calculation programmes were remodelled into LOTUS 1-2-3, Worksheets for data input were developed and data were entered into our main ISIS database. Preparations are being made to introduce essential aspects of GLP (Good Laboratory Practice). This will be part of the development of a complete GLP Manual which can be used in operational and management support of soil laboratories in developing countries.

Analytical work was carried out on several projects and subjects. Four monoliths from Ambon, Indonesia, were fully analysed and results will be compared with those obtained at Ambon as well as at Bogor, Java. Three monoliths were analyzed for the 1989 NASREC course. Supplementary analyses were done on several Andosols for the data set of Soil Monograph 2.

As usual, for several departments of ITC a large number of soil and water analyses were carried. Also LABEX was duly served. Special analyses were requested by the Netherlands Soil Survey Institute for projects in Jamaica and Tanzania, by the Soil Science and Geology Department of the Wageningen Agricultural University and by ACSAD, Damascus. Participation in the ITC/University of Pattimura project (Ambon, Indonesia) was continued.

3.3 MICROMORPHOLOGY

Technical work

As from January 1, 1989, the technician of ISRIC was transferred to the Winand Staring Centre, where the preparation of thin sections for ISRIC is now carried out.

During 1989, 43 thin sections were prepared for the regular collection of ISRIC, all of these are related to the NASREC sampling programme: Brazil (4), Ecuador (29), Indonesia (8), and Mali (2).

Samples for special projects included: Brazil (3) (Dr. W.G. Sombroek), Colombia (1) (Prof. A. Zinck, ITC) and Sri Lanka (6) (Dr. W. Siderius, ITC).
Porthmouth Polytechnic (Portsmouth, U.K.) paid for the preparation of 29 thin sections for research carried out by Dr. P. Farres of Portsmouth.

In 1989, 14 samples from Indonesia were received for treatment.

Investigations

Description and interpretation of thin sections was carried out for soils collected in relation to the NASREC project. These included soils from Indonesia and Mali. Photomicrographs and descriptions were prepared for posters to be exhibited in these countries.

Hand-outs in the English and Dutch language were prepared for course participants and visitors. The hand-outs contain information on the systematic description of soil thin sections.

Preparatory work was also carried out for the preparation of a working paper on photomicrography.

Preparatory work was done to facilitate the computerized storage of micromorphological description of thin sections.

3.4 DOCUMENTATION

ISRIC Soil Information System (ISIS)

The soil pedon documentation with information on site and soil in the field and chemical, physical and micromorphological data is essential for ISRIC to function as a reference and information centre.

The Soil Information System ISIS will help to improve storage, retrieval and selection of the data. Although it has been primarily developed to handle extensive site and soil description, including for instance climatological data, as used at ISRIC, it can be considered as a concept for soil information systems with other purposes. Anyone familiar with dBase application language can change the unprotected programme to fit other objectives. In fact, this programme has already been applied in some countries, while it was used as the basis for the development of the FAO/ISRIC Soil Data Base.

At the end of 1989 the data of about 250 monoliths were stored.

Map collection and Library

The coverage of maps and publications is the whole world, with strong emphasis on developing countries. The collection is dominated by soil and related geographic information on climate, vegetation, land use, land capability, geology and geomorphology. At present the map collection includes about 4500 sheets and some 600 photo-negatives and transparencies.

One of the purposes of maintaining the map collection is its use for updating of the Soil Map of the World at scale 1:5 million and the compilation of a new, computerized world soil map at 1:1 million.

Efforts are being made within The Netherlands to have information on available maps included in a database. The work is being coordinated at an office located in the Royal Library, The Hague. Mr. J. van Baren is member of the 'Council of Participants' of this project. A project proposal for an additional staff member for three years has been made. It is the objective to have the entries in the database available on-line in 1992.

The library collection includes about 5000 publications, about 2500 of which are on a regional basis, mostly reports on soil and land surveys. The remainder is constituted mainly by textbooks on soil science and related subjects, bibliographies and more-and-more atlases. The map and book collection increasingly serves as a source of basic information for scientists, students and consultants in soil correlation studies and in the preparation of missions. There is especially an increase in its use by students of Wageningen Agricultural University, participants of international courses and consulting companies.

Since the beginning of the year the titles of newly acquired publications are entered in a database using the Cardbox Plus computer programme. This facilitates the use of titles stored in Agralin, the database of Wageningen Agricultural University and many other agricultural establishments in The Netherlands.

In the course of the year ISRIC was accepted as "World Data Center-C for Soil Geography and Classification". The system of World Data Centers is being organized by ICSU.

3.5 SOIL CLASSIFICATION, CORRELATION AND MAPPING

With publishing World Soil Resources Report 60 by FAO and Technical Paper 20 by ISRIC as a pocket edition of the revised FAO/Unesco Soil Map of the World legend, the ad-hoc Working group on the revision of the 1974 legend was superseded.

Towards the end of the year a start was made with proposals for the third level of classification, as well as with proposals for a revised edition of the Guidelines for Soil Profile Description (FAO, 1977).

ISRIC staff is involved in both activities.

3.6 TRANSFER OF KNOWLEDGE

Group visits

About 1100 persons visited ISRIC in groups, mainly from educational institutions such as universities, agricultural and technical colleges, and from international training courses, congresses and meetings. The ISRIC collection has been incorporated by the Wageningen Agricultural University for courses on regional soil science, and for its M.Sc. Course on Soil Science and Water Management. ISRIC has been visited several times by students of the College for Land and Water Management, Velp, the National Agricultural College at Deventer, and international courses held in the Netherlands, e.g. ITC, Enschede, and ILRI, Wageningen.

In addition, ISRIC has received students from Universities and Colleges from Belgium, Federal Republic of Germany, Sweden and the United Kingdom.

The facilities of ISRIC were repeatedly used for lecturing, courses and meetings organized by institutes outside ISRIC, such as the International Agricultural Centre, the Winand Staring Centre, the Wageningen Agricultural University, the "Tropenbos" programme, and various commission and working groups of the Wageningen agricultural scientific community. For complete list see Appendix 1.

Individual visits

On 26 January 1989 ISRIC was honoured by a working visit of H.R.H. Princess Maha Chakri Sirindhorn of the Kingdom of Thailand.

The number of people coming individually or in small groups is estimated at about 350. Most visitors are professional soil scientists, the majority coming from abroad. The purpose of their visit concerns discussion with staff members, consultation of the soil collection, the library or the collection of soil and other maps.

Extramural lectures

As in the preceding years, staff members of ISRIC participated in the Basic Course Soil Survey of ITC in Enschede, by giving lectures and training of soil genesis and classification, mineralogy and soil chemistry. Both the FAO-Unesco Soil Map of the World and the USDA system of soil classification, Soil Taxonomy, were discussed. These lectures were illustrated with slides, hand-outs and lecture notes, and other materials derived from the ISRIC collection.

ISRIC was invited by the Swedish University of Agricultural Sciences, Uppsala, Sweden, to give lectures on classification of soils in the tropics and on land evaluation.

ISRIC was invited to lecture on soil classification at the Fourth College on Soil Physics at ICTP, Triest, Italy. Both occasions were attended by J. van Baren.

Publications issued in 1989

Technical Paper

TP 20 FAO-Unesco Soil Map of the World. Revised Legend, field edition, 1989.

Soil Monograph

SM 2 Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions, 1989. C. Mizota and L.P. van Reeuwijk.

Working Paper and Preprint

89/1 Land evaluation for rainfed farming using global terrain information on a 1° longitude x 1° latitude grid. A.F. Bouwman.

89/2 Micromorphological features of some Yermosols developed on Fluviatile Clastic deposits southwest of the Oman Mountains. E.M. Bridges, D. Creutzberg.

89/3 SOTER Procedures Manual for small-scale map and database compilation and Procedures for interpretation of soil degradation status and risk. (Revised version of Working Paper and Preprint No. 88/2). Compiled by J.A. Shields and D.R. Coote.

89/4 International Conference "Soils and the Greenhouse Effect". Draft Background Paper. A.F. Bouwman.

89/5 Selection procedure of geographic information system software for SOTER. V.W.P. van Engelen.

89/6 Estimation of the waterholding-capacity of soils in Europe. The compilation of a soil dataset. H. Groenendijk.

Consultancy/Mission Report

89/1 Chemical analysis of some soil and tissue samples from Tanzania.

89/2 Report on Missions to: Madrid (13-14 March, 1989): Working Group on Erosion Mapping; Nairobi (10-20 April, 1989): UNEP; Syria (22-26 April, 1989): ACSAD and ICARDA. GLASOD-SOTER Project. L.R. Oldeman.

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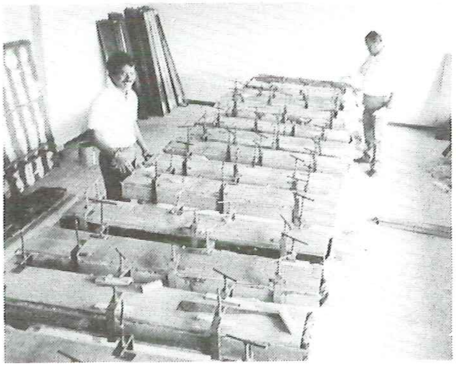
- ISSS (1989). Report of a Workshop on Implementation Plan for North American Pilot Area of the SOTER Project (NASOTER). M.F. Baumgardner (ed.) ISSS, Purdue.

- Oldeman, L.R. (1989). Global Assessment of Soil Degradation. Poster presentation, 6th Int. Soil Conservation Conf., Addis Abeba, Ethiopia.
- Van Reeuwijk, L.P. and C. Mizota (1989). The binary composition of the clay fraction of Andosols. Abstr. Ninth Int. Clay Conf., Strasbourg, 413.
- Van Reeuwijk, L.P. (1989). Andosols. In: P.M. Driessen and R. Dudal (eds.). Lecture notes on the major soils of the world, 47-54. Agric. Univ. Wageningen, Kath. Univ. Leuven.



Activities in field and workshop for building up a Soil Reference Collection in Indonesia.

4 NON-REGULAR ACTIVITIES

4.1 PROGRAMMES

NATIONAL SOIL REFERENCE COLLECTIONS (NASREC) 1986-1988

Contents

SUMMARY

Since its establishment as International Soil Museum in 1966, ISRIC has been working on the acquisition of a world collection of soils. During the last decade ISRIC has been requested by soil institutes in more than thirty countries to support the establisment of National Soil Reference Collections. A few of them have already been assisted through ad-hoc project support. For several others, initial steps have

been taken through ISRIC's annual international course on Soil Reference Collections and Databases, given since 1981. A country support programme (NASREC) was started in 1986, with funds from DGIS/UNEP Clearing House Facility. These funds covered two and a half years of activities, during which national reference collections were initiated or strengthened in Brazil, Ecuador, Ghana, Indonesia, Sri Lanka, Mali and Venezuela. It is expected that the NASREC programme can be continued within the framework of UNEP's Guidelines and Action Plan for the strengthening of National Soil Policies.

1. HISTORY

Since the early beginning of soil science attempts have been made to collect relative large soil bodies in the field for comparative studies. A summary of a number of soil expositions and soil museums, the techniques used and a bibliography on the subject is given by Van Baren and Bomer (1979). The objective of these soil collections was to show the variation in soils at a national scale. With the establishment of the International Soil Museum (ISM) in 1966 for the first time an attempt was made to sample soil profiles on a global scale.

