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Extended Abstracts of the International Symposium on Soil System Behaviour in Time and Space

Mitteilungen der
Österreichischen Bodenkundlichen Gesellschaft

Communications of the Austrian Soil Science Society

Heft 55

November 19-21, 1997

Vienna, Austria

Österreichische Bodenkundliche Gesellschaft

Universität für Bodenkultur
Gregor Mendel-Straße 33 Tel. 0222/3106026
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29. Dezember 1997

E I N L A D U N G
zur
Ordentlichen Generalversammlung 1998

am **Mittwoch, den 21. Jänner 1998** von **14.00 – 15.00 Uhr** s.t. im Hörsaal VIII der Universität für Bodenkultur, **Gregor Mendel-Straße 33, 1180 Wien**.

Tagesordnung

* Begrüßung und Feststellung der Beschlußfähigkeit
* Genehmigung des Protokolls der letzten Generalversammlung
* Tätigkeitsbericht 1997
* Veranstaltungsprogramm 1998
* Kassabericht
* Bericht der Rechnungsprüfer und Genehmigung des Rechenschaftsberichtes
* Abstimmung über Verleihung der Ehrenmitgliedschaft an Dr. Walter Kilian
* Verleihung des Kubiena Preises 1997
* Wahl des Gesamten Vorstandes
* Allfälliges

Hinweis: Laut § 13g der Satzungen der ÖBG müssen Anträge von Mitgliedern, über die die Generalversammlung zu entscheiden hat, mindestens 8 Tage vorher dem Vorstand vorgelegt werden.

Andreas Baumgarten
Generalsekretär

Eduard Klaghofer
Präsident

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Vortragsveranstaltung

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Dipl.-Ing. A. Pehamberger
Finanzlandesdirektion für Wien, Niederösterreich und Burgenland, Wien

Die Böden Ostösterreichs unter landwirtschaftlicher Nutzung

Beschreibung der Hauptbodentypen im Osten Österreichs nach den Ergebnissen der Bodenzustandsinventur Niederösterreichs und des Burgenlandes und ihre ertragsmäßige Bewertung.

Zeit: **Mittwoch, 21.1.1198, 15:00 Uhr c.t.**

Ort: **Hörsaal VIII der Universität für Bodenkultur**
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Einladung zur

Exkursion der ÖBG 1998 ISTRIEN

Nach längerer Zeit wird die Exkursion der ÖBG wieder ins benachbarte Ausland, und zwar nach Slowenien und Kroatien, führen. Schwerpunkt sind die Landschaftsräume der Halbinsel Istrien. Die Exkursion findet von

Do., 24.9. - So., 27.9.1998

statt. Der Exkursionsbeitrag steht derzeit noch nicht fest, da er wesentlich von der Anzahl der Anmeldungen abhängt, wird jedoch ca. bei **ATS 2000.-** (incl. Hotel, HP) liegen. Sollten Sie an einer Teilnahme interessiert sein, bitten wir Sie, die beigefügte Voranmeldung an unseren Generalsekretär zu retournieren. In diesem Fall erhalten Sie alle weiteren Informationen zum Ablauf der Exkursion.

✂
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Voranmeldung für die Exkursion 1998 der ÖBG

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Some papers which arrived after the deadline did not pass the reviewing process.

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CONTENT

Posters

Models of Soil System Processes

Lectures

Posters

World Reference Base for Soil Resources and Soil System Behaviour in Time and Space

Lectures

Posters

Preface

The University of Agricultural Sciences, Vienna (Universität für Bodenkultur Wien, BOKU) is celebrating its 125th anniversary this year, an excellent reason to invite colleagues and friends from all over the world to celebrate with us.

Our way of commemorating the founding of BOKU is to develop perspectives, to take a look into our scientific future.

It is therefore a great pleasure to convey my best greetings to all participants of this International Symposium „Soil System Behaviour in Time and Space".

Your conference theme fits this anniversary very well, as soil system behaviour in time and space means to look into the genesis and development of an important system within our environment, and it is in full harmony with the continuous task of my University, to reach out and to give space to further development of sciences dealing with land use and land management.

Moreover, with its many different programmes in research and education, this University offers a broad spectrum, reaching from agricultural and forest sciences to rural technology, biotechnology and food processing, as well as landscape management and landscape planning, partly based on partnerships and projects with institutions in many parts of the world.

I am convinced that this Symposium will contribute to new developments and will show new highlights and provide insights in the field of soil science, and exactly in this sense, I wish this International Symposium full success.

Prof. Dr. Dr.h.c. L. MAERZ, Rector

Preface

Soils as open systems are dynamically interacting with the atmosphere as well as with the geological subsystem. A change of a single controlling parameter in one of the systems has a balancing impact in the other systems. The investigation as well as the assessment of this temporal and spatial dependency and variability of the overall highly complex soil system, acting as filter, buffer and catalyst, represents a very important topic in sciences at the present. Thus, the Austrian Soil Science Society hosted the International Symposium on 'Soil System Behaviour in Time and Space' in Vienna, 19th -21st November, '97.

Summarising the most significant results for its participants in the published symposium proceedings represents a major intent of our society. But these proceedings shall also inform non-participating scientists about the scientific outcome of the symposium.

E. Klaghofer

President of the ASSS

Preface

During the XVth World Congress of Soil Science in Acapulco, Mexico, 1994, the idea was born to organize an international symposium of Commission V "Soil Genesis, Classification and Cartography", in the forthcoming years. One of the possible locations taken into consideration was Vienna. As a primary topic, basic processes of soil formation and soil system behaviour were targeted.

These vague ideas were put into practice when the University of Agricultural Sciences in Vienna prepared for its 125 years' anniversary, inviting scientists from all over the world to cooperate with the organisation of international symposia and workshops.

Consequently, we developed the programme for an international symposium with the title "Soil System Behaviour in Time and Space", focusing on three main topics of soil research: soil as a complex system, describing the soil as an open, multifaceted system of biospheric interactions and taking into consideration specific aspects of soil components, as well as the time scale of processes and the spatial distribution of both. As a second topic, it was decided to include models of soil system processes, focusing on general aspects of modelling in soil science, as well as models for specific processes and case studies, based on experimental data. - As we felt that these two topics would generate rather theoretical knowledge, we planned to confront these theoretical approaches with the reality of the World Reference Base for Soil Resources, thus counterchecking theory with practice on a worldwide level, asking how soil diagnostic characteristics and soil groupings are adapted to reflect the behaviour of soil systems in time and space.

We do hope that at a time when basic research is often neglected due to a lack of funding, or to the fact that practical soil problems have to be solved within a short time, we will be able to harmonize theory and practice in this international symposium, and to present a sound forum for discussion.

We thank many colleagues for their helpful support in organizing this symposium. Specifically, we thank the University of Agricultural Sciences and the Austrian Society of Soil Science. Moreover, we are satisfied that the Working Group on "World Reference Base for Soil Resources" will have a forum for discussing their final results before they are printed and presented at the XVIth World Soils Congress in Montpellier, France.

We wish all participants a very successful international symposium.

Winfried E.H. Blum
Secretary-General, ISSS

Victor O. Targulian
Chair, Commission V, ISSS

SOIL AS AN OPEN COMPLEX SYSTEM OF THE EXOGENIC BIOTIC AND ABIOTIC INTERACTIONS

TARGULIAN Victor O.

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The problem of soil system (SS) complexity has a lot of different aspects ranging from relatively simple abiotic components and reactions to very complex combinations of hierarchically organized bio-abiotic components and complex interactions among the macro-, mezo- and microbiota, gases, solutions and solid components. M.Gell-Mann (1995) proposed a new term «plectics» to reflect the interrelations between simple and complex components and processes within the complex systems. Synergetics discusses the transition from «complexity to perplexity» to describe such phenomena. Maybe these terms will be perceived for the system approach in soil science.

The main goals of our two papers with Prof. W. Blum are to analyze the basic concepts describing the soil as one of the open complex systems of biotic-abiotic interactions on the Earth surface and particularly the problems that concern soil system behavior in time.

The system approach to the soil body and mantle integrates a lot of traditional definitions of soil, both applied and fundamental: soil as a fertile media, as a mixture of mineral and organic materials, soil as a function of factors, as a vertically anisotropic horizonated in situ body, etc. Now we can conclude (Smeck et al, Targulian) that soil system either in scale of pedon or in scale of soil mantle is one of the open, non-linear, exogenic, multicomponent, bio-abiotic, synergetically interactive, mantle-like, surface-planetary system. In this sense the SS is not the sole and unique system. Nowadays other similar systems are well-known for example photic and benthic zones of the ocean.

The main particularity of the SS that distincts it from other systems consists in functioning and developing of the SS within the enclosing relatively stable and laterally immovable solid matrix: lithogenic, organogenic or even anthropogenic (generally - lithomatrix). The SS is the system that functions and develops in situ within such lithomatrix (concept of siton, by Targulian).

The general model of the SS should include the characterization of the:

- boundaries and/or interfaces of SS with other nonsoil and soil systems: surface, lateral, basal; the most of them are obligatory, some of them – facultative;
- external substantial and energetic inputs into SS through different boundaries;
- internal components of the SS: predominant enclosing solid-phase matter and penetrated gases, solutions, macro-mezo-microbiota;
- internal structure or arrangement of the SS, i.e. spatial distribution of the components: horizonation, pedality, porosity, gas water roots canals, etc.;
- internal functioning of the SS: interactions among all components cycles and fluxes acting within the SS and producing a lot of microeffects in each span of time, both in components and/or in arrangement of the system;

- external outputs from the SS through different interfaces and separation of the products of functioning: outgoing of gases and solutions, reproduction of biota, accumulation of solid products in situ within the SS ;
- external functioning of the SS that means the balance between the inputs and outputs of the SS; such balance as a feedback from soil to environment can play a very important role in regulation and transformation of many external fluxes coming into and/or passing through the SS.

According to such model the soil system emerges immediately after the «meeting» and interaction of the main labile external systems (atmo-, hydro-, bio-, anthropo- fluxes and cycles) with the stable surface lithomatrix. The SS starts to function externally and internally from the zero-time when these fluxes penetrate into and/or pass through the initial lithomatrix.

We propose to generalize extremely diverse aspects of the SS complexity and reflect them in three facets or images of this system:

- as a reactor of the internal interactions of all system's components, i.e. internal functioning of the SS as a belowground tier of the land biosphere;
- as an external regulator and transformer (producer, filter, buffer, etc.) of the most part of external fluxes and cycles entering, penetrating and passing through the SS, i.e. external functioning of the SS within the biosphere and geospheres.
- as a block of memory of the long-term external and internal functioning, i.e. developing solid-phase structure of the SS horizonated in situ, due to gradual accumulation of those solid -phase results of functioning that can not quit the system.

All three facets of the SS are very closely interlinked, interdepended and interacted in time and space. External functioning of the SS creates the internal functioning that consists of vertical and lateral cycles and fluxes within and through all the SS. It is reflected in emerging and diurnal seasonal and annual fluctuation of the labile functional horizons and profiles within the whole thickness of soil system (ortho-, para-, meta-biotic horizons, heat, gaseous and hydrological profiles, etc.). The solid-phase thickness of the SS lithomatrix is simultaneously the enclosing media, selector and transformer, filter and buffer for the functioning processes and at last the recepient and accumulator of all pedogenetic solid-phase transformations.

The solid-phase vertical in situ horizonation of soil body and/or mantle is the result of long-term rotation, superposition and synergetic combinations of the horizons and profiles of soil system functioning (heat, moisture, solutions and suspensions, macro -,mezo-, microbiota). In this sense the SS functioning and the pedogenesis are not the identical phenomena. In a broad sense, the pedogenesis can include both the functioning of the system and solid-phase transformations of the lithomatrix into pedomatrix (horizonated soil body and mantle). But, in narrow sense, pedogenesis means only those changes in soil system behavior in time that are reflected in steady and resistant soil solid-phase features.

The complexity and versatility of the SS mean that the modeling of the SS behavior in time should be very accurately focused on the concrete problem and /or process, and/or characteristic of the system. Models of the external and/or internal functioning, models of mono- or polypedogenesis can sometimes use the same data and parameters, but they mainly need quite different information to build the correct model.

SOIL AS AN OPEN, COMPLEX SYSTEM OF BIOTIC AND ABIOTIC INTERACTIONS - ENERGY CONCEPT

W.E.H. Blum

Institute of Soil Research, Universitaet fuer Bodenkultur, Vienna, Austria

All kinds of soil processes are dependent on energy. Therefore it seems interesting to identify the energy sources on which these processes are based, as well as their time scale, in order to answer the question if soils can be regarded as a steady-state system.

Three main forms of energy for soil processes can be distinguished:

1. Gravity, which is dominating the entire soil system, and therefore all solid, liquid and gaseous forms of soil material. Gravity is an inherent form of energy and also determines the velocity and the vector of fluxes within the soil. Moreover, gravity is responsible for all transport processes on the soil surface, e.g. erosion through water and within the soil. As natural erosion occurs on all soil surfaces, gravity is also a dominant factor in topomorphic processes (morphogenesis).

2. A second form of energy is herited from the rock parent material through orogenesis (pressure and temperature), which has formed very different kinds of minerals and rocks. This is an endogenic heritage of energy, deriving from energies and processes inside the earth. As this energy is not normally renewed for very long time intervals, except for such cases as for example volcanic eruptions or earthquakes, this pool of energy is constantly decreased by exogenic forces derived from solar sources, e.g. by weathering.

   In this context it seems very important to understand that different minerals contained in different rock parent materials have very different capacities of energy, which can be seen by comparing a quartz or iron-oxide with a feldspar or a mica. Through physical and chemical weathering processes, induced by solar energy, this energy pool derived from minerals and rock parent material is constantly lowered, because secondary minerals, such as clay minerals, oxides and hydroxides, or water soluble salts contain much less energy than primary minerals, such as micas, feldspars, pyroxenes, amphiboles and others. - A good example is the resistance against weathering of different minerals or the very different buffer capacity of soils against acidification. For example, all the buffer pools, such as carbonates, exchangeable alcali cations, earth alcali cations and others, the silicates and finally the Al and Fe oxides are limited, which means that buffering against acidification is only possible, as long as these substances are available. These are therefore finite reactions or processes.

   The energy content of the different minerals is not only based on the cristalline structure but also on the very different element distribution within these minerals, which is important for specific soil functions, especially the production of biomass, but also weathering, buffering and other reactions.

Therefore, through weathering processes, the total energy pool in the soil is constantly lowered, thus increasing the entropy of the system.

3. The third form of energy available for soil processes derives from solar radiation, which can be subdivided into direct radiation (including diffuse radiation through reflection etc.) and forms of solar energy contained in organic matter, which means that this second form of solar energy has a different time constant. Both, direct and indirect forms of solar energy are exogenic forces. Direct forms of solar energy comprise also wind and rainfall and therefore a wider range than only the direct radiation, e.g. through convection. Solar energy can be defined on the basis of climatic systems or sub-systems.

   Solar energy is not only the cause of physico-chemical reactions, but is also influencing their velocity (see rule of van t'Hoff). It is the source of all kinds of biological and biochemical reactions. Energy derived from solar radiation can also act against gravity, especially in arid and semi-arid areas, where water movement in the soil occurs against gravity through capillary rise, leading to the formation of new soil components, e.g. water soluble salts and others, such as carbonates and sulphates. Therefore, solar energy may have very different impacts according to the prevailing climatic systems.

   In contrast to the energy derived from orogenesis (minerals, rocks), this form of energy is renewable and is acting constantly at the soil surface as well as within deeper parts of the soil body.

Raising the question of steady-state or non steady-state, it becomes clear that soils are by far no steady-state systems, because the increase of entropy and the lowering of the energy pools derived from minerals and rock parent material is constantly progressing through external energies, mainly derived from solar energy.

Further forms of energy for soil processes, such as energy transfer from the inner part of the earth, can be neglected and might only be of importance at deeper weathering layers, compare e.g. the permafrost soils in the northern and southern hemisphere.

It seems to be possible to use this energy concept to understand all kinds of soil processes and to answer the question, why certain forms of energy can be preserved irreversibly, e.g. in the form of secondary minerals, which are testifying historical soil forming conditions with very different energy impacts.

It seems also important to mention that the two factors: gravity and energy derived from minerals and rocks did not change essentially during soil forming processes in historical times, but solar energy showed very specific oscillations, which can be derived from the deviation of the equator and the inner tropical zone during the Pleistocene and the Holocene. Therefore, herited features in soils are mainly due to a change of solar energy in historical and prehistoric times.

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SPATIAL AND TIME ASPECTS OF THE SOIL COVERS

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Introduction

Soil cover is a continuous natural body that has three spatial and one temporal dimensions.

I - Space: the structure of the soil cover

- The different levels of organization for the soil cover are: elementary organizations (aggregates, voids, cutans, nodules, biological features,...), assemblages, horizons, pedological systems. The profile (pedon) is not a real organization level, but an observation level.
- The pedological system level is the last to have been discovered. Its discovery is the result of field and microscopic works, with a morphological approach focused on limits between the different pedological volumes. One of the main consequences of this discovery is the possibility to go from 2D(imensions) towards 3D(imensions): this corresponds to a detailed cartography with representation of the « isodifferenciation curves » that indicate where are the real lateral morphological modifications in the soil cover.
- The morphological approach is very important:
  - for the geometrical description and interpretation of the different volumes which are part of the soil cover;
  - for the spatial analysis of the isodifferenciation curves;
  - to be introduced to the dynamic of the soil cover: from space to time.

II - Time: the permanent transformation of the soil cover

To understand the actual soil evolution and to reconstitute the history of a soil cover, it is necessary to study in detail the morphology of the limits that separate the structures that are, in the soil, in contact between them: limits between two elementary organizations, between two assemblages, between two horizons. The morphological study of the limit concerns mainly the modifications about structures and constituents.

The morphological study of a limit permits to know about the dynamic of the structures: which is the structure that is being formed by modification of another structure. Here comes the concept of transformation: between two elementary organizations, or between two assemblages, or between two horizons, there is, frequently, a transformation front.

From this, it is possible to go until the discovery of the dynamic of a soil system and, in some case, to discover that in a landscape we have the transformation of a system by another system: this is what we can name a transformation system, with or without convergence of patterns.

III - Time is visible in space

Time is visible in space:
- the cartography of transformations fronts (limits) permits to deduce the system's dynamic (at a detailed scale) (one example taken in French Guyana - « St Elie »);
- the study of spatial distribution of the different steps of a transformation system, is a key to decipher the diversity of a pedological cover (at a regional scale):
  - one example taken in French Guyana « Barres prelittorales »;
  - two examples taken in boreal zone: transformation due to 1) lateral growth of peat bog, 2) karst development.

These studies have consequences on considering two main types of explanations frequently applied to soil genesis:
  - pedological transformations and geological evolutions: in many cases, we can now demonstrate that « geological sediments » are, in fact, the result of pedological differentiation;
  - pedogenesis and morphogenesis: the relief evolution is the result of the soil cover transformation.

Conclusions

- The morphological approach is the first key to enter the soil cover organisation, in space and time.
- The concept of internal transformation of the soil cover, at the scale of the pedological system, is valid whatever the climatic zone on the Earth.
- The importance and the future of field working is becoming obvious, with the necessity to carry on with the inventory of transformation systems.
- Pedological data acquired at the proper scale of pedological system will have to be related with data coming from surface images: in between the scales of aerial photographs and the scales of satellite images, relevant scales and resolution may be defined.
- Whereas efforts are made to model the functioning of the Earth Planet, it seems rather essential to work for and succeed in modelling the soil cover. However, this scientific trend is still too weak, since the structure of the pedological cover is not taken into account in the different existing classifications.

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SOIL PHYSICAL CHARACTERISTICS IN SPACE AND TIME SCALES

Miroslav Kutilek

Emeritus Professor of Soil Science and Soil Physics, Prague, Czech Republic

The quality of our predictions on soil system behaviour depends upon our understanding of soil basic characteristics. Soil physical characteristics and especially soil hydraulic functions belong to them. Their alteration mainly due to man's activity extends in a wide range of time. When we are describing the soil physical characteristics, we have to define the scale of our observation. In further steps of modeling and predictions we should keep within the scale of our observation unless we need to clear up unexpected phenomena. For their explanation we shift usually to a lower scale.

I. Definition of Scales (Kutilek and Nielsen, 1994)

1. Pore (microscopic) scale has the dimensions of individual pores and of their arrangement in microscopic clusters and ensembles. Pore scale is introduced when we are studying e.g. the transport of water and solutes in individual pores and in their defined arrangements, or the interaction of individual plant roots with the soil matrix and with solutions in pores etc.

2. Darcian or pedon (macroscopic) scale is related to the size of the pedon. It is the most frequent scale in our theoretical studies, in models and in field measurement technics. At this scale, individual pores and their clusters are not microscopically described but considered as a part of the whole soil porous body defined in size by the representative elementary volume (REV, Bear, 1972).

3. Pedotop scale is related to the soil district where individual pedons are unified into the lowest soil taxon, pedotop. In spite of taxonomic homogeneity, the soil is heterogeneous from the point of view of soil physical characteristics and we can denote this variability as strictly stochastic. Measured data and modeled solutions on pedon scale are applicable to pedotop scale by a combination of various procedures.

4. Mapping unit (regional) scale covers the area in orders of magnitude greater than that of an average district of one pedotop. Since the mapping unit consists of several pedotops which are clustered into the higher taxonomic unit, the variability is both, stochastic and deterministic. A simple transfer of knowledge from the pedotop scale to the regional scale is not correct and brings about enormous errors, especially when transports are considered.

II. Pore Scale

Majority of soil physical properties are related and dependent upon the soil porous system. Pores are variable in their shape, size and mutual interconnections. The size of pores is estimated either indirectly from the laws of hydrostatics (Laplace equation) and hydrodynamics, or from direct observation and visualization of pores. The combination of both is advantageous. We are classifying three basic categories of pores according to laws of hydrostatics and hydrodynamics (Corey, 1977, Kutilek and Nielsen, 1994):

1. Submicroscopic pores without continuous flow paths. Pores belonging to this category are usually neglected.
2. Micropores, or capillary pores with capillary meniscus formed at the air-water interface. We distinguish between
2.1. matrix (intrapedal) pores, and
2.2. interaggregate (interpedal) pores.
3. Macropores, or non-capillary pores of such a size that capillary menisci are not formed accross the pore. Origin of macropores is closely correlated to their stability and persistence in time:
3.1. Macropores formed by the activity of pedo-edaphon as decayed roots, earthworm channels etc. They have usually tubular form and they are well persistent in time and relatively independent upon the variation of the soil water content.
3.2. Fissures and cracks occuring as the consequence of volumetric changes in swelling-shrinking soils. They have planar forms and they are dependent upon the soil water content. Some of them may occur on the transition to the category 2.2. micropores.
3.3. Macropores due to the soil tillage. Their depth is limited, they are dependent upon the soil water content, meteorologic situation and type of plants, too. They disappear usually in less than one vegetation season.

The accelerated (or by-pass) flow exists in pores belonging to categories 2.2. and 3. Since this flow is called preferential flow, too, those pores are classified as preferential pores.

The porous systems visualised by micromorphological technics, or formed by models are described by fractals and the arrangement of individual pores into porous systems is modeled by fractal fragmentation (Perrier, 1995). However, models related to soil micromorphology and to soil structure typical for pedologic horizons are still missing.

III. Pedon Scale

The information on soil porous system on Darcian scale is routinely derived from the derivative curve of the soil water retention curve (SWRC) obtained on the undisturbed soil sample. If we find more than one inflection point on SWRC plotted by spline, we have the evidence on a bi- or tri-modal PSD (pore size distribution, see Othmer et al, 1991, Durner, 1991). However, in SWRC with one inflection point a bi-modal distribution can exist, too. In swelling/shrinking soils the interpretation of SWRC as the summation curve of PSD is not appropriate, the shape of PSD changes substantially with the change of soil water content (Schweikle, 1962). Solutions of transport processes in porous systems consisting of micropores, category 2, are based upon the Richard's equation, RE.

If macropores are detected on routine core samples, their number and density are rarely representing the field reality, since REV increases substantially above the size of routine core samples in soils with macropores. For detection of macropores, other procedures than SWRC are applied. Solutions of transport processes in macropores are based upon Chezy equation or kinematic wave equation (Germann and Beven, 1985).

From SWRC and from Ks (saturated hydraulic conductivity), the functional relationship of the unsaturated conductivity K is computed (van Genuchten, 1980). The independently measured Ks serves as the matching point. The procedure is correct if the porous system is mono-modal, i.e. it is homogeneous from the point of view of PSD. Due to the existence of interpedal pores (2.2. category) we recommend to use the measured K at the pressure head at one value of h between -10cm and -50cm as the matching point for K of the intrapedal porous system, while Ks is used as the matching point of K in the interpedal porous system (Kutilek and Nielsen, 1994).

Soil tillage or no-tillage technics modify SWRC, K(h) and Ks. In compacted soils, the extreme decrease of Ks and K(h) in its wet range are due to the reduction up to liquidation of interpedal porous systems.

IV. Pedotop Scale

Since the soil cover of one taxonomic unit shows heterogeneity of physical characteristics, the variability of measured data on pedotop scale is studied statistically. The great majority of soil physical characteristics are estimates of exactly defined physical parameters. When a physical property A is studied, an observational sample of A is the estimate (A+e) where e is the error of the measuring method. The real PDF, probability density function of A is not necessarily equal to the PDF of (A+e). E.g. values of the sorptivity S and of Ks were determined by ponded infiltration tests. The infiltration data were fitted to four different infiltration equations: Philip's two terms (P2) and three terms (P3), Swartzendruber's (Sw) and Brutsaert's (B) equation. On a Chernozem, there was log-normal distribution of S(P2), S(P3), S(Sw) and Ks(P2), whereas Ks(P3) and Ks(B) manifested a Weibull distribution and Ks(Sw) had a Beta distribution. On Oxisols the studied PDF were varying from normal and log-normal to Erlang's and Gamma distribution, the evaluated parameters had PDF in majority of instances different from those PDF on Chernozems (Nielsen et al., 1996). Geostatistical evaluation of data is a common practice nowadays. In order to extend observation and modeled solutions from pedon to pedotop scale, scaling procedures are used.

On pedotop scale we are observing the time and space variation of physical data. We define time stability if covariance exists between a spatial variable (e.g. soil water storage) and linked pedotop characteristics as e.g. texture, topography (Vachaud et al., 1985). This stability may be restricted to certain meteorologic conditions as e.g. to evaporative-drying period.

V. Mapping Unit (Regional) Scale

Starting from the pedotop scale, and dominantly on mapping unit scale, proper methods as e.g. Kalman filtering are used to account for noise in parameter estimation (Katul et al., 1993). When this procedure is combined with geostatistics, the characteristics related to the studied area as Ks or K(W) are obtaimed. We attempt to simplify the RE and we introduce soil water storage W (in mm) to a depth of about 30cm instead of soil water content varying with depth. The partial differential equation is approximated by the ordinary differential equation with K(W) expressed in the exponential form (Nielsen et al., 1996). Thus, the combination of field pedon observation with remote sensing will offer reliable data on soil physical characteristics and on soil water storage in mapping unit scale and in appropriate time scale.

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SPATIAL AND TEMPORAL HETEROGENEITIES OF GAS FLUXES IN FOREST SOILS

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1. Introduction

Quantification of soil-gas fluxes and of the key processes that control them are of actual interest, because the role of forest soils in the global C-balance and in the exchange of greenhouse gases is undoubtfully very important, but until now, its quantification remains uncertain. This applies especially for processes in deepest soil horizons. We developed a concept to measure gas fluxes in forest soils based upon the gradient method. (SCHACK-KIRCHNER, 1993). The „hardware" of this concept consists of diffusive sinks, which are placed in different soil depths and which allow to measure gas concentrations with high spatial dissolution and with a replication number appropriate to the heterogeinity of forest soils (SCHACK-KIRCHNER et al., 1993). By this way, we are able to measure soil-air composition within the macropore space being preferential habitate of roots, hyphae (von WILPERT et al., 1995) and other micro organisms.

If we want to parametrise diffusion equations (e.g. FICK's laws), the most important parameter function is the relation between temperature, the diffusion coefficient and moisture content (**Fig. 1**). However for a successful application of a diffusive gas transport

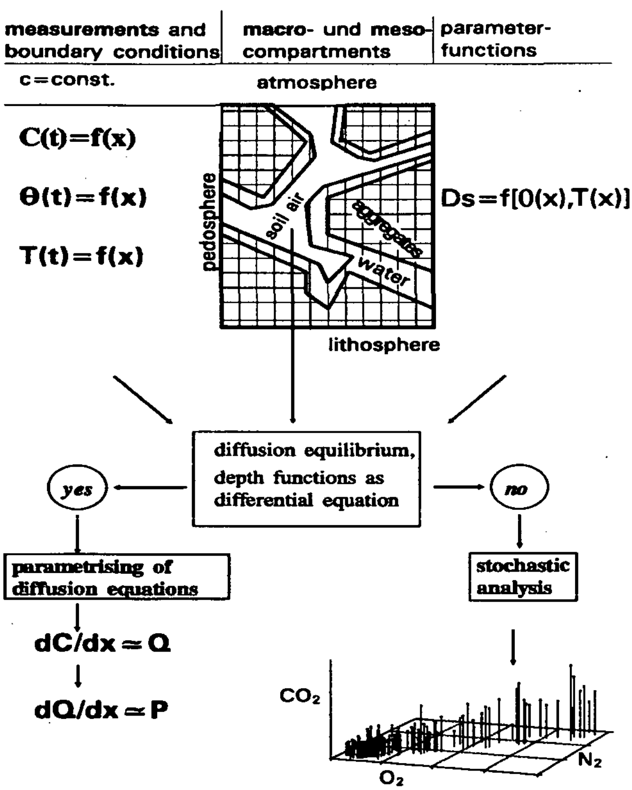

Figure 1: Concept of a gas budget model

model in soils, two elementary requirements have to be met (Stolzy et al., 1981):

- it must be ensured that in the space-/time-scale of our measurements convective fluxes do not control net gas transports;
- depth functions of gas concentrations must be differentiable.

This paper deals with an operational procedure which shows, if these requirements for diffusive gas budget models are fulfilled.

2. Results

2.1 Diffusion equilibria in soil profiles

Gas concentration profiles allow calculation of gas fluxes, assuming knowledge of diffusion coefficients and fulfillment of boundary conditions of diffusion transport equations. These assumptions are generally met, when gas transport by convection is of minor importance. Simple diffusion laws (e.g. The FICK's Laws) will fail, if nonequimolar gas production and gas consumption occurs. In soils where gas fluxes are dominated by equimolar, counter-current flows of O_2 and CO_2 (this is the case for well aerated soils when the respiratory quotient RQ is 1), a constant gradient ratio of 1.2 will be established. The underlying model based on the kinetic gas theory has been published by WOOD & GREENWOOD (1971). In **Fig. 2** we compare measured values of CO_2 and O_2 in the soil air with this deterministic model. We see, that nearly all measurements of our experimental site „Conventwald" (mixed stand from *fagus sylvatica, abies alba picea abies*, dystric cambisols parent material paragnaiss, black forest near Freiburg) correspond to diffusion equilibria. Mass flow occurs, e.g. if the CO_2 partial pressure increases when the removal is slow with regard to the production rate, and consequently a portion of CO_2 „disappears" by solubilization. This apparently applies more often for the site of the experimental station „Altensteig" (*picea abies*, gleyic cambisols parent material triassic sandstone, black forest). If CO_2 concentrations exceed $\cong$1%, a considerable amount of the CO_2 uses the water pathway to get out of the rhizospere.

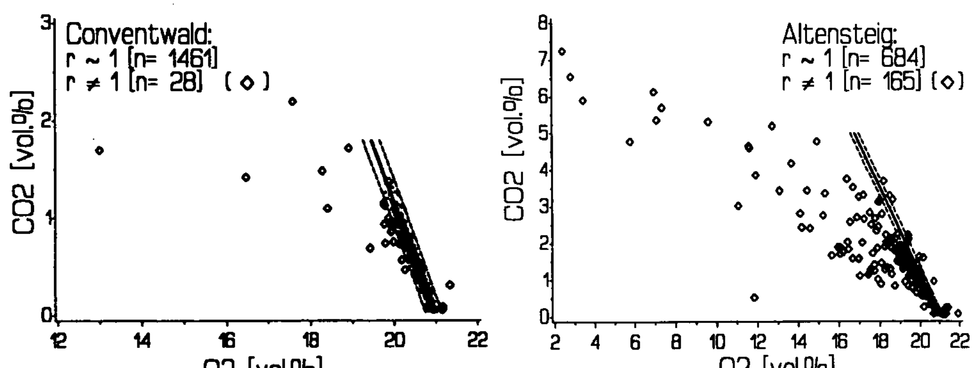

Figure 2: Measured gas concentrations and the model of diffusive equilibrium after WOOD & GREENWOOD (1971), **left**: experimental site „Conventwald", **right**: experimental site „Altensteig" (r: flux ratio of CO_2/O_2). Within the dashed lines we assume a constant CO_2/O_2 gradient ratio of 1.2 $\pm$ analytical error.

2.2 Differentiable depth functions

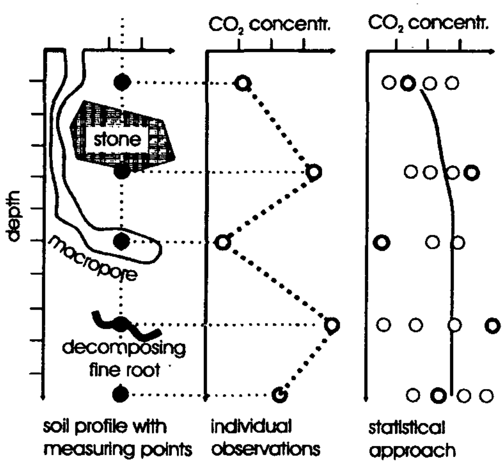

Figure 3: Unsteadiness of real depth functions

In real soils gas concentrations do not show differentiable, smooth depth functions. The reason for this problem is schematically presented in **Fig. 3**. Since it is not operational to measure gas concentrations with a spatial resolution allowing numerical differentiation, it is clear that we need statistical tools to get a base for model calculations. However polynominal fits would produce uncontrolled results and ignore available information.

We tried to solve the problem in the following way:

- the soil is divided into discrete compartments (soil horizons);
- in the compartments we assume constant gas production leading to 2nd degree polynoms for the depth profile of gas concentrations(Schack-Kirchner, 1994);
- a quadratic spline function is fitted to the measured values, with unsteadiness of the first derivative defined by the ratio of the diffusion coefficients.

3.3 Modelled gas fluxes in different soil depths

In **Fig. 4** are plotted the flux rates of CO_2 and N_2O in different soil depths of the experimental station „Altensteig" in the year 1995 and 1996. Besides of a typical pattern, caused by increased biological activity in the vegetation period, we see, that the production of both, CO_2 and N_2O, is most active in the top soil. The removal of CO_2 at the soil surface corresponds to 5.3 tons C/ha/a. The release of N_2O of less than 300 g. N/ha/a is without importance for the N-budget of the site, however it might become important as greenhouse active trace gas. It is noteworthy, that the maximum of CO_2 release appears in deeper horizons with a time lag, apparently corresponding to the delayed temperature maxima.