Since its foundation over 800 soil specimens ["monoliths"] have been collected in 60 countries. After some years of experimentation a succesfull technique of soil monolith sampling and the necessary preservation was published in 1979 as Technical Paper No. 1. For most soils the technique proved to be successful, however, it is felt that for hydromorphic soils, e.g. peat soils and unripe clay soils, and strong shrinking soils, such as volcanic ash soils, improvements were and are still needed.

A strong development took place in the amount of information for visitors of the collection. The soil monolith collection is linked to a comprehensive information bank containing data on soil, land use, climate and other ecological aspects, including all chemical, physical and mineralogical data. In addition to this, ISRIC has a cartotheque, a library and a diatheque which show the geographical distribution of the world soils, their land use or vegetation, their potential productivity and erosion susceptibility. As such ISRIC is an information centre in the fields of research, education and extension for individuals and soil and land-oriented institutions, especially those from developing countries.

In addition to a world soil collection, which has proven its use as a world information centre, the need was more and more felt for establishing national soil collections (NASREC). The use of a soil collection as training, research and extension instrument has been recognized by an increasing number of countries. In section 2.1 the reasons are discussed. Especially during the last decade, this need is evident from the large number of requests to ISRIC to support the establishment of national soil collections in combination with a data bank.

The most important means to comply with these requests is technology transfer in combination with a relative small material support. Over the years, three methods of technology transfer were developed:

1. Publication of ISRIC Technical Papers in which techniques, materials and equipment are described.
2. Training of personnel of national soil & land resources institutions (University Departments and/or Governmental Services). Coordinators of future national soil collections are given a basic training in all aspects related to the establishment and maintenance of soil collections, including the use of a computerized database.
3. After-training service in the countries involved. This form consists of in-service training in the countries, in combination with material support. Until now this has been financed for the major part through ad-hoc bilateral projects, and more structurally in the period 1986-1988 by the NASREC project (UNEP-DGIS Clearing House funds).

Below an account is given on the NASREC project during this three year period.

2. SOIL REFERENCE COLLECTIONS

2.1 General outline of the problem

In spite of many efforts made so far, the different soils of many developing countries are insufficiently known to soil scientists mainly working indoors, agronomists, biologists and specialists working in other environmental disciplines. A soil is difficult to study, not only because it is a 'hidden' object, but also because soil properties are generally gradually changing geographically, with depth and in time. This is one of the main reasons why soil types or soil specimens are till today difficult to define. After a century of soil research a large number of soil types have been recognized and defined in national and international soil classification systems. In the preparation of the 1:5.000.000 FAO-UNESCO Soil Map of the World 106 major soils were distinguished to show the distribution of the main soil units. On more detailed maps many thousands of soil types could be shown.

Nobody disputes that in the coming decades agricultural production in the developing world has to be increased. Basically there are two options to achieve this goal:

- to expand the extent of agricultural land, and
- to stimulate the increase of agricultural production per unit area.

Additionally, many of the world's agricultural soils are threatened by current soil degradation (erosion, salinity and pollution), having disastrous consequences for

agricultural production. Therefore, the prevention of the decrease of production per unit area caused by soil degradation should also be considered.
An understanding of the soil factor is paramount and to achieve these goals many nations need to define a National Soils Policy as advocated by UNEP.

In view of an urgent need to increase agricultural production and at the same time prevent soil degradation, a comprehensive and well-accessible knowledge on soil and other environmental factors should be regarded as a necessary prerequisite. Currently soil and other environmental information as published in different soil maps and reports embraces a wide array of such aspects as: geographical distribution, soil characterization, soil classification, actual and potential capacity as well as the limitations to support sustainable agriculture, and the ecological significance in respect of soil erosion, waterlogging, salinization and pollution.

This information is usually not utilized adequately by the educational, agricultural research and extension institutions in the country. Some reasons for this situation are:

- Established soil characterization and classification systems implied in the soil maps and reports require highly qualified staff to use them for local practical situations.
- Lack of a representative soil specimen collection, as used in botany (herbarium) and geology, is one of the main reasons which necessitates soil scientists to gain many years of field experience before they are trained and fully confident. In education and extension activities, it hampers the transfer of knowledge because the different soil types can only be shown during costly field visits.
- Low accessibility of information, especially for the situations of data stored in a classical way (i.e. manual archives). This hampers new selections and treatment of data. A computerization of the soil and other ecological data will alleviate this.

2.2 National Soil Reference Collections

A national soil reference collection consists basically of a soil monolith display in combination with a soil information bank. An exposition of soil monoliths shows specially prepared soil specimens, representative of the major soil types, which are displayed together with selected 'key' information, photos of landscapes, land use, etc. Soil reference collections are generally recognized as a practical training and extension instrument to bridge the gap between the highly abstract classification systems and the soil types as they appear in practice to people working in research, education and extension institutes, and ultimately, to the farmer.

A computerized soil database comprises a collection of soil data and relevant other environmental data. Such a system will help in the transfer of soil information to users.

In the following, the functioning of a soil reference collection and a soil data base at national soil and land resources institutions - in some countries already named as National Soil Reference and Information Centre (NASRIC) - will be discussed. The establishment of a NASRIC at such institutions will help to remove a part of the above mentioned constraints to the national development of soil science and its practical applications.

2.3 Objectives and target user groups of the NASREC programme

The **long term** goal of the programme is to improve the use and extension of knowledge of soil and land resources, their potentials and constraints, for a chosen land use activity.

The main objectives are institutional and manpower development through the establishment of National Soil Reference and Information Centres at national soil and land resources institutions in developing countries.

The **short term** objective is the reinforcement of the education, extension and research capacities of the national soil and land resources institutes.

The principal activities are:

1. The establishment of an exposition of representative soil types as a core collection in six developing countries.
2. The establishment of a computerized soil information database.

Target groups

Soil collections and soil databases are being used for education, extension and research purposes. The fields of interest are manifold, some important ones are agriculture, hydrology, ecology and physical planning.

The main functions and users of collections are:

1. Reference and research - Soil Research/Survey Institutions.
   Soil and land evaluation specialists from land resources institutions can be better trained in aspects of soil characterization, soil classification and land evaluation, contributing therefore to a better performance of soil survey and land use planning staff. Interesting soil sequences, intergrading soil types, etc. could be better studied.
2. Technical information transfer - Agricultural Research Institutions.
   Specialists in other agricultural sciences, e.g. agronomists have access to a clear arrangement of soil types and soil-crop related information; ecologists can be shown the range of soil-related constraints in land development programmes.

3. Scientific education - Universities, Agricultural Schools.
   Students can be better trained in soil-related subjects because a soil collection offers the best substitute for costly field visits in which the soil types can be shown.
4. Summarized information - Planning and Extension Institutions.
   Planners and extension specialists can familiarize themselves with the differences in soil characteristics, the use possibilities and limitations of major soils in the country.
5. Popular information
   With the reference collection and relevant audio-visual information, the general public can be shown for example the degradation hazards threatening the production capacity of the nation's land resources, thereby contributing to the promotion of awareness about the local soils as a finite resource that merits careful conservation and management.

2.4 Countries and institutions involved

An essential condition for the establishment and functioning of a NASRIC is the existence of a National Soil Institute, Soil Survey Service, or another institution such as a Soil Science Department of a University, willing and capable to adhere to the aims outlined above. Such an institute will be further indicated as National Soil Institute - NSI.

During the cooperation period, the core collection will be housed and managed by the NSI. Enlarging the core collection into a full collection will continue after ISRIC's involvement has ceased. This is normally carried out over a long period and often realized in combination with the institute's tasks, e.g. soil survey fieldwork.

A distinction between 'major' and 'minor' support countries is used, based on the amount of after-training service and (financial) support given by ISRIC.

Names of institutions responsible for the creation of a NASREC, as well as location of the exposition and persons responsible for the collection are given below. For full address information contact ISRIC.

Major support countries

Ecuador

Institution: The National Soil Science Department of Ecuador (PRONAREG) directly responsible to the Ministry of Agriculture, has taken the initiative and has the responsibility for the creation of the Centro Nacional de Referencia y Informacion de Suelos (CENRIS).

Exposition:	The soil collection is housed in excellent exposition facilities of the Museo Ecuatoriana de Ciencias Naturales, which forms part of the National Museum in the centre of Quito.
Coordination:	Mr. Guillermo del Posso, Head of the Soils Department is Director ad-honorem of Cenris.

Indonesia

Institution:	The Pusat Penelitian Tanah (PPT) or Centre for Soil Research (CSR) in Bogor.
Exposition:	The soil collection is housed on the sixth floor in the central building of the same institute.
Coordination:	Mr. A.M. Sudihardjo of PPT.

Mali

Institution:	The Projet de l'Inventaire des Ressources Terrestres (PIRT), a division of the Ministère des Ressources Naturelles et de l'Elevage.
Exposition:	The small collection is housed in the main hall of PIRT's offices at the national research station in Sotuba, 5 kilometers from Bamako.
Coordination:	Mr. Oumar Doumbia of PIRT.

Minor support countries

Ghana

Institution:	The Soil Research Institute (SCI) at Kwadaso - Kumasi.
Exposition:	The incipient collection is actually housed in CSR's exposition hall in Kumasi and will be partly moved to the new SCI building in Accra.
Coordination:	Mr. R. Asiamah, Head of the Soils Department and Mr. Owuso Dwomo, technical officer.

Sri Lanka

Institution:	The Land Use Division of the Irrigation Department in Colombo
Exposition:	The incipient collection is housed in the Land Use Division.
Coordination:	Mr. S. Dimantha, Head of the Land Use Division and Mr. Ekanayake, technical officer.

Venezuela

Institution:	Instituto de Edafologia of the Facultad de Agronomia - UCV in Maracay.

Exposition:	The incipient collection is housed in a large hall of the Instituto de Edafologia.
Coordination:	Prof. A. Rosales and Mrs. Maria José Mendez Oubel.

Brazil

Institutions:	Serviço Nacional de Levantamento e Conservação de Solos (SNLCS) of EMBRAPA in Rio de Janeiro and Recife; Centro de Pesquisa Agropecuaria de Cerrado (CPAC) in Planaltina.
Expositions:	Incipients collections are in the same institutions.
Coordination:	Dr. Francesco Palmieri (Rio de Janeiro), Dr. Paulo Klinger (Recife) and Dr. Jose Madeira (Planaltina).

3. ACCOMPLISHMENTS

In this chapter the different activities are presented in a summarized way per major and minor support country. In chapter 4 the results are summarized for each country individually.

3.1 Inventory

All requests to ISRIC from National Soil Institutions (NSI) to support the establishment of a soil collection are scrutinized after a detailed questionnaire on the current conditions at the NSI's to establish a NASREC has been completed. The responses to the questions form the basis for the selection of countries as mentioned in 2.4.

3.2 Training course

During the project period a six-week training course was held in Wageningen in 1986 and 1987.

The first took place from 12 May-20 June 1986, with the participation of NSI staff members coming from Argentina, Ecuador, Indonesia, Mali, Peru and Venezuela.

The second course took place from 18-20 June 1987, with the participation of NSI staff members from Ethiopia, Ghana, Kenya, Peru and Sierra Leone.

The objective of the course is to train soil scientists in all aspects to establish a National Soil Reference Collection. The major elements of the course are:

- Sampling of soil profiles, preparation and preservation of soil monoliths.
- Description and photography of soil, landscape, vegetation and land-use.
- Handling and treatment of data for the soil exposition and a soil database.
- Building up a soil exposition.

- The use of a soil collection for classification and land evaluation purposes.

The courses are given by 20 persons, mainly ISRIC staff, but for some subjects external contributors have assisted.