3.4 Patterns of concentrations relations

If overlaying convective and diffusive transport processes occur, the application of mechanistic transport models is not possible (e.g. when the CO_2/O_2-relation do not allow the assumption of equimolar counter-current diffusional fluxes (**Fig. 2**)), the ecological information, which is „hidden" in gas concentrations must be gained by stochastic approaches. Such a tool is presented in **Fig. 5.** The measured N_2/Ar ratios of the experimental station „Altensteig" are plotted against the straight line which reflects a diffusion equilibrium. In this case the increase of N_2 concentration is explained by relative enrichment due to solubilization of CO_2.

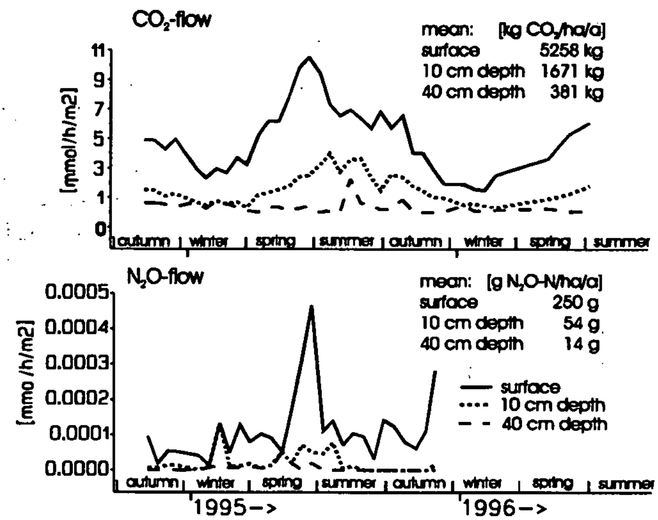

Figure 5: CO_2 and NO_2 fluxes in the experrimental station „Altensteig"

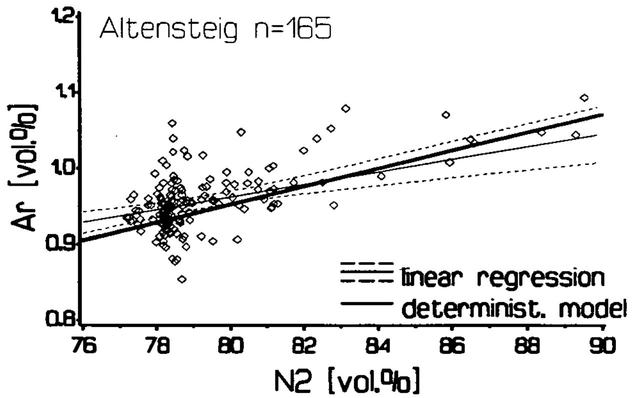

Figure 6: Measured and modelled Ar/N_2-ratios

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CHANGES IN FOREST SOIL FERTILITY - SOIL DETERIORATION OR ARTEFACT

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1 Introduction

Many forest soils underwent severe acidifiction during the last decades. Results have been presented from areas with intense air pollution, as well as from remote areas with apparently little anthropogenic influence (Stöhr, 1984, Hedin *et al.*, 1994, Johnson *et al.*, 1991, Knoepp and Swank, 1994). At formerly moderately acidic soils a marked decline in *p*H was observed, whereas already strongly acidic soils showed decreasing base saturations. Controversy on possible causes did arise as it seemed unlikely that the input of acidity by 'acid rain' could significantly change the huge pool of acidity already stored in mineral soils, thereby totally offsetting the buffering capacity of soils. The magnitude of soil chemical changes remained uncertain since artefacts, introduced by inconsistencies in lab analytical methods, could compromise the comparability of the old reference data and the recently collected data. Also spatial variation of soil chemical data has rarely been investigated in older studies, therefore it is not known if older data are truly representative for the sites investigated.

Here results from a homegenous forested region with above-average deposition loads are presented. The changes in soil chemistry between 1984 and 1995 are compared to nutrient distributing biogeochemical key process (nutrient sequestration in forest biomass and nutrient supply by atmospheric deposition) and are evaluated with respect to soil fertility, *i.e.* the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of plants (Glossary of Soil Science Terms as given at http://www.agronomy.org).

2 Material and Methods

The study sites are located in the 'Weilhartsforst', an extended forest area in Innviertel/Upper Austria (ÖK50 No. 48, 48°10' N / 12°55' E, elevation approx. 400 m a.s.l.). Quaternary overburdens overlay tertiary moraines. Soils are mostly Dystric and Ferralic Cambisols. Forests stands are composed of mature Norway spruce with some Scots pine.

Soil samples were collected from 3 soil pits and combined to a single sample per horizon. Chemical analysis included *p*H (in $CaCl_2$-suspension), contents of total carbon and nitrogen, exchangeable cation content ($BaCl_2$-extract) and acid-soluble cations (HNO_3/$HClO_4$-extract). See Englisch et al. (1992) for details of analytical methods.

Forest growth rate was derived from a stand inventory in 1984 and re-measurements of diameters in 1990. Bole increment was estimated from locally valid yield tables. Nutrient content in the aboveground biomass was estimated from data by Englisch (1987) and Raisch

(1983), belowground biomass was estimated from conversion factors given in Kurz et al. (1996). Data for atmospheric deposition were taken from the Austrian Forest Decline Survey Project (WBS-Level-II).

3 Results and Discussion

The data presented in figure 1 indicate that soil *p*H has remained stable between 1984 and 1990. Since soils have already been fairly acidic (Al-buffer range) at the beginning of the soil survey, no dramatic change has been expected. The C:N-ratio has remained stable in the forest floor, but has obviously narrowed in the mineral soil. Figure 1 yields strong evidence that the soils have undergone a severe loss of exchangeable calcium and magnesium. This observation is not a peculiarity of the particular site but is consistently true for other regions with similar acidic soils, that have been investigated (*e.g.* Mühlviertel, Waldviertel, Upper and Lower Austria). Acid input has become apparent by a decline in base saturation rather than by shifting *p*H-values. Depth gradients of nutrients give no indication that cationic nutrients would have accumulated in deeper mineral soil horizons, but are rather lost from the biogeochemically cycled nutrient pool. The cation exchange capacity has somewhat increased, possibly a consequence of subtle changes in the quality of soil organic matter.

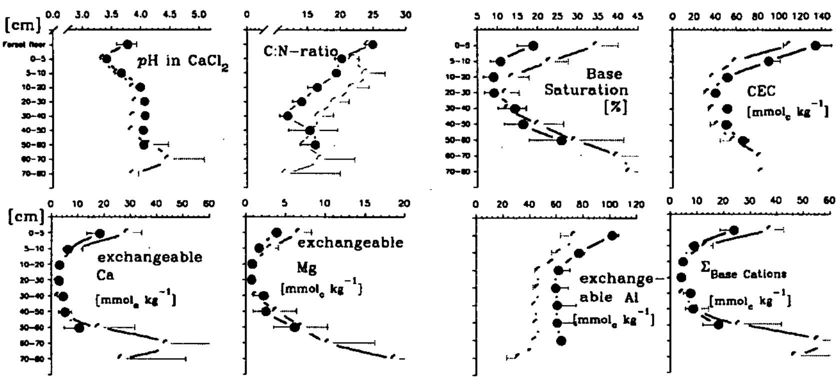

Figure 1: Temporal change of selected soil chemical parameters between 1985 and 1990..
Data are averages and standard deviations of 7 soil profiles in and near Weilhartsforst, Innviertel, Upper Austria. ' 1985. ● 1990.

Several questions remained when the data set from figure 1 was analyzed. The magnitude of the observed changes in soil chemistry in only 5 years could easily be attributed to artefacts:

- the short term experiment (5 years) does not necessarily represent the dynamics of a mature forest ecosystem. Much longer cyclic processes in forests, possibly related to stand development may override short-term patterns.
- the experimental design did not allow to separate temporal changes in soil chemistry from seasonal and spatial variability. Inconsistencies in lab methods may add to mere variability, that erroneously is interpreted as temporal change.

Support for the hypothesis of dramatic soil acidification was drawn from similar results found in other regions of Central Europe. We tried to corroborate our data by re-sampling one of the sites with an improved experimental design (n=3, separate analysis instead of composite sample) and by converting the old data by means of conversion factors, that have been derived from re-analyzed archived soil samples. The results are given in figure 2. The loss of exchangeable base cations has been corroborated. The Al-saturation of the soil matrix has further increased at the expense of base cations. No statistical analysis was possible since the soil sampling strategy prior to 1995 (single values for each horizon) provides no information on the standard deviation of soil parameters.

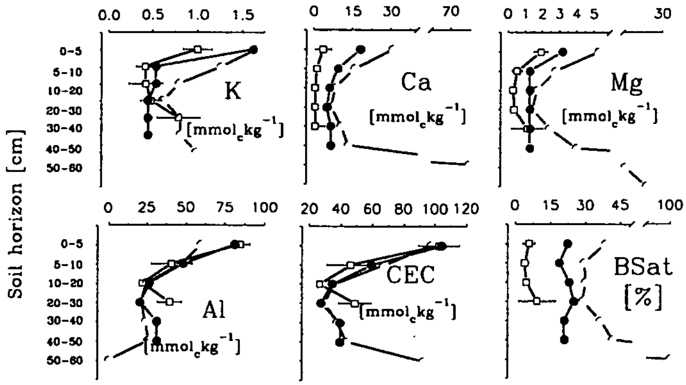

Figure 2: Temporal change in contents of exchangeable cations. Symbols for 1985 and 1990 represent composite samples from 3 soil pits, in 1995 pits have been analyzed separately and averages. and standard deviations are given. ' 1985, • 1990, ▫ 1995.

A conservative estimate of base cation fluxes between 1985 and 1995 gives a total loss of exchangeable base cations of approximately 4.1 mol$_c$ m^{-2}. In the same period bulk deposition yielded 1.8 mol$_c$ m^{-2} of base cations and 0.3 mol$_c$ m^{-2} have been sequestered in the above- and belowground biomass of trees. The flux of base cations due to mineral rock weathering has not been determined yet.

If the observed losses of base cation reflect a natural long-term pattern, many now strongly acidic soils must have been rather nutrient rich soils only a few centuries ago. This conclusion has little support, since forest ecosystems have been subject to continued nutrient exploitation (*e.g.* litter raking), and have acidified due to organic acids upon nutrient uptake and mineralization of organic matter. The novel impact to forest ecosystems in the 20th century is the deposition of strong mineral acids. Whereas organic acids are immobilized (complexation by metals, adsorption to surfaces of clay minerals and oxides, formation of B_h-horizons) or biodegraded in the mineral soil, the anions of H_2SO_4 and HNO_3 are not or only temporarily retained in the mineral soil. Even if NO_3^- is entirely taken up by plants, leaching of SO_4^{2-} from bulk deposition can mobilize the entire pool of exchangeable base cations depicted in figure 2 within 50 years. Evidence for such recent and strong changes in soil chemistry is given by data from Baden-Württemberg. Data from the Austrian Forest Soil Survey show that the majority of soils is strongly acidic and highly buffered soils with *p*H values greater than 4 are already the exception. We therefore conclude that the observed changes in soil chemistry do not depict a long-term trend, but rather have occurred in only a few decades.

If loss of base cations is an indicator for soil fertility the widely observed increase in forest growth rates contradicts the soil dynamics given in figures 1 and 2. However there is support that forest growth is solely an effect of 'tissue-fertilization' that promotes the lifting of N-limitations due to N deposition and is mostly independent of the current soil status.

4 Conclusions

- Forest soils of the Weilhartsforst/Upper Austria have responded to deleterious impacts of various human activities
- Acidification of soils (either decreasing *p*H or loss of base cations) is an ongoing process
- N deposition has, probably among other factors, so far compensated for decreases in forest soil fertility. Nevertheless soil fertility already has decreased.
- both soil *p*H and the pool of exchangeable base cations are reduced to rock-bottom levels. ('Eiserner Bestand').

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SOIL CONTAMINATION---CAN WE PREDICT SOIL-BORNE CHEMICAL TIME BOMBS?

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Society's ever-increasing affluence and increasing world population ensure that more chemicals will be produced for consumers' satisfaction. The concomitant production and use of chemicals, both inorganic and organic, guarantee their release, accumulation, and eventual dispersal in the environment. These anthropogenic activities will likely contaminate soils, sediments, and water resources, the magnitude of which varies from place to place, country to country, and region to region. Numerous contamination events, especially those directly affecting humans, have produced severe environmental risks that will likely require environmental restoration.

Although wind and water erosion still represent the most important agents of soil degradation, chemical degradation is becoming more and more important. Of the total degraded area of 1,965 million hectares, ~55% is due to water erosion, ~20% to wind erosion, and ~12% to chemical degradation. As more accurate inventory of chemically degraded soils become available this value will rise. Chemical degradation of land may occur in the form of loss of nutrients from deforestation, salinization due to agricultural mismanagement, industrial pollution, and acidification due to combustion of fossil fuel and emission of nitrous and sulfur dioxide. Credible evidences have now been gathered that chemical pollution of our environment may affect the life expectancies of residents of some regions. For example, a survey in Northern Bohemia (Czech Republic) indicates the life span of residents in the region may be shortened by ~5 years, while those in the neighboring Upper Silesia (Poland) may be shortened by 2 to 3 years.

The United States has over 1,200 Superfund sites, while the countries of the European Community have over 33,000 critically contaminated sites inventoried. Cleanup of these hazardous waste sites has been projected to cost billions of dollars. The treatment and detoxification of the pollutants in soil and sediments using conventional, mechanical, and/or chemical techniques to meet the U.S. Environmental Protection Agency's recommended levels are prohibitively costly, i.e. $50-1,000 per ton, which translates to a minium cost of treating soils at about $500,000 per hectare. Therefore, scientists are in search of not only quicker and cleaner but also more cost effective cleanup technologies.

Soil degradation from chemicals has become a major concern because of the soil's finite capacity as a sink for pollutants. Because of the soil's limited resiliency to transform and contain chemicals, these substances can attenuate in soils and become more mobile and eventually more bioavailable to plants, animals, and humans. Polluted soils are not only a social and health issue but an economic issue as well. Chemically degraded soils may adversely affect a region's economy not only through lower production of commodities but also through diminished quality of the products, a consequence of which is inability to compete in the global economy. Other potential major consequences of chemically degraded soils include poor physical-biochemical properties, more susceptibility to erosion, loss of production sustainability, diminished food chain quality, tainting of water resources, economic loss, and human illness.

Soil chemical degradation might be viewed as accumulated adverse effects caused by anthropogenic chemicals on the soil's physical, biological, and chemical properties. The propensity of degradation depends on the properties of the soil (i.e. soil type) as well as the type, amount, longevity, and bioreactivity of the chemicals in question. Knowledge of the nature and properties of, and prevailing processes in soil and the behavior of chemicals in question is necessary to be able to predict when such soil-borne chemical time bombs would likely occur. Examples of such predictable scenarios include soil acidification, phosphate attenuation, and contamination with metals, radionuclides, and pesticides. Because of the soil's spatial variability, such undertaking should be site specific, chemical specific, and organism specific.

SHORT-RANGE SOIL ORGANIC CARBON VARIABILITY IN FORESTED AND CULTIVATED FRENCH SPODOSOLS

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1. Introduction. Recent rising levels of atmospheric CO_2 has directed attention to the stores of OC in soils, and to changes due to conversion of forest to cropping. However, changes in soil properties with time might be difficult to detect because of the inherent soil spatial variability. Few studies have been conducted on short-range variability of OC in soils, and some of them have assumed or have shown these elements to be randomly distributed while few others pointed out the spatial dependance between sample locations. It is probable that land-use changes may affect the range and the spatial dependance of soil organic carbon contents. However, there is very little information on this subject, especially concerning the effects of forest clearing and cultivation.
The main objective of this study is to document the short-range variability of soil OC in an area where forest lands have been converted to continuous cropping, using a case study in France: (i) to study the spatial structure of soil OC content in both forested and cultivated plots, (ii) to optimize sampling design for monitoring the changes following forest clearing and cultivation.

2. Material and methods. Three forested and 5 cultivated sites were used in this study. Soils were sandy spodosols developed from sandy eolian deposits. The forested sites were of mature Maritime Pine (*Pinus pinaster* Ait.). Understory vegetation was composed of *Molinia coerulea*, *Erica ciliaris*, *Erica tetralix*, *Pteris aquilina* and *Ulex nanus*. Forest-floor humus was not collected. Agricultural sites had been cleared and converted to corn cropping. Neither manure, nor any organic material had been applied. Stalks were returned to the soil.
Sampling was realized on both forested and cultivated sites by following systematic grids. Most sites had decametric or pluridecametric spacings. In order to study short range variability of OC a systematic 1.4 X 1.4-m grid was applied on a cultivated plot (C5). On a forested site inframetric sampling was conducted on 19 pairs of points in order to examine the local variability. Samples were collected with a 7.5 cm diameter auger from the 0-0.3-m layer. Samples for C analysis were oven dried for 24 h at 105°C and sieved through a 2 mm mesh, and homogenized by rotating the plastic flasks. None of the soils contained particles >2 mm. Inorganic carbon is insignicant in these acidic soils. Organic matter content was estimated by the loss-on-ignition (LOI). A 40-g aliquot was taken up and warmed to 800 $\pm$ 25 °C for 5 h. Errors in estimation of organic matter by LOI due to loss of bound water are small because these soils have very low (< 2%) clay contents. Carbon content was estimated by dividing organic matter content by the standard coefficient of 1.724. In order to assess analytical variability 8 replicates of a 40-g subsample were realized for a randomly selected sample of both forested and cultivated sites.

If measurements are spatially independent and normally distributed, the number (n) of samples needed to obtain a mean value can be calculated as a function of variability [(CV) = coefficient of variation], accuracy (ER) and the desired probability level [using t : the Student "t" value for the desired probability or confidence level].

$$n = t^2 \, CV^2 / ER^2$$

We estimated semivariograms for soil organic matter contents in both forested and cultivated sites. The semivariogram is a curve describing the spatial autocorrelation for a particular random variable measured on a sample spatial set. It displays the change in the semi-variance between two sample points as the distance between them increases. The semi-variance $\gamma(h)$ is defined as half the expected squared difference between sample values separated by a given distance or lag, h. A classical estimator of the semivariogram at lag h is

$$\hat{\gamma}(h) = 1/2N(h)\sum_{i=1}^{N(h)}\left[z(x_i) - z(x_i + h)\right]^2$$

where Z is a regionalized variable, $z(x_i)$ and $z(x_i+h)$ are measured samples at points x_i and x_i+h, and $N(h)$ is a number of pairs separated by distance or lag h.

A model describing the experimental semivariograms was fitted through a weighted least squares procedure. The weights were the number of couples $N(h)$. Variogram computation was performed separately on forested and cultivated plots.

3. Results and discussion. The semivariance of OC in cultivated plots (Fig. 1) increases with distance to ~20 m where it reaches a plateau (sill = 17 $(g.kg^{-1})^2$). The sill is less than the total variance on cultivated plots. This is due to significant differences in OC content among cultivated plots. This result suggests that even though samples may be considered as independant when separated by more than 20-m within a plot, strong differences may occur when changing of site, as a result of larger spatial structures or of different plots histories. The nugget effect (nugget = 0.5 $(g.kg^{-1})^2$ is very small relative to the sill, indicating that most of the observed variation is due to spatial autocorrelation, as evidenced by the height of the intercept above the origin. This nugget effect, which is due both to measurement accuracy and to structures of spatial variabilities at distances less than the smallest distance considered in the sampling design, is less than 1% of the total variance and 3% of the sill value. This result suggests that OC content can be considered as a continuous variable. OC content values are strongly autocorrelated at distances less than 20-m

We computed the semi-variogram of the plot M5 separately. In this plot the semivariance is continuously increasing (Fig. 2), showing ordered spatial variation through the plot, and it exhibits neither sill nor range values. This suggests that the sampling area is not large enough to accurately describe the spatial structure of OC content. This is consistent with the range value (20 m) found using all cultivated plots. Moreover, the nugget effect (0.7 $(g.kg^{-1})^2$) is near zero.As analytical variance (8 replicates) was 0.02 $(g.kg^{-1})^2$ the nugget effect was mainly attributable to variability occuring at scale less than the smallest distance of sampling suggesting that semivariance remains low for pairs of points less than 2 m apart, and then increases sharply. This curve pattern can be fitted by a gaussian model (Fig. 1 and 2).

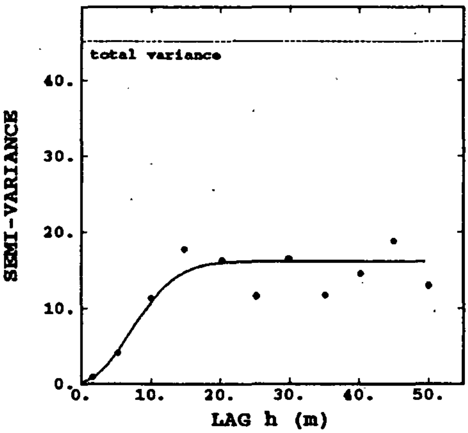

Fig. 1 - Experimental semi-variogram of soil organic carbon content in cultivated sites (points). Semi-variance is expressed in $(g.kg^{-1})^2$. Solid line is fitted gaussian model. Total variance on sites is broken line.

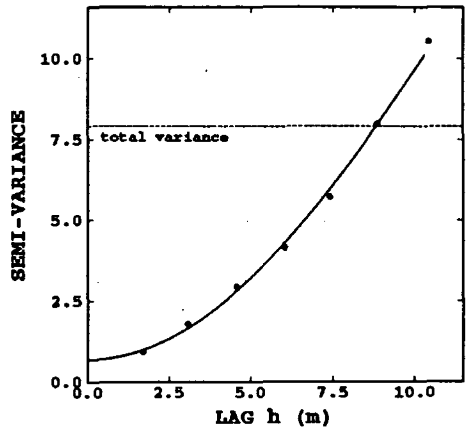

Fig. 2 - Experimental semi-variogram of soil organic carbon content in site M5 (points). Semi-variance is expressed in $(g.kg^{-1})^2$. Solid line is fitted gaussian model. Total variance on sites is broken line.

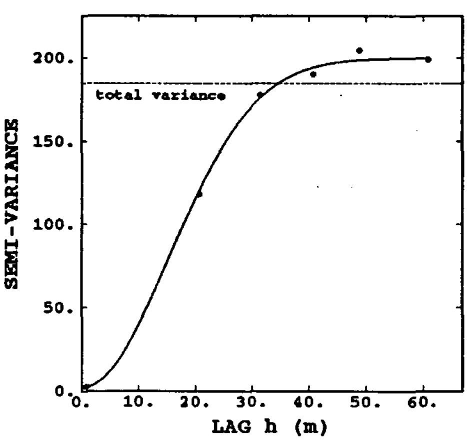

Fig. 3 - Experimental semi-variogram of soil organic carbon content in forested sites (points). Semi-variance is expressed in $(g.kg^{-1})^2$. Solid line is fitted gaussian model. Total variance on sites is broken line.

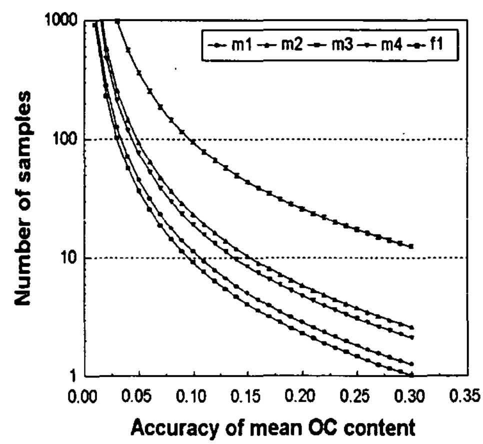

Fig. 4 - Theorical number of sample and accuracy for estimating a mean value of soil organic carbon content in one forested (f1) and four cultivated (m1 to m4) sites (confidence level = 95%).

(1) $\gamma(h) = co + c\,[\,1 - Exp\,(-h^2 / r^2)\,]$ $(r \cong 0.58 \times range)$

The semivariance of OC in forested plots (Fig. 3) increases with distance for distances between couples of points < 40 m apart, and reaches a plateau (sill = 200 $(g.kg^{-1})^2$) thereafter. The nugget effect (nugget = 2 $(g.kg^{-1})^2$) is higher than for cultivated plots, even though its relative value (0.9% of the total variance, 1% of the sill) suggests that most of the observed variation is due to spatial autocorrelation. This result shows that OC content in forested sites can be also considered as a continuous variable, even if very short-range variability is higher under forest than under cultivation. As analytical variance (8 replicates) was only 0.07 $(g.kg^{-1})^2$ the nugget effect was mainly attributable to microvariability at scale less than the smallest distance of sampling. This curve pattern can also be fitted by a gaussian model (Fig. 3).

Overall, we must stress the difference in total variance, nugget effect and sill values between forested and cultivated plots. Within-plot short-range variability is much higher under forest vegetation than after cultivation. The tillage and the evolution of soil OC under cultivation may have smoothed the heterogeneity of the upper layer soil OC content.

Samples separated by more than the range distance have OC contents that are not autocorrelated. Therefore, providing samples are separated by a distance longer than to the range value, the minimum number of samples necessary to estimate the mean value on the plots can be given by classical statistics. The relationship between the number of samples and the confidence level for estimating the mean value of OC contents in cultivated (c) and forested (f) sites is negative and non-linear. On the other hand, to avoid spatial autocorrelation, sampling distance intervals should be greater than the range value. We can calculate the minimal area necessary for a sampling network for monitoring of OC after forest clearing and cultivation.

4. Conclusion. This study addresses one of the methodological concerns facing the general scope of OC monitoring. Short-range variability of soil OC contents in French Spodosols appears to be high, and higher in forested than in cultivated sites. However, as OC is a continuous variable,the very-fine range variability (nugget effect) is small. This study enabled us to build an appropriate sampling design for monitoring this important soil characteristic. Moreover, this work suggests that inappropriate sampling design combined with an insufficient number of samples collected may result in a serious bias in estimations. Before setting monitoring programmes, preliminary studies on soil spatial variability and sampling reference locations are necessary. However, the high number of samples required may affect the cost and the feasability of such studies.

CONCEPT FOR A TIME INTEGRATED INDICATOR FOR EVALUATION OF SUSTAINABLE SOIL USE

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1. Introduction

Since the international meeting „World Conservation Strategy" of the „International Union for the Conservation of Nature and Natural Resources" in 1980 the expression „sustainable development" has become a model of responsible resource management on a global scale. The „World Commission for Environment and Development" (WCED 1987) announced 1987 „sustainable development" as guidelines for environmental policy and the United Nations Conference on Environment and Development (UNCED) agreed 1992 on the „Agenda 21" as a world wide framework for local, regional and national wide policy of sustainable development for the next century. On recommendation of the UNCED the United Nations founded 1994 a „Commission on Sustainable Development", (UNCSD) which should guide the process of sustainable development.

For the soil resource sustainable development means, that the use of soil has not to exceed the potential of regeneration at the same time. Pedological time scales have to be taken into account to get an idea of the potential soil use per time-unit. An indicator for evaluating sustainability of soil use consequently has to integrate time. Many indicator systems have been developed until now, but non of them integrates the time as a leading parameter. This paper presents a proposal how to compensate this deficit.

2. Time and sustainability of soil use

Soils are no unchanging masses, soil characteristics are no constants (Kubiena 1986). Soil characteristics change in typical rhythms, for example the yearly rhythm of moisture variation. These rhythms arise from soil characteristics oscillating around the phenological median line. If the observed space of time is longer, the oscillation leaves the median line and orientates in a irreversible direction - pedogenic development takes place. This development is due to a dynamic process, that depends on the starting substrate and environmental given facts along the time-scale. If change of soil characteristics caused by soil use must be evaluated, the right time-scale corresponding to the pedogenic potential has to be choosen.

Soils can be regarded as the result of long pedogenic processes and from this point of view, soils represent an accumulation of time. In a similar way Nutzinger (1995) describes the use of fossile energies as a consumption of time. Simultaneously soil use can be described as a use of pedogenic time. This leads to a definition of sustainable soil use that implies to integrate time as central factor and that can be expressed by the dimensions

- space (m^2),
- depth (cm) and
- pedogenic space of time (year).

For balancing the use of space, sufficient methodical knowledge exists. In contrast to this, the depth isn't subject of soil use balancing methods. Approximately the demanded depth can be expressed by the advance of pedogenic processes, that take effect in vertical direction. Besides the given geological substrates and the climatic influences, mostly time is important for the progress of these processes. Time can be regarded as leading parameter for the balancing of the use of soil depth. The used space (sp) multiplied with the used time (t) results in the soil use (SU) per time-unit:

$$sp(m^2) \times t(year) = SU\ (m^2 \times year)$$

If the pedogenic loss of soil use (PL) has to be taken into account on n different spaces (sp_L) which correspond to different spaces of time (t_L), the formula reads as follows:

$$PL = \sum_{i=1}^{n} (sp_L \times t_L)_n$$

Besides the pedogenic loss, also a pedogenic gain (sp_G), where pedogenic processes can take place for a certain time (t_G), can be balanced. The difference of pedogenic loss and pedogenic gain is a pedogenic balance (PB), that shows if present soil use can be called sustainable from a pedogenic point of view:

$$PB = \sum_{i=1}^{n} (sp_G \times t_G)_n - \sum_{i=1}^{n} (sp_L \times t_L)_n$$

This formula shows a first approach how to calculate time and space in order to survey sustainability of soil use. Many more aspects can be integratet in this concept, for example types of soil and soil functions could be differentiated in the formula. The time scale for this calculation system should be restricted on holocene soils.

3. Development of a time integrated indicator

Balancing soil use by using a time integrated indicator requires in particular two sources: pedogenic knowledge has to be systematised to get a basis for the evaluation of the pedogenic potential of soils which suffer impact. On the other hand a knowledge basis is needed to evaluate the potential pedogenic impact per time-unit caused by any soil use.

The knowledge basis of pedogenic potentials can be derived from scientific researches on chronosequences in the research fields of:

- glaciers (Arctic, Antarctic, Alpes etc) (Höfle and Ping 1996)
- at the coast (sea-level chronosequences) (VandenBygaart and Protz 1995)
- lakesurroundings (Barrett and Schaetzl 1992)
- in the environment of river-terraces (Madsen and Nornberg 1995)
- on spaces with airborne sediments (Nettleton and Chadwick 1996) and
- on landslide scars (Zarin and Johnson 1995)

The evaluation of these references suggests the huge knowledge with respect to natural soil chronosequences, which can be used for a pedological basis of soil use evaluation. Beyond this, we also have to consider man-influenced soils or technical substrates e. g.:

- recultivation after browncoal-mining (Schneider 1993)
- colliery spoil heap (Fohrmann et al. 1989)
- sand-dunes after sand-mining (Prosser und Roseby 1995)
- agricultural land (Pennock et al. 1994)
- fallow land (Schmidt 1981)
- habour-mud (Schneider und Schröder 1991)

Again the recent literature suggests, that there is also sufficient scientific material to evaluate the genetical potential of man-influenced soils and technical substrates. Parallel to this scientific works on soil development observations about biotic succession can be integrated in the knowledgebasis of the indicator. Many of these investigations show a direct relation between succession of fauna or flora and pedogenic processes along time-scale. Other indicators which describe soil development parallel to time like micromorphological indexes (Dorronsoro 1994) or phosphate-leaching (Letkeman et al. 1996) can be used for this concept.

An interdisciplinary database for the prognosis of pedogenic regeneration can be build like this, which represents the basis for the calculation of pedogenic losses expressed in time and space due to any soil use. The gain of soil development, also expressed through time and space, can be summarized upon the knowledge of pedological potentials of substrates and transformed soils. This can lead to the calculation of a balance, that shows the „real soil resource use" in time and space.

4. Conclusions

The beginning research on a new indicator for sustainable soil use shows the feasibility of the integration of time by pedological knowledge. By taking the time into account a totaly new evaluation method can be developed, that helps to quantify and regulate use and the use-induced impact on soils. It refers not only to agricultural soil use, but to all possible form of soil use (also for urban spaces). It could be a good to handle measure for environmental impact assessment, the environmental planning practice and even a basis for political discussions about environmental quality standards. The observance of standards for soil use can be assisted without influencing the standards, because the indicator represents a neutral scale without own valuations. It supports diminishing the „time-lag" that exists between the human impacts on soils and the pedological time scale. Integrating time allows moreover to draw parallels to biotic succession processes, which accompany the soil development to better describe the soil-system. By calculating with time and space the use of the renewable „resource soil" can be managed in a more sustainable way.

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PHYSICAL PROPERTIES OF TROPICAL SOILS AMENDED WITH COWDUNG AND RICE-MILL WASTES.

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1.0 Introduction

Physical degradation of soils in the tropics results mainly from soil erosion by water and mechanical land clearing and is manifested in high bulk density, low total and macroporosity, reduced water infiltration and transmission rates and both low water retention and available water capacities within the root zone. These poor physical conditions in conjunction with chemical constraints resulting from low reserves of essential plant nutrients and high subsoil acidity (Unamba-Oparah, 1985; Mbagwu 1989), result in poor crop productivity.

Metzger and Yaron (1987), reported that the organo-biological farming system promoted the development of chemical reactions(redox reaction, hydrolysis etc.), physicochemical reactions (dissolution, precipitation, adsorption, bonding) and microbiological processes (microbial multiplication, metabolite production and enzymatic reactions). These reactions determine the physico-chemical status and stability of the soil. Dalzell et al. (1987) reported that application of mixtures of wastes of different origins performed better than the single waste materials, accordingly wastes of high C:N ratio are mixed with wastes of low C:N ratio for easy decomposition.

The variability in research reports on soil physical properties such as hydraulic conductivity (Khaleel et al., 1981) aggregate stability and the non-availability of a universal relationship between the stability of aggregates and soil physical behaviour according to Molope (1987) is attributed to the lack of joint consideration of both the biological and physical processes involved in the formation and destruction of soil aggregates. While the biological processes give rise to organic binding substances (Tisdal and Oades, 1982), the physical manipulation of the soil gives rise to a reorganisation of soil particles with resultant increases in the strength of clays recognised as thixotropic change by Seed and Chan (1957) and Mitchell (1960). Thixotropy was reported responsible for the increases in stability of aggregates observed during ageing of freshly cultivated soils (Kemper and Rosenau, 1984) and of artificial aggregates during ageing in the absence of biological activity (Blake and Gilman, 1970). It is therefore important to separate the contributions of biological processes from those of the physical processes involved in the use of organic wastes as soil conditioners in order to provide maximum conditions necessary for the efficiency of the applied wastes.

The three main objectives of this study were: (i) To distinguish changes in physical properties of organic waste-amended soils due to biological processes from those due mainly to physical processes; (ii) To compare the different wastes on the basis of the spontaneity of their action i.e., whether immediate or delayed; (iii) To test three hypotheses: Organic materials from animal source are superior to those from plant sources as soil conditioners. The use of a mixture of plant and animal wastes is superior to the use of either. The effectiveness of these wastes varies with time.

2.0 Material and Methods:

Two soil textural types , a sandy-clay-loam Ultisol, and a clayey Entisol were used. They are classified as Typic Kandipaleustult and Lithic Ustorthent respectively (Nwadialo, 1989).

2.1.0 Soil Collection and Characterisation.

Samples were collected from the 0-20cm depth of each soil and air-dried in the green house. The lumps were gently crushed and gravels and roots separated from the mineral soil before sieving through a 2mm mesh. A representative sample of the sieved soil was used for analysis of some physico-chemical properties shown in Table 1.