Except for minor changes, the course curricula for both courses were similar: 25% fieldwork, 15% workshop activities, 25% lectures and exercises in the exposition hall, 15% excursions, 10% final presentation and 10% for other activities.

Based on experiences with the past courses, the curriculum of future courses will be expanded with lectures and exercises on computerization of a soil database and the use of a soil exposition.

3.3 Field missions

Eight missions totalling 10 months were realized by ISRIC staff to Brasil, Ecuador, Indonesia, Mali and Venezuela. The main objectives of these missions are institutional and manpower development.

3.3.1 First missions to Ecuador, Indonesia and Mali

The activities executed with the counterparts during these missions consisted of similar elements, such as:

- Drafting of a detailed workplan for the establishment of a National Soil Reference Collection including fieldwork and data collection, soil analysis, soil database, housing and the installation of the soil exposition, and a seminar for the target groups.
- Selection of representative sites for the core collection.
- Identification of and discussion with the target user groups.
- Execution of the fieldwork.
- First input of field data in the database.
- Collection of the information on geology, climate and other required ecological data.
- Provision of materials and tools when required during the activities.

Between one-half and two-thirds of the time was used for the execution of the fieldwork.

The period between the first and the second mission covered about one year. This time was used by the NSI to finalize fieldwork, to organize export and transport of samples to ISRIC and, if facilities were available, to analyze samples at a national soil laboratory.

All samples collected during the fieldwork were split and one batch was sent to the ISRIC laboratory. All analytical data coming from the national and ISRIC laboratories were stored in the soil database.

Treatment of data, i.e. calculations, statistics and graphics, was partly done at ISRIC and partly at the NSI during the second mission.
Further details on computerization is given in section 3.4.

3.3.2 Second missions to Ecuador, Indonesia and Mali

The activities executed with the counterparts during these missions were as follows:
- Preservation and preparation of soil profiles.
- Completion of the soil database.
- Statistical treatment and graphical presentation of climatic and soil data.
- Drafting an outline of a technical paper for the users of the soil collection.
- Housing and installation of the exposition.
- Organization of the inauguration of the soil exposition and a workshop for target user groups.

Unfortunately, insufficient time was available in-between the two missions of the ISRIC staff member, to prepare monoliths and organize the necessary exposition facilities. This resulted in a tight schedule of activities during the second mission to the three countries.

In addition to the missions to the major support countries, some additional visits were made to Brazil and Venezuela. Brazil is not a country selected for support within the framework of the NASREC project. However, since 1984 a cooperative programme between SNLCS and ISRIC existed already for the establishment of a NASREC. This resulted in fieldwork during the project period, in which one ISRIC staff member participated. Soil sampling of major soil groups took place as well as training of staff members of SNLCS-EMBRAPA and CPAC.

3.4 Automatization

ISRIC's Soil Information System (ISIS) became operational mid 1986. With this programme all data collected about soils, landform, climate, vegetation, land-use and other relevant ecological data are stored in a computerized database. ISIS is developed for IBM XT and AT personal computers or compatibles and built with the database management program dBASE III. For details on the programme see ISRIC Technical Paper 15. The description of soil and environment follows to a great extent the FAO guidelines for soil profile description (FAO, 1977), but when more detail or specifications were necessary, other guidelines were adopted. For details see ISRIC Technical Paper 14.

The use of lightweight portable computers during the fieldwork is nowadays feasible. It was decided to use the ISIS programme and such computers during the field missions. In the beginning this caused some delay in the elaboration of field data because of the strict coding and input procedures. However, it proved soon to be very advantageous for the missions to Mali, Ecuador and Indonesia.

Soil and environment datasheets could be printed during the fieldwork and directly discussed with the counterparts. Selections of data can be taken from the database and further treated. Graphical presentation, mathematical and statistical calculations of climatic and soil analytical data with application programmes such as dBASE III, LOTUS and Symphony and statistical programmes were also introduced.

Besides these advantages the portable computer proved also a powerful instrument as a text processing facility. Draft workplans for meetings with the counterparts, minutes of meetings, bookkeeping and interim reports could be produced on-the-spot.

In the major support countries Ecuador, Indonesia and Mali a database of the soil collections could be demonstrated. In all cases the NSI's expressed the need for adaptation of the soil database to fit the national conditions. These adaptations will be further discussed under follow-up activities in Chapter 6.

4. RESULTS PER COUNTRY

4.1 Ecuador

In line with the objectives of the NASREC programme, the results achieved during the project period are the realization of a soil exposition, a soil database, and an inauguration in the form of a seminar.

The soil collection consists of twenty soil monoliths of representative soils of the Amazon, the Inter-Andean Valley, the Coastal area and the Galapagos Islands, which are the major ecological regions of Ecuador.

The collection is housed in the Museo de Ciencias Naturales in the centre of Quito. The collections comprises nine soil profiles from the Sierra region (mainly from the Inter-Andean Valley area), seven from the coastal region, two from the Amazone region and two from the Galapagos Islands.

The collection is organized according to the following principles:

- to show per ecological region a number of major soils;
- to show soils on which important crops are grown;
- to present key information about the soils exhibited, such as location, classification, climate, actual land-use and an evaluation of land suitability;
- to demonstrate the ecological risks of certain land-use types, e.g. erosion in the Inter-Andean valley and destruction of original vegetation in the Amazon region and the Galapagos Islands.

A computerized database of all soil and other environmental data of the NASREC collection was demonstrated.

The soil exposition was officially inaugurated by the Minister of Agriculture, Mr. Rafael Serrano in presence of a large number of representatives of MECN and MAG on 14 April 1988. This was followed by an one day seminar for agricultural specialists. A special session was held for geography and biology teachers of high schools. The news of the establishment of a soil collection was widely covered by press, radio and television.

A technical paper for users of the soil collection is in preparation. An English draft version of this paper and the translation in Spanish is in progress.

4.2 Indonesia

The results achieved during the project period are similar to the ones in Ecuador. The soil collection consists of 22 soil monoliths of representative soils of the major ecological regions of the Island of Sumatra. Six profiles from the Toba and Merapi volcanic highlands and sixteen from the tropical lowland region.

The collection is housed in an exposition hall of the Centre for Soil Research in Bogor. The collection is organized according to the following principles:

- to show representative soils of ecological regions, i.e. the tropical lowland and the volcanic highlands;
- to show soils of an altitude sequence or "catena", e.g. the Toba and Merapi volcano areas;
- to show soils of the transmigration areas Kuamang Guning and Sitiung;
- to present key information of the soils exhibited, such as location, classification, climate, actual land-use and an evaluation of land suitability;
- to demonstrate ecological risks of certain land-use types, e.g. a comparison is made between soils under lowland tropical forest with recently cleared sites showing soil compaction, as a result of land clearing using heavy machinery.

A computerized database of all soils and other environmental data of the NASREC collection was made operational. With the computer section a first computerized translation in the Bahasa Indonesia of the printed information sheets was made. This must be considered a draft version awaiting comments of the users.

The soil exposition was officially inaugurated on 29 September 1988 by the Director of the Centre for Soil Research, Mr. Sudjadi, in presence of a large number of representatives of Agricultural Research Institutions and the Agricultural University. This was followed by explanatory sessions in the exposition hall by staff members of CSR for the invited agricultural specialists. The news of the establishment of a soil collection was widely covered by press and television.

Comprehensive datasheets are available for users of the soil collection and a paper, in which a comparison is made between the analytical results of the laboratories of ISRIC and CSR is in preparation.

4.3 Mali

The results achieved are similar to the ones in the other major support countries. The soil collection consists of eight soil monoliths of representative soils of the major ecological regions.

There was great difficulty in finding adequate housing facilities in Bamako or surroundings. An ideal location would have been the agricultural school of Katibougou, but the director was not able to allocate a suitable exposition room. At present the collection is housed in a large room at the Sotuba Agricultural Research Station, where a number of Agricultural Research Institutions is located. The collection is organized according to the following principles:

- to show representative soils of Sudanian, Sahelian and Saharan regions and the irrigation scheme of the Office de Niger;
- to present key information on the soils exhibited, such as location, classification, climate, actual land-use and an evaluation of land suitability;
- to give special attention to climatic hazards, e.g. trend analysis of rainfall over the past 60 years shows clearly the extreme droughts of the beginning of the seventies and the eighties;
- to show ecological risks of land-use, e.g. desertification in the Sahelian zone and salinization in irrigation schemes.

A computerized database of all soil and other environmental data of the NASREC collection is available. With the computer section of ISRIC a first computerized translation programme to the French language of the printed information sheets was made. This must be considered a draft version awaiting comments of the users. The soil exposition was officially inaugurated by the Director of the Agricultural Research Station in presence of a large number of representatives of the Agricultural Research Institutions on 12 December 1988. This was followed by explanatory sessions in the exposition hall by staff members of PIRT and ISRIC. For users of the collection comprehensive datasheets are available.

4.4 Ghana

The Ghanian soil collection is in a stage of development. At the end of 1988 the Soil Research Institute reported that ten monoliths are on display in Kumasi and six monoliths are in Accra for national exhibitions such as the Science and Technology Fair.

Lack of adequate means of transport was the main bottleneck to expand the collection during the project period. UNEP organized additional financial support to overcome part of the transport problem.

The workplan comprises the collection of twenty soils from all over the country for exposition in Kumasi and Accra.

4.5 Sri Lanka

At present the Sri Lankean soil collection comprises six monoliths. Further expansion of the collections and a consultancy mission of an ISRIC staff member to the Land Use Division is scheduled.

4.6 Venezuela

Besides the assistance of the NASREC programme, the Instituto de Edafologia received financial support from CONICIT for the creation of the Venezuelan soil collection. At the end of 1987 the collection comprised fourteen soil profiles of which four were exhibited with ample information, photos and diagrams in a large room of this institute in Maracay. The Maracay collection aims at an expansion to about 25 monoliths.

The long term goal is to have also small collections in all regional universities. The Maracaibo University was granted support from CONICIT to start with such a collection. Training of a staff member of the Maracaibo University is scheduled for ISRIC's course in 1989.

4.7 Brazil

After the 1984 and 1986 field missions 29 monoliths are available for the Brazilian NASREC. The collection comprises the major soils from ten states. The objective is to display representative soils of Brazilian soil classification units. Special attention is given to the dominant group of "Latossoles" [Ferralsols] in Brasil. Thirteen profiles are sampled to show the diversity in the major types of Ferralsols in Brasil. The other profiles are representative for Acrisols, Luvisols, Nitosols, Planosols, Podzols, Solonetz, Plinthosols and one Antrosol from the Amazone basin.

Soil analyses have been executed by laboratories of SNLCS and ISRIC. Field data on soil, climate, other relevant ecological data, and the soil analytical data are stored in a computerized soil database. A statistical comparison between the results of SNLCS and ISRIC laboratories was made.

Still needed from SNLCS side is the preparation of the soil profiles and the organization of the exposition. The participation of a SNLCS staff member at the 1989 course is scheduled.

5. PERSONNEL AND CAPITAL INVESTMENT

5.1 Personnel

The project activities and results as described above were realized as a cooperative effort between the National Soil Institutes (NSI) and ISRIC.

The number of personnel involved varied for each NSI, but at least one national coordinator and one technician were charged with the tasks.

Twenty three staff members of the NSI's have been trained at ISRIC's international course and 'on the job' during fieldwork, workshop and office activities.

The support of ISRIC to the NASREC project comprises:
For the whole project period one senior soil scientist in charge of the project.
Additional support was given by the following ISRIC sections:

- Workshop: purchase and organization of transport of materials and equipment to the NSI's.
- Drawing and photography section: preparation of drawings, organization of printing and mounting of enlargements of photos for the expositions in Ecuador, Indonesia and Mali.
- Information section: prints of datasheets, adaptation of data input programmes and key files.
- Laboratory: from the reference profiles of the collections of Ecuador, Indonesia and Mali 190 samples were analyzed.
- Micromorphology section: from a selection of soil profiles of Ecuador, Indonesia and Mali 50 samples were analyzed and micrographs of relevant micro features were made for the soil expositions.

Besides the full-time participation of the project coordinator and one soil technician, thirteen other staff members of ISRIC and six external contributors were involved in the realization of the six-week training course programmes in 1986 and 1987.

5.2 Capital investment

Basically the assistance given by ISRIC to the NSI is technology transfer in combination with a relative small material support. The NSI is responsible for the organization and purchase of necessary equipment and materials. In principle only for those materials and equipment, which are lacking or difficult to acquire in the countries of the NSI, ISRIC is giving support.

Containers with these materials and equipment necessary for the collection of the soil profiles in the field, as well as for conservation, preparation and mounting of monoliths were sent to Ecuador, Indonesia, Mali and Venezuela in 1986 and 1987.

6. CONCLUSIONS AND FOLLOW-UP

6.1 Conclusions

The results show that ISRIC is in the position to realize simultaneously cooperative activities with a number of National Soil Institutes.

First reports from Ecuador and Mali indicate a great interest for the exposition. However, for an evaluation of the long term objectives, i.e. the reinforcement of the institute's education, extension and research capacity, more time will be needed.

6.2 Follow-up activities

During the project period several institutions requested ISRIC to support the establishment of soil collections and databases.

The Ain Shams University in Egypt, CATIE in Costa Rica, ONERN in Peru and the Sriwijaya University in Indonesia prepared project documents and funds to meet these requests are presently being sought.

Several others have applied for participation in ISRIC's international training course. Experience gained in the past years stresses the need for continuation of training, advice and some material support in the countries after the basic training at ISRIC. Countries having requested ISRIC for support are:
Africa: Egypt, Ethiopia, Gabon, Ghana, Kenya, Mali, Morocco, Mozambique, Nigeria, Sudan, Sierra Leone, Senegal, Tanzania, Tunisia, Zambia and Zimbabwe;
Asia: P.R. of China, Indonesia, Japan, Malaysia, Pakistan, Philippines, Sri Lanka and Vietnam;
Latin America: Argentina, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Peru, Uruguay and Venezuela;
Europe: Czechoslovakia, Italy, Portugal and Spain.

To meet these requests a project proposal for the establishment of NASREC's and databases for a number of development countries was prepared and submitted to UNEP. A proposal for fellowships to attend the training course and supply after-training service was submitted DGIS.

Most of the activities of the NASREC programme in the period 1986-1988 have been evaluated and the results are being used as a guide for workplans in other countries.

On the following aspects more attention will have to be given in a second NASREC programme phase:

- Environment
  The study of soils in their ecological setting, important soil toposequences, climasequences, etc. in view of the need for multidisciplinary information on (major) ecological regions;
- Land evaluation
  Fast access to key data on soil, climate and land management qualities and information to the users about major limitations and available techniques of improvement. Some topics of interest are soil fertility, soil nutrient cycling, soil degradation, etc. See for a listing of such topics Sombroek, 1989.
- Soil database
  The development of the soil database programme itself and of application programmes in the field of characterization, classification and especially land evaluation in a (portable) PC working environment.
  The adaption of the existing soil database to national requirements. First of all the database has to be adapted to the national language. Further modifications can be expected in the classification of geology, climate, land-use and soil analytical properties. Coding systems will be developed based on existing guidelines used by the NSI.
- Audio-visual means
  The use of audio-visual means in the soil exposition to vizualize dynamic processes, the impact of certain land-uses after land clearing, forms of soil erosion and their prevention techniques, etc.

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LABORATORY METHODS AND DATA EXCHANGE PROGRAMME (LABEX)

The LABEX Programme was initiated by ISRIC on recommendation of the Second International Soil Classification Workshop in 1978. The main aims were to cross-check, correlate and standardize analytical methods for soil characterization to facilitate and improve international soil classification and correlation studies. During the experimental phase from 1980 to 1984, 20 laboratories participated in the programme. After a research grant from the Directorate-General for International Cooperation (DGIS) of the Dutch government, the number of participants increased to over 90 in 1989.

Presently the funding of the programme by DGIS is extended till 1990. For the years 1988, 1989 and 1990 the funding by DGIS is limited to 100%, 75% and 50 % of the total costs respectively. For this reason the participants in the industrialized countries are asked to pay a participation fee. Additional funds are received from sponsors as USAID/SMSS and GTZ.

One of the main objectives of the LABEX Programme is to assess and possibly reduce the within-laboratory and between-laboratory variability. Another aim is to promote quality control and Good Laboratory Practice (GLP) in order to improve the mutual acceptance of soil analytical data for soil classification, correlation and other purposes.

The LABEX programme continued the collection of analytical data received from the previous round, entered them in the database and elaborated them statistically. Laboratories who participated in this round received the final report enabling them to compare their performance with that of others.

In August 1989, The International Symposium on Soil Testing and Plant Analysis in Fresno USA was attended and a poster on the LABEX programme was presented.

In the 1989 Exchange Round approximately 50 laboratories are participating. A computer programme was written to eliminate the time consuming statistical elaborations of analytical data. A preliminary was report written and distributed to those laboratories who submitted their analitical data in time. A final report is due at the end of December.

Two bulk samples from Zambia were received and prepared for distribution in the LABEX 1990 Exchange Round, which is expected to take place in February 1990.

WORLD SOILS AND TERRAIN DIGITAL DATABASE (SOTER) AND GLOBAL ASSESSMENT OF SOIL DEGRADATION (GLASOD)

One of the elements of the World Soils Policy of the United Nations Environment Programme (UNEP) is the development of methodologies to monitor global soil and land resources. Methods are required which can reliably detect significant changes in those soil and terrain characteristics which directly or indirectly effect the quantity and quality of the land and its ability to produce food, fibre and timber. An assessment of the status and risk of soil degradation will provide one of the essential data sets for such a global understanding.

The following activities are undertaken:

"World Soils and Terrain Digital Database" (SOTER) - an ISSS project [1, 2]
There is a recognized need to collate and correlate national and regional geographic soil databases and to bring them under a common denominator that can serve as a legend for a new soil map of the world. A scale of 1:1 M is proposed.

"Global Assessment of Soil Degradation" (GLASOD) - a UNEP/ISRIC/ISSS project in cooperation with the Winand Staring Centre, ISSS, FAO, and ITC
The aims of this project are:

1. production of a global soil degradation map at a scale 1:10 M.
2. generation of soil degradation maps and soil and terrain databases for five test areas at a scale of 1:1 M.
3. storage of data collected under the project in the Global Resource Information Database (GRID), from where they will be readily transferable to users as required.

ISRIC administers and coordinates all activities related to the accomplishment of two activities:

1. the preparation of a world map on the status of soil degradation at an average scale of 1:10 M.
2. the preparation of a detailed assessment on the status and risk of soil degradation for one pilot area in Latin America, covering portions of Argentina, Brazil, and Uruguay, accompanied by a 1:1 M map.

This project is a first step towards a global soil degradation assessment and the establishment of a world soils and terrain digital database.

Objectives

The immediate objectives of SOTER is to improve the capability to deliver accurate, timely, useful information about soils and terrain resources to decision-makers. More specifically the following results are expected:

- An orderly arrangement of resource information.
- An improvement in standardization and compatibility of reporting soils and terrain data/information.
- An improvement in accessibility of soil and terrain and related resource information.
- A dynamic resource information system with updating and purging capabilities.
- An information service for resource planning in developing countries.
- A systems model for technology transfer.

The project has been divided into three phases, each with a set of tasks designed to move quickly towards an operational system.
Phase 1: (years 1 and 2) Development and testing of methodologies.
Phase 2: (years 3, 4 and 5) Refinement and testing of all elements in the Database System (data acquisition and correlation; data input and output).
Phase 3: (years 6-15) Operational input to and output from the Database: transfer of technology.

The pilot area activity within the GLASOD project should be considered as the first phase of the SOTER project.

The immediate objectives of GLASOD is to strengthen the awareness of decision makers and policy makers on the dangers resulting from inappropriate land and soil management to the global well-being and to improve the capability in regional and national institutions to deliver accurate information on qualitative and quantitative soil degradation processes for national and regional agricultural planning purposes. Soil degradation is defined here as a process that describes human induced phenomena which lower the current and/or future capacity of the soil to support human life.

On the world map as well as on the map of the pilot areas we want to describe and delineate areas where the balance between climatic aggressivity and the potential resistance of the terrain has been or is being broken by human action: the present status of human induced soil degradation. In the pilot area we also need to assess the relative fragility of the land system: the risk of soil degradation.

The status of soil degradation is described by three elements of degradation:

1. Type of soil degradation refers to the process that causes the displacement of soil material by water and wind, as well as in-situ deterioration by physical, chemical and biological processes;
2. Degree of soil degradation refers to the present state of the degradation process (none, slight, moderate, severe, extreme);

3. Recent-past rate of soil degradation refers to the apparent rapidity of the degradation process (slow, medium, rapid).

For each delineated mapping unit the relative extent of each soil degradation type and the dominant causative factors are also reported.

Implementation

It is obvious that the preparation of both maps requires a completely different approach. Although the basic concepts and the legend for the global assessment should also be applicable for the regional assessment of soil degradation, the approach for the 1:10 M soil degradation status map is qualitative, while the risk assessment for the pilot area has to be as quantitative as possible.

Global Soil Degradation Status Map

The following steps are taken to implement the preparation of a global soil degradation map at an average scale of 1:10 M.

- Preparation of guidelines. Descriptive rules are formulated for the preparation of this global map to ensure uniformity of interpretation by experts around the world. After consultation with an international panel of soil degradation specialists the Guidelines for General assessment of the Status of Human-induced soil Degradation have been published [3].
- Designation of regional institutions and/or qualified specialists. The world has been divided into 21 regions. For each region an institution or an individual qualified specialist has been approached to prepare a regional soil degradation map and complementary data sets according to the Guidelines on base maps at an average scale of 1:5 M.
- Regional map preparation. By December 1989 19 regional maps and complementary data sets were completed.
- Map compilation. The regional soil degradation status maps, prepared at a scale of 1:5 M will be correlated and then reduced to 1:10 M. The Winand Staring Centre (formerly Soil Survey Institute, Stiboka) in Wageningen will prepare the compiled global soil degradation status map. By December 1989 16 regional maps were generalized and compiled.
- National approval. National soil research organizations will be invited to comment on the draft soil degradation map.
- Preparation of a multi-coloured global soil degradation status map will be carried out by the Winand Staring Centre and publication is expected by July 1990, for presentation at the ISSS Congress in Kyoto.

Soil and Terrain Database for the pilot area in South America

The Land Resources Research Centre in Ottawa, Canada, prepared a Procedures Manual for Small Scale Map and Database Compilation [4]. This manual was thoroughly discussed during a workshop in Montevideo in March 1988 [5]. The three participating countries (Argentina, Brazil, Uruguay) appointed national correlation teams to acquire soil and terrain attributes for the pilot area (28°-32°30' South; 54°-60° West). The teams participated in two field trips and correlation meetings to assess the workability of the Procedures Manual and to discuss the interpretation of the status of human-induced soil degradation. The results of eight months field work was presented and discussed during a workshop in Porto Alegre in December 1988 [6]. Meanwhile a SOTER database structure was developed, using ORACLE5 as relational database management system [7]. Also a separate climate database file was developed.