2.1.1 Preparation and characterisation of organic amendments.

Rice-mill waste (RW), cowdung (CD), and a mixture of 50% RW and 50% CD, were used as organic amendments. The RW and CD were air-dried in the green house. Both were then separately passed through a 2mm mesh and characterised for the properties shown in Table 2.

2.1.2 Incubation and ageing studies.

The soils were thoroughly mixed with the organic amendments (RW, CD, CD+RW), in clay pots and brought to field capacity (20%w/w). The amendments were applied at the rates of 0, 2.5, 5.0 percent equivalent to 0g/kg, 50g/kg ,and 100g/kg respectively. To separate the contributions of the biological from the physical processes to changes observed in the amended soils, solutions containing sodium azide and mercuric chloride each at the rate of 0.5mg/g/soil (0.05%), were used as a general sterilant (Tisdall et al, 1978) and applied to one set of the experiment. After the sterilisation treatment the clay pot contents were then covered with polythene perforated at the surface to allow minimal air and avoid excess evaporation.

2.1.3 Soil sampling and data collection.

Soil samples for saturated hydraulic conductivity (Ksat), dry bulk density (BD), and total porosity (PT) were collected at two weeks (T_2), and twenty weeks (T_{20}), while samples for water stable aggregates (WSA) > 0.20mm estimated by mean weight diameter were collected at two weeks, twelve weeks (T_{12}), and twenty weeks. Soil samples were also analysed for changes in organic carbon due to organic waste application at the three sampling periods. All data generated were subjected to simple linear correlation analysis with organic carbon content of the soils due to the respective organic amendments.

3.0 Result and discussion.

Results show that improvements in saturated hydraulic conductivity (Ksat), dry bulk density (BD), and total porosity (PT) were lowest with the soil with higher amount of clay. While higher improvements in saturated hydraulic conductivity and bulk density were observed in the incubated soil compared to the aged soil at (T_2), the reverse was the case at (T_{20}). A significant negative correlation between BD and organic carbon (OC), for all the amendments (except RW at T_2) was observed only with the incubated Ultisol. Improvements in water stable aggregates (WSA) on the other hand, were generally lower for the soils with lower amount of clay. Thixotropic age hardening was also indicated by an increase in WSA in the aged soil even at (T_2).

5.0 Conclusions

The higher improvements in some soil properties under incubation than in ageing conditions especially with CD+RW, and CD, shows that the effect of these amendments was biologically mediated. The peak of improvements in these soil properties due to amendments was observed at twelve (T_{12}) of incubation and ageing. The general order of improvement in the soil properties indicate that the admixture of the amendments outperformed either of the amendments when used alone. The organic amendment from animal source (CD) was superior to that from plant source (RW) in improving these soil properties.

Table 1: Some properties of the soils used for the study.

Parameter	Entisol	Ultisol
Coarse sand(%)	16	38
Fine sand(%)	14	18
Silt(%)	14	12
Clay(%)	56	32
Texture	Clay	Sandy-clay-loam
pH 1:2.5(H_2O)	4.72	5.11
pH 1:2.5(KCl)	3.88	4.72
ΔpH	-0.84	-0.39
Organic carbon(%)	2.19	1.28

Table 2: Properties of the rice-mill waste and cowdung used for the study.

Property(%)	Rice-mill waste(RW)	Cowdung(CD)
Organic carbon	37.11	7.98
Total nitrogen	0.95	1.19
C:N Ratio	39.1	6.70

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THE MEMORY OF SPATIAL AND TEMPORAL DISCONTINUITIES IN PEDOGENIC CARBONATES.

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Introduction. Horizons of carbonate accumulations have widely been accepted as becoming better expressed with increasing age of land surfaces (Gile and Grossman, 1979;; Forman and Miller, 1984, Machette, 1985; MacFadden, 1988). In most cases, the rate of $CaCO_3$ accumulation was concluded to have remained gradual and unchanged by minor climatic oscillations (MacFadden, 1988; Pendall et al., 1994). Therefore, spatial variability of pedogenic carbonates , generally, assumed to reflect the complex imbrication of land surfaces of different ages. Morphogenetic changes in calcitic features have been linked to discontinuities through time of possible palaeoenvironmental significance (Amundson et al., 1994).
Other studies have illustrated how the lateral variability of local factors and complex interactions of geomorphic and pedogenic processes exert a strong influence on carbonate redistribution through time that are reflected by spatial and vertical changes of calcic horizons (Courty, 1990). The purpose of this paper is to better document how carbonate accumulations helps us to understand differentiation of soil-landscapes through time. This is illustrated by cryosols with calcitic pendents in the Svalbard archipelago in the high Arctic zone.
True carbonatation in Arctic soils is one of the dominant pedogenic process contributing to horizon differentiation (Mann et al., 1986; Ugolini, 1986). Calcitic pendents formed beneath clasts represent the most common form of secondary carbonates that results from ionic exclusions upon solution freezing (Op., Cit., Marlin et al., 1993). Dissolution and precipitation were shown to simultaneously occur at all depths depending on local exchanges between the solid-liquid and gas phases that are controlled by thermic and hydric factors. Calcitic pendents develop from a seasonal rhythm of accretion that have remained active since the last ice retreat (Courty et al., 1994). Their complex laminated morphology was demonstrated to result from successive changes in biogenic productivity, flux transfers, and seasonal thermic contrasts.

Materials and methods. The study area is located in the western part of the Svalbard archipelago and receives high humidity due to a deviation of the North Atlantic Gulf Stream . The climate is oceanic polar climate with two thermic seasons that define an annual cycle of freezing-melting. This controls the behaviour of a ca. 1.5 m thick active layer lying on a continuous, thick permafrost. The mean annual temperature is -6.2°C and the annual precipitation averages 375 mm, with a regular distribution throughout the year, and 2/3 occurring as snow fall.(reference or Spitzbergen?)

The study concerns part of the Brögger peninsula formed of dissected uplands that are composed of a complex association of phyllites, micashists, limestones and dolomites. It is restricted to the upland toeslope and to the littoral plain that present two types of geological settings: (1) patchy glacial deposits formed of frontal moraines and fluvio-glacial fans, often imbricated with marine deposits; (2) outcrops of deeply fissured limestone bars.
Topographical variability exerts strong influence on the local thickness of the snow cover and the local drainage. Presence of the permafrost induces waterlogging at the end of the melting season and constrains drainage to only operate laterally. The region presents a complex diversity of surface ground patterns due to differential effects of frost heave that are controlled by lateral variations of drainage. The soils are classified as of Pergelic Cryopsamments on the stratified fluvio-glacial or marine deposits and Pergelic Lithic Cryumbrepts on fragmented bedrocks (reference). They show a reduced horizonation of A(B)C type with a thickness of the B horizon not exceeding a few cm. The humic horizon is a few cm to 10 cm thick, except in the poorly drained micro-depressions where the organo-mineral horizon can reach 50 cm .
A selection of 15 soil profiles was designed to study effects of variability in mico- and macro-topography, vegetation, parent materials and age of land surfaces on the redistribution of carbonates, and particularly on lateral and vertical changes of calcitic pendents. Soil profiles on fluvio-glacial and marine deposits were exposed down to the limit of permafrost in summer (ca. 110-140 cm), whereas the ones on fragmented bedrocks were dug down to the non- cryoturbated zone (ca. 80 cm). A micromorphological study was performed by analysing under the petrographic microscope thin sections made from undisturbed samples and SEM observations of calcitic pendents. Stable isotope anlayses and measurements of the ^{14}C content were performed on calcitic pendents that were detached with a hand drill to avoid contamination with the host clast.

Results and discussion. At a macro-scale, calcitic pendents only occurs in soil profiles developed on parent materials with primary carbonates, either present as both coarse fragments and calcite crystals disseminated in the fine mass, or only as coarse fragments. Absence of primary carbonates can be due to the source of parent materials, but can also result from their total dissolution. The latter is particularly efficient in zones of active lateral drainage and in poorly drained low-lying depressions with high biogenic productivity.

Vertical distribution, micro-fabrics, isotope geochemistry and ^{14}C values of calcitic pendents allows to identify four types of soil profiles.
*1 - **Homogeneous soil profiles***, on fragmented bedrocks. They present similar polyphased calcitic pendents at all depths (except in the totally decalcified upper 15 cm) for which ^{14}C values suggest a continuous accretion since 13 500 BP. The high $\delta^{13}C$ values (ca. 8 ‰) reflect rapid progradation of freezing caused by continuity of the solid phase and low water content.
*2 - **Heterogeneous soil profiles, without discontinuities,*** on fluvio-glacial or marine deposits. The heterogeneity is expressed by vertical variations of $\delta^{13}C$ and $\delta\ ^{18}O$ values that reflect the simultaneous upward/downward progression of freezing, controlled by a step by step slow freezing process. The pendents are morphologically similar at all depths and both their complexity and ^{14}C values reflect a long period of accretion of various duration between the

different profiles studied (ca. 5 kyr, 9 kyr or more than one interglacial cycle). Cryoturbation is generally restricted to minor deformation that has not affected the trend of carbonatation.
*3 - **Heterogeneous soil profiles, with discontinuities,*** that occur on fluvio-glacial/marine deposits. Distribution of isotopic values with depth indicates a mode of calcitic pendent formation similar to the second case. The discontinuities are evidenced by the presence of a soil layer at mid-depth devoid of calcitic pendents. In addition, calcitic pendents from the upper and the lower part present differences in the number and micro-fabrics of the successive laminae. ^{14}C values indicate a shorter period of accretion for the ones of the upper layer in comparison to the lower one. Presence of polyphased calcitic pendents in an upper layer of one of the studied profiles showing strong cryo-induced deformation indicates that the major effects of cryoturbation took place at an early stage of soil-development, possibly just after the ice retreat, while the geometry of coarse fragments was not later modified.
*4 - **Complex profiles*** that occur in micro-depressions either on fluvio-glacial deposits or on fragmented bedrocks. Lack of a clear vertical distribution of $\delta^{13}C$ values would suggest the interaction of rapid progradation of freezing and slow upward/downward progression of freezing due to the particular topographic conditions. In the soil profile with a thick organo-mineral horizon on fragmented bedrocks, ^{14}C values and micromorphology indicate that after successive stages of accretion, calcitic pendents are now altered by dissolution due to the high biogenic productivity. Soils on the fluvio-glacial deposits show displaced, fragmented calcitic pendents and embedment of the calcitic pendents within the soil fine mass. These features, as well as isotope values, indicate that their formation has been interrupted due to a modification of the soil arrangement caused by cryoturbation in response to a deterioration of drainage.

The lateral variability of the soils with calcitic pendents has been more precisely documented from a series of profiles distributed along a gentle slope at the 80 m high terrace of Ny Alesund. The four profiles studied, that belong to the type 2, are noticeably different: P1, located at the highest position, presents abundant calcitic pendents at all depths with five stages of accretion and presence of secondary carbonates in the fine mass. The low ^{14}C values indicate that formation of the calcitic pendents was initiated long before the Holocene, possibly during earlier non-glaciated periods. In P2, calcitic pendents only present 3 to 4 stages of accretion and no secondary carbonates in the fine mass. In P3, located at the lowest part, calcitic pendents are rare, thin, only present beneath the very coarse fragments, and with signs of dissolution. In P4, on the other side of the slope, calcitic pendents only present 1 to 3 stages of accretion. Micromorphology would suggest that formation of calcitic pendents of profiles 2, 3 and 4 has been interrupted at different stages of soil development due to a progressive increase of the subsurface water flow, possibly in response to more important snow fall that accumulates just behind the depression. The insufficient amount of carbonates in the successive layers of P2, P3 and P4 profiles did not allow to perform measurement of ^{14}C values from each calcitic pendents that would have been necessary to precisely determine at what stage their accretion was interrupted. The record of a long period of accretion, still active under present-day conditions, has only been preserved at the highest position (P1) located on the edge of the main drainage axis.

Three types of discontinuities can be distinguished in the pedogenic carbonate studied.

Type 1 : expressed by the succession of different micro-fabrics within each calcitic pendent. They result from changes of organic productivity, speed of freezing and water throughflow that reflect modifications of the seasonal thermic and hydric regimes, in response to significant climate shifts, more particularly driven by fluctuations of the oceanic influence.
Type 2 : expressed by differences of the properties of calcitic pendents between layers of each profile. They result from the re-working of soil materials and/or input of fresh materials in response to hydric and thermic changes that have disrupted the equilibrium of the soil system. The subsequent restoration of the carbonatation process for a long duration indicates that these geomorphic events are rapid, short and episodic.
Type 3 : expressed by lateral changes in the properties of calcitic pendents that cannot be assigned to differences in the age of parent materials or in their depositional history. They result from modification of environmental conditions that has, gradually, generated lateral variations of local factors, particularly drainage. The discontinuity evidenced in the studied case is linked to a more efficient percolation that has induced dissolution and retrogradation of calcitic pendents in profiles 2, 3 and 4, while calcitic pendents were still forming in P1.

Conclusions. The possibility to study the history of soil-development from an initial stage (i.e. the last ice retreat), in addition to the lateral variability of vegetation, drainage and surface dymanics, and lack of bioturbation, has provided a system of rather simple behaviour, but, , sufficiently complex to study the interaction of soil-forming processes and dynamic factors of soil landscapes. This has been greatly facilitated by the combination of micromorphology, isotope studies and radiometric dating. None of the processes discussed here is, however, particular to periglacial environments. The three types of discontinuities identified are, in fact, the expression of the three frequencies that rhythm soil differentiation: types 1 and 2 that are, respectively, induced by cyclical and episodic events, and type 3 that is controlled by the stochastic functioning of the soil system itself. Although the later one is, indeed, a major cause of distortion of the record of climate changes by carbonated soil systems, its influence can be efficiently decoupled from the ones of cyclical and episodic events through a detailed spatial study and the use of complementary analytical tools. A general application of this approach should highlight how carbonatation is, indeed, a time dependant process, but certainly not linear and, therefore, of great potential for soil data to challenge other proxy record in the comprehensive understanding of the Global Change.

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SHORT AND LONG TERM SOIL SYSTEM BEHAVIORS IN HYPER ARID ENVIRONMENT (A CASE STUDY IN THE OUARGLA CHOTT, SAHARA OF ALGERIA)

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Introduction. In soils of dry regions, it is, generally, difficult to decouple the effects of earlier periods of soil development achieved under climates of the past from the ones that relate to the present-day functioning. This difficulty can be solved by studying, more particularly, the soil forming processes that are highly reactive to environmental conditions and have been operating for a long time period. The dynamic of soluble salts and gypsum that results from the interactions between the solid and liquid phases is one of the way to determine the role of hydric and thermic regimes on soil functioning (Fedoroff and Courty, 1989). The temporalities of this process have remained, so far, poorly documented. The objective of this study is to characterize at different scales sequences of salt accumulations in the endoreic system of the Ouargla chott, with a special attention given to understanding their dynamics at different time scales. This is based on field and micromorphological observations, combined with a mineralogical study of salt crusts.

Materials and methods. The investigated catena is located in the Ouargla chott of, North Eastern Sahara of Algeria. The chott belongs to a larger depression that is part of a dry paleo-vally Oued Mya which runs from the Tadmait plateau in central sahara to the chott Melghir (Dubief, 1953). The valley is a long structural basin dissected in the continental Pliocene bordered by an extended plateau on the west and on the east a range of tabular residual landforms (Gara) that ends with the oriental Erg. Chotts separated by low aeolian dunes divide now occur from the north to the south of the valley.

The climate is mediterranean hyper-arid with a mean annual rainfall of 34,6 mm, high temperatures and therefore a potential evaporation of more than 2000 mm. The monthly mean temperature of the last ten years has been 22,5 °C with January minimum of 10,7 °C and an August maximum of 34,4 °C. The annual mean of relative humidity is 41,5%, the winds are mostly either from north-east or from south-west with an average above 9 $m.s^{-1}$ mean velocity during 50 day/years. Violent dust winds are frequent (20 $m.s^{-1}$) in spring. The pedoclimate is hyper-thermic and aridic.

The area is characterized by uniform parent material of Mio-Pliocene clayey quartzic sandstones. The clayey quartzic sand is strongly eroded from the upper slope to the depression, and covered by mixed aeolian and colluvial deposits at the lower slope. The bottom of the depression is occupied by the chott showing soluble salt enrichment at the surface that are produced by fluctuations of the sub-surface ground water.

Seven saline soils profiles were investigated along a southeast-northwest catena through the chott (Salorthids) and edges (Petrogypsic Gypsiorthids) and 42 ground water samples were collected. Chemical analyses data were combined with the results of X-ray diffraction (XRD) and micromorphological observations performed at different scales. Selected clods and grains taken from the undisturbed samples were analyzed under the SEM equipped with an EDXRA microprobe. Ionic strengths, activity coefficients, ion activities, distribution of complex species and equivalent pCO_2 were calculated for all ground water and saturation extracts of soils analyzed using a ion pair model AQUA (Valles and De Cockborne, 1992).

Results and discussion. Chemical analysis of ground water and saturation extracts of soils were performed for neutral way salinization: $Cl^- > SO4^{-}$ and $Na^+ > Mg^{2+} > Ca^{2+}$, (Tabl. 1) classified as sodic-chlorinized facies in Piper diagram.

The salt efflorescence and/or surface saline crusts presents three mineral assemblages with different macro and micromorphology: (1) SO_4-Cl-Na-Mg-Ca association, dominated by mirabilite/thenardite, halite, eugstrite and bloedite (fig. 1), present as powdery efflorescence in the wettest part of the chott; (2) Cl-SO_4-Na-Mg-Ca association, with gypsum, halite, bloedite, glauberite and bassanite, present as small bulges on the most part of the chott and oasis). (3) SO_4-Ca assemblage with gypsum and bassanite, developed on polygonal surface crusts at the edges of the chott).

Salts efflorescence type (1): Field observations shows partially altered, euhedral centimetric crystals on white powdery thenardite that are identified as mirabilite. Because of the mirabilite instability (Driessen and Schoorl, 1973; Timpson et al., 1986) and desiccation during exposure to X-ray, this mineral cannot be detected in XRA (Gumuzzio et al., 1982). Under arid conditions, even in winter, mirabilite is rapidly altered into the dehydrated form (i. e. Thenardite).The geochemical model AQUA confirms that sulfate molality of the most concentrated solutions in the salt efflorescence type (1) is strongly controlled in the mirabilite, thenardite, eugstrite and bloedite precipitation domains (fig. 2).

In the system Na_2SO_4-H_2O, the transition from mirabilite phase to thenardite phase is situated between 32 to 38 °C (Timpson et al., 1986) and decreases to 18 °C in up-saturated solution on NaCl (Halitim, 1988). By using this temperature dependence of mineral solubilities, we can infer that formation of efflorescence results from the shortest pedological process, probably seasonal or even daily.

*Surface salts crust type (2):*Field experiments show that some months after scouring, the capillary rise of saturated sub-surface ground water again induces the formation of this fragile crust; crystalloturbation produced by the voluminous swelling of gypsum crystals and up rising of surface soil material produce bulging of this crust.

*Surface salts crust type(3):*The gypsum/bassanite polygonal crust is formed by three millimetric layers that are formed from the surface to the bottom of: (i) coalescent stacking of weathered subhedral crystals with spongy porosity, (ii) stacking of loosely euhedral lenticular crystals, (iii) stacking of weathered subhedral crystals. Sand grains, recently transported by wind, are trapped in the longitudinal polygonal crust cracks in the form of loose infilings. Morphology of this weakly compacted crust and scarcity of high soluble salts refute a formation controlled by seasonality, and suggest that this type 3 crust might result from the medium term functioning of soils in the chott edges.

Sub-surface petrogypsic horizons: The Salorthids on the downstream (chott) is formed of low amount of gypsum crystals that are randomly distributed on the clayey quartzic sand host material, and sometimes of welded concentrations. The petrogypsic horizons of Petrogypsic Gypsiorthid soils at the edges of the chott are characterized by various sizes and abundance of gypsum crystals which do not show preferential orientation pattern. However two forms have been recognized: (1) lenticular euhedral loose crystals predominantly formed of microcrystalline gypsum <20 µm, associated with coarse crystals 0.2 to 1 mm, (2) Irregular anhedral crystals roughly welded, with a size ranging from 0.2 to 3 mm, typically of ground water origin.

Microsparitic calcite crystallisation have been also observed in these horizons as inclusions in the gypsic features. Their diffuse boundary and irregular shape indicate an in-situ precipitation, but under more humid conditions, higher pCO_2 and biological productivity than the present ones in soil. Stratification of some petrogypsic horizons seems to relate from sedimentation episodes during their pedogenesis. Ghosts of gypsum crystals are present in the medium part of some Gypsiorthid soils together with where fresh-looking gypsum crystals. The juxtaposition of these two crystal shapes indicate an interruption of gypsum accretion, most probably caused by a rainfall increase that has resulted in a decrease of sulfate concentration and gypsum dissolution.

Conclusion. The dynamics of soluble salts can be assigned to seasonal variations, whereas the ones of gypsum-carbonate association is likely to reflect the long and medium term functioning.

In the downstream of the sequence, gypsum and high soluble salts are transported by ground waters and concentrated by evaporation. This define two of salt precipitation processes, as previously recognized in various places in northern Africa: (i) water evaporation from shallow ponds in the salt-lake in which salts concentrate and crystallize at the bottom (efflorescence type 1); (ii) the rising of groundwater by capillary "per ascensum" through the profile that induces salt enrichment at the soil surface after water evaporation (surface salts crust type 2). The mineral species, the macro and micromorphology of the efflorescence express the mode and rapidity of groundwater evaporation. Complexity of the geochemical composition of efflorescence and/or surface crusts geochemical composition can be assigned to major morphological changes through time. Combination of the time control and of the system structure gives to distribution of carbonates, gypsum and more soluble salts in landscape the value of a mineral crystallization chrono-topo-sequence.

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Table 1: Chemical composition of soils studied and the salt crusts.

Depth (cm)	pH	EC ($dS.m^{-1}$)	saturation extract soluble salts ($meq.l^{-1}$)							Gypsum (%)	$CaCO_3$ (%)
			Cl^-	SO_4^{2-}	HCO_3^-	Na^+	Mg^{2+}	Ca^{2+}	K^+		
					Salorthid						
0-2	6,9	160,7	4390	2751	9	4917	1439	-	12,4	20,1	0,8
2-5	7,1	79,20	943,1	433	9	864,6	274,6	28,1	32	20,4	0,8
5-40	7,6	-	435,3	233	4	391,4	131,5	29,5	16,3	14,7	0,7
40-80	7,5	38,2	385,8	233	5	353,1	111	28,9	11	10,8	0,4
80-120	6,8	58,5	554	433	4	630,6	157,8	24,1	13,5	10,5	0,9
					Petrogypsic Gypsiorthid						
0-2	6,7	193,8	4227	982,6	5	4923	455,1	10	-	8,2	1,9
2-20	7,2	160,4	376,7	641,2	2	-	-	-	-	13,9	1
20-45	7,1	23,2	234,9	253,1	4	475,7	64,5	38,4	8,5	63,6	0,1
45-75	7,2	60,5	731,4	189,4	5	451,4	319,9	43,2	33,7	32	0,2
75-110	7,4	18,9	173,7	108,2	7	126,1	64,5	31	8	67,5	0,3
>110	7,1	24,4	228	128,9	6	168,7	74	30,4	6	76	0,8
					Salts efflorescence type (1)						
0-1	8	116,1	843,8	2814	3	2540	218,3	18,4	1,8	2,7	-
					Surface salts crust type (2)						
0-2	7,4	175,9	4133,2	2013,6	7	4340,8	1031	-	304	23	2
					Surface salts crust type (3)						
0-2	6,9	45	523,7	102,8	3	400	49	51	13	67	0,1

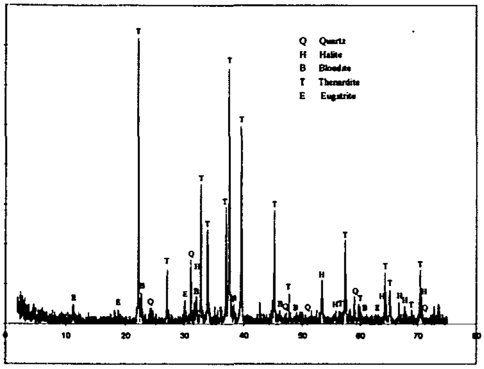

Figure 1: XRD trace of salt efflorescence type (1).

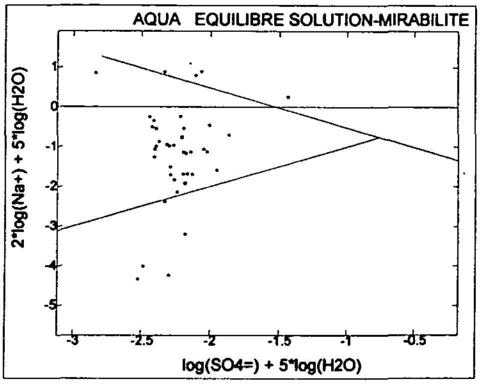

Figure 2: Equilibrium diagram of solution respect to mirabilite

EPIPEDON AS AN ESSENTIAL PART OF SOIL SYSTEM AND ITS FUNCTIONING IN TIME AND SPACE

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1. Introduction. Formed as a result of soil-plant relationship in the superficial part of soil cover, epipedons reflect by their composition also the properties of the soil's mineral part (indirectly via biogeochemical cycling and directly via soil disturbing activity of edafon) as well as the impact of vegetation cover via feedback relations (litterfall, formed food webs etc.). Therefore the epipedon can be treated as a space or contact area of soil-plant interaction, which results from variegated processes of accumulation-humification-mineralization and depends on the existing ecological conditions (among these soil edafon) on the one hand and on the mineralogical-chemical potential of soil parent material on the other hand. The character of these processes needs much more consideration to understand the regularities of the functioning of soil cover and to assess the role of soil cover in these processes (Müller, 1887; Wilde, 1971). The main tasks of the present research were the following: (1) to study relationships between the epipedons of natural soils and the composition and productivity of vegetation cover as well as soil cover and its taxonomical units and (2) to evaluate changes taking place in the fabric and properties of the epipedon when natural soils are transformed into arable soils, and vice versa.

2. Materials and Methods. When characterizing classification units of epipedons and their relation with soils and vegetation, use was made of Estonian soils and vegetation classifications as well as ordination matrices elaborated by us. For studying changes related to the transformation of land use by comparative method, the database PEDON created during 1967-85 was employed. PEDON consists of 211 experimental areas in forests and 159 on arable lands. Soils are characterized by 53 parameters and vegetation by 56 parameters.

3. Results and Discussion. Formed in *frigid-udic* pedoclimatic conditions, the epipedons of natural soils are characterized by the presence of the forest floor layer whose thickness depends not so much on annual litterfall as on the biological activity of soil organisms. Biological activity increases from mor type to mull type epipedons. Along this trend the role of endogenic humus increases. In ground vegetation this is reflected by increase in floristic diversity and the higher phytomass and productivity of herbaceous plants. The impact of moisture conditions on the fabric and humus quality of epipedons is evident. The total list of epipedons in relation to the forest site type (Lõhmus, 1984) and soils is presented in Table 1. Considering the total area of different soils, the first place is occupied by peat type of epipedons (eutrophic 16.1%, oligotrophic 13.7%), followed by wet types (mull 12.1%, moder-mull 8.0%, mor 5.1 etc.). Some properties of epipedons are presented in Table 2. The productivity of epipedons is calculated in relation to the productivity of moist moder type where the annual phytoproductivity of stems in tree layer is on an average 21 10^2 kg ha^{-1}. Analysis the functioning of epipedon on the time scale (seasonal dynamics) allows to

conclude that the most profound changes take place in the fabric of forest floor of mull type epipedon: the visible forest floor layer accumulated in autumn may be totally decomposed during the following spring period. Epipedons of the mor type are relatively stable on time scale.
When transforming natural areas into arable land, the forest floor on soil surface is mixed with humus horizons in consequence of which their properties and functions are drastically changed. In the place of natural epipedons principally new epipedons are formed with a changed edafon (biological activity), chemical composition (pH, stage of saturation) and the tillage practice used. In this case the rate of mineralization and stage of saturation increase. The restoration of natural epipedons is in certain cases impossible, which is clearly revealed in the development of mor type epipedons.
The regularities of changes in the properties of these epipedons as well as the ecosystem components related with them (vegetation, soil cover) are well depicted in matrix tables. It is established that the patterns of taxonomic units of different components do not coincide, and there appear interference fringe areas. At the same time, the direction of changes is distinct, which gives evidence of a demonstrated strong correlation between soil and plant cover.

4. Conclusions. (1) The fabric of epidons reflects the influence of both vegetation and soil cover. The main determinator for epidon is soil cover as a stable component of the ecosystem; (2) In the course transforming forests into arable land exogenic epipedons are totally destroyed. The forest floor disappears, and in its place a humus horizon is formed which was undeveloped in natural conditions; (3) Being in steady state conditions the forest floor as ingredient of epipedons reflects the mineralogical-chemical-textural potential of soils via productivity level and induced by it the biogeochemical cycling; (4) Forest floors of the mull type change to a great extent during the vegetation period; (5) Forest floors play an essential soil protective role on sloped landscape by increasing soil water infiltration ability. (6) The correlation between the classification units of various related ecosystem components is substantial but not absolute due to the phenomenon of interference. Cultivation of land declines the epipedon toward homogenization and decrease in natural diversity; (7) Steady state epipedons can be regarded as benchmarks in the evaluation of the degree of functional disturbances of soil cover. In this aspect, the chemical composition of forest floor as ingredient of epipedon is of great value as indicator.

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Table 1: List of studied forest land epipedons and their correlation with soils, forest site types and arable land epipedons

Epipedon of forest soil	Predominant soil	Forest site type	Epipedon of arable soil
Dry mull	Calcari Rendzic Leptosols	*Arctostaphylos* alvar	Calcic low humous
Fresh mull	Calcari Mollic Cambisols	*Hepatica-Calamagrostis* alvar	Pebble or neutral mild humous
Moist mull	Calcari Gleyic Cambisols	*Aegopodium-Sesleria* alvar	Neutral mild humous
Wet mull	Calcari Mollic Gleysols	*Dryopteris-Sesleria* alvar	Eutrophic organo-mineral
Peaty mull	Calcari Histic Gleysols	*Equisetum*	Eutrophic organo-mineral
Fresh moder-mull	Eutri Haplic Luvisols	*Hepatica*	Eluvic moder humous
Moist moder-mull	Eutri Gleyic Luvisols	*Aegopodium*	Eluvic moder humous
Wet moder-mull	Orthi Cambic Gleysols	*Filipendula*	Mesothrophic organo-mineral
Dry moder	Dystri Haplic Podzoluvisols	*Oxalis*	Mesothrophic organo-mineral
Fresh moder	Albi Glossic Podzoluvisols	*Oxalis*	Acid low humous
Moist moder	Orthi Gleyic Podzoluvisols	*Myrtillus*	Eluvic or fulvic moder humous
Wet moder	Stagni Albic Gleysols	*Polytrichum*	Mesothrophic organo-mineral
Peaty moder	Orthi Histic Gleysols	*Carex*	Mesothrophic organo-mineral
Fresh moder-mor	Dystri Albic Podzoluvisols	*Rhodococcum*	Acid low humous
Moist moder-mor	Sombri Gleyic Podzoluvisols	*Rhodococcum-Myrtillus*	Fulvic low humous
Wet moder-mor	Spodi Albic Gleysols	*Polytrichum*	Oligotrophic organo-mineral
Dry mor	Areni Haplic Podzols	*Cladonia*	Acid low humous
Fresh mor	Sombri Haplic Podzols	*Cladonia-Calluna*	Acid low humous
Moist mor	Ferri-placi Gleyic Podzols	*Calluna*	Fulvic moder humous
Wet mor	Spodi Albic Gleysols	*Vaccinium ulginosum*	Oligotrophic organo-mineral
Peaty mor	Spodi Histic Gleysols	*Vaccinium ulginosum*	Oligotrophic organo-mineral
Eutrophic peat	Eutri Terric Histosols	*Alder-birch swamp*	Eutrophic peat
Mesotrophic peat	Dystri Terri-Fibric Histosols	*Transitional bog*	Mesothrophic peat
Oligotrophic peat	Dystri Fibric Histosols	*Raised bog*	Oligothrophic peat

Table 2. Morphological, agrochemical and productivity characteristic of epipedons

Epipedon of forest soil	n	Thick-ness, cm	SOM kg m^{-2}	Cff/Chh	Base saturation percentage	Relative produc-tivity , %	Phytomass of ground layer kg m^{-2}	Moss/herb phytomass
Dry mull	7	17	14.9	13.4	93	33	2.0	3
Fresh mull	19	19	11.3	13.2	85	67	1.9	2
Moist mull	2	21	54.8	31.9	58	33	2.6	2
Wet mull	3	25	21.6	no det.	no det.	71	1.6	2
Fresh moder-mull	7	22	11.9	13.0	74	81	1.9	3
Moist moder-mull	7	26	14.4	14.0	65	95	1.6	1
Wet moder-mull	4	28	20.6	10.6	67	90	1.4	1
Fresh moder	21	21	8.1	5.7	36	90	1.8	3
Moist moder	23	17	7.4	3.9	32	100	2.1	4
Wet moder	2	14	10.7	1.2	15	86	5.1	37
Fresh moder-mor	10	7	4.0	0.4	21	90	3.9	18
Moist moder-mor	5	8	4.7	0.1	18	76	4.1	9
Wet moder-mor	4	11	5.9	<0.1	15	71	5.5	>100
Dry mor	5	4	1.9	<0.1	14	43	4.8	>100
Fresh mor	10	4	3.1	<0.1	27	76	4.6	65
Moist mor	4	6	3.3	<0.1	23	86	5.1	44
Wet mor	2	14	6.9	<0.1	16	76	6.0	>100
Peaty mor	11	15	8.0	<0.1	28	52	5.9	>100
Eutrophic peat	7	47	58.7	-	73	38	1.6	1
Mesotrophic peat	3	51	43.7	-	29	19	6.2	27
Oligotrophic peat	6	50	29.4	-	13	24	5.6	>100

SOM - soil organic matter; Cff carbon in forest floor; Chh - carbon in humus horizon

SPACE AND TIME SCALES OF SOIL FORMATION

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Introduction

V.I. Vernadsky (1988) gave the important meaning to a problem of ration of time and space at study of biosphere. He believed, that natural bodies of biosphere exist in an uniform structurally connected system of time and space, at alteration of which change and property of natural bodies. The purpose of our work is to establish parameters describing the intensity and time characteristic soil of formation, and ratios of these characteristics with influencing factors and properties. We have accepted, that it is necessary to investigate soils in that state of evolution, in which they are at the moment, instead of in relation to their equilibrum state. Results of researches of a number of authors on irreversible changes soils and characteristic times various processes are discounted (Poljinov, 1956, Jenny, 1948, Targulian, 1984 a. oth.). Considerable input for the understanding of the problem was published by A.D. Armand and other authors.

Materials and Methods

For the analysis of the problem 14 soils on morpho-genetic types and mineralogical-crystallochemical societies were investigated. The representation about mineralogical-crystallochemical societies was developed earlier (Gradusov, 1996). For the research soils with a wide range of propertieswere chosen. Therefore the obtained characteristics of derification represent the common laws of the investigated phenomena.

The comparison of soil in time and space in our work was carried out on intensity. As known, the intensity represents mass or energy refferde to time periods.