The soils and terrain data and the climate data were entered into the SOTER database and checked on possible errors and omissions. As Geographic Information Systems for SOTER, PAMAP was chosen after carrying out a benchmark test [8, 9].

As soon as funding for hardware/software has been allocated and the systems are installed, preliminary tests of the SOTER database will be conducted to assess the use of the system in producing interpretive maps such as on water erosion hazard, potential productivity, irrigable land, and others.

Related SOTER developments

- WASOTER: A project proposal for a second pilot area in West Africa was prepared [10] (portions of Benin, Burkina Faso, Ghana, Niger, Nigeria, and Togo) and discussed during a FAO-sponsored West and Central African Soils Correlation Committee meeting in Cotonou, Benin (November 1988). The proposal is endorsed by four of the National Governments involved, and the E.E.C. has been approached for funding. Many international and national organizations have already indicated their interest in this West African SOTER activity.
- NASOTER: A project and implementation plan for a third pilot area located in North America has been formulated by a joint working group of the U.S. Soil Conservation Service and the Canadian Land Resources Research Centre in March 1989. This project will be completed in 1990.
- SWASOTER (South-West Asia, including portions of Iraq, Jordan, Saudi Arabia, Syria and Turkey). A project proposal has been prepared.
- CASOTER (Central America, including portions of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua). A project proposal has been prepared.

Finally, an expert meeting on the implementation of a pilot project on erosion mapping and measurement in the Mediterranean Coastal Zones took place in Madrid (December 1989). It was decided to map soil erosion on the basis of physiographic units, which could be further subdivided into smaller units, following the procedures developed by SOTER. ISRIC's role will be in providing assistance in the preparation of a procedures manual, participating in project formulating missions and providing technical advice during the execution of pilot area activities.

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4.2 CONSULTING AND PROJECTS

INTERNATIONAL CONFERENCE "SOILS AND THE GREENHOUSE EFFECT".

The final preparations by the conference secretariat (formed by A.F. Bouwman, W.G. Sombroek and L.R. Oldeman, and assisted by the organizing committee) for the Conference "Soils and the Greenhouse Effect", which started in April 1987, comprised the completion of the background paper, the conference programme, and reviewing of all the texts, which were submitted by contributing participants.

The number of participants of the conference was 120, including 32 from the Netherlands. Twelve scientists were invited to present a paper, while 28 participants offered extended abstracts of research papers. All the texts were discussed with their authors during the conference week to give suggestions for changes and improvements. Final texts including these suggestions, were received soon after the conference.

The major part of the conference was formed by the working group discussions. This resulted in important conclusions and recommendations for future research.

The working group conclusions, the invited papers, background paper and the extended abstracts are included in the proceedings which will be published by John Wiley & Sons (UK) in 1990.

Activities performed in 1989, related to the conference:

- Preparation of an article entitled "Soil and Land use related Sources of Greenhouse Gases. Present emissions and possible future trends" for the Journal Land Use Policy.
- Writing of a conference report for various journals and newsletters.
- Participation in Dahlem workshop on "Exchange of trace gases between terrestrial ecosystems and the atmosphere" in Berlin in February 1989.
- Introduction on technical options to reduce methane emissions, in workshop organized by US Environmental Protection Agency, December 1989.

Report of the Conference

The International Conference "Soils and the Greenhouse Effect", held in Wageningen, The Netherlands, August 14-18 1989, was organized by the International Soil Reference and Information Centre (ISRIC) on behalf of the Dutch Ministry of Housing, Physical Planning and Environment (VROM). It forms a contribution to the International Geosphere-Biosphere Programme (IGBP) of the International Council of Scientific Unions (ICSU). The scientific programme of the Conference consisted of oral presentations of papers, poster presentations and working group discussions.

A number of invited papers covered the complete field of research and knowledge with respect to the contribution of world soils and their land use/land cover to global climatic change. P.J. Crutzen (Max Planck Institute, Mainz, FRG) gave an introduction on sources of greenhouse gases and atmospheric chemistry. Van Breemen (Wageningen Agricultural University) and Sombroek (ISRIC, Wageningen) discussed soil properties influencing gas fluxes and geographic aspects of soils, respectively. H.J. Bolle (Berlin University, FRG) and A. Henderson-Sellers (Macquarie University, New South Wales, Australia) covered the relations between land cover, soil moisture and the partitioning of net solar radiation into latent heat, sensible heat and soil heat emphasizing the present status of land surface parameterization schemes for use in global climate models. G. Esser (Osnabrück University, FRG) discussed global fluxes of carbon dioxide (CO_2); M. Umarow (Moscow University, USSR) and H. Rennenberg (Fraunhofer Institut fur Atmosfärische Umweltforschung, FRG) covered biogenic N_2O and CH_4 fluxes, respectively. Available gas flux measurement techniques and future developments in this field were presented by A.R. Mosier (USDA-ARS, Fort Collins, USA) and E. Matthews (NASA-GISS, New York, USA) gave an overview of available global climate and vegetation/land use data bases for global estimates of gas fluxes. Furthermore, the programme included oral and poster presentations of accepted extended abstracts related to one of the above topics.

Four Working Groups met during the conference to identify research gaps and to give concise and practical recommendations.

1. Working Group 1 - STATUS (chairman R. Brinkman, FAO) was to review the *present day knowledge of the emission* of greenhouse gases, evapotranspiration and the surface energy balance for world soils and their land cover.

The relative importance of the three major greenhouse gases emitted by soils and/or their land cover - CO_2, CH_4 and N_2O - discounted over their atmospheric residence time, is 15:3:4. While CO_2 is chemically inert, the relative importance of CH_4 and N_2O will further increase if their impacts on atmospheric chemistry are also accounted.

For CO_2 better models are available than for the other gases. However, model validation with regard to CO_2 sources and sinks should receive attention, in addition to data on biomass and rates of deforestation and other land use changes. Important are tundra boreal peatlands and areas of caliche in deserts. Both represent large carbon stores and at any climate change they may release CO_2. The effect of increased atmospheric CO_2 on the production, C/N ratio and decomposition rates of litter and the resulting effect on the total soil C storage are still uncertain. Plants will become more drought resistant, but other nutrients may become limiting. These questions deserve priority attention.

The total budget of CH_4 is relatively well known, but individual sources are poorly known. About 70% of all atmospheric methane is of biogenic origin, the rest is emitted by coal mining, gas exploitation and old peat layers. For global extrapolations there is a need for more flux measurements and for data on process regulating factors. Wetland rice systems are especially important, since it would appear feasible to introduce management practices to minimize the emission. Permafrost areas are likely targets for an early reaction to a climate warming and should receive attention. Data are lacking for a proper balance calculation on methane exchanges in landfills. The latter emissions can be harvested and such actions should be promoted to minimize losses to the atmosphere.

The global N_2O budget is still very uncertain. About 90% of all N_2O is emitted by soils. Intensive search for sources to match the atmospheric sink is needed. Special attention should be paid to areas with high rates of organic matter and N turnover such as tropical (rain)-forests, areas with marked dry-wet seasons (tropical and subtropical savanna) as well as heavily N-fertilized areas.

2. Working group 2 - TRENDS (chairman P.A. Sanchez, North Carolina State University, USA) evaluated the *changes in the patterns* of greenhouse gas fluxes, evapo (transpi-) ration and surface energy fluxes occurring due to *land use changes*.

Four major areas or ecosystems deserve priority attention: paddy rice areas, tropical forest areas, areas threatened by desertification and permafrost areas.

Paddy rice areas, a major source of CH_4, are likely to increase in Africa and South America. This trend should be monitored. Better data are needed on harvested areas including fertilizer applications, organic matter incorporation, cultivation practices and possibilities to control emissions using soil and water management practices.

Tropical forest areas are recognized as ecosystems important as a pool of carbon, and in addition are important sources of N_2O and possibly CH_4. The result of deforestation is a large injection of CO_2 into the atmosphere, increasing albedo and decreasing latent heat fluxes. N_2O fluxes appear to be higher in grassland established after forest clearing, but it is not certain whether this high flux will be maintained during prolonged periods. Drainage of swamp areas in tropical forests will probably decrease CH_4 fluxes. Decreasing fallow periods in shifting cultivation are also recognized as major sources of CO_2. Reduction of tropical deforestation can provide alternatives to slash and burn agriculture via sustainable management options such as agroforestry.

Desertification may have a large impact on climate because bare soil surfaces are exposed during major parts of the year resulting in high albedo values, affecting the boundary layer energy fluxes and also the general circulation. Afforestation and improved range management are probably the most practical ways of reversing desertification in many Mediterranean and semi-arid areas, the former at the same time supplying critical fuelwood needs.

As global warming proceeds many permafrost areas are likely to release large quantities of greenhouse gases and suffer serious erosion. An efficient monitoring system is required in these regions.

3. Working group 3 - METHODS (chairman W.G. Mook, Groningen University, Netherlands) inventorized *existing and new methods for estimating* greenhouse gas emissions, including sampling and measurement techniques, modelling, remote sensing techniques, extrapolation of results using databases of soils, vegetation and land use, climate.

This group concluded that international coordination is needed to integrate flux measurements (process studies) with geographical mapping. In this respect it is recognized that data requirements for process studies should drive data base development, particularly in terms of developing new data sources such as new satellite sensors.

Another element is the use of existing data bases for developing a framework for extrapolation of results of process studies applied to local scale landscape units, to global scale ecoregions. In general a combination of measurement techniques (chamber, eddy correlation, gradient) is necessary to appropriately quantify the spatial and temporal variability of a system.

The information on source strengths of trace gases from isotope studies has so far been under-utilized, particularly their use as an independent constraint for global tracer models.

4. Working group 4 - POLICIES (chairman G.P. Hekstra, Ministry VROM, Netherlands) assessed *policy options* with respect to land use control, agriculture and forestry practices necessary for a reduction of greenhouse gas emissions by soils. The two major recommendations are related to education and information exchange and sustainable land use. The first recommendation comprises: providing data and information - including long time series of historical data related to global change studies - in a timely fashion; supporting national data centers that are part of established systems operated under the auspices of ICSU, WMO, UNEP and other such agencies; and finally to take steps to maintain low cost availability of this information to scientists and government decision makers. With regard to the second recommendation, concerning sustainable land use, national governments should support actions to reduce slash and burn agriculture by improving farming practices, as well as undertake general forest management practices to reduce carbon emissions and to promote rapid re-afforestation of waste lands; ensure that expansion of agricultural and other land uses be evaluated in respect of land suitability; discourage the expansion of unproductive cattle pastures, often the land use after uncontrolled forest clearing and other unsustainable systems; increase the effectiveness of N fertilizers; develop agronomic techniques to reduce methane and nitrous oxide emissions without sacrificing rice yields;

The conclusions and recommendations are included - with the conference background paper, invited papers and extended abstracts of accepted presentations - in the book: Soils and the Greenhouse Effect, published by Wiley & Sons (U.K.), 1990, ISBN 0-471-92395-8.

The proceedings were edited by A.F. Bouwman, assisted by M.B. Clabaut. Members of the Editorial Committee were W.G. Sombroek, Chairman, G.P. Hekstra and J.W.M. LaRivière.

Participants Symposium "Soils and the Greenhouse Effect".

5 GUEST RESEARCH

Soil Horizon Designations

Dr. E.M. Bridges, University College, Swansea, U.K.
Funding: Fellowship of the Dutch Ministry of Agriculture, Nature Management and Fisheries - International Agricultural Centre.

During stays of several months in 1987, 1988 and 1989, a discussion document was formulated on the historical development of systems of horizon designation, on systems currently in use with their areas of agreement or disagreement, and on proposals for unification based upon current practices and in line with the International Reference Base for soil classification of the ISSS.

After the circulation of a draft report published in 1987, changes were incorporated and presented to the Working meeting on Soil Horizons of ISSS Commission V in Rennes, France in September 1989. The final text will be published in 1990 as Technical Paper 19.

Dr. S.B. Kroonenberg, professor in Geology, Wageningen Agricultural University, explains the formation of bauxite, as on display in ISRIC's front yard.

6 TRAVEL AND MISSIONS

Visit to World Meteorological Organization, Geneva, Switzerland, January 1989. *Participant: W.G. Sombroek.*

To attend a meeting of the Inter-centre's Working Group on Agro-ecological Characterization, CGIAR, on the formulation of common methodologies for the characterization and delineation of climatic and soil conditions of experimental grounds and regions of interest to the CG centres.

IGBP Working Group Meeting for Design of Pilot Studies for Data and Information Systems*) Geneva, Switzerland, January 1989. *Participant: W.G. Sombroek.*

On invitation, to attend and give a lecture on Land Cover Change Pilot Study: site selection criteria and convergences towards a region(s) for the pilot study.

Dahlem Workshop on "Exchange of trace gases between terrestrial ecosystems and the atmosphere", Berlin, Fed. Rep. of Germany, February 1989. *Participant: A.F. Bouwman.*

To attend the workshop in view of the role of soils in the greenhouse effect.

Visit to IGBP Coordinating Panel on Terrestrial Biosphere-Atmospheric Chemistry Interactions with SCOPE/IGAC, Mainz, Fed. Rep. of Germany, February 1989. *Participant: A.F. Bouwman.*

The IGAC programme for the 1990's was discussed; it can be seen as an atmospheric chemistry component of IGBP.

Consultancy to Ambon, Indonesia, January-February 1989. *Participant: J.R.M. Huting.*

During this follow-up mission to the Muluku Regional Development Project, University of Pattimura, some apparatus was repaired, instruction and trainaing was given in analytical methods, laboratory management data handling, and pricing for commercial purposes. Some computer programmes were made and installed. At four locations profiles were collected for ISRIC, the Centre for Soil Research in Bogor, and the University of Pattimura.

Visit to Instituto Nacional para la Conservación de la Naturaleza (ICONA), Madrid, March 1989. *Participant: L.R. Oldeman.*

To attend a Working Group Meeting on Erosion Mapping in the framework of Inventory and Network of Erosion Measurements in the Mediterranean Zone for an Environmentally Sound Management.

FAO Consultancy to Brazil (Amazon Region), February-April 1989. *Participant: W.G. Sombroek*

On FAO's invitation as team leader and expert on soils, ecology and land evaluation of a mission to formulate a project proposal for systematic agro-ecological zonification and land use planning of the Brazilian Amazon Region. The produced document will probably be finalized in 1990.

Visit to FAO, Rome, Italy, April 1989. *Participant: J. van Baren* (on behalf of ISSS).

To attend the first meeting of FAO, UNEP, ISSS, Syria and Uganda to discuss the programme of the project: "Advisory services to Syria and Uganda on the Formulation of National Soil Policies".

Visit to United Nations Environment Programme (UNEP), Nairobi, Kenya, April 1989. *Participants: W.G. Sombroek and L.R. Oldeman.*

To present the mid-term progress report on ISRIC's GLASOD projects and to discuss the second phase of the NASREC project.

Visit to Unesco, Paris, France, April 1989. *Participant: W.G. Sombroek.*

To discuss future research orientation of Unesco's Man-and-the-Biosphere programme, and ISRIC's involvement in backstopping the two newly appointed Dutch associate soil scientists/ecologists in South America and Africa.

Visit to a Meeting of IAASA, in Budapest, Hungary, April 1989. *Participant: W.G. Sombroek.*

Discussions on scope, content and potential contributors to a proposed IIASA publication on Global Soil Change.

Visit to Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Damascus, Syria, and the **International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria,** April 1989. *Participant: L.R. Oldeman.*

To discuss progress on the GLASOD regional map for North Africa and the Middle East, and to discuss possibilities for a South-West Asian SOTER pilot area with representatives of ACSAD and ICARDA.

Consultation on Documentation; Issues related to Disaster Studies. Disaster and Emergency Reference Centre (DERC), Delft, The Netherlands, May 1989. *Participant: J. van Baren.*

To give advice to DERC on setting up a reference centre, including library, computer documentation systems, input sheets, database development and thesaurus building.

Visit to Bratislava and Piestjani, Czechoslovakia, May-June 1989. *Participant: W.G. Sombroek.*

To have discussions with soil scientists of Eastern Europe.

First International Soil Testing and Plant Analyses Conference, Fresno, U.S.A., August 1989. *Participant: J. Brunt.*

Discussions were centered around the within and in-between laboratory variability of chemical analyses. Promoting LABEX quality control programme by means of a poster presentation.

Eurolat Summer School on Laterites and 9th International Clay Conference, Strasbourg, France, August-September 1989. *Participant: L.P. van Reeuwijk..*

To attend the Summer School and present the paper "The binary composition of the clay fraction of Andosols" (with C. Mizota, Kyushu University, Japan) at the Clay Conference.

Workshop on "Ecological and Economic Sustainability of Tropical Rainforest Management", Unesco-MAB, Paris, France, September 1989. *Participant: W.G. Sombroek.*

To arrive at a collaborative research proposal, aiming at an interlinked network of a limited number (4-10) of field projects of research, training, demonstration and information diffusion on sustainable management of tropical forest.

Meeting on the International Reference Base for soil classification (IRB), Rennes, France, September 1989. *Participant: W.G. Sombroek* (see Section 3.5).

Working Meeting on Soil Horizons, Rennes, France, September 1989. *Participant: E.M. Bridges.*

To attend the meeting of ISSS Commission V and to present a paper "Soil horizon designations. A Technical Paper 19 under the same title will be published in 1990 (see also Chapter 5).

Second Southern African Soil Resources Workshop, Zimbabwe, August-September 1989. *Participant: J. van Baren.*

To attend the workshop and field trip and to present papers on the new FAO/ Unesco Soil Map of the World legend and over the GLASOD/SOTER project.

International Conference and Workshop on "Global Natural Resource Monitoring and Assessments: Preparing for the 21st Century", Venice, Italy, September 1989. *Participant: W.G. Sombroek.*

To attend this IUFRO/FAO meeting and present a keynote paper on "Importance of global data in monitoring the soil and water resources" (with ir. H. Colenbrander, Secretary-General of the International Association of Hydrological Sciences).

An introduction on "The IGBP Plan-of-Action", especially on the proposed "Land Cover Change Pilot Study" was given also.

Workshop on "Laterites and Application in Environmental and Agricultural Purposes", Marseille, France, October 1989. *Participant: W.G. Sombroek.*

This EEC workshop was intended to draw up specific research proposals, and the formulation of apolicy paper on tropical soil research in general and on lateritic soils/materials in particular.

ISRIC may become involved in the compilation of a compendium on lateritic materials in soils and saprolites, accompanied by colour plates of specimens.

Visit to Sweden, October 1989. *Participant: D. Creutzberg.*

At the invitation of the Royal Academy of Agricultural Sciences, an excursion in Central Sweden was held to discuss the classification in the 1974 and 1988 FAO/ Unesco Soil Map of the World legends.

Visit to E.E.C., Brussels, Belgium, October 1989. *Participants: W.G. Sombroek and L.R. Oldeman.*

Discussions on West African SOTER project proposal and possibilities to obtain EEC funding.

6th International Soil Conservation Conference on "Soil Conservation for Survival", Nairobi, Kenya and Addis Abeba, Ethiopia, November 1989. *Participant: L.R. Oldeman.*

To attend conference, participate in pre-, mid-, and post conference study tours in Kenya and Ethiopia. To present a poster on GLASOD while in Nairobi, visit to UNEP to discuss follow-up activities of GLASOD/SOTER project.

Visit to Malaga, Spain, December 1989. *Participant: V.W.P. van Engelen*.

To attend expert meeting on the Implementation of the Pilot Project on Soil Erosion Mapping and Measurement in the Mediterranean Region. Discussions on possible involvement of ISRIC for implementation of SOTER approach.

Workshop on Greenhouse Gas Emissions from Agricultural Systems, Washington D.C., U.S.A., December 1989. *Participant: A.F. Bouwman*.

To attend the workshop organized by the Subgroup on Agriculture/Forestry of the Response Strategies Working Group of the Intergovernmental Panel on Climate Change. A talk was given on "Technical options for reduction of methane emissions from rice paddies".

*) travels partly or wholy made by W.G. Sombroek in his capacity of Secretary-General of the International Society of Soil Science (ISSS).

Symposium "Soils and the Greenhouse Effect".

Left: reception hosted by the City of Wageningen. In the centre, the mayor, Mr. M.J.E.M. Jager. Right: the symposium organizer Ir. A.F. Bouwman.

7 RELATIONS WITH OTHER INSTITUTIONS

7.1 INTERNATIONAL RELATIONS AND ACTIVITIES

Contacts and activities with international institutions included the following:

Food and Agricultural Organization of the United Nations (FAO, Rome)

- Further development and completion of an improved legend for small-scale soil mapping, as a successor to the FAO-Unesco Soil Map of the World Legend.
- Collection of maps for the updating of the FAO-Unesco Soil Map of the World at scale 1:5 million, and for a digitized soil and terrain map at 1:1 million.
- Exchange of publications and documentation on soils and their management, agroclimatic zones, etc.

United Nations Educational, Scientific and Cultural Organization (Unesco, Paris)

- Unesco's financial support and identification of candidates for ISRIC's International Course on the Establishment and Use of National Soil Reference Collections.
- Unesco's interest to have several associate experts ecology/soil science cooperate with the Dutch "Tropenbos" programme. ISRIC provides technical backstopping of associate experts in Africa (Nairobi, Kenya) and Latin American (Montevideo, Uruguay).

United Nations Environment Programme (UNEP, Nairobi)

- Advise on the promotion of UNEP's World Soils Policy and National Soil Policies programmes.
- UNEP/DGIS financial support, through its "Clearing House Facility", for ISRIC's programme to assist in the establishment of national soil reference collections in a number of developing countries (NASREC programme).
- Consultancy to assess the global extent of soil degradation at an average scale of 1:10 million, and its quantification in a pilot area in South America (GLASOD project) at a scale of 1:1 million.

International Society of Soil Science (ISSS)

- Administrative assistance to the Secretariat-General of ISSS, housed at ISRIC.
- Organizing and editing of the book-review section of the six-monthly Bulletin of the Society.

- Participation in the ISSS Working Group "International Reference Base for soil classification" (WG/RB), through formulation of proposals and assembling of documentation.
- Participation in the ISSS Working Group on the preparation of a digitized international soil and terrain map (WG/DM).
- Establishment of a reference collection of soil thin sections for the ISSS Subcommission of Soil Micromorphology.
- Registration of visual training aids on soil science.
- Repository of biographical material on outstanding soil scientists and on the early history of organized soil science for the ISSS Working Group on the History, Philosophy and Sociology of Soil Science (WG/HP).