The intensity (I_s) is described with help of the variety and value of properties, stipulated by soil formation for all time of their existence. This is the relative characteristic in time. It represents the unit of physical time, referred to intensity. To determine the intensity of formation of soils, a matrix of 15 parameters was developed (tabl.1). These parameters characterize the intensity of changes of properties resulting in pedogenic processes. All parameters form 3 groups.The first group is entered by parameters of a condition: temperature, humidity and so on. The second group will be formed by parameters of destruction or removal of substances. The third the group contains parameters of formation of new components: synthesis of minerals and other.

The meanings of parameters are appreciated on a 4^{th} grade scale. A parameter of intensity was determined from a sum of parameters different from zero, multiplied by the number of such parameters.The specified meanings I_s were represented as percentage of the maximum meaning.

Results and discussion

The intensity of soil formation is divided into 4 groups (tab. 1, figure 1). The soils in group 1 are characterized by the maximum intensity. Red earth can be found in this group.

Table 1. Matrix of indexis of intensity on variety and quantity of properties and composition of the soils.

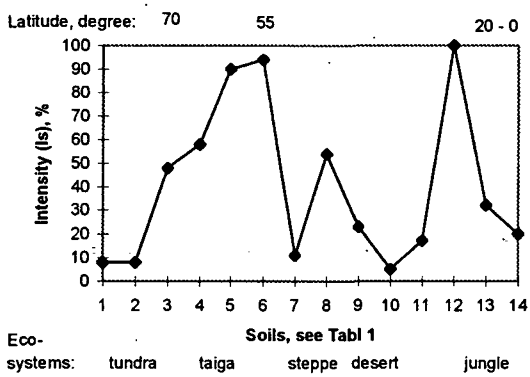
Community	Group of indexies															Valuation	
	Condition				Solution, removal							Newformations				Valuati-on	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Is	Ts
1. Serpentine lithopodburs	2	1	1	1	1	0	2	1	0	2	0	1	0	0	1	8	12
2. Chlorite-smectite lithopodburs and granuzems	2	1	1	1	1	0	2	1	0	2	0	1	0	0	1	8	12
3. Chlorite-hydromica podburs and podzolic AL-Fe- humus soils	2	1	2	2	2	0	2	3	3	1	1	1	0	0	1	48	2
4. Allophane soddy- and ochro-podzolic soils	3	1	2	2	2	0	2	2	1	1	0	1	0	2	2	58	2
5. Vermiculite-smectite-hydromica podzolic	1	2	1	1	3	1	1	1	1	0	0	2	2	0	2	90	1
6. Illite-kaolinite podzolic soils	1	2	1	1	3	2	1	1	2	0	1	3	3	0	3	94	1
7. Quartz podzolic soils	1	3	1	1	3	1	0	1	1	0	1	2	1	0	1	11	9
8. Hydromica- smectite chernozems	1	3	1	1	3	2	1	1	1	0	0	1	1	0	2	54	2
9. Chlorite-illite sierozems	2	2	2	2	2	0	2	2	3	2	1	0	0	1	2	23	4
10. Palygorskite dezert red- braun soils	2	2	2	2	2	3	1	2	3	1	2	0	0	1	2	5	20
11. Smectite Vertisoils	3	3	3	3	3	0	3	1	1	3	0	0	0	3	2	17	6
12. Kaolinite-smectite krasnozems	3	3	3	1	3	0	0	1	0	0	3	0	0	1	1	100	1
13. Kaolinite red soils	3	2	2	1	2	0	0	1	1	0	0	0	0	1	1	35	3
14. Ferritic soils	3	3	3	1	3	0	0	0	0	0	0	0	0	0	1	20	4

1 - humidity, 2 - temperature, 3 - solution, 4 - CEC, 5 - mineralization of plant litter, 6 - carbonites, gypsum, 7 - plagioklase, biotite, 8 - K-field spar, K-mica, 9 - hydromica, 10 - smectite, 11 - kaolinite
12 - carbonites, 13 - hydromica, 14 - halloysite, 15 - humus; Is, Ts - see text.

The second group covers soils with moderate intensity of formation, for example, podzolic loam-like in the taiga. The third group of soils is characterized by an average intensity of formation. In this group tropic and subtropic soils are included, advanced on weakly changed rocks. Soils of group 4 are characterized by low intensity of formation. In this group chernozems and others soils of a steppe zone, and also soils of deserts (vertisol and red ferric - siallitic) are contained.

Soils can be grouped according to the characteristic relative time of changes.The first group unites soils with a small characteristic time.Such soils are red earth, podzolic loam-like taiga and chernozems. By average meanings of the characteristic time red ferralitic and ferric soils, and also podburs of the taiga on igneous rock are differed.They form the second group of soils.The third group covers soils with long characteristic time.Soils of cold areas and deserts belong to this group.

Figure 1. Distribution of intensity of formation on soil and geographic space



It is established, that with increase of absolute age 3 groups of soils with the maximum intensity and small characteristic time are available.The first maximum concern to vulcanic soils, which have small absolute age (decades or hundred years). With increase of age up to 10 - 20 thousand years maximum of intensity and minimum of characteristic time for podzolic soils and podburs is observed. The last maximum is dated for reds earth. The age of these soils is measured in several hundreds thousands of years. With another increase of age, that is characteristic for ferallitic soils, I_s sharply decrease.The low intensity of formation is the peculiarity for soils at cold and aridic conditions. These soils, as a rule, have low absolute age.

The higher is the intensity of formation the higher is the potential ability of the reflection of an evolution of the factors of soil formation or self-organization of soils. The transformation of this ability to memory is reached then,when we establish a connection between properties of soils and events of history of an evolution. This connection is established with knowledge and methods of geology, geography and other sciences. The memory is the property of another system: soils - crust of Earth -observer. The distribution of intensity and characteristic time in a so-called zonal line of soils does not basically correspond to the distribution of components of the climatic or biological factors in that meaning of this concept, which is accepted in pedology. It is caused by two reasons. The first reason is, the representation about zone accomodation does not take into account the role of soil forming rock. The second reason of special distribution of intensity and characteristic time of soils is the offered representation bases on own properties of soils, caused as bioclimatic and lithogenic factors.The complexity of distribution of intensity and characteristic time of soils reflects protractical processes of evolution crust of Earth and its biosphere, including philogenetic changes of soil formation.

The special type of allocation I_s and Ts is stipulated by a complex combination of litogenic and the bioclimatic factors, and also own properties of soils. These last in present-day reactions is source material, that is a factor of soils formation.
The main areas of intensive soil formation are dated to humidic borealic territories, instead of to humidic tropics. The basic types of soils with high intensity of formation are loam-like podzolic soils and in a smallest measure to chernozems, instead of red ferallitic soils. The reason of such type of distribution of soils with different intensity and characteristic time is asymmetry of an evolution of biosphere on late kajnozoic epock. Glacial activity has resulted in deep reorganization of lithogenic basis of soil formation in borealic belt, whereas on the area of low altitudes this basis is extremely changed by lithogenic processes. For this reason some soil scientists (Sokolov, 1989) connect superficial formations of tropic areas with hydrotermalic, instead of pedogenic processes.

Conclusions
The complexity of the law of distribution of intensity and characteristic time of formation of soils reflect presence of accident in structure of the external factors and advanced on their basis of internal organization of soil as systems. The habitually formulated law of soil zonality is not the shorter program, inducing a sequence received by us. Therefore, from the point of view of the theory of the information, the received representation about time-space of soil formation is valuable with another law distribution.

The law of change of intensity and characteristic time of formation is immonent quality of soils.They directly connected to properties of soils, their irreversible changes, factors and space.

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WATER REGIME OF RECLAMATED DUMPS - MONITORING OF SOIL MOISTURE USING DIELECTRIC METHOD

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1. Introduction.

Measurement and monitoring of time variation of soil moisture, or more generally water regime in unsaturated zone appears to be an important aim in soil physics. This doesn't include only the evaluation of the water balance in soil profiles, or until the scale of watershed, but the mentioned data may be used as input and calibration data for numerical models and in the area of optimalization of the water regime of reclamated surface dumps.
Czech Republic is one of the countries with the highest load concerning the amount of raw minerals mining per area.. The decisive factor, nevertheless the present suppressing of mining activities, is the surface brown coal mining. Reclamation of dumps caused by the mentioned surface mining seems to be a complicated technical and also economical problem. Regardless further exploitation of dumps, the optimatization of chemical composition, hydrophysical characteristics and water regime is the basic supposition of further employment of the mentioned anthropogenic soils.
A considerable effort has been orientated on the study of both space and time variability of the water regime of the reclamated dump profiles. Kuráz et al (1993) have proved a negative influence of the stratification of the surface layers, when organic matter was used as mulch (surface layer of high hydraulic conductivity overlying the basic part of the profile with very low hydraulic conductivity).
A dielectric method has been used for the monitoring of the distribution of soil moisture. The main advantages of the „Dielectric soil moisture meter" (Kuráz, Matoušek, 1978, improved 1984,1992) for measurement in heterogeneous soil profile are:

- the simplicity of the measurement,
- the possibility to measure the soil moisture distribution in the whole profile - beginning from 5 cm under the surface.
- the linearity of a calibration curve .

Due to the fact, that during long term stationary measurement, the data set could be enormous, the manual registration and preparation of data for further evaluation is difficult; the „Dielectric soil moisture meter" was improved, what enables the automatisation of data storage including evaluation of data and further interpretation of results.

2. Materials and Methods.

Cellulose sludge is frequently used as organic material for reclamation of surface dumps. During the vegetation period 1996, following variants of the cellulose sludge were applied to a forest type of reclamation - surface dump „Radovesicka" , North - Bohemian brown coal region"(near the town Bílina):

- S1 - without application of organic matter
- S2-S7 -with application of 100,200,400,600,800 and 1000 t/ha respectively - in the form of mulch (100 t/ha corresponds approximately to a layer of 1 cm)
- S8-S13 - with application of the same dosages of organic matter as variants S2-S7, but as mixture of organic matter with the surface horizon to the depth of approximately 10 cm.

The „Dielectric soil moisture meter" in improved form has been used for monitoring the time and space distribution of soil moisture. During the testing period the system for automatization of data collection has not yet been used, but the software for the further data processing based on the system „Control Panel 2" (delivered by the Alcor - Moravian Instruments Zlín, CR) has been utilised. The „CP 2" software, which is commonly used for the development of software operation for technological procedures, provides quite acceptable windowed graphic environment (started from MS DOS). Very important was the development of proper software driver for the CP 2 system, which is essential for data communication from external devices (e.g. soil moisture meter) into the computer system. For the development of the driver a special tool DDK (Device Driver Kit) is used. Service routines written in C language were compiled with Top Speed compiler into a final DLL (Dynamic Link Library) driver file. The mentioned software is until now under development.

The distribution of soil moisture contents was measured in a one week period in the depth increments of 10 cm until 50 cm in each profiles, the mentioned software based on the CP 2 system was used for interpretation and further processing of data.

3. Results and Discussion.

The results of time variation of soil moisture content in different reclamation variants are shown in Figure 1 (at 10 cm depth) The time dependencies of water stock in a soil horizon from 0-30 cm are presented in Figure 2. The results are presented for the reclamation variant S1 - without reclamation (as a standard variant), variants S2 and S4 - reclamation in the form of „mulch" (depth of mulch 2 cm, respectively 4 cm), and variants S9 and S13 - reclamation in the form of mixture with the surface horizon (200 t/ha, respectively 1000 t/ha). Regardless an anomalous distribution of precipitation in the vegetation period, heavy texture of basic soil profiles and high degree of heterogeneity, following conclusions concerning the influence of different treatments on the water regime can be formulated:

- by applying organic reclamation material in the form of mulch -in a dosage greater than 200 t/ha, improvement of the water regime was observed. This concluded, that the surface should be uniformly covered, by an organic matter layer of approximately 2 cm. From the technical point of view it seems to be suitable to use dosages of 400 t/ha. The depth of the organic mulch should not exceed 10 cm to avoid layered profiles with a surface layer with high water capacity.

- technological processes based on mixing of organic reclamation material with the surface layer seems to be efficient in the case, that the dosage of the organic material is higher then 1000 t/ha. As indicated by laboratory experiments it seems to be suitable to use dosages of organic matter of about 600 t/ha - to increase the water capacity and hydraulic conductivity of surface layer. The main problem seems to be again technologically: provide a homogenous mixture of soil of organic matter under field conditions, and keep the improved hydrophysical soil characteristics stable over time.

4. Conclusions.

The suitability of using the„Dielectric Soil Moisture Meter" for monitoring the water regime in the condition of very heterogeneous artificial soil profiles - reclamation of surface dumps has been proved. The software developed on the basis of commercial CP 2 system seems to be an appropriate tool for registration and further interpretation of results.

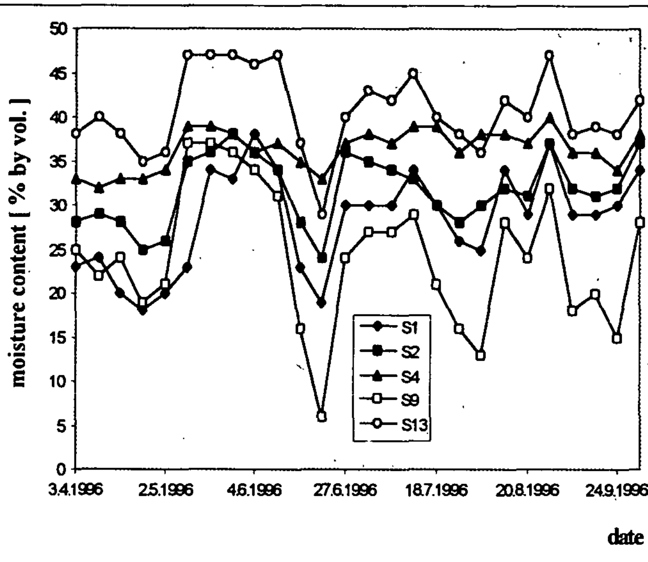

Fig. 1.: Time variation of moisture content, depth 10 cm

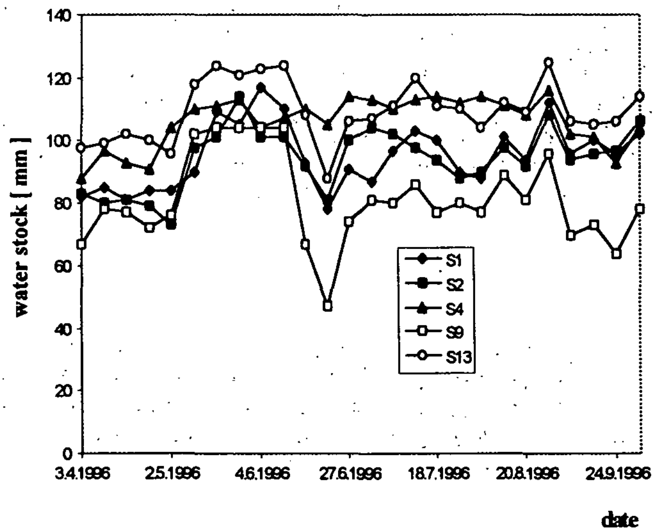

Fig. 2. : Time variation of water stock, horizon 0 - 30 cm

5. Acknowledgements.

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TRANSFORMATION OF THE PROPERTIES IN LOCALLY OVERMOISTENED CHERNOZEM SOILS ON SLOPES.

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Introduction. The soil is very complex, multiphase, open thermodynamic system, which constantly varies in time and space. Openness and the complexity of the considered system provides the analysis of apparent equlibrium or relative stability in behaviour of these systems. At a certain stage of development the stability of system is caused by amount and intensity of the influencing factors. Occurrence of a new factor or change of intensity of influence results in destabilization of the system and provokes it to transition to another level, on which it also aspires to a certain equlibrium. An example of rapid changes in rather stable systems of chernozem soils, is the transformation of the soil which is periodically overmoistened and called motchar. Motchar - is an overmoistened site on slopes among automorphic chernozem soils, which are characterised by local and periodical overmoistening.

Occurrence of overmoistened soils on slopes in the steppe zone is caused by extensive economic activities of man, both in industry, and agriculture. Now motchars have become an essential part of the agrolandscape structure of the steppe zone. Their occurrence indicates some change of the hydrological regime of the territories and requires a development of new ways of motchar soils management, application of special agrotechnical practices to solve economic and nature-conservation problems. The rate of changes in these soils is very high. The morphological structure, the exchange complex and the salt profile vary greatly within periods of 5-10 years. A morphologically distinct compact (vertic) horizon is formed.

The aim of the research was to study changes of the morphological characteristics and the fine fractions mineralogical composition of motchar soils.

Materials and methods. The detailed morphological description of motchar soils technique developed by V.V.Dokuchaev Soil Science Institute was applied.

In mineralogical researches the samples of chernozem-meadow motchar soil derived from tertiary clay were studied. The fine fractions (>5 µkm, 5-1µkm, 1-2 µkm, 0.2-0.08 µkm, < 0.08 µkm) were isolated from the soil by ultrasonic treatment and centrifugation. The X-ray diffraction analysis of the clays was made on the diffractometer DRON-2. The quantitative estimation of the clay mineral contents was made by the E.A.Kornblum method modified by T.A.Sokolova.

Results and discussion. *Dynamics of the morphological characteristics.*
Our researches, commenced in 1986, revealed, that the morphological structure of the soil profile on motchar site is characterized by the following: presence of a compact soil horizon at a depth of 20-60 cm; an aquifer of the light texture at a depth of 120-160 cm; a dense confining layer at a depth of 160-240 cm; soil neoformations throughout the soil profile. In the upper layer of the soil profile the neoformations appear in the form of dots, threads, and veins of white colour (0,5-1 mm in diameter, 1000 pieces per square decimeter. The bulk of the neoformations is located at a depth of 40-70 cm. In addition to these well distinguished neoformations, in the process of drying, all the surface of the soil profile is covered with a white efflorescencing layer. Meso- and micromorphological investigations have shown that neoformations are composed of well crystalized gypsum, and the white efflorescence appears to be in one case a finely dispersed carbonate, and in other cases an easily soluble salt. You can find carbonates in the form of white soft spots, clay impregnations and loess dolls below the salt horizons.

The formation of a compact horizon in motchar soils is explained by the use of agricultural machines which causerepacking and reorientation of finely dispersed soil particles.

A new attempt to investigate motchar soils at the same overmoistened sites was undertaken in 1996, ten year later after the initial research. The repeated morphological description of the soil profile in 1996 has revealed the displacement of the compact horizon in direction of the soil surface at the overmoistened sites, that were excluded from the agricultural use. Probably, the displacement was promoted by elimination of the agricultural machines as a factor of the soil compaction.

An origin of the compact horizon of motchar soils, and, especially, the depth of its disposition, are to a considerable extent caused by the deaggregation, reorientation and repacking of the finely dispersed particles of the soil under the variable soil hydrological regime.

Besides, the soil morphological characteristics of this horizon have remained the same - black with glossy hue colour, firm block structure, without small cracks, very dense. Dislocation of the gypsum neoformations, which in 1986 were located at a depth of 80-130 cm changed in 1996. The gypsum now is distributed almost evenly throughout the motchar soil profile. The appearances of carbonates became more vast and now are forming an independent well distinquished soil horizon. Our data suggest that soil transformation processes in the profile is going on.

In 1996 slickensides, the diagnostic criterion of vertic soils, were found in all investigated motchar soil profiles at depths between 57-85 cm. From the center to the border of motchar site the upper border of slickensides horizons lowers from the soil surface.

According to the slickensides manifestation extent, it is possible to present the motchar soils profiles as combination of the three zones: transitive zone (57 / 85 - 80 /90 cm), small-dimension slickensides zone (80 / 100 - 90 / 120 cm) and large-dimension slickensides zone (90/120 - 150 cm). The morphometric characteristics of slickensides of each zone are as follows: transitive zone of small slickensides of dimension from 1*1 cm to 5*5 cm of the surface, angle inclination of 20-30^0, vertical interval of slickensides recurrence 10-20 cm, occurence is sporadical; the second zone is characterized by the slickensides of moderate dimension of 8*10 cm , angle inclination of 30-35^0, sometimes more or less, vertical interval of slickensides recurrence 5-10 cm, occurrence is abundant; the third zone concentrates primarily the large slickensides of dimension up to 45*20 cm and more, which are indicated by the slipping surfaces, going inside the section wall, the vertical interval of recurrence is increased up to 20 cm, occurrence is abundant, a wedge-shaped structure in this zone was found, which is a concomitant circumstance of slickensides formation. Wedge-shaped structure of the first type has a wedge on one side. Our data are the basis to classify the investigated motchar sites as deeply-firmed, belonging to the 3-rd degree of compaction.

Characteristics of mineralogical composition of clays.

The fraction < 0.08µkm. The diffraction maximas are diffuse with the a basis and very low intensity in relation to a line of a background, they are displaced to the area of smaller angles (1.4-1.5 ii), the background being high. These characteristics are thought to be caused by the small size of crystals, presence of mixed-layered illite-montmorillonite and weak crystallinity of clays. Mixed-layered illite-montmorillonite is the only component of the fraction < 0.08 µkm. It is characterized by extremely irregular interstratification and very high dispersity and is likely to contain kaolinite and chlorite layers. K+ saturation has resulted in the lattice collapse and displacement of basal (001) spacings up to 1.0 ii. Hence, montmorillonite layers in mixed-layered minerals, probably, has high charge.

Fraction 0.2- 0.08 µkm. Diffractograms of fractions of coarse colloids are distinct, the diffraction maximas are well recorded, the mineralogical composition of clays is diverse. Chlorite is identified by the presence of 1.4 ii diffraction maximum after heating the sample at 550^0 C. Displacement of the first basal spacing at saturation with glycerine up to 2.0-2.3 nm and the occurrence reflex at 0.32 nm after heating up to 550^0 C indicates the irregular interstratification of illite and montmorillonite layers with the content of expandable layers exceeding 50 %. Kaolinite and chlorite are present as individual minerals. Illite, is likely to be in the form of mixed-layered illite-montmorillonite formations with a neglectible fraction of montmorillonite layers (< 20 %). Unlikey to fine colloids having expanding layers as their essential component the fraction of coarse colloids contains kaolinite and chlorite (10-13 %) and illite (20-24 %).

Fraction 1- 0.2µkm. The X-ray diffraction patterns are characterized by distinct intensive diffraction maxima. The expanding silicates in fine clay fraction make up 35-50 %. They are present as mixed-layered illite-montmorillonite with irregularity random interstratification of montmorillonite and illite layers, mixed-layered the proportion of the former being rather low. In this fraction the kaolinite and chlorite content is 22-37 %. Both minerals are present as individual components with good crystallization. The proportion of chlorite as a whole is higher than that of kaolinite. Finely dispersed quartz is present there.

Fraction 5-1µkm. In fine silt fraction clay minerals are found. The content of expanding silicates is equal to that in fine clay fraction (37-50 %). The availability of illite is a littles bit (21-24 %), but that of kaolinite and chlorite is higher in this fraction than in fine clay fraction (20-40 %). The displacement of the first basal spacing up to 1.8-1.9 nm at saturation with glycerine shows the presence of mixed-layered phase with the proportion of montmorillonite more than 50 %. Illite, kaolinite and chlorite occur as individual components perfectly crystallized. Significant amounts of quartz and feldspars are found in fine silt fractions.

Faction > 5µkm. Clay minerals are presented by hydromicas, trioctahedral chlorites and kaolinite. Montmorillonite was not indentified.

The conclusion. Increasing hydrogeological underflooding of motchar sites promotes further transformation of the soil profile. The detection of slickensides in chernozem, transformed under the influence of overmostening, justifies the concept of slickensides developed by N.B.Khitrov (Soil Science Inst., Moscow) as a suitable diagnostic characteristic to recognize an anthropogenic compaction of chernozem soils.
The study of clay material in subfractions of clay fraction and in coarser fractions allows to obtain more detailed information about clay material composition and its structural characteristics. The specific feature of clay material in motchar soils is the increase in mixed-layered minerals content in all given fractions and the increase in irregularity of their crystal lattices. The degree of crystallinity of clays decreases from fine silt to colloidal fractions.

ELIMINATION OF THE SOIL DEGRADATION AS THE MOST IMPORTANT STAGE IN REALIZATION OF THE CONCEPT OF STABLE DEVELOPMENT OF THE UKRAINE

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Introduction

One of the main documents accepted at UN Conference on Environment and Development held in Rio de Janeiro in 1992 was AGENDA-21. In the document the necessity to join efforts to protect the environment from constantly increasing anthropogenic influence and for transition to the stable development is emphasized. In fact, the document proposes the conceptual program for governments, ministries, politicians whose activity is directed to the improving of the environment. However, it is impossible to apply the idea of the Conference for solving the problem of land use in the Ukraine (as in other countries) without estimation of the status of the topsoil and real degree of its degradation. It determines measures for elimination of the negative phenomena and use of appropriate technologies, i.e. it determines content of the national program of soil conservation. Everything stated below is an attempt to summarize some existing data on the predominant Ukrainian chernozemic soils, basically in relation to their physical and chemical properties, and to determine the main directions towards realizing of the concept of stable land use and stable development of the Ukraine on the whole.

Materials and Methods

Typical chernozems, ordinary chernozems, southern chernozems (located at the Sumskoy, Kharkivskiy, Dniepropetrovskiy, and Khersonskiy regions correspondingly) were chosen as the objects of the study. Soil sections were made on virgin, fallow, and arable lands. Major soil physical, water-physical, and chemical soil properties were determined (see Tables). Analytical field and laboratory methods, generally accepted in the Former USSR, were used. Also modeling experiments on investigation of soil compactibility with the help of specific device were carried out, Medvedev V.V. and V.G. Cibylko (1995).

Results and Discussion

In Table 1 the average values of some properties of arable lands are presented in comparison with virgin analogues; it is evident, that when compaction increases aggregation in chernozems, aggregates quality, water permeability decreases. Additionally, in chernozems that have been tilled for a long period humus content significantly decreases, acidification and water erodibility increases, processes connected with organic matter neoformation are inhibited.

The presented data give evidence that changes in arable land properties became irreversible. Figure 1 confirms partially this fact, because significant difference in bulk density between arable and virgin lands (reliable down to the depth of 0.5 m) is temporarily stable.

For the reason of this evident physical degradation arable lands loose resistance to loads that is inherent to the natural soils (Figure 2).

Experimental data presented above proved that physical degradation of soils in the Ukraine gains a great importance. This fact was stated in a lot of studies carried out both in our country and abroad. It even showed up (relatively to the Ukraine) at the map of soil degradation which was prepared for presentation at the Conference in Rio de Janeiro by Oldeman et al. (1992). The primary reason of soil degradation wide spread in chernozems is a great amount of shortcomings in soil cultivating technologies: pressure of agricultural vehicles and devices 2 - 3 times greater than permissible one; extremely high amount of mechanical operations; prolonged time of cultivation, seeding, intercultivation and conducting of these operations outside the interval of soil physical tilth; application of a very small dose of manure (Table 2).

The lack of quantity of organic fertilizers and significant mechanical pressure on soil causes its compaction, loss of structure, deterioration of water, air, and root penetrability. All these are so-called old, well-known phenomena. Simultaneously, new kinds of degradation are developing, which are considerably deteriorate restorative and productive ecological functions of topsoil:

- decreasing of root layer thickness due to gradual accumulation of deformation in subsurface layer;
- narrowing of available water range (due to increasing of soil bulk density);
- deterioration of technological parameters of arable layer due to colds formation increasing (caused by shortening of time during which soil is in physical tilth condition);
- deterioration of arable layer water regime (due to decreasing of layer capacity, increasing of evaporation, and internal soil down-tending streams at the plow pan boundary);
- frequent dry periods and crusting due to greater contrast of wetting and drying regimes and loss of calcium from absorbing complex in arable lands.

Physical degradation deteriorates water, air, and gas regimes, conditions for vital functions of different cenoses, renovation of organic matter, decreases harvest, efficiency of fertilizers and irrigation water, decrease soil resistance to destructive influence of water, wind, contaminants. This is why physical degradation and, particularly, soil compaction should be taken into account in the system of soil conserving measures and generally in the concept of sustainable land use.

To determine content of optimal strategy of ecologically restorative and productive soil functions, we made an expert estimation of actual situation. Sustainable land use in the Ukraine could be possible if the following problems would be solved gradually:

- elimination of soil degradation;
- improvement of soil properties and lands optimization in accordance with their ecological restorative and productive requirements;
- stabilizing of soils optimal parameters.

Elimination of soils degradation (and first of all, physical degradation) could be achieved if conditions enumerated in the Table 3 would be fulfilled.

Conclusions

1. Compaction of root layer and deeper soil layers became irreversible; it is one of the reasons of wide spreading of physical degradation and other kinds of degradation of Ukrainian arable lands having numerous negative consequences for ecologically restorative and productive functions of soil.
2. Optimal strategy of lands restoration was substantiated; without fulfillment of the strategy transition to the sustainable land use and stable development of the country is impossible.

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Table 1: Average values of properties of virgin chernozems and chernozems that have been tilled for a long period (soil layer 0 - 30 cm; differences between virgin and arable land are reliable within the confidence interval 0.95)

Condition	Equilibrium bulk density, g/cm^3	Dry aggregates content, %	Content of water resistant aggregates >0.25mm,%	Water permeability, mm/h	Humus content, %	pH_{KCl}	Soil loss due to water erosion, t/ha/year
Virgin land	1.13	80	53	71	4.8	5.9	0
Arable land	1.27	66	31	55	4.2	5.3	12.8

Table 2: Parameters of arbitrary optimal and actual soil cultivating technologies (average data for the Ukraine).

Parameters	Soil cultivating technologies	
	optimal	actual
Application of organic fertilizers, t/ha per year	10 - 12	<5
Application of mineral fertilizers, kg/ha per year	200 - 250	<50
Quantity of mechanical operations, machines passage/ha of row crops area per year	5 - 7	20 - 25
Quality of soil cultivating operations execution, mark	10	3
Pressure applied to soil by mobile aggregates, kg/cm^2	0.5 - 1.0	1.5 - 2.5

Table 3: Quantitative expert estimation of the investment policy for elimination of soils physical degradation and soils restoration.

Priority	Measure	Percentage from the whole amount of investment, %
1	Construction and reconstruction of vehicles and devices in accordance with permissible pressure to the soil	35
2	Reorganizing of lands structure, agricultural lands, crop rotations	25
3	Following to the scientifically substantiated technologies and standards of land cultivation, agrochemicals application, management requirements	25
4	Promoting of promising technologies (minimum tillage, structure formers, plant growth stimulators, evaporation depressors, etc.)	25

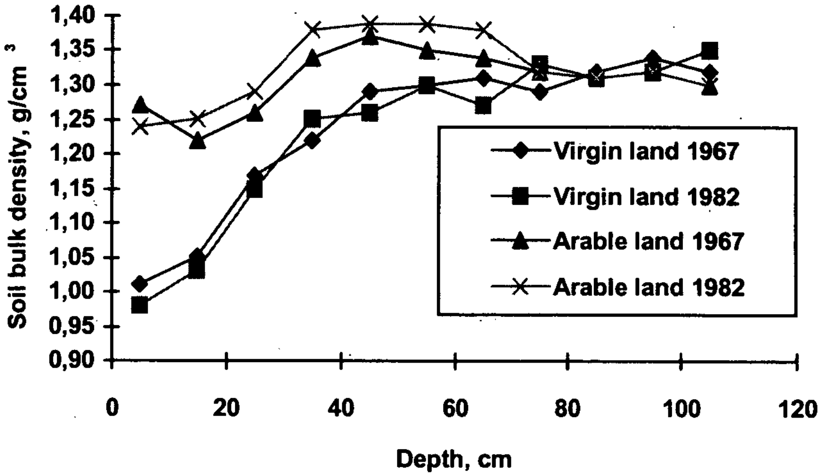

Figure 1: Bulk density of southern chernozem in the virgin and arable conditions (Askania-Nova, Khersonskiy region, 1967 and 1982 years)

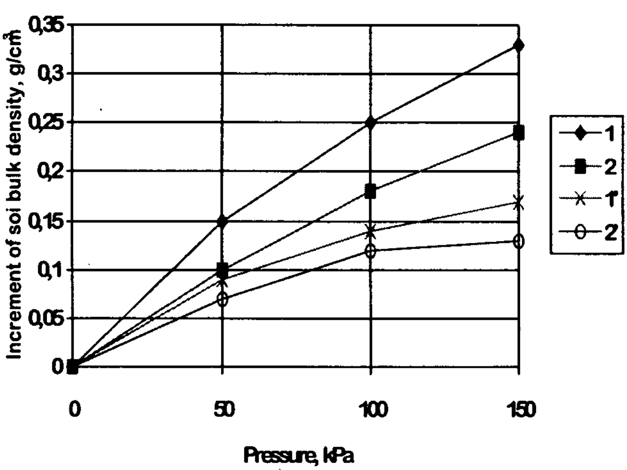

Figure 2: Relation between bulk density increments and pressure at optimal soil tilth within the layer 0 - 10 cm: 1 - typical chernozem, arable; 1' - typical chernozem, fallow; 2 - southern chernozem, arable; 2' - southern chernozem, fallow. All soils have heavy granulometric composition.

STUDY ON THE GENESIS OF MUDHUPUR TRACT OF BANGLADESH

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INTRODUCTION:

Mudhupur Tract occupies the major portion of an area bounded by four rivers, the Padma, Jamuna, Brahmaputra and Meghna covering an area of about 41,000 sq. km and is always above the riverine floodplain. The Mudhupur tract appears as a terrace landscape, but in fact, represents a series of fault blocks (Khan 1965). The parent clay is remarkably homogeneous over a great distance suggesting that the sediments were laid down under stable marine or tidal condition (Brammer 1964).

This area lies under the influence of tropical monsoon climate with an average rainfall of 73.79 inches of which 68.69 inches fall between April and October and 3.63 inches in February and March. The rainfall is the highest towards the end of the Monsoon season in August. The mean annual temperature is 77.9 F.

The native vegetation comprises weeds and shrubs of bhart, bantulshi, sheworah and native grass species. Mango, (Mangifera indica L), Jackfruit, (Artocarpus heterophyllus Lamk), Guava, (Psidium guajava L.) Palm, (Boressus flabelifer), Sal (Shorea robusta) and other trees are found scattered throughout the area.

The objectives of the present work were to (a) study some physical, chemical and mineralogical properties of the soils of Mudhupur tract (b) evaluate the process of soil formation and (c) assess the extend of pedogenic weathering in this soils.

MATERIALS AND METHODS:

Mechanical analysis was carried out by the Hydrometer method. Organic carbon was determined by wet oxidation method of Walkley and Black (Jackson 1961). Particle density and Bulk density of the samples were analysed by Pycnometer method as described by Black (1965). pH measurement was carried out by a Pye pH meter. Cation exchange capacity was determined by the Ammonium acetate method as described by Jackson (1961) and exchangeable cations determined from the same extract using a Unicam flame spectrophotometer. Free iron and free Aluminium oxides were determined according to the method of Kilmer (1960). Fusion analyses of whole soil, silt and clay fractions were carried out after Piper (1950). Iron and aluminium were determined colorimetrically by developing orange colour with a-a dipyridyl and duminon Chapman and Pratt (1961) respectively. Total calcium, magnesium and potassium were determined by the flame spectrophotometer.

RESULTS AND DISCUSSIONS:

The particle density remains more or less constant with depth. The surface has lower values of particle density than the subsoils. The values range from 2.62 to 2.72. The bulk density range from 1.20 in the surface to 1.74 at the subsoils.