Other international contacts

- Commission of the European Communities (Brussels); submission and screening of research proposals; contacts on support for educational functions of ISRIC.
- International Service for National Agricultural Research (ISNAR, The Hague); exchange of programmes information.
- International Development Research Centre (IDRC, Ottawa); support for soil data centres.
- Institut français de recherche scientifique pour le développement en coopération (ORSTOM, Paris); exchange of information.
- Centre Technique de Coopération Agricole et Rurale of EEC/Lomé Convention countries (CTA, Wageningen/Ede); exchange of data.
- U.S. Agency for International Development (USAID) and several of its soil-related programmes (IBSNAT, SMSS); exchange of information; attendance of workshop; requests for financial support.
- Several of the International Agricultural Research Centres of the Consultative Group on International Agricultural Research (IITA, IRRI, CIAT, ICARDA); exchange of information.
- International Union of Biological Sciences (IUBS); cooperation on formulation of a proposal for network research on Tropical Soil Biology and Fertility (TSBF), and preparation of a manual for the project (site selection and characterization; methods for chemical analysis of soil and water samples).
- National Soil Survey, Soil Research Institutes and Agricultural Universities in many countries.

7.2 NATIONAL RELATIONS AND ACTIVITIES

- Royal Netherlands Academy of Arts and Sciences (KNAW, Amsterdam); continuation of cooperation programme with Nanjing Institute of Soil Science of the Academia Sinica; participation in a Dutch national committee for MAB/SCOPE/IGBP.
- Netherlands Foundation for the Advancement of Tropical Research (WOTRO); board membership.
- International Institute for Aerospace Survey and Earth Sciences (ITC, Enschede); management servicing of ISRIC; lecturing at ITC Soils Course; analysis of soil and water samples; soil database development.
- Department of Science Policy of the Dutch Ministry of Education and Sciences (MOW-WB, The Hague); cooperation on the elaboration of a multidisciplinary research programme on tropical forests (Tropenbos).
- Centre for World Food Studies (SOW, Wageningen/Amsterdam); exchange of information.
- Department of Soil Science and Geology of Wageningen Agricultural University; cooperation on clay mineralogy; exchange of information; representation at international meetings; lecturing.
- International Agricultural Centre (IAC, Wageningen); visitors accommodation; guest researcher's fellowships; advice on soil-related projects in developing countries.
- M.Sc. Course in Soil Science and Water Management of Wageningen Agricultural University; guidance of students at thesis work.
- Winand Staring Centre (WSC, Wageningen); cooperation on micromorphology, including methodology of description; exchange of information; representation at international meetings.

8 PERSONNEL

8.1 BOARD OF MANAGEMENT

Members of the Board of Management on 31 December 1989 were:

- Dr. J.P. Andriesse, Chairman Netherlands Advisory Council
- Dr.Ir. A.W. de Jager, Free University, Amsterdam
- Prof.Dr. L. van der Plas, Wageningen Agricultural University
- Dr.Ir. F. Sonneveld, Government Service for Agricultural Research, Ministry of Agriculture, Nature Management and Fisheries, Wageningen (Chairman)
- Dr.Ir. L. Fresco (personal member).

8.2 INTERNATIONAL ADVISORY PANEL

The International Advisory Panel (IAP) met in 1967, 1972, 1979 and 1983. The members of the last IAP were:

- Dr. F. Fournier, Division of Ecological Sciences, Unesco, Paris, France
- Dr. H. Ghanem, Institut Agronomique et Vétérinaire, Rabat, Morocco (for northern Africa)
- Prof. E.G. Hallsworth, IFIAS Save-Our-Soils Project, Brighton, U.K. and past President ISSS (for Australia and ISSS)
- Mr. G.M. Higgins, Land and Water Development Division, FAO, Rome, Italy
- Dr. C.S. Holzhey, USDA Soil Conservation Service, Lincoln, Nebrasca, U.S.A. (for North America)
- Dr. M. Jamagne, Service d'Etude des Sols et de la Carte Pédologique de France, Olivet, France (for Western Europe)
- Mr. F.N. Muchena, Kenya Soil Survey, Nairobi, Kenya (for Africa South of the Sahara)
- Dr. A. Osman, Soil Science Division, Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD), Damascus, Syria (for the Middle East)
- Dr. C.R. Panabokke, Sri Lanka (for South and East Asia): could not attend
- Dr. C. Valverde, Programa Nacional de Suelos, Lima, Peru: at present International Service for National Agricultural Research (ISNAR), The Hague, The Netherlands (for Latin America and CGIAR institutes)
- Dr. G. Varallyay, Research Institute for Soil Science and Agricultural Chemistry, Budapest, Hungary (for eastern Europe).

8.3 NETHERLANDS ADVISORY COUNCIL

Members of the NAC on 31 December 1989 were:

- Ir. J.G. van Alphen, International Institute for Land Reclamation and Improvement, Wageningen
- Dr. J.P. Andriesse, International Course for development oriented Research in Agriculture, Wageningen
- Ir. G.W. van Barneveld, DHV Consultants, Amersfoort
- Prof.Dr. J. Bouma, Department of Soil Science and Geology, Wageningen Agricultural University
- Prof.Dr. P.A. Burrough, State University Utrecht
- Prof.Dr.Ir. A. van Diest, Royal Netherlands Society of Agriculture, Wageningen
- Dr.Ir. P.M. Driessen, Department of Soil Science and Geology, Wageningen Agricultural University
- Ir. A.L.M. van den Eelaart, Euroconsult, Arnhem
- Dr.Ir. G.W.W. Elbersen, International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede
- Ir. J. van der Heide, Institute for Soil Fertility, Haren
- Ir. W.B. Hoogmoed, Soil Tillage Laboratory, Wageningen Agricultural University
- Ir. E.R. Jordens, M.Sc. Course in Soil Science and Water Management, Wageningen Agricultural University
- Prof.Dr.Ir. H. van Keulen, Centre for Agrobiological Research (CABO), Wageningen
- Prof.Dr. S.B. Kroonenberg, Soil Science Society of the Netherlands, Wageningen
- Prof.Dr. Th.W.M. Levelt, Free University, Amsterdam
- Prof.Dr. J. Sevink, University of Amsterdam
- Prof.Dr. A.W.L. Veen, State University Groningen
- Ir. M.M. Vierhout, Haskoning Royal Dutch Consulting Engineers and Architects, Nijmegen
- Ir. W. van Vuure, Government Service for Agricultural Research, Ministry of Agriculture, Nature Management, and Fisheries, Wageningen
- Drs. R.F. van de Weg, Winand Staring Centre, Wageningen
- Dr.Ir. A.L.M. van Wijk, Winand Staring Centre, Wageningen

8.4 ISRIC STAFF

Staff members of ISRIC on 31 December 1989 were:

Dr.Ir. W.G. Sombroek	:	Director, soil classification and correlation, soil ecology
Drs. J.H.V. van Baren	:	Curator, documentation and publications
Ir. A.F. Bouwman	:	ISEC project
Drs. D. Creutzberg	:	Soil micromorphology, educational matters
Ir. J.H. Kauffman	:	NASREC programme
Dr.Ir. L.R. Oldeman	:	GLASOD project
Dr.Ir. L.P. van Reeuwijk, M.Sc.	:	Soil chemistry, mineralogy and physics
Ing. R.O. Bleijert	:	Soil micromorphology, map documentation
W.C.W.A. Bomer	:	Technician, photography and drawing
Ing. A.B. Bos	:	Monolith preparation, technical services, soil documentation
Ir. J. Brunt	:	LABEX programme
J. Brussen	:	Internal administration*)
Drs. V.W.P. van Engelen	:	GLASOD project
J.R.M. Huting	:	Laboratory analyst
Drs. P.J.M. Mulder	:	GLASOD project
Ing. A.J.M. van Oostrum	:	Senior laboratory analyst
Ir. J.H.M. Pulles	:	GLASOD project
R.A. Smaal	:	Laboratory analyst
Ms. M.B. Clabaut	:	Clerical services
Ms. Y.G.L. Karpes-Liem	:	Clerical services
Ms. J.C. Jonker-Verbiesen	:	Library assistant

*)External administration by ITC, Enschede.

8.5 GUEST RESEARCHERS

Soil and other scientists working at ISRIC during (part of) 1989 as guest researchers were:

- Dr. M.F. Baumgardner, U.S.A.
- Dr. E.M. Bridges, U.K.
- Prof. W.L. Peters, Venezuela
- Dr. N.M. Pons-Ghitulescu, The Netherlands

APPENDIX 1 - GROUP VISITS IN 1989

Institutions	Approximate number of persons
Belgium	
- Dept. of Agric. Science, University of Ghent	6
- International Training Centre for Post-graduate Soil Scientists, Ghent	30
Fed. Rep. of Germany	
- University of Bochum	20
- University of Hamburg	30
- University of Kiel	18
- Fachhochschule Osnabrück (2 visits)	48
The Netherlands	
- Free University, Amsterdam	12
- University of Amsterdam (2 visits)	45
- HeideMij, Arnhem	35
- Land Tenure Board, Arnhem	35
- International Institute of Hydrologic and Environmental Engineering, Delft	40
- National Agricultural College, Deventer (3 visits)	60
- International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede	28
- Horticultural College Warmonderhof, Kerk Avezaat	25
- University of Utrecht	50
- College for Forestry and Land and Water Management, Velp (7 visits)	150
- International Course for Development Oriented Research in Agriculture (ICRA), Wageningen	26
- International Institute for Land Reclamation and Improvement (ILRI), Wageningen	30
- Wageningen Agricultural University (10 visits)	250
- Free School, Teachers College, Zeist	10
- Landbouwvoorlichtingsdienst	20
Sweden	
- University of Agricultural Sciences, Uppsala	22
- The Royal Institute of Technology, Stockholm	18
United Kingdom	
- Portsmouth Polytechnic, Portsmouth (2 visits)	30
- University of Reading	25

APPENDIX 2 - LABORATORIES PARTICIPATING IN THE LABORATORY METHODS AND DATA EXCHANGE PROGRAMME (LABEX)

Inst. de Investig. Agronomica
C.P. 406
Huambo
ANGOLA

Inst. de Evaluacion de Tierras
Lab. de Suelos CIRN-INTA
1708 Castelar-Pcia Buenos Aires
ARGENTINA

Dept. of Primary Industries
Meiers Road
QLD 4068 Indooroopilly
AUSTRALIA

Div. of Trop. Crops and Pastures
306 Carmody Road
QLD 4067 St. Lucia
AUSTRALIA

CSIRO Division of Soils
Private Bag no. 2
SA 5064 Glen Osmond
AUSTRALIA

Institut für Bodenforschung
Gregor Mendelstrasse 33
A 1180 Wien
AUSTRIA

Dept. of Soil Science
Bangladesh Agric. Univ.
2202 Mymensingh
BANGLADESH

Bodemkundige Dienst van Belgie
De Croylaan 48
B-3030 Leuven-Heverlee
BELGIUM

Mision Brit. en Agricult. Trop.
Casilla 359
Santa Cruz
BOLIVIA

Laboratorio Agrícola CORDECH
P.O. Box 156
Sucre
BOLIVIA

Soil Mapping and Advisory Unit
P.O.B. 54
Gaborone
BOTSWANA

SNLCS-EMBRAPA
Rua Jardim Botanico 1024 Gavea
22.460 RJ Rio de Janeiro
BRAZIL

Departamento de Solos
Fac. Agronomia, UFRGS
P.O. Box 776
90.001 RS Porto Alegre
BRAZIL

Bureau National des Sols
B.P. 7028
Ouagadougou
BURKINA FASO

IRA/CNS Ekona
PMB 25
Buea
CAMEROON

Canadian Forestry Service
5320 122 Street
Alberta T6H 3S5 Edmonton
CANADA

Land Resource Research Centre
Neatby Bldg. Centr. Exp. Farm
Ontario K1A 0C6 Ottawa
CANADA

Direction de la Recherche
2700, rue Einstein
Ouebec G1P 3W8 Sainte Foy
CANADA

Soil, Plant & Feed Laboratory
P.O. Box 8700, Brookfield Road
St John's, NFLD
CANADA A1B 4J6

Universidad de Chile
Depto. Ingeniera Y Suelos
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APPENDIX 3 - ACRONYMS USED IN ANNUAL REPORT 1989

ACSAD	Arab Centre for the Studies of Arid Zones and Dry Lands, Syria
CABI	Commonwealth Agricultural Bureaux International, U.K.
CABO	Centre for Agrobiological Research, The Netherlands
CASOTER	SOTER Project, Central America
CATIE	Centro Agronomico Tropical de Investigación y Ensenanza, Costa Rica
CENRIS	Centro Nacional de Referencia y Informacion de Suelos
CGIAR	Consultative Group of International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical, Colombia
CORLAT	International Collection of Reference Laterite Profiles, ISRIC
CPAC	Centro de Pesquisa Agropecuaria de Cerrado, Brazil
CSR	Centre for Soil Research, Indonesia
CTA	Centre Technique de Cooperation Agricole et Rurale, The Netherlands
DERC	Disaster and Emergency Reference Centre, The Netherlands
DGIS	Directorate-General for International Cooperation, Ministry of Foreign Affairs,
DHV	DHV Consultants, The Netherlands
DLO	Government Service for Agricultural Research, Ministry of Agriculture, Nature Management and Fisheries, The Netherlands
EEC/EC	European Economic Community
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria, Brazil
EUROLAT	European Network on Laterites
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GLASOD	Global Assessment of Soil Degradation project, ISRIC
GLP	Good Laboratory Practice
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit, F.R.G.
IAC	International Agricultural Centre, The Netherlands
IAP	International Advisory Panel of ISRIC
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer, U.S.A.
IBSRAM	International Board for Soil Research and Management, Thailand
ICA	International Cartographic Association, U.K.
ICARDA	International Center for Agricultural Research in the Dry Areas, Syria
ICONA	Instituto Nacional para la Conservación de la Naturaleza, Spain
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
ICSU	International Council of Scientific Unions
ICTP	International Centre for Theoretical Physics, Italy
ICW	Institute for Land and Water Management Research, The Netherlands
IDRC	International Development Research Centre
IFIAS	International Federation of Institutes for Advanced Study
IGBP	International Geosphere-Biosphere Programme, Sweden
IITA	International Institute of Tropical Agriculture, Nigeria
ILRI	International Institute for Land Reclamation and Improvement, The Netherlands
IRB	International Reference Base for soil classification, ISSS

IRRI	International Rice Research Institute, The Philippines
ISIS	ISRIC Soil Information System
ISM	International Soil Musem
ISNAR	International Service for National Agricultural Research, The Netherlands
ISSS	International Society of Soil Science
ITC	International Institute for Aerospace Survey and Earth Sciences, The Netherlands
IUBS	International Union of Biological Sciences
IUFRO	International Union of Forestry Research Organizations
KNAW	Royal Netherlands Academy of Arts and Sciences
LABEX	Laboratory Methods and Data Exchange Programme, ISRIC
MAB	Man and the Biosphere Programme, Unesco
MAG	Ministerio de Agricultura y Ganaderia, Ecuador
MECN	Museo Ecuatoriano de Ciencias Naturales, Ecuador
MOW-WB	Department of Science Policy, Ministry of Education and Sciences, The Netherlands
NAC	Netherlands Advisory Council for ISRIC
NASOTER	SOTER project, North America
NASREC	National Soil Reference Collections, ISRIC
NASRIC	National Soil Reference and Information Centre
NSI	National Soil Institution
ONERN	Oficina Nacional de Evaluación de Recursos Naturales, Peru
ORSTOM	Institut français de recherche scientifique pour le développement en coopération, France
PIRT	Projet de l'Inventaire des Ressources Terrestres, Mali
PPS	La Productivité des Pâturages Sahéliens, Wageningen Agricultural University
PPT	Pusat Penelitian Tanan (Centre of Soil Research), Indonesia
PRONAREG	Programa Nacional de Regionalizacion Agraria, Ecuador
SRI	Soil Research Institute, Ghana
SCOPE	Scientific Committee on Problems of the Environment of the ICSU
SCS	Soil Conservation Service, USDA, U.S.A.
SMSS	Soil Management Support Services, SCS, U.S.A.
SOTER	World Soils and Terrain Digital Database, ISSS
SOW	Centre for World Food Studies, The Netherlands
SWASOTER	SOTER Project, South-West Asia
TSBF	Tropical Soil Biology and Fertility Programme, IUBS/Unesco
UCV	Universidad Central de Venezuela
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organisation
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VROM	Ministry of Housing, Physical Planning and the Environment, The Netherlands
WASOTER	SOTER Project, West Africa
WDC	World Data Centre of ICSU
WG/RB	ISSS Working Group on International Reference Base for soil classification

WG/DM	ISSS Working Group on the preparation of a digitized International Soil and Terrain Map
WG/HP	ISSS Working Group on the History, Philosophy and Society of Soil Science
WMO	World Meteorological Organisation
WOTRO	Netherlands Foundation for the Advancement of Tropical Research
WSC	Winand Staring Centre, The Netherlands

ISCO — International Soil Conservation Organization

6th International Soil Conservation Conference

6-18 November 1989, Ethiopia and Kenya

This is to certify that

ROEL L. OLDEMAN & R.T.A. HAKKELING
Wouter C.W.A. BOMER

were awarded

4th prize

for their excellent poster presentation at the 6th Soil Conservation Conference held in Ethiopia and Kenya 6-18 November 1989.

International Soil Conservation Organization — ISCO

President of ISCO

Addis Abeba, 15 November 1989

Fellowships at ISRIC

During the last decade a number of foreign soil scientists have spent a period from a few months up to one year at ISRIC, mostly for the preparation of a Soil Monograph or a Technical Paper.

Soil Monographs are publications of 100-150 pages on a major group of soils, taking ISRIC's soil monolith collection as starting point. The general aim is to strengthen the state of knowledge on the world's soil resources. They are intended for teachers and students in soil science at university level, soil survey institutes, etc. Up to now Soil Monographs on Podzols and Andosols have been published, those on Ferralsols and Vertisols are in preparation.

Technical Papers mostly concern methods, procedures and standards of analysis and work, and are of varying length.

ISRIC should like to get in touch with soil scientists who are acquainted with an important group of soils, e.g. soils in arid regions (Calcisols, Gypsisols), saline/sodic soils (Solonetz, Solonchaks), claypan soils (Planosols) or low-activity-clay soils (Lixisols, Acrisols).

The fellowships only cover lodging and full board, pocket money and insurance. No travel funds are available. Since the fellowships are tenable for scientists from OECD countries, only citizens of these countries need apply.

Please direct your interest to the Director of ISRIC.

REQUEST FOR MAPS AND REPORTS ON SOIL RESOURCES

Cartographic materials form an important part of ISRIC's documentation section. Geographic coverage of the collection is the whole world with emphasis on developing countries. The subject emphasis is on soils, but related geographic information on climate, ecology, vegetation, land use, land capability, geology, geomorphology, etc. is also of importance to the collection.

The acquisition policy is to obtain world coverage of maps at reconnaissance and smaller scale; examples of more detailed maps and index maps/lists of soil and related surveys carried out in a country. The selection criteria are relevance of the maps for soil science, agricultural development and environmental issues.

The major purpose of maintaining and enlarging the map collection at ISRIC is its use for the possible updating of the FAO-Unesco Soil Map of the World at scale 1:5 million and the compilation of a new, computerized world soil map at 1:1 million. The map collection serves also as a source of basic information for scientists and students using ISRIC's facilities for guest research or training.

You are kindly requested to send maps and accompanying reports,

of the types indicated above, either:
— directly to ISRIC, P.O.Box 353, 6700 AJ Wageningen, The Netherlands;
— through the Dutch Embassy or Consulate in your country;
— or through the Regional Offices of Unesco and FAO.

REMARKS & COMMUNICATIONS

Please send to: ISRIC Secretariat
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PUBLICATIONS

Soil Monolith Papers

1. Thionic Fluvisol (*Sulfic Tropaquept*) Thailand, 1981
5. Humic Acrisol (*Orthoxic Palehumult*) Jamaica, 1982
6. Acri-Orthic Ferralsol (*Haplic Acrorthox*) Jamaica, 1982
7. Chernozem calcique (*Vermustoll Typique*) Romania, 1986

Technical Papers

1. Procedures for the collection and preservation of soil profiles, 1979 - out of print
2. The photography of soils and associated landscapes, 1981
3. A new suction apparatus for mounting clay specimens on small-size porous plates for X-ray diffraction, 1979 (exhausted, superseded by TP 11) - out of print
4. Field extract of "Soil Taxonomy", 1980, 4th printing 1986
5. The flat wetlands of the world, 1982
6. Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part I: CEC and Texture, 1982; 1984 - out of print
7. Field extract of "classification des sols", 1984
8. Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part II: Exchangeable bases, base saturation and pH, 1984
9. Procedures for soil analysis, 1986; 2nd edition, 1987, 3rd ed. in preparation
10. Aspects of the exhibition of soil monoliths and relevant information (provisional edition, 1985) - out of print
11. A simplified new suction apparatus for the preparation of small-size porous plate clay specimens for X-ray diffraction, 1986
12. Problem soils: their reclamation and management (copied from ILRI Publication 27, 1980, p. 43-72), 1986
13. Proceedings of an international workshop on the Laboratory Methods and Data Exchange Programme: 25-29 August 1986, Wageningen, the Netherlands, 1987
14. Guidelines for the description and coding of soil data, revised edition, 1988
15. ISRIC Soil Information System - user and technical manuals, with computer programme, 1988
16. Comparative classification of some deep, well-drained red clay soils of Mozambique, 1987
17. Soil horizon designation and classification, 1988
18. Historical highlights of soil survey and soil classification with emphasis on the United States, 1899-1970, 1988
19. Soil horizon designations, 1990
20. FAO-Unesco Soil Map of the World. Revised Legend, field edition, 1989
21. Technical Report on Agroclimatic Characterization of Madagascar, 1990

Soil Monographs

1. Podzols and podzolization in temperate regions, 1982
   with wall chart: Podzols and related soils, 1983
2. Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions, 1989
3. Ferralsols and similar soils; characteristics, classification and limitations for land use, in prep.

Wall charts

- Podzols and related soils, 67 x 97 cm, 1983 (see Soil Monograph 1)
- Soils of the World, 85 x 135 cm, 1987 (Elsevier Publ. Company, in cooperation with ISRIC, FAO and Unesco)

AIMS OF ISRIC

- to serve as a documentation centre on land resources - through its collection of soil monoliths and reports and maps on soils of the world; with emphasis on the developing countries
- to improve methods of soil analysis - through research and international correlation; with emphasis on soil characterization and classification
- to transfer specialized information - by lecturing and by publishing on the collected materials and on research data, and by advising on the establishment of national and regional soil reference collections and databases
- to stimulate and contribute to new developments in soil genesis and classification, soil mapping and land evaluation - through active participation in international scientific working groups
- to carry out consultancies and give training in aspects of soil science and agro-climatology - by employment of staff in developing countries or at ISRIC and by giving training and education at ISRIC and elsewhere

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