The soil pH of Mudhupur tract varies from 4.7 to 4.9. The organic matter contents vary from 0.24 - 2.12% in these soils. The organic matter content decreases with depth. The soils have the total cation exchange capacity ranging from 8.64 to 12.04 me%. Percent base saturation varies between 32.65 to 55.43 in the soils. The exchangeable metal ions varies from 4-6 me% of the soils. The vertical distribution pattern shows a fair constancy in the soils. Since the potassium oxide content was analysed with Na-saturated clay, it may be assumed that the potassium present in the clay fraction are all inside the lattice structure of minerals. In the present investigation, K_2O has been taken as the basis for calculating the illite present in soils. The review of geological history of the Mudhupur tract leads us to say that all the soils from a heterogeneous parent material of the pleistocene age which was of mixed origin. The following important characteristics of the soils in question were measured thoroughly to classify the soils.

a) Grey friable A horizon of loamy texture.
b) Reddish clays B horizon with pockets of bluish white clay materials.
c) Presence of innumerable red iron concretions throughout the whole with a preferential accumulation in the B horizon.
d) Presence of mottling in the C horizon.
e) Profile leached of alkalis and alkaline earths.
f) Accumulation of clay in the surfaces with the maxima in the subsoils.
g) Reaction moderately acidic (pH 4.7- 4.9).
h) Presence of free oxides of iron and aluminium throughout the profile.
i) Very low cation exchange capacity varying between 10. About 50% of the reaction exchange position are occupied by pH ions i.e., the colloidal complex is considerably base unsaturated.
j) Silica-sesquioxide ratio of clay varies from 1.08 - 2.23.
k) Silica-aluminium ratio of clay ranges from 1.3 - 2.9.

The above characteristics indicate that the soils may be classified the `Lateritic' group. The presence of red iron concretions throughout the profile is a `Lateritic' criterion. The soils underlies the effect of monsoon climate which is a variant of the warm humid tropical climate in which soils belonging to the groups Laterite, Lateritic, Red loam, Red earth, Yellow earth, Brown earth, dark colour soils, etc. are found to occur. The soils in question may belong to any one of the above groups. The movement and distribution of iron oxide in a soil profile have long been counted as the most significant indices in soil genesis and classification.

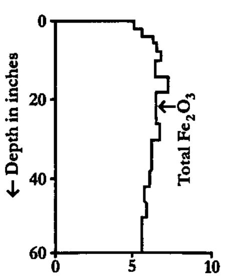

Fig 1. % Fe_2O_3 in soil

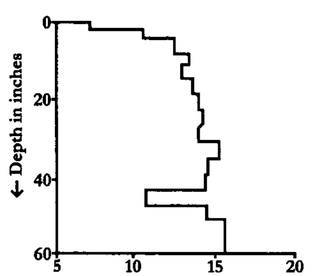

Fig 2. Al_2O_3 % in soil

The distribution pattern of free iron oxide in the successive depths in soil shows an illuviation which points out that the soils have gone slight podzolization. Free iron oxide content in different depths varies considerably (Fig 1). The movement of manganese and ist distribution are never the less significant criteria to characterize a pedogenic process as it behaves in general like the other sesquioxides consitutent. There is a subsoil accumulation of MnO in the soils. It is interesting to note the content decreases from the surface down to a depth of 6 inches showing a definite surface accumulation, which may be considered as a sign of laterization. Again the high accumulation of MnO in the subsoils might have been inherited from the parent material. Total aluminium oxide of the soils shown (Fig 2) an increasing trend with depth following a fall, indicating a pronounced mark of eluviation and illuviation. It is a sign of podzolization. The silica -sesquioxide ratio of clay fraction of the soils varies from 1.08 - 2.23; and the silica - alumina ratio from 1.3 - 2.9. Both the ratios show a fall with depth following a rise. In consideration of the silica - sesquioxide and silica - alumina ratios of the soils under the investigation, it can be suggested that the soils belong to the lateritic group.

From mineralogical analysis it appears that there is abundant feldspar and less mica present in the sand fraction of these soils. In view of higher percentage potassium in the soils, it may be said that they are probably primary and secondary silicate minerals in soils. There is downward increase of potassium oxide, presumably as a result of aulthigenic origin of potassium bearing minerals. From concluding data it assume that there is abundant kaolinite and illite minerals in the clay fraction. The amount varies from 35 to 48% and 26 to 52%, respectively. The clay fraction also indicates that the 2:1 layer lattic minerals present abundantly, are probably of trioctahedral types. The cracks that developed in the dry season in these soils indicate that the soils probably have a 2 : 1 type expanding lattic secondary silicates minerals like as montmorillonite and vermiculite. The irregular distribution of illite suggests the alluvial nature of parent material of the soils of Mudhupur clay.

CONCLUSIONS:

The investigation deals with physical, chemical, mineralogical and consequently the pedological studies of the soils of the Mudhupur tract.

Colour of the soils are in different shades of grey to dull-red colour. Both the soils are clayey textured below the surface. Red iron concretions occur throughout the whole profile in the soils.

The parent materials in the soils have been found to be homogeneous both in texture and chemical composition as evident from the fine sand coarse sand ratio and mean percentage of clay and also from the chemical analyses.

The soil reaction is strongly acidic. The organic matter content falls steadily with depth showing a surface enrichment. The low organic matter content is a consequential to the extreme mineralization that occurs under the tropical sun. The presence of free iron oxide and enough aluminium oxide ensuring the exixtance of free alumina in surface horizon indicates a lateritic sign. They also may be grouped under the order oxisols. In considering the findings of both field and laboratory investigation, the soils in question have tentatively placed in the leteritic group of soils.

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INTERACTIONS BETWEEN THE SOIL, SOIL-ECOLOGICAL UNITS AND LAND CAPABILITY OF THE DANUBIAN LOWLAND

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1. Introduction

There exist many examples that soils with identical or very similar morphogenetic features occur in markedly dissimilar sites. It is also known that in many books of soil science is stressed the interrelation among soil, vegetation and other ecosystem factors. Less frequently is cited the statement of Tüxen (ex Zonneveld 1966), that "any property of the land not indicated by vegetation is not of practical importance". The indicator value of the vegetation is a realistic one, because the starting point is the living vegetation, which is wholly determined by all factors of the natural environment in time as well as in space (Zonneveld 1966).

Based on the long-term stationary field observations of interactions between soil and vegetation units on Danubian Lowland we came to the conclusion that the "Chernosem-like soils" or "tschernosemartiger Auenböden" on alluvial plains of the forest zone can neither be identified with the meadow soils of the steppe zone, nor with Chernosems of the loess hills. These "Chernosem-like soils" of Danubian Lowland, denominated as "Chiernicas" (Gleyic and Haplic Phaeozem), did not originate by successive drying up of the Anmoors, but are products of the intensive formation of mull humus in semi-hydromorphous conditions of the Ulmion forest associations (Dzatko 1972, 1974).

If we admit that in morphogenetic soil classifications were are such relationships taken into consideration, in reality the vegetation units structure, particularly crop production on the same soil units is not always the same. And just here is an open question - in what rate are soil unit properties decisive factor of phytomass production. In correspondence with Kubiena (1958) "the knowledge of the genesis of property is very important in systematic since only by this can a property or a unit of properties be fully known and understood".

2. Materials and Methods

The starting basis for the polyfactorial analysis of the relationships between the environment properties and crop yield is the System of Pedo-ecological Units (PEU) of Slovakia, which have been outlined and mapped on the basis of soil properties, climate and relief. The pedo-ecological units are defined as homogenous land units having own specific properties and productivity potential. In the framework of PEUs, the following hierarchy of topical and regional units from Basic Pedo-ecological Units (more than 8 000 BPEUs), through 430 Main Pedo-ecological Units (MPEU) to 80 Pedo-ecological Regions (PER) and 4 Pedo-ecological Areas (PEA) have been distinguished (Dzatko et al., 1973, 1995).

The BPEUs represent combination of 11 agro-climatic regions (T), 37 genetic soil sub-types (P), 19 parent material groups (G), 4 soil textural categories (Z), 6 terrain sloping categories (S), 4 skelet content categories (K), 3 soil profile depth categories and 4 territory exposition categories (E). All the BPEU have been mapped in the scale 1 : 5 000. They have obtained official recognition also from economic and legislative aspects for both the soil evaluation and land use.

Quantitative assessment of the soil and PEU capability is based on the factorial and multiple non-linear regression analyses of the relationships among the real yields in 1979 - 1985 and PEU properties on the 476 homogenous fields. For these purposes the programs of factorial analysis BMDP 4M and consecutive step non- linear regression BMDP 2R (Dixon, 1975), purposefully modified by Marko have been used (Dzatko, Marko 1985).

3. Results and Discussion

In Table 1 are presented only summary data on spatial and temporal winter wheat yields differentiation, as well as maize on selected Main Pedo-ecological units of Danubian Lowland for period 1981- 1985. Can be stated that in this way obtained and evaluated data are only confirming, not concretizing real dependencies between yields and soil, or PEUs properties. They can be more detailed ascertained only based on factorial analysis. In given case (Table 2) the main pedo- ecological components (T, P, G, Z, S, K, H) are divided into three cofactors F1 - F3. It is logic that the factors influence on wheat and maize yields are not the same.

Table 1. Average crop yield indexes on selected Main Pedo - ecological Units of Danubian Lowland in 1981 - 85.

Climate Region	Soil unit (P)	Texture (Z)	Wheat (in %)	Maize (in %)
T 1	02 Calcaric Fluvisol	medium	100	92
T 1	19 Calcaric Phaeozem	medium	99	98
T 1	20 Calcaric Phaeozem	heavy	99	100
T 1	17 Haplic Phaeozems	medium	95	94
T 1	37 Calcic Chernozem	medium	90	92
T 2	39 Luvi-haplic Chernozem	medium	93	88
T 2	44 Haplic Luvisol	medium	95	86

Table 2. Rotated factorial schemes and their shares in %

	Wheat				Maize		
	F1	F2	F3		F1	F2	F3
T	0.87			P	0.82		
P	0.76			T	0.81		
Z	0.64			Z	0.65		
K		0.85		H		0.92	
H		0.81		K		0.91	
S			0.72	S			0.75
G			0.65	G			0.67
	38.8 %	32.3 %	27.9 %		37.8 %	36.4 %	25.8 %

In next step the original set of factors by pH, available nutrients, fertilizer rates and precipitation dynamics have been extended. In given case the new set of 18 factors have been divided into seven cofactors F1 - F7, which have different influence shares on yields. As limited extent of this paper does not enable whole factorial schemes to be documented, in such case we are pointing out only verbally on the fact that into the cofactor F1 for wheat were incorporated basic soil properties H, K,P, however at maize as F1 and F2 is the precipitation dynamics. Soil properties influence, as H,P,K, on maize yields was confirmed only as F3, or lower. Based on in this way obtained data we can specify more detailed the state how these mutual relationships are changed not only in space, but also in dependence from weather dynamics in time.

This paper objectives are based on the knowledge that the influence of individual soil property, e.g. texture, or soil profile depth in other factorial combination, is not the same.

4. Conclusions

Based on presented results, is preferred approach that consistent interpretation of ecological methods in soil science requires to analyze not only partial soil properties, but also their interactions with other environmental components. In this aspect we see next perspectives of soil science in obtaining more complex information on interaction between the soil and other landscape components and vice versa the landscape components influence on soil properties changes.

Such point of view does not reduce significance and functions of present soil classifications which were developed on the gradual findings evolution. In this aspect we want to indicate that in the future soil classifications have to be more expressed regional and capability aspects which are functions of the all land components in space and time. In this aspect most suitable indicator of real differences in space is natural and present vegetation. One of the approximation of such classification is also the System of Pedo-ecological Units that is fully accepted in remaining scientific disciplines and practice in Slovakia.

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NUTRIENT CONTENTS EVOLUTION IN SOILS AND LEAVES IN ATLANTIC OAK STANDS IN GALICIA (NW SPAIN)

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Introduction

The most important factor which affects evolution of Galician soils is the climate. The high precipitation causes horizon differentiation in an inverse proportion with the slope of the soils (Bará, 1990).

Quercus robur L. is the most abundant deciduous broadleaf tree in Galicia. The oak forests with *Quercus robur* and *Quercus petraea* are the formations climax which extend from sea level to elevations of 1.400-1.500 m, in the region (Silva-Pando & Rigueiro, 1992). These types of oak forests need deep and fertile soils to grow in good conditions.

Soil properties in oak forests are oligotrophic or mesotrophic when the substrate is acid, being similar to those of pine and eucalyptus stands (Bará *et al.*, 1985). The C/N ratio is quite high and the saturation percentage very low. The pH is acid, and exchangeable ions (K, Ca and Mg) are low compared to those of pine and eucalyptus forest soils. Phosphorous content in oak forest soils is high, and for its level it is considered abundant (Bará *et al.*, 1985; Díaz-Maroto, 1997) (Table 1).

Carbon content in *Quercus robur* leaves is low when compared with other tree species abundant in Galicia such as *Pinus pinaster* and *Pinus radiata* (Carballas & Guitián Ojea, 1966; Díaz-Maroto, 1997). C/N ratio are higher in *Quercus robur* leaves. Despite of these higher concentrations in foliage elements and a higher annual leaves-fall, annual inputs of elements in conifers soils are usually higher that in *Quercus robur* stands soils, with the exception of Calcium (Díaz Fierros *et al.*, 1982).

In this study, the soil and foliar nutrient contents in two oak forests are shown. We also analyzed the correlations between these two parameters as a consequence of nutrient translocation between tree canopy and soil through litterfall.

Materials and Methods

The study area is located in the NW Península Ibérica, in two oak stands in Cerceda (A Coruña) and Lourizán (Pontevedra). Both stands are close to the Atlantic Ocean, with more maritime influence noticeable in the Lourizán location.

The type of vegetation is denominated as *Rusco aculeati-Quercetum roboris* Br.-Bl., P. Da Silva and Rogueira, 1956. The Lourizán stand is mainly *Quercus robur* mixed with some isolated *Castanea sativa* and *Robinia pseudacacia* trees. The Cerceda stand has *Quercus robur* and *Castanea sativa* as the most representative species with also some *Betula celtiberica* trees (Díaz-Maroto *et al.*, 1993; Díaz-Maroto, 1997). Both stands are on an acidic substrate, granite in Cerceda, and gneiss in Lourizán.

The soil samples were collected every month and the leaves every two months. Three plots were established per study area. Soil samples were collected at 20 cm of depth; for the analysis we used a representative aliquot from a composite of the material collected in all three plots.

Results and Discussion

Organic matter percentage was higher in the Cerceda stand. The macronutrients content is similar in both stands, except for Ca and P levels which are higher in the Lourizán stand (Table 2) (Díaz-Maroto, 1997). Our results are not very different from those reported by Bará *et al.*, (1985) (Tabla 1).

The seasonal fluctuations of soil nutrients were similar in both locations. We found a decrease in K, Ca and Mg levels, related with changes in meteorological conditions, long rainy periods affected in terms of elements losses, because of percolation and runoff.

The dynamics of nutrients in an ecosystem are related with the annual meteorological conditions (Claridge, 1975). Díaz-Fierros *et al.*, (1982) have reported higher decreases of C, S, N and Al when compared with other elements in pine stands. They reported higher decreases of Ca, Mg, Na and K in oak forests similar to our results.

Conclusions

The pH values, organic matter content, total N and C/N ratio, did not indicate noticeable seasonal fluctuations. Potassium levels showed slight variations throughout the year with a small decrease in summer. Seasonal fluctuations were more noticeable in Ca with decreasing levels also in summer. The cycle of Mg is influenced by atmospheric inputs.
Phosphorous did not follow a seasonal pattern but showed fluctuations throughout the year.

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Table 1. Soil mean composition under *Quercus robur* stands (Bará *et al.*, 1985)

Depth	C %	M.O. %	Nt %	C/N	pH	K_C (ppm)	Ca_C (ppm)	Mg_C (ppm)	P_{II} (ppm)
0 -20 cm	6,64	11,16	0,386	17,2	4,71	116	187	81	24
$\sigma_{(n-1)}$	0,38	3,30	0,140	2,7	0,18	25	219	46	44

Table 2. Soil surface (20 cm) mean composition

Mean composition	LOURIZAN		CERCEDA	
	0-20 cm	$\sigma_{(n-1)}$	0-20 cm	$\sigma_{(n-1)}$
C %	5,04	1,75	12,66	0,69
M.O. %	8,69	3,02	21,82	1,19
Nt %	0,289	0,052	0,802	0,037
C / N	17,1	2,9	15,8	0,2
pH	4,55	0,14	4,25	0,11
K_C (ppm)	103	6	143	21
Ca_C (ppm)	212	133	73	37
Mg_C (ppm)	53	29	76	8
P_{II} (ppm)	12,5	3,4	6,6	0,4

Table 3. Mean composition of *Quercus robur* leaves.

Mean composition	LOURIZAN		CERCEDA	
	0-20 cm	$\sigma_{(n-1)}$	0-20 cm	$\sigma_{(n-1)}$
Nt %	2,425	0,196	2,605	0,515
K (ppm)	8.657	1.498	8.860	2.008
Ca (ppm)	8.405	2.998	5.915	951
Mg (ppm)	1.315	353	1.672	363
P (ppm)	1.852	280	1.607	704

ALTITUDINAL VARIATION OF SOIL NITROGEN IN OAKWOOD STANDS (GALICIA, NW SPAIN)

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Introduction

Nitrogen is essential for plants in the soil of forest ecosystems. The ratio between different forms of this element in the soil, is a limitant condition for its availability. The presence of inorganic forms of N is affected by soil conditions such as: pH, temperature, moisture, mycorrizae and other microorganisms; conditions of the cover type such as: species sustained, light interception, quantity and quality of vegetation debris; and other environmental conditions, for example, relative humidity, temperature, precipitation, seasonality.

The influence of topographical characteristics on the presence of different forms of N in the soil of forest ecosystems is one of the least known issues in ecology. Several studies have been conducted on the effects of elevation on soil nitrogen content and litter decomposition, producing a gradient that implies differences of species established at different elevations (Narain *et al.*, 1989; Tavant *et al.*, 1989; Garten *et al.*, 1991; Alexander *et al.*, 1993;).

Other works such as Zak *et al* (1991) have studied N mineralization and nitrification processes in a stand of *Quercus ellipsoidallis* E.J.Hill to search for the influence of elevation on the spatial variability of N transformations.

The objective of this study is to determine the influence of elevation on the spatial variability of N and its inorganic forms in oak forests (*Quercus robur*) in Galicia, and to establish the relatioships between the studied factors.

Material and Methods

The study was conducted during October of 1995. The study area was a transect crossing the province of Pontevedra (Galicia) from North to South, with locations equidistant from the Atlantic Ocean. Three plots were established at each location.

Three soil samples were collected from the 0-20 cm horizon, for each plot, to then obtain a composite sample per plot. These were taken immediately to determine soil moisture content in a laboratory furnace at 105°C during 5 hours. A 10 g fresh soil fraction was extracted with ClK 2M to determine $N\text{-}NH_4^+$ using the Blue- Indophenol method (Kempers, 1974 & Keeney and Nelson, 1982) and $N\text{-}NO_3^-$ by reduction to nitrite through Cupperized-Cadmium columns (Keeney and Nelson 1982). Inorganic nitrogen is interpreted as the sum of both ionic forms. The remaining fraction was air-dried, sieved through a 2 mm mesh and grinded for N determination using Kjeldahl semi-micro method.

The locations were classified by elevation. Low elevation for plots at less than 400 m over sea level, and mid-high elevation for plots between 400 m and 600 m.

To study the effect of elevation and location on the concentration of nitrogen compounds, one-way analysis of variance was used. The same was applied to test the effect of location. In both cases, an α of 0.05 was considered. Simple linear regression was used to correlate chemical parameters with elevation.

Results and Discussion

The parameters studied have been total N, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ and soil moisture.

We found significative differences between the parameters studied depending on the location except for nitrate. We also obtained significant differences between different elevation levels in total N ($p= 0.049$), amonia levels ($p= 0.045$) and inorganic N ($p= 0.042$). This fact implies altitudinal variations in total N and its inorganic fraction, mainly the amonia form. Nitrate concentration showed typically low values during autumn (Rozados *et al.* 1997), and no differences were found between elevation levels. (Figure 1-I).

$N\text{-}NH_4^+$ content was higher in the stands located in valleys than those located on hills, according with findings reported by Garten *et al.* (1994). Narain *et al.* (1989) obtained higher values of total N and organic matter percentages in high elevation areas.

Moisture content was similar for all the stands. (Figure 1-II).

Elevation and total N were possitively correlated ($R^2=0.7049$, $p\leq0.05$) (Figure 2). Total N levels had significantly higher percentages with elevation, probably due to lower mineralization rates of organic N. The temperatures are lower at higher elevations, during the fall. This may inhibit microbial activity and slow down mineralization, particulary amonification processes, and would favour the presence of stable organic compounds that contribute to an increase in total N.

On the other side, in valleys and lower elevation ranges, a microclimatic regime of mild temperatures, less estival drought and higher nutrients availability through runoff, help to mineralization processes. As a consequence, soil increase mineralization activity, there are more available inorganic N compounds to assimilate by trees, and total N levels decrease.

The locations classified as mid-high elevation in our study covered a limited range of native stands of *Quercus robur*. These trees endure a slight estival drought regarding soil moisture, but with still adequate levels of atmospheric humidity. Additionally, mineral N content contributed by litter decomposition presents acceptable values. Because of the good conditions for oak growth at more than 600 m above sea level we consider that the range studied was too narrow for the higher elevation class, and we suggest the inclussion of stands established at higher elevation, in next experiences.

Conclusions

The effect of elevation was significant on total N content, inorganic N concentration and extractable $N\text{-}NH_4^+$ levels, in oak forest soils of Galicia.

The possitive linear relationship found between total N content and elevation is related to microclimatic factors which are linked to organic matter decomposition.

Including higher elevation locations maybe neccesary in future experiences to test oaks behaviour in that conditions.

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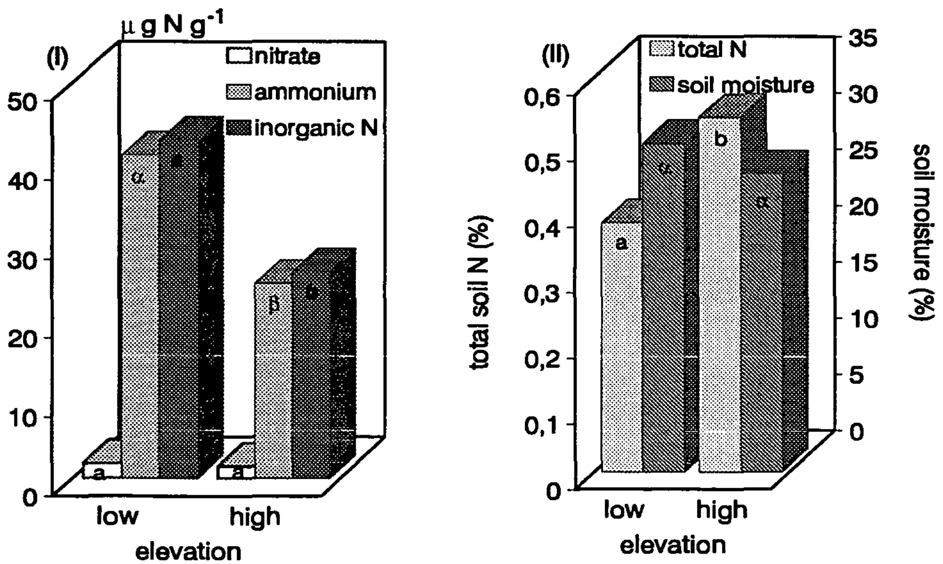

Figure 1.- Mean extractable soil N-NO_3^-, N-NH_4^+ and inorganic N concentrations (I) and total N and soil moisture (II) in different elevations. Different letters within the same letter type mean significative differences between altitudinal levels.

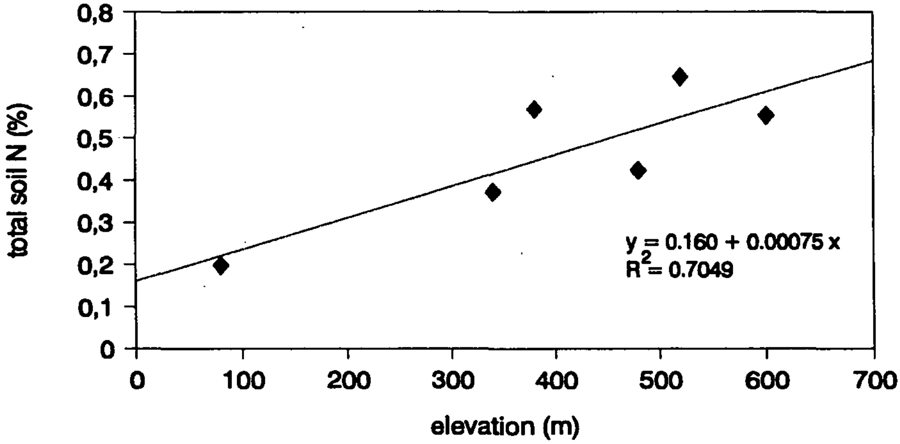

Figure 2.- Relationship between elevation and mean total nitrogen in mineral surface soils (0-20 cm) from experimental plots.

ALTERNATIVE PARADIGMS FOR MODELLING SOIL SYSTEMS

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1. Introduction. The soil is not an ideal medium for modellers. It is heterogeneous and spatially variable, and the water, solutes and gases it contains interact with each other and with the rest of the environment through complex and often non-linear processes. Some modellers have responded to this challenge by producing complex and non-linear models, but these run into two problems. The model's complexity often results in a demand for parameters and other input data that exceeds the capacity of the user to provide reliable information. The non-linearity can lead to errors unless allowance is made for its interaction with the parameter variances (Addiscott, 1993).

Planners and policy-makers are showing increasing interest in the use of models in decision-support systems to help in the attainment of environmental objectives. This often implies the use of models at scales other than those at which they were developed and evaluated, which raises questions of validity of use. The problem of scale also interacts with the problems of complexity, non-linearity and spatial variability, making some models difficult to use over large areas. Alternative paradigms for soil systems may help in resolving some of these issues, and some are discussed below.

2. Putting models into context: The Hoosbeek and Bryant (1992) Scale Diagram. The Scale Diagram is not a new type of model but a very useful framework for defining which model is appropriate at a particular scale. It was developed in the context of pedogenesis, and it comprises a hierarchy in which the pedon is the *i*th or base level and other levels are defined with reference to it. The hierarchical levels go from (i - 4), the molecular level, to (i + 4), that of the region. Each level comprises a plane within which model attributes are placed between *mechanistic* and *empirical* on one axis and *quantitative* and *qualitative* on the other. Other axes could be used in different contexts. For solute leaching, for example, the classification of Addiscott and Wagenet (1985) should be placed between *mechanistic* and *functional* on one axis and *deterministic* and *stochastic* on the other.

The Scale Diagram raises some interesting questions that are discussed elsewhere (Addiscott, 1997). Do models retain their positions in such classifications regardless of the hierarchical level, or does a model become more or less mechanistic, for example, if it is used at a higher or lower hierarchical level? Does an evaluation of a model made at one hierarchical level remain valid at another? When, during upscaling, units at one hierarchical level are aggregated to form a unit at the next level up, is the whole just the sum of the parts, or is it something more? The hierarchical levels defined by Hoosbeek and Bryant (1992) include peds, profile horizons, pedons, fields and catchments, so these questions are strongly relevant to soil scientists.

3. Decoherence. The levels of determinacy associated with different levels in the Scale Diagram lead us conveniently to the concept of decoherence (Stewart, 1995). The idea arose from consideration of the Solar System, which behaves in an entirely determinate Newtonian way, and the atoms of which it is made up, whose constituent particles obey the laws of chance. Decoherence is the term used to describe this loss of determinacy by large quantum systems. It should be a useful concept for soil modellers and others who deal with processes at different hierarchical levels and who are faced with the problem of upscaling models. One of its implications is that large areas of land should behave in a more determinate and therefore more predictable way then small areas, and this is supported by studies on denitrification (Corre et al.,1996).

4. Entropy. Soil scientists have used thermodynamic models since the time of Schofield (1935,1955), mainly to describe the behaviour of water or nutrients. Schofield used classical thermodynamics and was therefore concerned with processes that tend towards equilibrium, that is, maximum entropy. Equilibrium can be achieved only in a thermodynamically *closed* system that cannot exchange matter with its surroundings, although it may exchange energy with them. Shapiro (1953) and Tribus (1961) have argued that thermostatics is a better term for such systems than thermodynamics, because no dynamics is involved. Soil in its natural state clearly exchanges both energy and matter with its surroundings. Heat, kinetic and chemical energy may be involved, as may water, carbon dioxide and nitrate, to mention but three forms of matter. It is therefore dynamic and an *open* system in thermodynamic terms, one that does not come to equilibrium. Prigogine and Stengers (1984) defined three stages in thermodynamics, thermostatics, linear thermodynamics and far-from-equilibrium thermodynamics. Only the two latter stages are relevant to soils. The question of how far a system is from equilibrium is a difficult one, but one that is relevant because the two levels of non-equilibrium have differing implications (Çambel, 1993).

4.1. Linear thermodynamics. The terms 'linear,' 'near-to-equilibrium' and 'irreversible' seem to be interchangeable in the thermodynamic context. These thermodynamics are *linear* because they apply to systems in which the flows are linearly related to the forces, as in diffusion or the conduction of heat and electricity. The basic theory was developed by Onsager and its fundamentals are incorporated in his celebrated *reciprocal relations* (Onsager, 1931). Katchalsky and Curran (1967) gave an account of its application in biology, and Addiscott (1995) used it to define the sustainability of ecosystems in terms of the minimization of the rate of entropy production. The latter paper recognised the importance of the capacity for self-organization and related this to the biological potential. We probably need to turn to far-from-equilibrium thermodynamics to define self-organization further.

4.2. Far-from-equilibrium thermodynamics. In many dynamic systems, the flows are not linearly related to the forces and are sensitive to small changes in them. Such systems can easily move far from equilibrium, and are therefore described by far-from-equilibrium thermodynamics. This state has interesting consequences, explored by Prigogine (1947,1980), that include chaotic and complex behaviour and the capacity for self-organization.

5. Chaos. Chaotic dynamics is a consequence of mathematics itself and can appear in many physical systems (Rasband, 1990). It has nothing to do with random behaviour. A chaotic system evolves in a deterministic way, with the current state of the system depending unequivocally on the previous state. Chaos always arises from non-linearity in the system, but this not the only factor needed. The system has also to have more than one degree of freedom, that is, be non-autonomous. A feed-back loop is a common cause of chaotic behaviour. There are a number of manifestations of chaos. Of these, fractals have probably made the biggest impact in Soil Science, but Phillips (1994) has discussed the role of chaos in the development of landscapes.

6. Complexity. Complex systems evolve at the border between order and chaos, and they are characterized by the phenomena of emergence and self-organization. A key feature of an emergent system is that the whole is more than the sum of the parts. In this respect, the soil is surely an emergent system, very much more than an assemblage of mineral, organic and living matter. If we consider the hierarchical levels discussed above, we shall probably find emergence at all levels from the soil aggregate to the catchment.

7. Integrating the paradigms. Several concepts, including non-linearity, determinacy, scale, self-organization and the idea that the whole may be more than just the sum of the parts, are common to more than one of the sections above. They should, in conjunction with the two non-equilibrium stages in thermodynamics, form the links that help us to integrate the paradigms discussed above and use them to provide new ways of interpreting the behaviour of soils at different hierarchical levels.

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USING ICBM, THE INTRODUCTORY CARBON BALANCE MODEL, TO VIEW SOILS AS SIMPLE SYSTEMS

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Introduction

We present a minimum model that can be applied using a 30-year time perspective, with one-year time steps. Our aim was to only include processes that are absolutely necessary and comparatively well-known. On the other hand, the generation of parameter values for the model can be as complex as warranted and possible. For example, the annual input of carbon to the soil could be based on thorough research of annual surface and root litter input, including root exudates - or simply be the best available guesstimate, based on data on regional crop production, etc.

In a first paper we have described the model and suggested some basic principles for parameterisation (Andrén and Kätterer, in press). In a second paper we intend to validate the model using data sets from Northern European agricultural field trials, as well as develop stricter, possibly partly automatic, procedures for parameterisation.

As a test application, ICBM will be used as an instrument for predicting soil carbon balances in Swedish agricultural land. The country is divided into regions according to climate, soil and cropping system, and a strategy for parametrization for different regions is under development. It is our hope that the model will also be used for other estimates of soil carbon dynamics; for example, the Swedish regions could be replaced with any number of regions anywhere in the world.

Materials and Methods

The first model assumption is that two pools (young, Y, and old, O) of soil carbon are sufficient (Fig. 1). Second, outflows from the pools follow first-order kinetics (k_1, k_2). Third, external (mainly climatic, but also edaphic) factors can be condensed into one parameter, r, which affects the decomposition rates of Y and O equally. The parameter r does not affect the 'humification coefficient' (h), i.e., the fraction of the annual outflux from Y that enters O. Note, however, that h can be set differently depending on variation not only in litter quality but also external factors. For instance, for a given litter the value assigned to h in sandy soil could be different from that in a clayey soil. Fourth, mean annual carbon input to the soil can be described by one parameter, i.

Due to the model's simplicity, the differential equations were solved analytically, and parameter optimisations can be made using generally available non-linear regression programs. The calibration parameter values were derived from a 35-year experiment with arable crops on a clay soil in central Sweden. Model equations and model code (SAS, Excel, Visual BASIC) can be downloaded from *http://jordek10.eom.slu.se/olle/ICBM.html*.

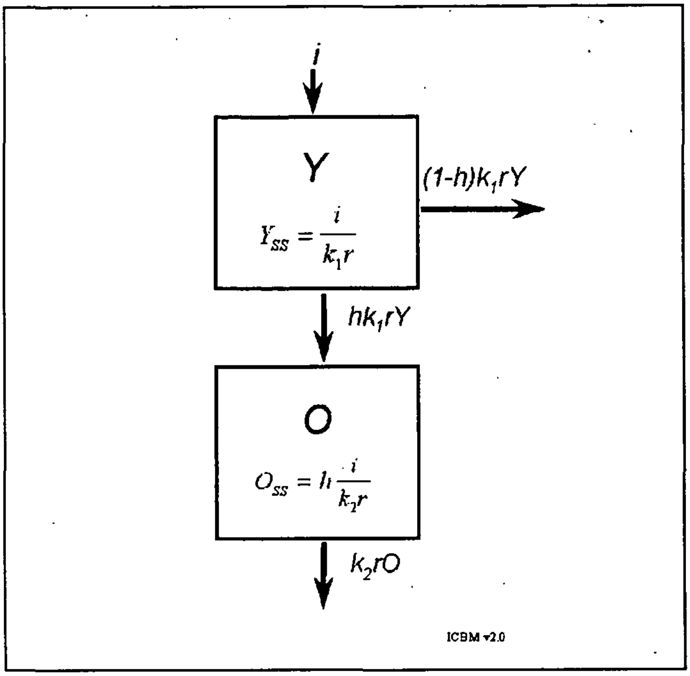

Figure 1. The ICBM model. Y_{ss}, O_{ss} = steady-state equations for the young and old pools, respectively. See text for further explanation. (From Andrén and Kätterer, in press).

The model was also applied to data from long-term agricultural field experiments in Northern Europe, including experiments with continuous bare fallow, varied levels of manure and fertiliser addition as well as crop rotations with different frequencies of grass ley etc. (Kätterer and Andrén, in manuscript). Another application of the model was to extrapolate observations made in short-term experiments with and without soil fauna to a 30-year time perspective (Andrén et al., in manuscript).

Results and Discussion

The model has been parameterised for a number of treatments, soils and climates, and has successfully reproduced the system behaviour in a 30-year perspective. For an example of parameter settings for various treatments see Table 1. It seems that the description of soil carbon dynamics does not necessarily have to be complex - and a simple, understandable model can have great explanatory power - the soil is not as complex as it might seem to be (Andrén et al. 1995, Smith et al. in press).

Table 1. Parameters used in the ICBM model, set for the results from Persson and Kirchmann (1994). For all treatments, k_1=0.8, k_2= 0.00605 year^{-1}. Total initial soil carbon content (Y_0+O_0) was measured in 1956, and we assumed that 0.3 kg C/m^2 was Y_0 in all treatments, except steady-state (0.25 kg / m^2). See text for further explanations. O_0 is in kg C/ m^2 in the topsoil; *i* is in kg C m^{-2} year^{-1}, whereas *h* and *r* are dimensionless. "Straw" includes carbon added as farmyard manure or sewage sludge, and "Roots" includes stem bases. NC = not calculated separately. * = weighted means for crop residues and organic amendments. For pure manure *h*=0.31, for sludge *h*=0.47. (Revised from Andrén and Kätterer, in press).

Treatments	O_0	*i*		*h*	*r*
		Straw	Roots		
Bare fallow	3.96	0.0	0.0	0.125	1.32
N, straw incl.	4.11	0.19	0.095	0.125	1.00
No N, straw incl.	4.05	0.19	0.058	0.125	1.22
No N, no straw	3.99	0.0	0.057	0.125	1.17
N, no straw	4.02	0.0	0.091	0.125	1.07
Farmyard manure	3.99	0.19	0.082	0.25*	1.10
Sewage sludge	4.14	0.19	0.106	0.34*	0.97
Steady-state	4.16	0.20	NC	0.125	1.00

Conclusions

The ICBM model is easy to use and understand and it can be parameterised even when data available are far from complete. However, the model's simplicity does not allow for, e.g., treatments gradually changing soil properties which may affect model parameters - but 'front-end' models can be used - or the model can be run in sequences with manually altered parameters.

Everyone interested in soil carbon dynamics should use the ICBM model, but ICBM is not the only model they should use.

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CARBON AND SULFUR TURNOVER FROM ORGANIC AMENDMENTS IN A LONG-TERM FIELD EXPERIMENT

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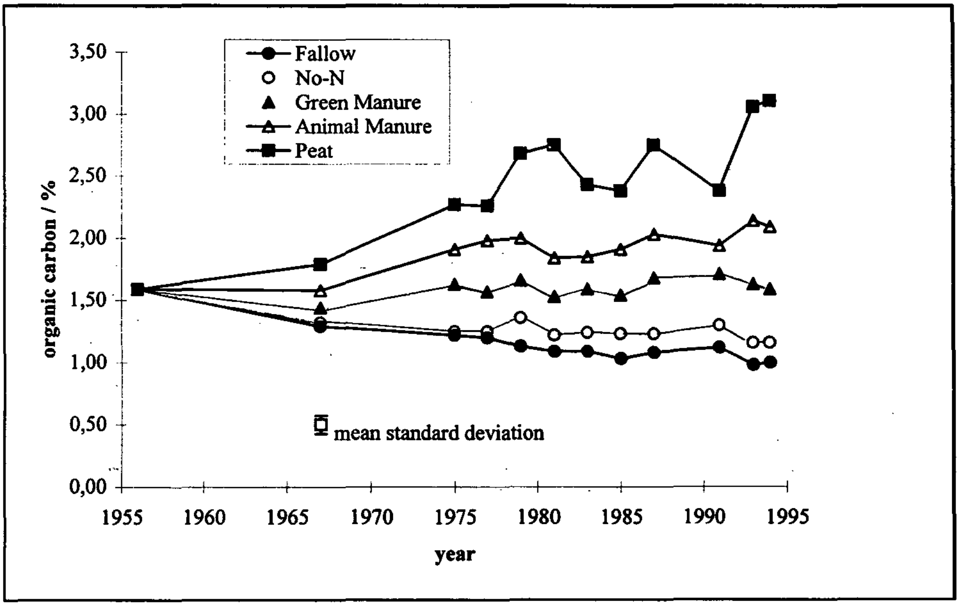
1. Introduction. The Ultuna organic matter experiment, started in 1956, was designed to study soil organic matter and structural changes in soils under a range of manurial treatments and inorganic fertilizers. The same amount of carbon (on average 2000 kg C ha^{-1} y^{-1}) has been applied through a range of organic amendments. The experiment therefore enables to compare changes in both amount and composition of soil humus as a result of application of different organic manures.

2. Materials and Methods. The field experiment is in central Sweden, Uppsala, on an Eutric Cambisol (FAO) with 37% clay and 41% silt. In 1956 the soil (0-20 cm depth) had 15 g kg^{-1} of organic carbon, 1.7 g kg^{-1} of nitrogen and a pH of 6.6. The individual plots (2 m x 2 m), were separated by pressure-treated wooden frames. Five of the treatments, fallow, no-N, green manure, animal manure and peat (sphagnum) were selected for the study of organic carbon turnover, for sulfur we evaluated the sewage sludge, the Ca-nitrate and ammoniumsulfate treatments in addition. The application of organic amendments, analysed before use, was based on equal amounts of ash-free organic matter amounting to 2000 kg C ha^{-1} on average. Organic matter was added in 1956, 1960, 1963 and thereafter every second year by hand. Cereals (70 %), rape crops (25 %) and fodder beet (5 %) were grown alternately. Topsoil samples (0-20 cm) were taken in autumn before the organic matter was added. They were airdried, passed through a 2 - mm sieve, and then stored. Total carbon, and $\delta^{13}C$ were measured in soil samples (1956, 1967, 1975, 1977, 1979, 1981, 1983, 1985, 1987, 1989, 1991, 1993, 1994), and in the green manure, animal manure, peat (1975, 1979) and spring wheat or rye (1987, 1989, 1991) using an elemental analyser coupled to a mass spectrometer. Total sulfur and $\delta^{34}S$ was determined in the soil samples from 1956 and 1991. Humic and fulvic acids in soil samples (years 1967, 1975, 1977, 1979, 1981, 1983, 1985, 1987, 1991, 1994) were extracted four times with 50 ml of 0.02 M tetrasodium diphosphate solution following the procedure described by Gerzabek *et al.* (1996) and quantified by extinction measurements including the determination of fractions like fulvic and humic acids. The humic substance extracts for 1994 were additionally used for Fourier Transform Infrared Spectroscopy (FTIR) analysis. The FTIR spectra of the extracts were recorded on a Spectra Physics 2000 (Perkin Elmer) instrument. Carbon and sulfur concentrations in the soil were converted to soil C and S amounts taking into account bulk density changes. For C we used the simple model described by Jenkinson (1966) for the calculations with a modification to account for up to three different C-pools (initial soil-C, root-C, manure-C) by using the difference method. The carbon balance for each plot was calculated using inputs of C through amendments (Kirchmann *et al.*, 1994) and root production and changes in the soil content of C. The half-life of the initial soil humus was calculated using the fallow plot. Half-lives of C in plots with root-C input were determined after subtracting the loss of the initial carbon, and half-lives in plots with organic manures by subtracting the losses from initial soil humus and root biomass. In addition the isotopic information was used to calculate the amount of carbon (C_{AM}) from animal manure remaining in 1993. A total S mass balance of the plots was calculated using yearly mean inputs and outputs of S and changes in the soil content of S. Leaching of S was estimated as the deficit in the S balance. A total S mass balance of the amendments was calculated according to the difference method using the no-N treatment as a control. The half-life of total S of the amendments was calculated assuming a logarithmic decomposition rate.

3. Results and Discussion. The organic carbon contents of the topsoils changed distinctively during the 37 years of treatment. In fallow C decreased from 15 g kg^{-1} to 9.8 g kg^{-1}, whereas peat application led to an increase to 30.1 g kg^{-1} during the same period. The soil organic matter (SOM) content remained fairly constant in plots treated with green manure but increased in the plots receiving animal manure (Fig. 1). The changes in the C contents of topsoils in the different treatments were linearly related, indicating that equilibrium has not yet been reached. Carbon balances for the 37-years showed that amounts of C added as organic amendments exceeded the input of C from roots. Total losses of C were greatest from the green manure treatment and least

Figure 1. C-contents of topsoils (0-20 cm) of the Ultuna long-term field experiment during the first 38 years (Treatments: fallow, no-N, green manure, animal manure, peat)



in the fallow plots. The same loss of C as native humus (1.53 kg C m^{-2}) was used in the calculation in all treatments assuming no priming effect. Losses of C originating from root decomposition derived from treatments not receiving organic amendments were on average 47.7% of the total root C input. More C was lost from native humus than from roots in all treatments. The portion of C from the total input present in 1993 from green manure C was less (12.8%) than that from animal manure (27.3%) and peat C (56.7%), and the corresponding half-life was 3.3 y for green manure C, 7.0 y for animal manure C, and 14.6 y for peat C. The initial humus had a half life of 57.6 y corresponding to a yearly decomposition of 0.012 y^{-1}. Jenkinson and Rayner (1977) suggested that for a time period of 10 to 100 years the fraction of physically stabilized organic matter (half-life 49.5 y) explained the data of the Rothamsted classical experiments, which also supports our findings. The initial humus (1956) had a $\delta^{13}C$ value of -26.3‰, which is typical for soils cropped with C3 plants for long times (Puget *et al.*, 1995). The fallow showed a slight, but significant increase in the $\delta^{13}C$ values ending with -25.9 ‰ in 1993. This effect is due to the preferential decomposition of the lighter ^{12}C isotope during mineralization (Becker-Heidmann, 1986). The topsoil of the no-N-treatment exhibited no significant isotopic changes indicating that a δ-value of -26.3‰ could be the value at equilibrium for the decomposing soil humus at constant input of the isotopically lighter plant root material (shoots: $\delta^{13}C = -27.08 \pm 0.92$‰). The $\delta^{13}C$ of green manure and animal manure were slightly more negative than the original soil humus, whereas that of peat was less negative. Changes in the isotopic composition of topsoil organic matter were significant only for green manure and animal manure, the latter showing a highly significant correlation with the years following the start of the experiment. From isotopic measurements we obtained a fraction of 55.4 ± 19.6% (mean ± standard deviation) of topsoil C which originated from animal manure. Comparing this quite uncertain estimate with the value of 34.5%, which can be calculated from the carbon balance, we cannot deduce a statistically significant difference. However, a difference could be due to the priming effect of the animal manure on the mineralization of native soil humus, which was not taken into account for the carbon balance. Mineralization of microbially available organic substances led to an increase in the degree of humification on plots not receiving organic amendments. Adding peat and animal manure resulted in a decrease of the humification index due to the continuous input of poorly humified material. The extinction ratio (E_4/E_6) and ratio of fulvic acid to humic acid changed considerably in the peat treated plots. FTIR - measurements of the extracts showed that in the case of peat treated soil an increase of relative intensities at 1140 and 902 cm^{-1} compared to the band at 1025 cm^{-1} and a new band at 726 cm^{-1} appeared. Comparing this spectrum with a peat extract , several bands, e.g. at 1067 cm^{-1}, occur only in the spectrum of the peat extract and not of the peat - treated soil. There are still some characteristics of the IR spectrum of the peat extract, however, which can also be observed in the spectrum of the peat - treated soil. The other amendments did not alter the characteristics of the extractable humic substances.

Total soil S decreased in all treatments where no organic material was added, the largest decrease occuring in the continuous fallow plots with a S mineralization rate of 6 kg ha^{-1} yr^{-1}. Sulfur added through $(NH_4)_2SO_4$ and sewage sludge was mainly leached whereas SO_4 leaching was reduced in the calcium nitrate treated plots as a result of increased crop uptake. S originating from organic manures remained in soil to an extent of 26-54% with a half life of: ammoniumsulfate (0.6 yr) < sewage sludge (6.2 yr) < green manure (10.4 yr) < peat (11.2 yr) < animal manure (13.1 yr). Recoveries of S from organic amendments in soil were correlated with their initial C/S ratio ($R^2 = 0.999$) excluding peat. In the peat plots a significant enrichment of ^{34}S was found, which was attributed to the fact that peat was more highly enriched in ^{34}S than the other organic materials studied and was more resistant to decomposition ($\delta^{34}S$ soil 1956 : 3.2; $\delta^{34}S$ peat: 9.2).

Table 1. Total S balance in eight selected plots of the Ultuna long-term organic matter experiment over the period 1956-1991

	kg S/ha.yr			
Treatment	manure + fertilizer	crop removal	annual change of total S in soil	Annual leaching losses
No-N, fallow	27	0	-6.0	43.0
No-N	27	8	-4.2	33.3
$Ca(NO_3)_2$	27	15	-2.0	24.1
$(NH_4)_2SO4$	118	17	-2.2	113.3
Green manure	38	14	+0.4	33.7
Animal manure	45	12	+5.5	37.6
Sewage sludge	94	21	+12.9	70.2
Peat	32	8	-1.9	36.0

Dry + wet deposition and seed input of 10.1 kg S ha^{-1} yr^{-1} was additionally introduced into the balance.

4. Conclusions. In this experiment addition of 2000 kg C ha^{-1} y^{-1} as a green manure, to a typical crop rotation was sufficient to maintain the soil's organic matter at its initial concentration. Animal manure and peat, applied at the same rate increased the organic matter almost linearly with time during the 37 years. The δ ^{13}C values of the amendments differed slightly from that of soil humus and led to changes of the isotopic composition of topsoil carbon with time. The continuous fallow and no-N treatments led to an increase in the humification with time as a result of a relative accumulation of highly humified material. Total S decreased in all treaments not receiving organic manures continuous fallow showed a yearly mineralization rate of 6 kg/ha. Sulfur added through ammoniumsulfate and sewage sludge was mainly leached. Half-lives of C and S were different, but in the same order of magnitude.

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SOIL FORMATION ON SULFIDIC MINE SPOIL IN THE LIGNITE MINING DISTRICT OF LOWER LUSATIA, EAST-GERAMNY

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1. Introduction. In the Lusatian lignite mining district of Eastern Germany, more than 750 km² of land has been claimed by open-cast mining. Of this total area, about 50 % has been subjected to recultivation so far (Häge, 1996). The environmental impact of open-cast mining activities is drastic. The natural landscapes and soils are destroyed completely. The outer appearance and the environmmental conditions of the post-mining landscape differ considerably from the cultivated landscapes in the neighbouring area not affected by mining.

The capability to recultivate a multifunctional post-mining landscape and especially to redevelop arable soils depends on the chemical, physical and mineralogical conditions of the substrates of the overburden sequence and on the mining technology. In the Lusatian lignite mining district, the lignite seam is covered by a sequence of Tertiary and Quarternary sediments. The Tertiary sediments are partly made up of marin-brackish carboniferous and sulfidic fine sands and silts with organic carbon contents ranging from < 2% to > 10%. Most of the sulfur of these sediments (up to 2% S) is pyrite and marcasit. The Quaternary sediments consist of fluvioglacial sands and in some small areas of the mining district of fluvioglacial sands and moraine till.

Due to the specific technology with overburden conveyor bridges the sediments of the overburden sequence are intensively mixed by dumping. Therefor, the chemical and physical properties of the toplayers of the dumps are highly heterogeneous. About 20% of the mine soils are mixtures of Tertiary and Quaternary substrates and about 20 % are made up of Tertiary sediments rich in carbon and sulfur (Abo-Rady et al., 1997). These substrates tend to a strong acidification because of the weathering of the original iron-disulfide content. Applications of very high doses of lime or brown-coal ash (100 tons lime/ha or 1.000 tons brown coal ash/ha, or even more) and mixing to a depth of 60 cm are necessary in order to ameliorate these substrates (Katzur & Haubold-Rosar, 1996). After amelioration with lime or brown coal ash and mineral fertilization the dumps are mainly used for forestry.

In the „Center of Excellence - Mine Site Recultivation" of the Brandenburg Technical University Cottbus, the development of minesoils on recultivated, primary carbiniferous and sulfidic substrates is studied by investigations of chronosequences of one to 35 years old pine and red oak stands. These investigations provide data to estimate the intensity of soil formation and the rate of mineralogical and chemical alterations in short time periods. In this context soil forming processes which are related to the weathering of iron-disulfides and subsequent acidication, pedogenetic salinization and neutralization are of special significance.

2. Materials and Methods. The research sites are located on dumps in the vicinity of Cottbus. They comprise a chronosequence of one to 35 years old pine stands. Some data of the mine spoil materials are given in Table 1.

Table 1: Characteristics of research sites.

name of site	year of dumping	year of amelioration/ reafforestation	texture of dump subtrate	org. C-content (as finely devided lignitic material)	total S-content
Weißagker Berg(WB)	1989	1996	fine medium sand	0,5-3%	0.2-0.5%
Bärenbrück BB)	1977	1981	light loamy sand	4-7%	0.2-2%
Meuro (MR)	1970	1977	light loamy sand	2-5%	0.1-0.4%
Domsdorf (DD)	1946	1963	light loamy sand	2-7%	0.2-1.4%

On each site soil profiles were sampled in a high vertical resolution (2 cm-intervalls from 0-20 cm depth, 10 cm-intervalls from 20-100 cm depth) for soil chemical investigations. In this paper, pH-values, electric conductivity (EC) and the composition of the 1:2.5 soil-water-extract (SO_4^{2-}, NO_3^{1-} and Cl^{1-} measured by Dionex IC; Ca^{2+}, Mg^{2+}, Al^{3+}, Fe^{3+}, Mn^{4+}, Na^+ and K^+ measured by Unicam AAS and ICP-OES) are presented.
Soil micromorphological investigations of thin sections and SEM-EDX analysis were carried out in order to estimate the rate of soil forming processes, e.g. pyrite oxidation, secondary salt formation and mineral weathering qualitatively.

3. Results and Discussion. pH-values and EC (Figure 1) have distinct depth functions for the profiles of the four sites, i.e. decreasing pH-values with increasing soil depth. This tendency is more distinct in the developed mine soils BB, MR and DD and only weakly expressed in the very young mine soil WB. The very low pH-values in the subsoils reflect the strong and rapid acidification by pyrite weathering, which in the uppermost soils is buffered by amelioration with brown coal ash. Except of the mine soil WB, the EC is strongly increasing with depth, from < 100 µS/cm in the uppermost soil layers to > 4000 µS/cm in the lower part of the mine soil BB.
The high EC-values are connected to pyrite weathering and a subsequent pedogenetic salinization (see below) which is stronger expressed in the mine soil BB because of a much higher original sulfur content compared to the mine soil MR (cf. Table 1). The low EC in the uppermost parts of the developed mine soils BB, MR and DD is due to a beginning translocation of salts.
Sulfate is the only watersoluble anion in the four profiles (Fig. 2). NO_3^{1-}, Cl^{1-} and F^{1-} are of no importance. Ca^{2+} is the most important cation in the upper parts of the four mine soils. The Ca-concentrations in the mine soils WB, BB an DD correspond to the solubility of gypsum. A pedogenetic gypsum formation can be seen micromorphologically not only in the upper parts which were ameliorated with Ca-bearing brown coal ash, but also in the subsoils. In the lower part of the young mine soils WB and BB high concentrations of soluble iron and aluminum are present. The high Fe and Al concentrations are related to current pyrite oxidation in the lower parts of these soils (Neumann et al., 1997) and a strong weathering of Al-bearing silicates, e.g. feldspars, which can clearly be detected by micromorphogy and SEM-studies.

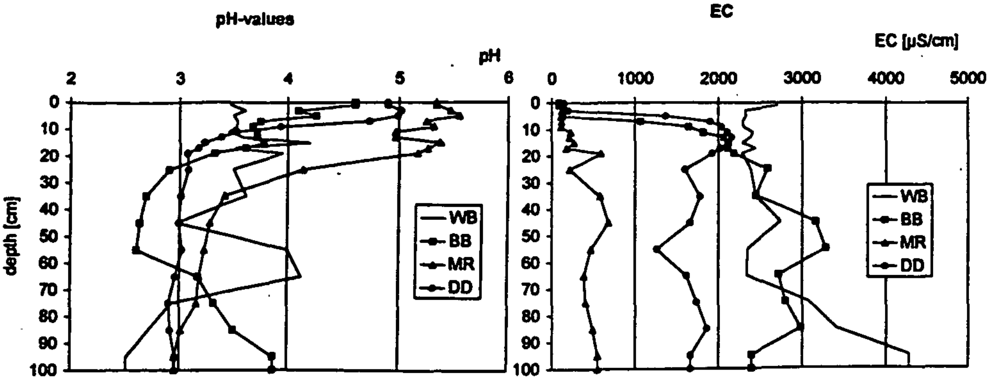

Figure 1: pH-values and electric conductivity (EC) of mine soils WB, BB, MR and DD

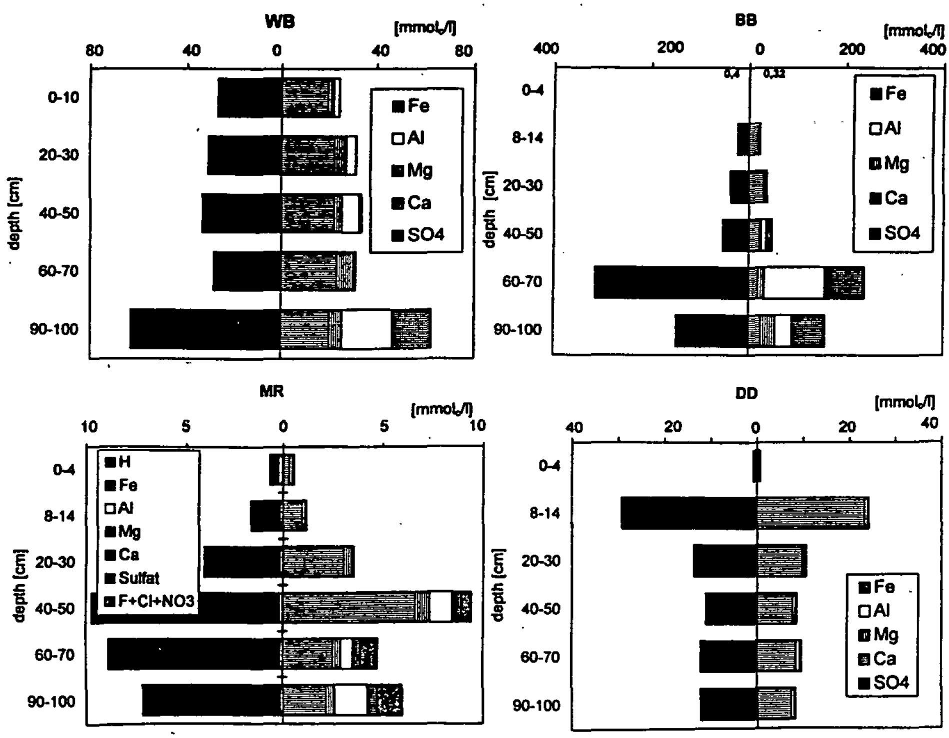

Figure 2: Soluble ions (1:2.5 soil/water-extract) of mine soils WB, BB, MR and DD

The high Al^{3+}, Fe^{3+} and SO_4^{2-} concentrations in the lower part of the mine soils WB and BB is probably controlled by highly soluble secondary Al- and Fe-sulfate salts (Karathanasis et al, 1988, Schaaf, 1997). After pyrite oxidation has come to an end, the secondary Al- and Fe-salts are translocated and removed from the soil profile. In the lower part of the oldest mine soil (DD) the SO_4-concentrations are controlled by gypsum solubility.

4. Conclusion. The chemical properties of mine soils which are derived from primary carboniferous and pyritic spoil material differ considerably from undisturbed soils in the Lusatian lignite mining district. They are characterized by strong acidification, weathering of primary minerals, secondary salinization and a subsequent translocation of highly soluble salts. By these fast running processes the chemical properties of the mine soils are being changed markedly within decades

The classification of mine soils derived from carboniferous and primary pyritic mine spoils according to the German soil classification system (AG Boden 1994) or to international systems, e.g. the WRB (ISSS/ISRIC/FAO, 1994) is somewhat insufficient, because these systems do not reflect the specific properties of mine soils. With regard to soil mapping for recultivation and land use planing a local classification system has been developed which is mainly based on the physical and chemical properties of the soil forming substrates.

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SIMULATION AND ASSOCIATED SOIL MONITORING IN AUSTRALIAN SUB-TROPICAL DRYLAND FARMING

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Introduction

The cracking clay soils of a zone between latitudes 23 deg and 33 deg south in north-eastern Australia have been used for dry-land cropping for periods of 10 to 70 years. Long-term average annual rainfall ranges between 400 mm and 700 mm, and its variability is extreme. Both winter and summer crops can be grown in the region. Successful farming depends upon high water storage capacity in the soil. This is especially so for winter crops, notably wheat, which receives little in-crop rainfall, requiring long fallow to achieve successful but ultimately un-sustainable production. The run-down of natural fertility and structure of the soil, has created a high probability of run-off of scarce water that will induce soil erosion.

Researchers perceived that in this environment of great uncertainty regarding seasonal rainfall, farm management could be aided using simulation of the key processes of water infiltration and storage in the soil, and nitrogen mineralisation and movement in the profile. The results of simple experiments investigating fertiliser response were so specific to prior storage of water and nutrients and the rainfall incidence of the particular season that simulation would be crucial to achieving generalisation to other seasons and soil states.

APSIM is a modelling framework that provides a suite of modules which can be configured to model diverse farming systems (McCown et al. 1996). Crops come and go, finding the soil in some state and leaving it in an altered state. Thus the soil is central, so that modelling of the dynamics of water and nitrogen in the soil lies at the heart of APSIM. When coupled with modules that are able to simulate the growth of crops, and their response to soil factors, the resultant production systems simulator provides a tool that can perform simulation experiments on land use issues as diverse as:

degradation of soil fertility (declining soil organic matter); salinity issues (leaching of solutes and deep drainage); nitrate pollution of ground-water; erosion; assess the returns from alternative fertiliser strategies.

We present in this paper a summary of the features of the APSIM model and two case studies, each of which was used recently to validate for demonstration purposes the soil water and soil nitrogen modules, respectively, of the APSIM model. We also outline briefly the technique used to characterise our principal soil types for their capacity to store plant available water, and we report on a study of the intensity of soil sampling required to cope with variability of soil water and mineral nitrogen..

Materials and Methods

1. APSIM (The Agricultural Production System Simulator). McCown et al. (1996) have described APSIM, including its development. They dealt with the need to simulate the performance of cropping systems, in terms of both crops and soils, and the software requirements for such a modelling framework.
   The APSIM modules that represent the soil comprise:
   - the water balance, for which there are alternative modules that describe the behaviour of water either as a cascading layer system (SoilWat) or in terms of Richards' equation for water flow and the advection-dispersion equation for solute transport (SWIMv2) (Verburg 1996;Verburg et al. 1997);
   - a soil organic matter module (*SoilN*) that deals with the transformations of soil carbon as well as nitrogen;
   - a module that deals with surface residues; and
   - a module that deals with soil loss through erosion.

   Much of the code for *SoilWat, SoilN, Erosion* and *Residue* modules has evolved from models of the CERES family, especially CERES-Maize (Jones and Kiniry 1986), and PERFECT (Littleboy et al. 1989). Probert et al. (in press) describe the enhancements that have been introduced into the APSIM modules. The most significant change has occurred in *SoilN* which, in common with many other models of soil organic matter (SOM), partitions organic matter into two pools that turn over at different rates. This treatment of SOM is necessary in order to simulate the enhanced nitrogen supply to cereal crops following legume pasture leys.
2. Refinement of a field technique for the measurement of plant-available water in the soil profile (Dalgliesh and Foale, in press). Heavy clay soil types are characterised in the following way to define their capacity to store plant-available water in a series of layers representing the potential root-zone of annual crops. A representative site is chosen in a farmer's field a few months prior to time of sowing of a crop. Water is trickled through multiple fine nozzles beneath a polythene sheet of 9 m^2 until readings on a neutron probe indicated that water has infiltrated the whole profile. The water content and bulk density of the soil are then measured using soil cores. Next the required crop is planted and subjected to water deprivation post-flowering (by means of a temporary rain shelter tent) in order to induce severe water deficit, thereby inducing extraction down to the lower limit of plant-available water. The upper and lower limit values thus obtained are used as settings for simulation of the performance of that crop on that soil type.
3. Assessment of required intensity of soil sampling to meet a nominated level of accuracy and confidence (Jones and Dalgliesh, unpublished data). In a preliminary study, sets of between 7 and 16 cores of 45 mm diameter were taken across a range of nitrogen treatments from four clay soil types in cropped fields in a fallow state, with a partial recharge of soil water from rainfall. The samples were used to determine the coefficient of variation of the mineral nitrogen and water content of seven sections of the soil core that represent the following soil layers (cm): 0-15, 15-30, 30-60, 60-90, 90-120, 120-150, 150-180. The results were used to determine how many samples would be required to achieve a required degree of accuracy of determination of mineral N and of water content, at a chosen confidence level.

Results and Discussion

1. Some examples of model validation are presented in the following paragraphs.

Probert et al (1996; in press) have examined the performance of the *SoilWat* and *SoilN* modules to simulate the changes in soil water content and accumulation of nitrate-N during fallows on both vertisols and alfisols. By restricting the evaluation to fallow periods, it is possible to isolate the performance of the modules describing the soil processes from any effects due to a crop (water use and nitrogen uptake). However, numerous other simulations of crop growth and nitrogen uptake (eg with wheat, maize, sorghum, cotton, sugarcane) provide evidence of the model's ability to simulate mineralisation of nitrogen.

A simulation case study on the redistribution of chloride under different surface soil managements of a wheat-fallow system was carried out by Turpin et al. (1996) using *SoilWat.* The contrasting managements were: **conventional tillage** ('clean' cultivation to control weeds in the fallow phase) with stubble burnt after each wheat harvest; and **zero tillage** with retention of all residue on the soil surface. The model was able to simulate the greater movement of chloride that occurred under zero tillage due to increased infiltration.

In simulations of a ley farming system at Katherine in northern Australia (Carberry et al, 1996) APSIM was able to reproduce the measured yield from sorghum, maize and *Stylosanthes hamata* as sole crops, as inter-crops, or in rotations of several years.

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2. The results of a field determination of plant-available water for a wheat crop in a grey clay soil are shown in Figure 1.

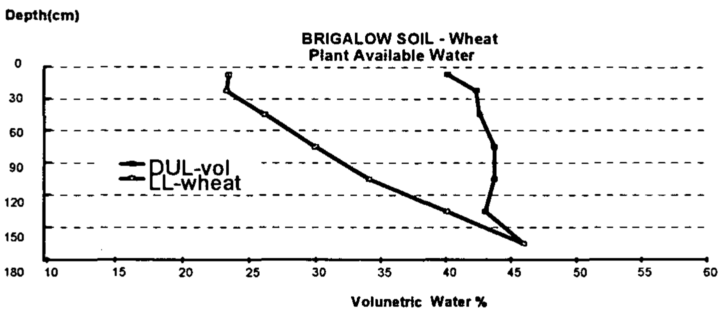

Figure 1.Plant available water for wheat in seven layers of soil to a depth of 180 cm in a grey clay soil in South-east Queensland, Australia. (LL = lower limit; DUL = upper limit)

These data are entered into the input files for a simulation of wheat growth on this soil type providing limits for the retention and extraction of water from each layer.

Table 1. Number of cores needed for **the specified degree of accuracy**: nitrate N ±20% of mean: and water % ± 2 units of % (eg 27% ±2%).

Confidence level	nitrate N	water content
2/3 (66%)	3	2
4/5 (80%)	5	3
9/10 (90%)	8	5

3. The data from the sampling intensity study (Table 1) show that the variation in concentration of mineral nitrogen in the soil is somewhat greater than that of water. For example when 5 samples are taken to measure mineral nitrogen with an accuracy of ±20% and a confidence level of 80%, the water content will be measured to within ±2 units of % and confidence of 90%.

Conclusions

The APSIM simulation model is performing a very useful function in research in the agricultural production systems of the semi-arid subtropics of north-eastern Australia. The individual modules that deal with soil water and organic matter (including nitrogen) are crucial to such models, because these are the principal limiting factors to crop production in the environments of interest. An outline of the performance of these modules and key published reports on their development are presented in this paper to show the rigour that has gone into the development of the APSIM model.

Reliable input data on the soil properties with respect to water storage and retention, and of soil water and nitrate N content for model specification and initialisation are crucial to achieve satisfactory simulation. Soil inputs based on the techniques described here have resulted in simulations in the context of collaborative on-farm research that have expanded the learning of all participants, to the benefit of risk management in dryland systems.

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A coupled equilibria model to describe the effects of acid inputs and forest practices on chemistry of forest soils: 3 case studies

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1 Introduction

Soil chemical models are useful tools for understanding or even predicting the chemical reactions involved in soils resulting from inputs of nutrients, acid and lime, and from forest practices. For example, acid precipitation may change the proton buffering reactions of soils, increase the desorption of Al and Fe ions and enhance the leaching of nutrient cations (Ulrich, 1989). Addition of nutrients and lime may also affect the chemistry of a soil in a significant way. Clearfelling of a forest may lead to a decrease in soil organic matter causing a reduction in the cation exchange capacity and proton buffer capacity (Ludwig et al. 1997a). Burning harvesting residues will increase the deposition of cations as ash on the forest floor and some losses as particulates and in the gaseous form. As the solubility of different cations in the ash varies, chemistry of solution and solid phases vary accordingly (Ludwig et al. 1997b). Many of the chemical processes are highly complex warranting the use of a model to assess the consequences of forest practices and changes in acid inputs. However, models should be validated properly and only be used at the scale they were validated (Addiscott, 1993).

Objective of this study was to assess the usefulness and limitations of a coupled equilibria model to study the changes in the chemistry of a number of acid soils. The model includes chemical reactions which involve cation exchange, inorganic and organic complexation, dissolution and precipitation. Model will be used for three cases involving surface soils: (a) to study the effects of continuing acid inputs to highly acid soils, (b) to assess the effects of clearfelling a forest, and (c) to describe changes in soil chemistry on burning of harvesting residues.

2 Materials and Methods

The model used is the one developed by Prenzel (1991). This model included the ions H^+, Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Mn^{2+}, Al^{3+}, SO_4^{2-}, Cl^-, and CO_3^{2-}, inorganic complexation, multiple cation exchange, and solubility of $Al(OH)_3$ for all the three cases, but additional reactions (given below) were included for each. For case a (acid inputs) which included sequential batch experiments with surface soils (3 Cambisols and one Podzol), the model included Fe-OH and organic complexes of Fe and Al. Complexation constants and average molecular weight of organic ligands were found by curve fitting and only one set of parameters was used for all the four soils under study. For case b (clearfelling) which involved batch experiments with soils taken 1 month, 2 yrs and 4 yrs after clearfelling a subalpine *Eucalyptus* forest, the model included a second cation exchanger: H^+, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, and Al^{3+} competed for exchange sites on the first exchanger (Ex-1, with permanent and partly variable-charge exchange sites) whereas the second exchanger (Ex-2, variable-charge exchange sites only) sorbed H^+ and $Al(OH)^{2+}$, as suggested by Bloom et al. (1979) (for details on the experiment refer to Ludwig et al. 1997a). For case c (burning), which involved batch experiments on soils collected from the ashbed sites 1 day, 2 years, and 4 years after the burn (Khanna et al. 1996), the model additionally included sparingly soluble magnesian calcites (for details on the experiment, refer to Ludwig et al. 1997b). Batch experiments were carried out for cases a, b, and c with water, diluted HCl, NaOH, and neutral salts as described in Ludwig et al. (1997a).

3 Results and Discussion

A) Modelling of cation sorption and acid titration of acid surface soils

For the three Cambisols, model results agreed well or satisfactorily with the measured pH (not shown) and sorption values of Na, K, Mg, Ca, Mn, Al, and Fe with some exceptions (Fig. 1 shows an example). Correlation coefficients were generally between 0.97 and 1.00 and slopes of linear regression for cations (modelled versus measured) between 0.6 and 1.3. The model was not able to handle the desorption of Fe properly, but described the Fe adsorption quite well. The model was restricted in predicting pH and sorption data of Podzol which was very low in CEC.

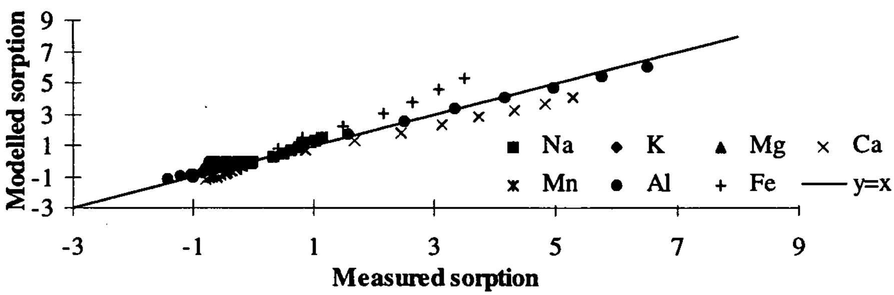

Figure 1: Modelled versus measured sorption of cations (mmol(+)/kg) for one Cambisol sample.

(B) Modelling of temporal changes in sorption characteristics and proton buffer ranges after clearfelling

After clearfelling, soil organic carbon (not shown), CEC (not shown), and buffer capacity (Fig. 2) decreased markedly with time in the surface soil. The modelled titration curves for the soils agreed well with the experimental data for pH (Fig. 2) and for concentration curves of Na, Ca, and Al (not shown), and were satisfactory for NH_4^+, K, and Mg (not shown). The model output indicated that added H^+ was adsorbed to a large extent by the second exchanger Ex-2 and only small amounts by the first exchanger Ex-1. The model incorporated a decrease in the buffer capacity of the organic matter exchanger. For OH addition, the model estimated that the desorption of exchangeable Al, followed by precipitation of $Al(OH)_3$, and the buffering by the carbonic acid system were important buffer reactions.

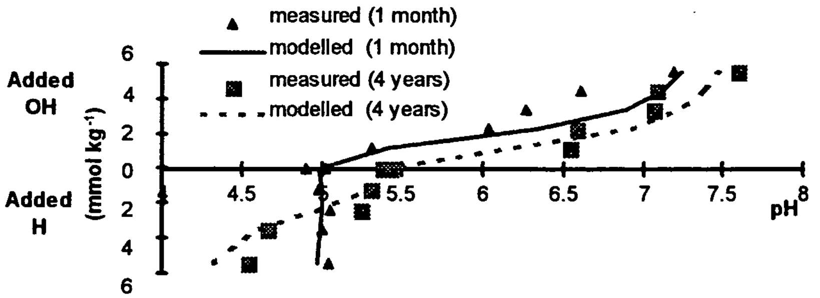

Figure 2: Changes in buffer characteristics of surface soil 1 month and 4 years after clearfelling.

C) Modelling soil chemistry and ash solubility after fire

Fig. 3 compares the modelled Ca concentrations in the field percolates with the measured ones. The initial high soluble concentrations of Ca (Fig. 3), Mg (not shown), and K (not shown) were related to the high amounts of chlorides in the ash. The model calculated that most of the cations added of the ash are adsorbed and that the desorbed Al precipitates as $Al(OH)_3$.

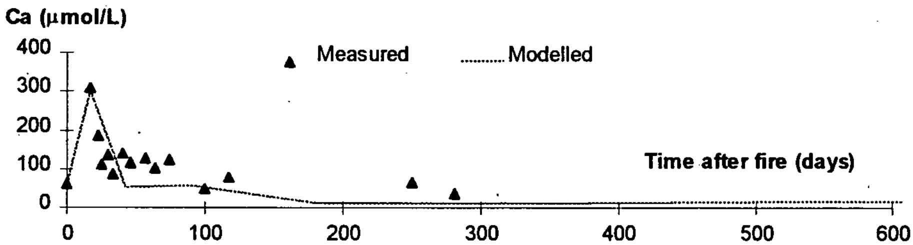

Figure 3: Modelled (lines) and measured (points) concentrations of Ca in soil percolates versus time after fire.

The modelled changes in exchangeable K, Mg, Ca, and Al after 66 months agreed well with the measured changes in extractable cations either immediately after fire or 3 years later (Fig. 4). Although measurements of extractable cations indicated that the amount and composition of exchangeable cations changed immediately after fire and then remained constant for at least three years, the modelling results suggested that this could not be so. It would take at least 66 months to obtain such drastic changes in exchangeable cations under field conditions (Fig. 4). It may even take longer to obtain these changes in the field, because some conditions (e.g., hydrophobic nature of the ash, rapid flow of rainfall through macropores) were not considered in the model.

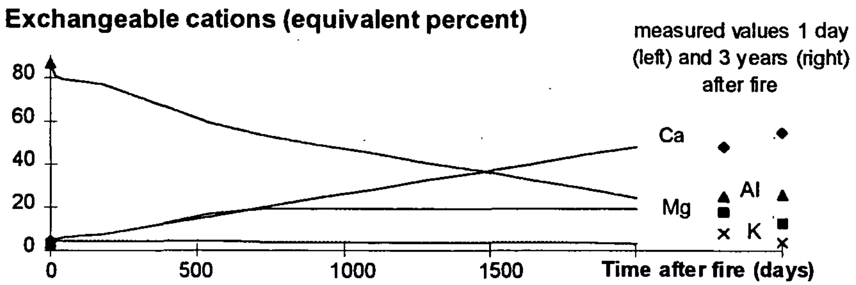

Figure 4: Modelled temporal change in exchangeable cations and measured values before fire (0 on x-axis) and 1 day and 3 years later. Values are given as percentage of CEC.

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The model estimates that the reversal process, the reacidification of the ashbed surface soil, is completed in about 50 years under an annual input of 0.5 kmol H^+ ha^{-1} (not shown). However, this is only a rough estimate, because biological processes (eg. mineralisation, decomposition, nitrification) were not included in the model, but bulked into the assumed annual H^+ input.

For batch experiments with surface soil ash mixtures, the model was able to describe the temporal changes in pH and in the sorption curves of Na, K, NH_4, Mg, and Ca. The results suggested that the composition of insoluble salts in the residual ash changes with time in the following manner: (a) One day after fire, the solubility of Ca and Mg from the ash was controlled by a magnesian calcite with a molar percentage of 10 % Mg (pK = 8.0). Four years after fire, the solubility of Ca and Mg is controlled by a more insoluble magnesium calcite ($Ca_{0.97}Mg_{0.03}CO_3$, pK=8.6). However, other processes not considered in the model may include precipitation of sparingly soluble compounds (e.g., aluminumhydroxides, calciumphosphates and magnesiumphosphates) on surfaces of ash particles and adsorption of organic matter which might have retarded $Ca_xMg_{1-x}CO_3$ dissolution.

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PHYSICAL AND NUMERICAL MODELING OF WATER TRANSPORT AND SOIL MOISTURE REDISTRIBUTION FOR LAYERED SLOPES.

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1. Purpose and background. The following investigations were part of a research project, funded by the Austrian Academy of Sciences (HAGER et al., 1996). The purpose of the project was to assess the impact of forest vegetation to surface and subsurface runoff generation in hillslope scale. Due to temporal and financial restrictions only limited in situ measurements and limited rainfall events could be analysed. Thus additional experiments in the hydraulic laboratory produced proper results for analysing the basic processes of soil moisture and water transport in porous media under different slope and rainfall conditions. The following paper summarizes the experiences in construction, application and modeling and point out the shortcomings of such applications compared with natural, undisturbed conditions.

2. Physical model. The application of physical models in the hydraulic laboratory provides several advantages which are listed in the following table. Also the shortcomings are refered in the table:

Tab. 1: Advantages and shortcomings of physical models:

Advantages	Shortcomings
• No model calibration	• Expensive construction
• Measurement of direct physical values	• High time demand for experiments
• Consideration of only relevant processes	• Limited variability of soil properties
• Process oriented analysis and interpretation	• Limitation of experimental scenarios
• Experiences for in situ measurement	

2.1 Construction and measurement equipment. The base of the application was a box made of wooden blankets and metal frame. The dimensions are 250 cm, 160 cm and 60 cm (length, width, height). One side wall has been made out of plexiglas to inject tracers and make the runoff pathes visible. In the front wall three seepage slots have been constructed, connected to the metal sheets (collectors) to drain the lateral runoff. Figure 1 shows the scheme of the construction. Comparable applications are described in MIYAZAKI (1993).

The box was filled with soil materials. Three artificial layers with different soil particle distribution and thus different soil physical properties have been filled and compressed. The first and third layers reflect the in situ conditions of A- and C-horizons. They are highly permeable with high rates of coarse material. Only sand and gravel fractions have been used. The second layer reflects the B-horizon and includes materials of silt and fine sand fraction.

For this soil also conductivity measurements have been carried out. The thickness of the layers are 10, 30 and 10 cm. The soil physical properties are listed in table 2.

Tab. 2: Soil physical properties of the artificial soils

Layer (thickness)	Hydraulic conductivity		Particle size distribution soil mass [%] with particle smaller than [mm]						Soil texture
	ks [cm/s]	*ks [m/d]*	*0.063*	*0.125*	*0.2*	*0.63*	*1*	*2*	
1 (10)	1.22E-01	105.0	1.57	1.6	1.64	6.6	80.9	100	S
2 (30)	5.69E-03	4.9	13.0	17.5	22.4	76.5	99.5	100	lS
3 (10)	1.21E-01	104.3	0.56	0.58	0.59	3.0	72.7	100	gS*)

*) 51.5 % gravel

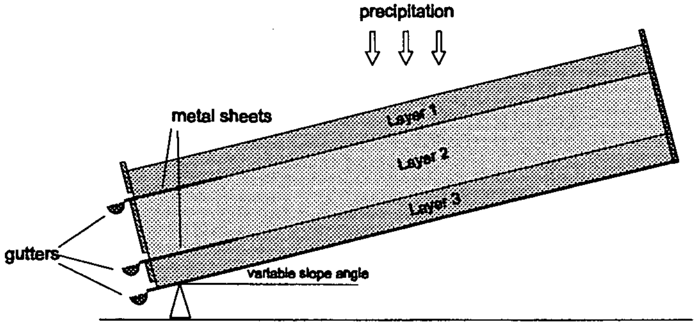

Fig. 1: Scheme of model application.

The artificial precipitation load infiltrates into the soil, redistributes and lead to lateral fluxes in the different layer zones. The infiltration process and soil moisture redistribution was monitored by measuring soil moisture contents and matric suction heads. For this purpose two tensiometers and 12 buriable TDR probes have been installed. The lateral runoff was collected in three containers, where the water head was continously measured with pressure probes. The filled containers were emptied by syphon tubes. All measurement data are collected in data logging devices.

2.2 Rainfall experiment. The advantage of artificial rainfall experiments lies in the variability of intensities and temporal distribution. For the rainfall experiments a sprincler with swinging axis was used. The axis has been situated in slope direction. The areal rainfall patterns have been controlled using collector pans. It shows nonuniform but symmetric distribution over the surface, that means decreasing intensities against the side wall boundaries.

For the rainfall experiment three rainfall scenarios representing constant, increasing and decreasing temporal distribution patterns with total rainfall of 44 mm/2h and three slopes with 14, 18 and 22 degrees have been choosen. Due to static reasons no higher slopes could be carried out. The experiments started under equilibrium conditions, that means no flux occured in the beginning of the period.

2.3 Measurement results. The observations (fluxes, soilmoisture contents, suctions) during the experiment reflected the basic assumptions used in hydrology. Near surface flux contributes to the fast runoff. Its hydrograph shows steep ascending limbs and high peaks. Runoff in deeper zones leads to time lagged and lower peaks. Steeper slopes accelerates the runoff, the peak levels are increased in the first and second layers, but decreased in the third layer. Figure 2 shows the observed accumulated flux in relation to the slope.

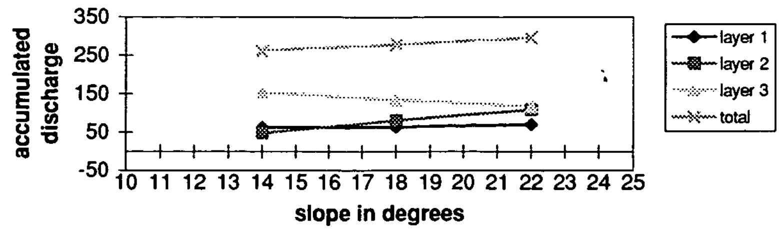

Fig. 2: Observed lateral fluxes regarding to slope angle.

3. Numerical model. Under the assumption of proper system representation, numerical models can provide results of a broad band of different scenarios. The main purpose of model application was to identify the impact of slope to the runoff response. Soil properties and rainfall scenarios have been defined similar to the laboratory experiment.

3.1. Software and data requirements. Infiltration and runoff processes in sloped areas reflect transient, two dimensional processes. Thus a numerical model was selected, which is able to compute the unsteady soil moisture transport under transient boundary conditions. For this purpose the model SWMS_2D for UNIX respectively HYDRUS-2D for Windows operation system has been used (see SIMUNEK et al., 1994). This model solves the Richards equation numerically, using Finite Element scheme for numerical solution. The following parameters have to be defined before simulation:

- **Boundary conditions:** They describe the spatial and temporal distribution of fluxes or pressure heads in the boundary elements.

- **Soil properties:** For each element a soil class has to be defined. This information includes bulk density, saturated hydraulic conductivity and Van Genuchten parameters (Van GENUCHTEN, 1994) for estimation of retention curve and unsaturated conductivities.

- **Root depth and potential evapotranspiration:** The model can also be potentially used to simulate natural conditions considering plant root extraction.

- **Starting conditions:** The soil moisture or the matric suction respectively has to be defined for each node element.

3.2 Model calibration. As noted before, the simulation model requires numerous model parameters. The aim of model calibration is to vary the parameters within plausible ranges to fit the simulation results to the observations of the rainfall experiment. These are the continous values of fluxes in the three layers, the two suction observations with tensiometers and soil moisture contents at 12 TDR probes. Initially the soil properties have only been roughly estimated using particle size distribution and saturated conductivity analysis. Thus the Van Genuchten Parameters, pore size, air entry point and anisotropy factors had to be calibrated for each soil layer.

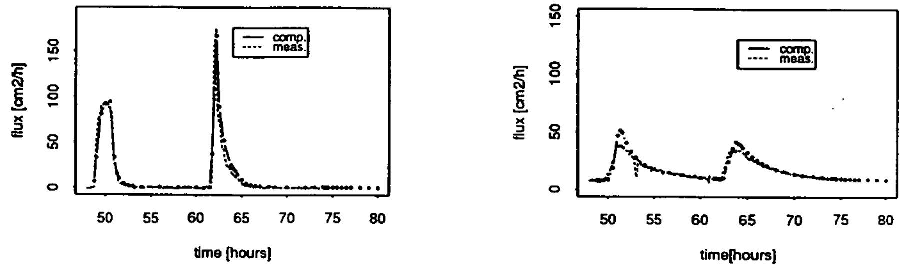

Fig. 3: Observed and computed fluxes for surface and mean layer.

After an iterative process (try and error) reasonable model fittings could be achieved. Figure 3 shows good coincidence between observed and computed runoff for upper and mean layers. Figure 4 shows the results for the mean layer regarding to soil moisture and matric suction.

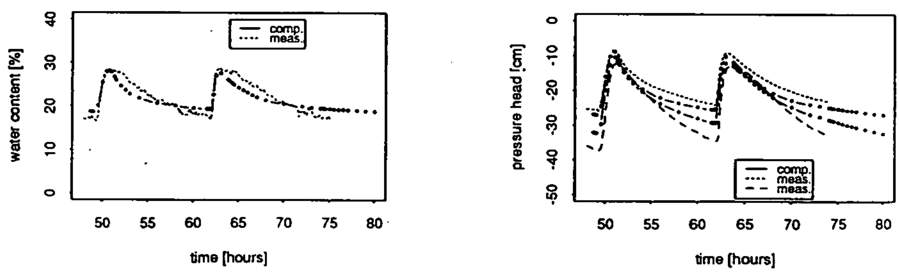

Fig. 4: Observed and computed values for soilmoisture content and matric pressure head.

3.3 Simulation scenarios. The number of experiments in the hydraulic laboratory has been limited. Thus additional scenarios concerning slope conditions have been simulated with the numerical model. The simulations cover a range between 14 and 34 degrees. As the starting conditions of soil moisture content significantly effect the model results, three different conditions (dry, mean, wet) have been defined. Precipitation of three hours duration was varied between 60 mm, 90 mm and 120 mm. The rainfall distribution was assumed uniformly. The combination of the different assumptions leads to 54 scenarios.

3.4 Simulation results. From the hydrological viewpoint the fluxes in the different layers are of main interest. They are defined by total discharge and peak level. Additionally the time lag of peak and the shape of descending limb (retention characteristic) include important information regarding to a unique classification.

Layer 1 (surface layer) shows little sensitivity to the slope. Flux discharge and peak values are nearly constant over the band of slope. The mean layer shows increasing values of discharge and peak with increasing slope. The bottom layer shows vice versa results, that means decreasing discharge and peak values with increasing slopes. The band of variation regarding to the different rainfall intensities is broader under wet starting conditions than under dry conditions. Table 3 shows the peak values of the three layer fluxes with low and high rainfall intensities.

Tab. 3: Flux discharges (in cm^3/cm) and runoff peaks (in $cm^3/h.cm$) under mean wet starting conditions.

Slope	Precipitation 60 mm / 3h						Precipitation 120 mm / 3h					
[deg.]	Layer 1		Layer 2		Layer 3		Layer 1		Layer 2		Layer 3	
	Flux	Peak	Flux	Peak	Flux	Peak	Flux	Peak	Flux	Peak	Flux	Peak
14	245.	87.	228.	23.	988.	235	530.	185	294.	48.	1969.	651
18	252.	89.	433.	52.	847.	211	540.	187	580.	102.	1753.	585
22	259.	89.	579.	64.	748.	195	549.	189	757.	124.	1624.	556
26	260.	89.	722.	81.	648.	173	551.	189	940.	154.	1479.	517
30	258.	87.	804.	88.	609.	161	551.	189	1043.	169.	1418.	508
34	253.	85.	-.	91.	-.	156	544.	187	-.	178.	-.	521

4. Conclusion. The main scope of the presented investigations was to describe soil moisture transport and fluxes in sloped, layered soils using physical and numerical models. It could be proved, that numerical models are applicable to reproduce natural process behaviour. Scenario analysis concerning slope variation showed little sensitivity of runoff response in the high permeable surface layer. The mean layer showed increasing runoff with increasing slope. The high permeable bottom layer provides reduced runoff with increasing slope.

This investigations can be carried out for further scenarios to lead to exhaustive conclusions of runoff generation under different topographical, soil physical and climatological conditions. Further effort have to focus to the upscaling procedures, to go from local processes to catchment scale processes.

5. Acknowledgements. The following investigations were part of a research project *Hydrological Functions of Alpine Forested Hillslopes* (HAGER et al., 1996), funded by the Austrian Academy of Sciences (HÖ3/96). The autors want to thank for the supply.

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ASSESSMENT OF DEEP PERCOLATION INTO A GRAVELLY AQUIFER: SIMULATION AND EXPERIMENTAL VERIFICATION

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1. Introduction. In dealing with practical problems concerning groundwater recharge as well as groundwater pollution the Institute for Soil Water Management is routinely developing and testing methods appropriate for assessing of the soil water balance of typical soil units in some important agricultural areas in Eastern Austria. Thereby deep percolation of water and solutes is measured directly using different types of simple lysimeters at the field sites (Feichtinger 1992, Murer 1997). Lysimeters disturb natural soil water movement and transport processes (Klaghofer 1991) and the measurements may be erroneous. Kastanek (1995) states, that systematic monitoring of soil water content and soil water potential would be more suitable to quantify undisturbed soil water movement and transport processes from such measurements by applying soil physical concepts. Yet another promising method is the use of simulation models: this paper presents the application of a simulation model in quantifying deep percolation, the model itself using hydraulic soil parameters derived from intensive soil water monitoring by modern nondestructive methods.

2. Materials and Methods.

2.1.Field Experiment. The experimental site is situated on the farmland of the Agricultural School in Obersiebenbrunn (48 ° N, 16 ° E), about 30 km east of Vienna, in the center of the socalled "Marchfeld". The soil profile at the measuring point represents a wide spread soil unit of this area: a schematic illustration of the installation pattern and of the different soil horizons is given in Fig.1. Soil moisture was measured by the TDR (Time Domain Reflectrometry) method, while soil water tension was determined by Granular Matrix Sensors and Gypsum Blocks down to a depth of 1.60 m below soil surface. The sensors were connected by cables to the dataloggers about 20 m apart, which automatically measured the soil water content eight times a day, while the soil water suction sensors were interrogated each hour. During installation undisturbed soil samples had been taken for determination of the soil moisture characteristic and the unsaturated hydraulic conductivity of the representative soil horizons. Ground water level was monitored at about 40 m distance by a ground water stage recorder and weather data were collected at the same place by an automatic weather station. During the observation period (November 1995 - March 1997) winter wheat and winter barley were grown at the experimental site.

2.2 Assessment of Groundwater Recharge and Evapotranspiration. Recharge of groundwater by deep percolation may be determined from groundwater fluctuations if the magnitude of the socalled "Storage Coefficient" is known (Burre 1960). For this purpose groundwater records of the years 1985 - 1997 were analysed for distinct periods of groundwater rise at the end of winter and were correlated to the corresponding amounts of rain and snow: the slope of the linear regression function corresponds to the mean value of the Storage Coefficient of the aquifer within the upper and lower boundary of the observed fluctuations of the groundwater table. Soil water balance equation then can be solved on daily base for the unknown evapotranspiration.

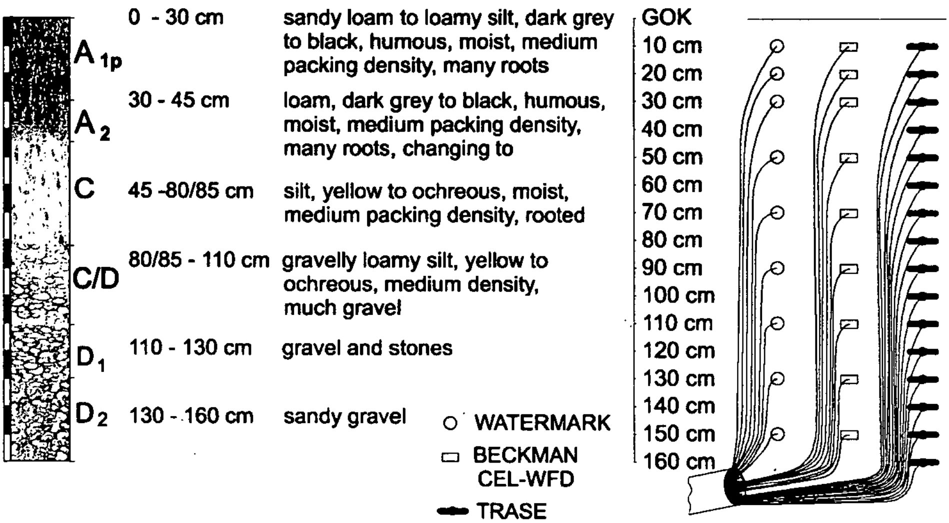

Figure 1: Soil profile and installation pattern of sensors

2.3 Simulation Model. The numeric model SIMWASER (Stenitzer 1988) simulates the water balance and the crop yield for any number of crop rotations and years, provided that daily weather records (air temperature, humidity of air, global radiation, wind and precipitation) are available. The soil profile to be simulated is divided into a number of layers, usually 5-10 cm thick, down to a depth, where seasonal change of the water content is believed to have minor impact upon the soil water regime. In case of capillary rise from groundwater the "model soil profile" is extended to the deepest groundwater level that is measured within the simulated period, and the daily course of groundwater level is included into the model calculations.

3. Results and Discussion. Daily precipitation, amount of soil water within the soil profile down to 1.65 m depth, and the well hydrograph are shown together in Fig. 2: from December to end of April the whole soil profile is at field capacity, and due to the low evaporative demand of the cold and humid atmosphere most of the precipitation is percolating down to the groundwater, causing the groundwater table to rise by about 130 cm. From the begin of May increasing evapotranspiration of the rapid growing winter wheat is exhausting the soil water storage to a great degree; at the same time, deep percolation ceases and the groundwater table even is lowered temporarily by limited local pumping. During winter 1996/97 soilwater storage subsequently is replenished by rains and snowmelt, but full field capacity of the whole soil profile is not yet reached at the end of March 1997. Under these circumstances no deep percolation was possible at the measuring site; therefore the recorded slight increase of the groundwater level is supposed to be caused by recharge from bare and less deep soil units nearby.

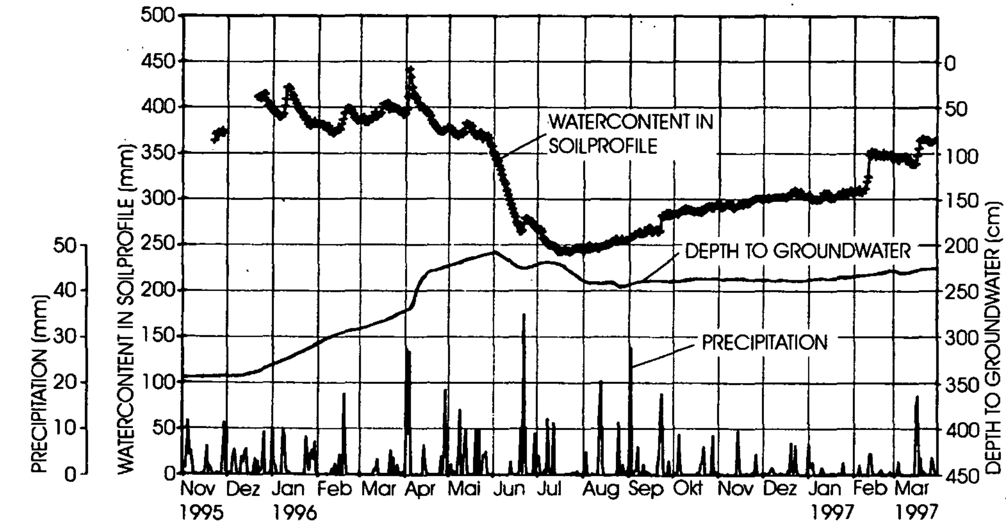

Figure 2: Water content of the whole soilprofile, groundwater level and daily precipitation at the study site

The value of the Storage Coefficient as derived from the slope of the empirical regression at the study site ("SUMRAIN" = 72.5 + 0.175 "GROUNDWATER RISE") was assumed to be 0.18; the corresponding deep percolation due to the measured groundwater rise during winter 1995/96 amounted to 245 mm, including some seepage from shallow soils near to the observation well. No recharge by seepage from soil at the study site was assumed for the rest of the period until end of March 1997. At this time the precipitation had accumulated to 785 mm; soil water content at begin and at end of the measurements was practically the same: actual evapotranspiration during the whole period therefore amounts to 785 - 245 = 540 mm.

Comparison of simulated soilwater content, evapotranspiration and deep percolation with their corresponding amounts derived from measurements is shown in Fig. 3: while the simulated and measured watercontents are full in line, there exists some difference between simulated and observed deep percolation due to the above mentioned problems in assessing the groundwater recharge from the observation well. Accordingly the same difference is to be seen between simulated and "observed" evapotranspiration, the latter of which being derived from the water budget equation, wherein the the amount of the deep percolation is uncertain at least for the period from mid of April to mid of May 1996. Considering the natural inhomogenities at field scale these deviations must be accepted in case of the given experimental setup.

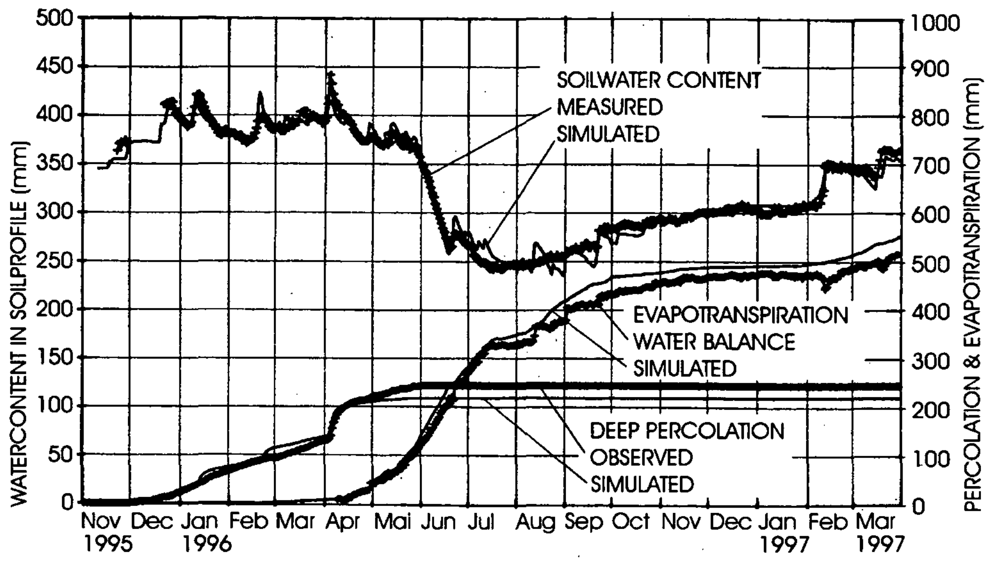

Figure 3: Comparison of simulated and observed soilwater content, deep percolation and evapotranspiration

4. Conclusions. Deep percolation may be assessed successfully by simulation, provided that representative soil hydraulic parameters are available.

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RECENT EROSION AND SPATIAL SOIL DISTRIBUTION IN SILTY ZONES OF INTENSIVE AGRICULTURE (NORTHWEST FRANCE)

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INTRODUCTION

The present work was conducted in the context of a broad-scale study of the erosion of silty soils in regions of intensive agriculture in northwestern France. It involved determining, at the scale of one spatial functional unit (catchment basin) (**1**), the effect and durability of erosional phenomena on the spatio-temporal redistribution of upper soil horizons.

At an intermediate observation scale (1:25,000) the soil coverage in the region studied ("Pays de Caux", Upper Normandy) is homogeneous, composed of slightly or moderately developed Luvisols and undifferentiated colluvial silty soils (**2**). On a large scale (>1:5000), that of the basic catchment basin, there is considerable spatial variability of the differentiation of the solums and the thicknesses of the A and Bt horizons that compose it.

This study thus had a dual aim:

. to define the distribution laws of the different volumes of pedology coverages (horizons) that would lead to extrapolation to broader zones (predictive model of thicknesses);

. to estimate the volumes of soils displaced over the course of time.

MATERIAL AND METHODS.

The catchment basin studied (350 hectares/≈ 900 acres) is situated in the "Pays de Caux" (between the Seine and Somme rivers in northwestern France). This region belongs to the system of the large chalky plateaux of northwestern France, characterized by:

. low altitudes: 160 m to the east, 80 m on the English Channel coast; gentle slopes with a mean of 1 to 5% that are long and convex-concave.

. a chalky substratum (Cretaceous) with beds of black silex, highly porous flint, considerably karstified and weathered into pockets, with a recent Loess coverage, 2 to 4 m thick, non-carbonated and attributed to the Medium Pleniglacial period (**3, 4**). Soils have developed in this coverage. This parental material rich in fine sand (15 to 25%) and depleted in clay (11 to 16%) (*Figure. 1*), explaining its considerable structural instability and high sensitivity to water erosion (**5, 6, 7**)

. an oceanic climate with abundant rainfall (750 to 1000 mm/m^2) but of low intensity;

. an open agricultural landscape whose plot distribution has increased over the decades.

* The catchment basin pedology was surved at the scale of 1:5000 on the basis of 353 auger holes (1.20 m deep) and A and BT horizons were identified, on field, by several caracteristics, specially the texture. 23 representative pedology profiles described and sampled for analytical characterisation (pedology trenches). Some horizons were also sampled for a micromorphology study.

All observation points were georeferenced and the characteristics of soil horizons identified by sounding were stored in a database.
* The terrain attributes of the site were obtained from a Digital Altitude Model (DEM) realized from field tacheometer measure.
The entire set of these data was used to create a geographic information system (GIS).
* Changes in plot distribution were studied on the basis of archives and aerial photos (coverage from 1947 to 1985).

Two successive procedures were used:
* a deterministic spatial approach, based on conventional mapping data and a structural analysis of sequential topology data;
* a quantitative approach by statistical analysis of the data and the crossover of different data layers of the GIS.

RESULTS AND DISCUSSION

The systematic prospecting and analysis of sequential topology data showed:
- considerable variations of the thickness of silty horizons A (20 to >120 cm) and silt-clay horizons BT (10 to 70 cm) (*Figure 2*) and a relatively large homogeneity of the other characters in the two groups of horizons,
- the absence of systematic relationships between horizon characteristics and the situation of solums in topography.

The morphological and micromorphological analysis of profiles observed in the trenches in some cases revealed an abnormal contact between horizons A and BT, as well as strata of old, ploughed, buried debris, features significant of a disturbance of the upper part of the solums. Mineralogy and particle size analyses, on the other hand, revealed no variation : the silty coverage was composed of a single material and so removal was done with no exogenous supply of material.

Since the characterisation of the different volumes of the pedology coverages and their mapping did not enable distribution laws to be determined, we chose another approach : quantitative by studying statistical correlations between pedology and morphometric variables derived from DEM

. Among the soil variables (characters of the 353 bourings), texture and thickness variables were selected and processed into two groups: silty horizons A (volume 1) and silt-clay horizons BT (volume 2).

. The morphometric variables of the terrain derived from DEM were altitude, slope, orientation, contributive surface and moisture index (**8**). The relationships between these variables were quantified by determining the correlation coefficient R.

* *Thickness of volume 1 h.E and terrain attributes Relationships*:
The correlation coefficients with i) altitude , ii) slope and iii) orientation were not significant (*Table 1a*) Concerning the slope, however, there were nuances, since we notice weak thickness of A horizons on slopes < 4% ; but these values concern a low catchment basin superficy. Relationships were much more clearcut with convexities, the contributive surface and moisture index. These three variables are considered as controlling volume and velocity runflow (**9**).

This suggests that the variability of silty horizons A (volume 1) resulted primarily from a redistribution by runoff processes..

* *Thickness of volume 2 h. BT and terrain attributes relationships*:
The linear correlation coefficients are not significant enough to relationships between morphometric variables of the present relief and short distance variability of BT horizons characteristics (*Table 1b*). Main part of this variability is a random combination of factors ; the too much low correlations are not enable to determinate effect of leaching and effect of surface hydrology processes.
In summary, the thicknesses of the two sets of pedologic volumes treated (volume 1 h. A and volume 2 h. BT) are not correlated with the same explicative variables, meaning that they evolved differently after leaching by effect of surface hydrology processes.
The results confirm the morphologic indices of disturbation observed in the profiles.

It is very difficult to determine the disturbed soils in the entire catchment basin in the absence of regional reference profiles that would lead to reasoning in terms of erosion or supply, or of continuous stratum reference points or markers (charcoal, stone tools, pottery, etc.). Similarly, measurements of the solids load conducted elsewhere for several years in this catchment basin cannot be extrapolated to the past, since the agricultural landscape and culture systems have changed considerably over the decades.

CONCLUSIONS.

The complementarity of the two approaches used in this work has enabled us to show:
- that the upper part of the silty Luvisols of the "Pays de Caux" were frequently removed principally by surface hydrology processes. This would confirm that soil erosion in this part of France is not a recent phenomenon.
Nonetheless, runoff and diffuse erosion do not explain all the heterogeneity of horizons A, and do not enable a predictive model of volume 1 silty h. A thickness distribution to be established. This must not probably be done without invoking other processes such as concentrated erosion and/or karstic draw-off.
- Quantification of soil volumes affected and the temporal dimension remain difficult to determine in the absence of a clearcut reference profile, or markers. The use of measurements such as isotopic techniques could undoubtedly provide elements of response.

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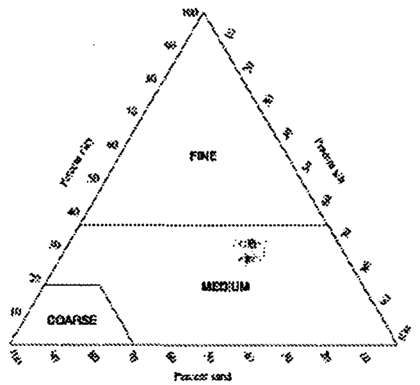

Figure 1 : Soil Horizons texture

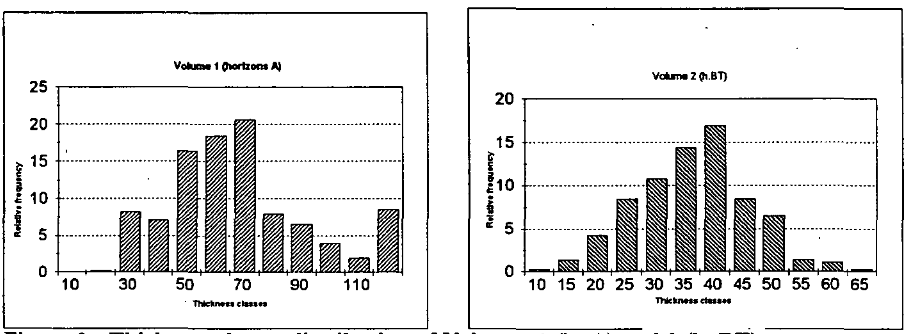

Figure 2 : Thickness classes distribution of Volumes 1 (h; A) and 2 (h. BT).

Table 1 : Correlations between terrain attributes and soil variables

a - Volume 1 = E horizons	!	Elv.	S	Sin φ	Cos φr	Pc	C	Sc	W
Thickness	!								
312	!	0.02	-0.14	-0.04	-0.01	-0.36	-0.40	0.32	0.45
Auger holes	!								
		no significant coefficient under 0.15 at probability level (5%)							
b - Volume 2 = BT horizons	!	Elv	S	Sin φ	Cos φ	Pc	C	Sc	W
Thickness	!								
231	!	0.21	-0.12	-0.16	-0.11	0.15	0.20	-0.24	-0.12
Auger holes									
		no significant coefficient under 0.18 at probability level (5%)							

Alt = Elevation; S = Slope gradient; Sin φ = Sin aspect; Cos φ = Cos aspect; Pc = plan curvature; C = Curvature; Sc = Contributive flow area; W = Moisture index

SURFACE SOIL MOISTURE AND TEMPERATURE A COMPARISON OF AIRBORNE AND GROUND MEASUREMENTS

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Introduction. Remote sensing techniques become more and more significant for various applications in Agricultural Hydrology due to technical development in sensoring and data handling. Information about soil surface characteristics in a high spatial resolution is important for a number of hydrological, agrometeorological and ecological aspects.

In this case study, the agreement of ground based measurements with data of soil surface temperatures and soil water content (upper layers) recorded from a helicopter is investigated. The measurements were carried out in two field experiments, first in Raasdorf near Vienna (Marchfeld) in autumn 1996, and second near Zwettl in summer 1997. The surface conditions of the investigated fields were ploughed bare soil and emergenced short winter barley in Raasdorf respectively ploughed bare soil and grass in Zwettl. Remote sensed data were recorded in 3 different heights with different ground speeds. Ground based data was measured with a grid size of 10x10 m.

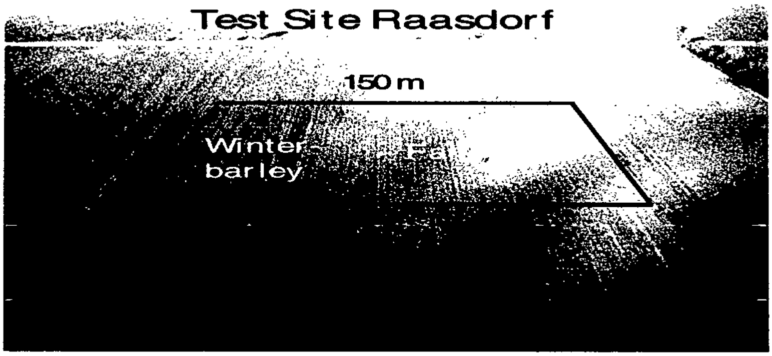

Figure 1. Different optical soil surface conditions of test site Raasdorf

2. Materials and Methods. The helicopter was equipped with an infrared sensor (8-14 µm) and a passive microwave sensor (L-Band Radiometer). For location of measurement points a GPS-system and a vertical mounted video recorder was used. Flight height over ground was measured by radar.

On ground, soil water content was measured gravimetrically and by using Time Domain Reflectometry (Trase System) and a capacitive sensor (Vitel). Besides soil bulk density was measured.

Figure 2. Test Site Raasdorf with an agrometeorological station on the left, L-Band Radiometer mounted on bottom of the helicopter on the right

Ground based soil surface temperatures were measured with an infrared gun (Everest 2000) and with thermocouples. The course of weather conditions during the day were measured as well.

3. Results and discussion. The soil surface temperature, measured with an IR-sensor from a helicopter, showed clear differences between the various test fields due to different soil coverages and surface characteristics. The relative agreement with ground based measurements was good although differences in absolute values were found.

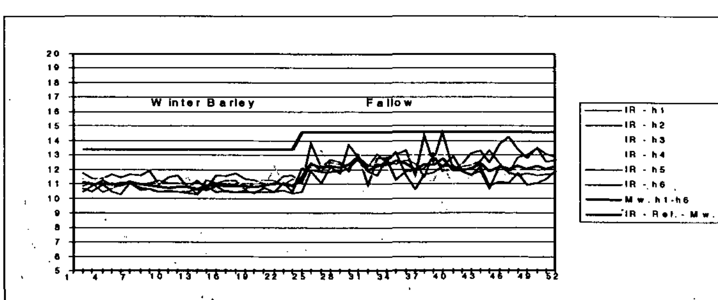

Figure 3. Comparison of soil surface temperatures at the test site in Raasdorf

The values of soil surface water content, measured on ground, showed significant variations, even within shortest distances. Therefore at each grid point a couple of measurements were carried out . The comparison by using the mean values shows good agreement between the three measurement methods on ground regarding the relative soil moisture distribution over the field. The different measurement depths of TDR (15 cm waveguide length), capacitive sensor (6 cm) and the gravimetric method (5-10 cm) showed an increase of soil moisture with depth.

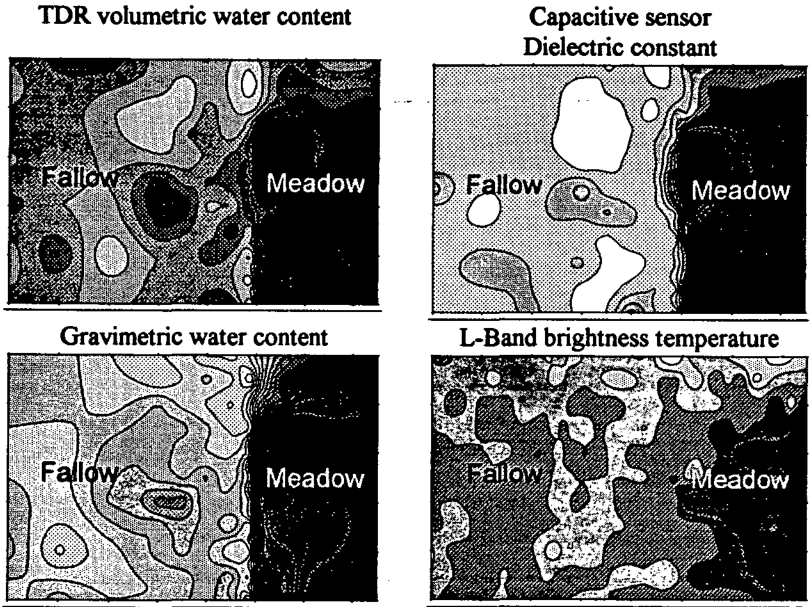

Figure 4. Comparison of the distribution of soil surface water content at the test site in Zwettl

The comparison of ground measurements with L-Band brightness temperatures in general shows a similar distribution. It becomes evident, that influences like surface temperature and roughness, plant stock and other additional information should not to be ignored when calculating the soil water content in absolute values. There are also local differences in the representative depth of calculated values, depending on soil bulk density, content of soil organic matter, circuit capacity and wave length used for the measurements.

4. Conclusions. Airborne L-Band Measurements can give an overview of soil moisture distribution of the observed surfaces. To calculate absolute values of water content, additional information of the investigated surface area is necessary. When this process can be automated, the result, the average water content over the relevant pixel size, could be used in an increased number of applications. In combination with spot measurements on ground, which are indicating the range of variability within small distances, we can improve our knowledge on what the average means and therefore on several problems regarding soil-plant-atmosphere interactions.

Models of soil system processes

Posters

The temperature dependence of decomposition - a modelling approach

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A novel approach, at least for laboratory conditions, is presented which analyses the dependence of soil C evolution on temperature using a two-component (labile and refractory organic C) parallel first-order model.

Carbon dioxide evolution from top- and subsoil samples of a clay soil was measured in the laboratory during 300 days at four moisture levels between the wilting point and water saturation and at -4, 0.3, 5, 15, 25 and weekly fluctuating -4/+5°C. CO_2 evolution after addition of roots or stubble of *Phalaris arundinacea* to the topsoil was also studied.

A first-order one-component model and a parallel first-order two-component model were fitted to the CO_2 evolution data using a least-square fitting procedure. Different functions describing the dependence of CO_2 evolution on temperature and moisture were fitted to estimated rate constants. A recalculation of the response to temperature to Q_{10} - values gave Q_{10} =2.2 at 25°C increasing to 12.7 at 0.3°C.

The CO_2 evolution rate per unit soil carbon was about two times higher for topsoil than for subsoil. Fluctuating -4/+5°C did not enhance CO_2 evolution significantly compared with incubation at constant 5°C and was even lower or not significantly different from samples at 0.3°C.

The two-compartment model resulted in a better description of CO_2 evolution dynamics (R^2_{adj} =0.96 and 0.81 for top- and subsoil) than a single-compartment approach (R^2_{adj} =0.88 and 0.76 for top- and subsoil).

The two-compartment approach was also successful in describing soil respiration data as compiled from several published papers. Data from 25 incubation experiments where time series for at least two temperatures were available were used in a comparison between a single- and a two-component model.

For the whole data set, a Q_{10} of 2 was found to be adequate for describing the temperature dependence of decomposition in the intermediate temperature range (about 5-35°C). However, for individual experiments, Q_{10} values deviated greatly from 2. At temperatures below 5°C, functions not based Q_{10} are probably more adequate. However, due to the paucity of data from low-temperature incubations, this conclusion is only tentative, and more experimental work is called for.

NON-LINEAR BEHAVIOUR OF SOIL SYSTEMS DURING HOLOCENE.

A CASE STUDY IN SOUTHERN RUSSIAN STEPPES

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1. Introduction. It is generally assumed that soil development is a linear function of time, particularly during the Holocene period, and that horizon differentiation results from the simultaneous interaction of soil-forming processes, the soil reaching at the end a steady state. Recently, an increasing literature has documented occurrence of repeated climatic changes during the Holocene with marked impact on the trend of soil development (e.g. Ivanov and Vassilyev, 1995 in southern Russia). Following this research line, we propose here to investigate the behaviour of a soil system during the last 4000 years with a resolution of a few centuries in order to test the linearity of soil development on which soil genesis is based. Soils of the southern Russian steppes, developed on loess deposited during Late Pleistocene, extensively distributed, with abundant patches never modified by cultivation, have been selected for this purpose. In addition, the profusion of funeral mounds, erected since approximately the third millennium BC and as late as the fifteenth century AD, under which ancient soils are well preserved, gives the possibility to investigate buried soils of different ages.

2. Material and methods. The investigated area is located in the Ergueni Hills, at the Volga-Don water divide, near the village of Abganerovo (45 km south-west of Volgograd), with a continental, semi-arid climate (300 mm annual rainfall and 7°C mean annual temperature). Soils are Solonetzic Light Chesnut (Kastonozem) with solontchak characters (according to Russian Soil Taxonomy) and could be classified as Borollic Natrargids in the US Soil Taxonomy. Each soil buried under a funeral mound was compared with the adjacent present day soil dug outside the funeral mound depression rim. A profile in a natural mound made by rodent ("souslik") mound was also investigated. The buried soils selected can be framed as following on the basis of archaeological data : (1) profile D-463, lying on the low terrace of the Axaï river (a few meters above the river bed): burial at the Early Bronze period (ca 4,500-4,000 years BP), (2) profile D-464, lying also on a low terrace of the Axaï burial during the XVII century BC; (3) profiles 452, D-457, D-454, D-455 to D-462, aligned along the water divide: burial between mid III - to early IV century AD (Late Sarmatian).
Results are based on micromorphological investigations (large thin sections 13 x 6.7 cm) and analyses of the bulk samples: grain size distribution, pH, carbonate, gypsum and soluble salt content, CEC and exchangeable sodium (the later performed in Pushchino, Russia).

3. Results. Comparison of the different buried soils show significant variations of many properties for the A1, B1 and to a lesser extend B2. The most striking differences concern the soils buried under the oldest funeral mounds, e.i. ca 4,500-4,000 years BP and 3600 BP.
Common attributes of all investigated soils. The parental material is characterized by a loose packing of well rounded to subrounded pseudosands (Ø 100-500 μm) mixed with quartz as well as some calcitic and ferrugineous grains and small nodules. Some (up to 20%) of the pseudosands are well sorted (this is silt size not sand?Ø < 8 μm), however not oriented and without bedding. The fine mass contains calcitic grains a few microns in size. Gypsum (8-10 %) is in the form of acicular crystals and idiotopic crystal intergrowths. More soluble salts are also present (1-2%). The parental material along the Axaï valley (profiles D-463 and D-464) is enriched in coarse quartz sand grain frequently bedded.
At a depth of 60-90 cm, the packing fabric merges progressively into a channel, subangular blocky microstructure while micron-sized calcitic particles increase. BCca horizons are characterized by micritic nodules which are : (1) developed on autochtonous material, (2) fragmented, (3) locally channelled, (4) locally superimposed by gypsum crystal intergrowths. At the top of Bcca horizons, the fine mass is progressively and irregularly depleted in calcite particles. However the fine mass remains calcitic to the top of rodent mounds while a few, loose, small calcitic accumulation are present at the periphery of some decaying roots. The calcitic profile is similar in old funeral mounds (ca 4,500-4,000 years BP and 3600 BP in age), as well as in young ones (mid III - to early IV century AD, with a decaclification of the upper 1 or 2 cm, and a progressive decalcification in the next 5 cm. In-situ calcitic nodule do not exist in the funeral mounds. The superimposition of an illuvial horizon by an albic eluvial one characterizes all investigated soils, except those on funeral and rodents mounds.
Specific attributes of soils of early third millennium BC. The A1 and top of B horizon present a loose packing of rounded to subrounded aggregates (Ø 100-300 μm) mixed with fine sand and coarse silt grains which resemble an "exploded" microstructure. It merges with depth
to a loose, blocky microstructure (aggregates Ø 0.5-1 mm). The A1 horizon display the juxtaposition of aggregates with an eluvial, an illuvial or a calcitic fabric. In the top few centimetres of A1, poorly oriented, surface and subsurface crusts, made of clay with silt (Ø up to 30 μm), exist and locally merge into a mediumly expressed lamellar fabric. The A1 contains various exogenous, fine silt-sized, mineral grains (clinopyroxene, olivine, zircon and calcite) and charcoal fragments. The decalcified B horizon contains brown, coarse clayey clay which are fragmented by the blocky microstructure. Frequent, dark brown ferrugineous features are in the form of irregular, small, concentrations in A1 whereas in B they coat regularly the blocky aggregates.
Specific attributes of soils of Late Sarmatian. A1 consists at the top (1 cm thick) of cross bedded laminae with frequent vesicles (Ø 500 μm) made of fine and medium silt (Ø up to 30 μm) and fine sand (Ø 50-200 μm). This fabric merges progressively into a well developed lamellar structure with loose fine sand concentrations in the voids. Carbonized fragments are present both in the fine sand concentrations (Ø 50-200 μm) and as microfragments (Ø up 30 μm, most < 5 μm) randomly distributed in the silty mass. The B is characterized by an irregular cross striated b-fabric, with common inclusions made of light brown clay textural features rich in micron-sized melanized particles. These features are almost isotrope, deformed, not or weakly oriented. Fine sand penetrate in the cracks of B.

Contemporaneous soils. Most of Late Sarmatian soil attributes are preserved in presentday soils, except in the upper part and some other churned areas of A1 where the lamellar structure is absent or mediumly developed. In this case, the structure is replaced by a loose packing of Enchytraied excrements, various plant fragments and roots. Fine sand and coarse silt infillings are almost absent whereas rather common elongated aggregates of B fabric are present in the reworked areas. Some large charcoal fragments are also present. Sub-surface, brown, clay crusts made of clay with fine silt and common melanized microfragments. Crusts are present in the form of lamellae and fragments.

4. Discussions. These observations help to describe formation of the studied soils as a sequence of pedo-sedimentary events that can be ascribed to contrasting soil-forming conditions relevant to define a series of environmental changes.

Late Pleistocene. This time period is marked by deposition of the parental aeolian material in the form of sands and pseudo-sands, no evidence of soil development.

Early Holocene. The main morphological characters of all investigated soil profiles have developed during the Early Holocene, i.e. over a time period of ca. 6000 years, and have not been, later, significantly altered. Horizonation which consists of an eluvial A, illuvial B and an excremental-calcitic BCca, for instance, developed at that time. However, lack of fossilized soils for this time period only allows to define the general trend of the soil behaviour. Therefore, the apparent linear development of soils during the Early Holocene only lies in the difficulty to have access to their sequential record that is expressed by their complexity.

The pedogenesis started by a complete reworking by the soil fauna to a depth of 60-90 cm of the aeolian parental material and a simultaneous accumulation of micritic calcite in the fine mass and in the form of nodules. The elu-illuvial phase has recorded the progressive decalcification of the upper soil, depletion clay and fine silt from A1, and their redeposition in the form of clay and fine silt coatings and infillings in the decalcified B. These coatings and infillings do not exhibit significant natric characters. Absence of overlapping between calcitic and textural features suggest that they respectively correspond to two successive phases. Occurrence of elongated, dense aggregates in A1 appears as relicts of a cryogenic fabric that can be ascribed to impact of frost at some moment during the Early Holocene.

Middle Holocene (ca 4,000 BP). Originality of this period lies in evidence of alteration not produced by soil-forming processes, and still not fully explained. Earthquake with violent shake , extremely violent tornado, or any regional mechanical stress might have created the « exploded » fabric of A1. Abundance of exogenous minerals and grains is clearly of aerial origin, and reasons for this selective input might be searched in a phenomena similar to the one documented at the same period in Syria and suggested to be linked to a volcanic or cosmic explosion (Weiss et al., 1993; Courty, 1997). The "exploded" fabric and exogenous minerals and grains are most probably related. The ferrugineous concentrations and coatings appear as the relicts of a root system that was preserved from total humification by exceptional conditions for bacteria activity. The simultaneous formation of surface and subsurface crusts indicate a short period of destruction of the vegetation cover, possibly by wild-fires. In the investigated profiles, analytical data as well as microphological observations do not show clearly an input of soluble salts and gypsum, however Demkin et al. (1995) have demonstrated elsewhere that such an input occurred during this period. Switch of the argillic characters of B horizons to natric ones after the mid Holocene, however, suggests an input of sodic salts. We have here the record of a crisis in the soil development, previously reported by various scientists and in different locations (Daftes et al., 1997). Gerasimenko (1997), in eastern Ukraine, a few hundred kilometres west of the investigated zone, has mentioned an aridification between ca 4,100-3,500 BP and four more, however weaker, shifts during the period ca 5,500-2,500 BP. Age of investigated funeral mounts do not allow us to differentiate these successive shifts.

Late Sarmatian (mid III-early IV centuries AD). A1 and B horizons have recovered a pedogenic fabric after the Middle Holocene crisis. The well expressed cryogenic fabric (lamellar structure and vesicles) of A1 means severe frost while the subsurface laminae are in relation with bare soils. Well expressed eluviation, characterized by fine sand and silt infillings, results of the fast melt of a thick snow cover in spring time. The B exhibits the morphological characters of a natric horizon which is confirmed by a pH above 9, e.g. 9.4 in B1 of D-452. Common carbonised microfragments indicate repeated burning of the steppe.

Present soil evolution. Frost action is presently weaker than during the Late Sarmatian as well as the eluvial process, while the vegetation cover and consequently the soil fauna are better developed in comparison to conditions during the Late Sarmatian. Carbonised microfragments are present, but however less common than earlier, although human pressure has recently increased. Abundance of subsurface crusts can be ascribed to overgrazing.

5. Conclusions. Results presented here demonstrate nonlinear soil development since the Late Pleistocene that is marked by a series of changes in soil-forming conditions and discontinuities: (1) the Late Pleistocene aeolian sedimentation; (2) an important bioturbation and formation of a calcic horizon synchroneous with the warmer conditions of the Early Holocene climate optimum; (3) a phase of elu-illuviation possibly correlated with the moisture increase of the second Holocene climate optimum at ca. 6000 BP; (4) at ca. 4,000 BP, interruption of pedogenesis with a severe disruption of A1 and B horizons, input of exogeneous particles, and probably a solonetzization of the B horizon; (5) later, a reactivation of soil-forming processes, however with fluctuations, e.g. the frost eluvial pedogenesis of Late Sarmatian versus the milder present day one. These investigations show that these southern Russian steppe soils have remained highly reactive to environmental factors which fluctuate widely and rapidly in this semi-arid area (Ivanov and Vassilyiev, 1995). Consequently a steady state was never reached. Pedologists classically would interpret such soils as the result of interlinked soil-forming processes, whereas our investigations show that they derive from the juxtaposition of pedological events, and interference with minor sedimentary episodes. The record of these past events has been partly preserved, but deformation and destruction of the signal by various phenomena is, indeed, a severe limitation for achieving a complete understanding of soil-development. In addition, several aspects deserve attention (1) since ca 4,000 BP, the calcitic profile has remained almost stable, soils on mounds are decalcified at maximum only on 1 or 2 cm while rare, very incipient calcitic accumulations exist in relation with the decayed roots in buried soils under mounds, (2) eluvial and illuvial features are not clearly correlated, e.g. the ones from Late Sarmatian.

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BEHAVIOUR OF SPATIAL SOIL SYSTEMS IN TIME: QUALITATIVE MODELS OF BOREAL KARST SOIL LANDSCAPES

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1. Introduction. For a long time, working on the problem of the genesis of a soil landscape (SL) and its behaviour in time, soil scientists created only verbal models. The "spatial" pedological concepts of Fridland (1972), Hugget (1975), Hole and Campbell (1985) and Ruellan et al. (1989), to some extent, move these studies closer to formalization. Nowadays, the application of numeric methods for spatial soil systems studies is widely discussed, for example by Webster and Oliver (1990) and Kozlovsky and Goryachkin (1994).Without depreciating any of the possibilities and promises of imitation modeling of SL behaviour, we believe that it is also necessary to develop a qualitative component in geographic and genetic soil science. Ecologists and other specialists often ask soil scientists to give a holistic and an immediate, but not always calculated, answer about the behaviour and possible changes of soils and soil cover as the components of ecosystem and landscape. For this purpose, the elaboration of methodology and methods of expert evaluation and qualitative model construction is required. Furthermore, in some cases a long-term collection of experimental data, necessary for mathematical modeling, is not available. These and some other particular reasons often force an investigator to stay with qualitative studies of genesis and evolution of SL.
The aim of the paper is to develop a genetic approach to studies of soil landscapes and to elaborate an algorithm for qualitative modeling of soil cover behaviour , i.e., to create a system of genetic-evolutionary models of soil landscapes. The suggested approaches to genesis and evolution modeling were applied to the spatial soil systems of the karst territory of the Russian European North.

2. Materials and Methods. The territory under study was an area of intensive karst processes in Permian hard gypsum (rock) of the south-eastern part of the Belomor-Kuloy plateau which is located between the rivers Severnaya Dvina and Mezen' in a northern part of boreal forests zone, approximately 120 km to the east of Arkhangel'sk, Russian European North. Soil survey and detailed mapping of several key plots in differently karstified areas were the basis for the soil landscape behaviour qualitative modeling. The set of soil landscape models was elaborated for that. It includes (I) a spatial model---soil cover pattern, presented on a detailed map: (2) a process-genetic model, reflecting processes and mechanisms that form SL, especially the soil boundaries; (3) a spatial-genetic model--a soil map with differentiated demonstration of soil boundaries connected to soil genesis and stability; (4) evolutionary and/or prognostic models of the soil cover, describing its behaviour (change in time).

3. Results and Discussion.. The soil cover spatial model is a basis for the further genetic and evolutionary interpretation. The soil landscape spatial model of a key plot with intensive karst formation is represented in Fig. 1 and Fig.2b. The territory is strongly dissected with deep karst forms. As a result, eroded steep slopes and sharp residual peaks covered by immature soils - Regosolsdominate throughout the territory. In some places Quaternary deposits are completely eroded, and gypsum appears at the surface. At karst hole bottoms, soils are formed under the condition of regular deluvial addition-these soils were referred to as deluvial soddy-mucky soils. In addition, a regular gravitational and eolian input of leaf fall takes place, resulting in the formation of specific dry soils with thick organic horizons in the deepest hole parts-organic-lateral-accumulative soils. In relief depressions, the Sulphorendzinas are found- soils formed on coarse colluvial fragments of hard gypsum. The only mature soils of the key plot are Podzoluvisols on loamy moraine and Haplic Podzols on sands.

The analysis of the whole complex of the processes leading to the soil cover differentiation (heterogenization) and association (homogenization) resulted in the established creation of SL process-genetic model (Table 1). The determining processes the soil covers are 1) the formation of forest ecosystems in the course of vegetation evolution, resulting in the main mechanism of surface disturbance in taiga-tree uprooting, 2) glacier movement and melting and 3) karst development along with tectonic processes leading to fissuring of a gypsum massif.

Table 1: Process-genetic model of the boreal karst soil landscape (SL)

SL-determing processes	Forest caenosis formation	Processes of glacier melting	Tectonic processes and fissuring of gypsrock and connected with them karst and corresponding denudation processes			
SL-forming processes	Surface disturbance by uprooting	Formation of glacial deposits	Sheet erosion and slope processes at the surface of karst forms			Organic colluvial accumulation at hole bottoms
mechanisms of SL differentiation	sheet erosion	lithogenic	sheet erosion	litho-genic	screes	gravitational organic accumulation
Boundaries between soils, formed by the process	P/Rg*	P/Po	P/Rg Po/Rg Dl/Rg	Rg/RO Dl/RO	S/Dl Rg/RO	Ol**/Dl
A share of soil boundaries in their total length, %	12,8	4,3	48,9	14,9	10,6	8,5
Degree of boundary changeability in time	Changeable	Stable	Changeable	Changeable	Changeable	Potentially changeable
Boundary numbers on Figure 1.	1	2	3	4	5	6

* Soil indices see Figure 2. ** Organic-lateral-accumulative soils of karst holes bottoms

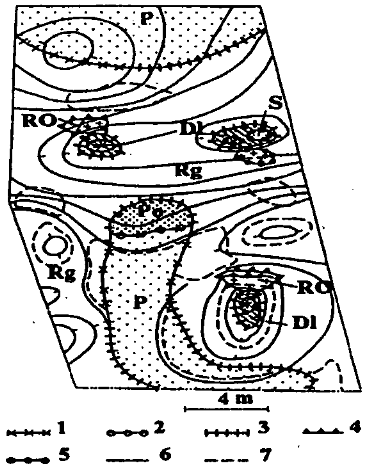

Figure 1: Spatial-genetic model of the karst soil landscape. Soil boundaries: 1-6 are listed in Table 1 - implicit boundaries might appear due to karst development
Soils indices see in Figure 2.

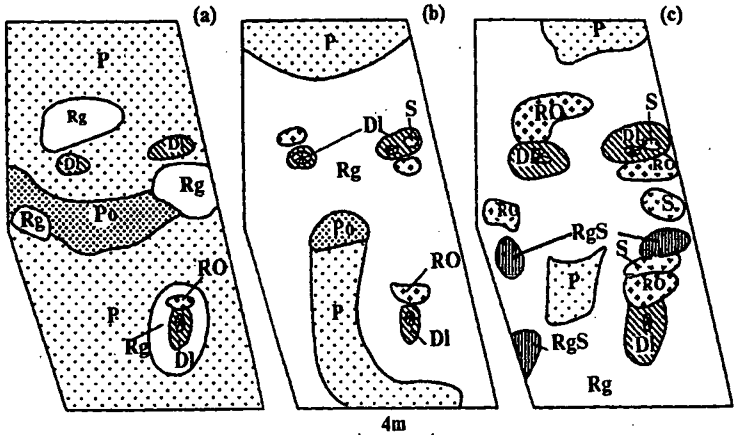

Figure 2: The model of the karst soil landscape behaviour in time:
(a) n* 100 years ago; (b) present day; (c) in n*100 years
Soils: P-Podzoluvisols, Po-Haplic Podzols, Rg-Regosols, Dl-deluvial soils, S-Sulphorendzinas (soils on solid gypses), RgS-Regosols/Sulphorendzinas (soils on loose material with shallow gypses), RO - rock outcrops

Soil landscape-forming processes and "SL differentiation mechanisms". (according to Fridland,1972) are placed in Table 1 below the cover-determining processes. The first line of the table characterizes the results of the processes and mechanism effect and shows soil boundaries appearing in the SL as a result of this effect. The next line describes the quantitative input of every mechanism in SL differentiation. It is represented as a percentage of the length of the boundaries caused by a given mechanism in the total boundary length at the key plot. Boundary length was measured by a curvometer. The assessment of soil boundary dynamics is represented below. There is a stable boundary (that is, without location change) between Podzoluvisol and Podzols on sands, as it is caused by different lithology. Other boundaries are changeable - they are evidently connected to recent erosion processes. A contemporary character of erosion is indicated by immature soils and stratified deluvial deposits. The process-genetic model demonstrates that SL of the plot undergoes an evolutionary development, as 87% of soil boundaries are changeable.
The spatial-genetic model of SL of the studied territory is represented in Fig.1. Besides the boundaries described in detail above, it contains implicit boundaries that could have appeared at much earlier or much later future stages of SL development. They separate different relief conditions and the depth of solid gypsum, which is much less near local tops.
Before the creation of final SL-behaviour models, we analyzed analogue models of SL describing the soil cover of the territories with higher and lower intensity of karst and denudational processes. The knowledge of the SL regularities of these territories, the analysis of possible boundary changes (Table and Fig.1) and ^{14}C-dates of wood fragments in recent soils(200-700y) allowed us to create an evolutionary and prognostic model (Fig. 2). The models demonstrate that an implicit boundary appeared in SL and that the SL of a karst area develops towards an increase in the proportion of immature soils and a more complex composition and geometric structure of SL because of the diversification of a lithologic background caused by active denudation.

4. Conclusions. An algorithm for a qualitative modeling of soil landscape behaviour in time is suggested. It is based on the analysis of the genesis and changeability of soil boundaries, of the analogue models and on ^{14}C data. An application of the algorithm to the soil landscape of the karst area in Russian European North gave the possibility to evaluate its behaviour as leading to an increased complexity of the composition and the geometric pattern.

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A MULTI LEVEL APPROACH OF STRUCTURATION IN TIME OF SOIL SYSTEMS IN NORTH-EASTHERN SYRIA

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1. Introduction. It is generally admitted that the development of soil horizon properties, particularly soil structure, results from successive stresses that act at the soil-atmosphere interface, and affect soil material according to a vertical gradient. In cumulative soils, maked by interactions of sedimentary processes with pedological ones, the different horizons are not the result of the same pedological history (Butler, 1982 ; Simonson, 1995). Several earlier studies (e.g. De Crecy and al., 1979 ; Tessier, 1984) have highlighted the effects of « energetic histories » on soil structure and physical properties. Tessier (1984) has particularly documented the influence of different level of stress on structure and underlined the importance of energetic maximun stress on soil clay material behaviour. These results however only concern pure clayey materials studied in controlled experimental conditions.
The objective of this study is to better understand , under natural conditions, how soil physical properties are constrained by the successive steps of stress history along short to medium time period (seasonal to secular). The possibility to compare soil horizons of different ages, and buried more or less rapidly under different types of sediment, has allowed to tackle the development of soil structure with time.

2. Materials and Methods.

2.1 Investigated Soils

The studied area is located in the Djezire region (North-Eastern Syria).Three main types of landscape systems, associated with archeological sites, have been identified: (i) simple and (ii) complex alluvial dominant sedimentation systems, and (iii) eolian dominant sedimentation system. Only this latter will be presented here and correspond to the Abu Fara site. This system is characterized by a slight depression with no functional ouadi at the present time. The archeological site is located in the center of the depression (fig 1).

2.2. Soils

The soils are calcaric Cambisols (FAO, 1974). They are clayey to loamy-clay and the carbonate content ranges from 30 to 40 % (table 1). A previous study (Courty, 1994) provided a model of landscape evolution for this region, in relation with climatic changes and human occupations. Correlations between this regional model and Abu Fara landscape local evolution is presently achieved through the use of granulometric and mineralogical data.

2.3. Analysis of the structure

Trenches were dug (numbered AF.1, AF.4, AF.7, AF.8) and soil profiles were described and sampled (fig.1). Soil structure was studied by (i) measuring the porosity of undisturbed samples (small clods of 1 to 2 cm^3) and (ii) analysing the fabric in optical microscopy of thin sections. The total porosity of the clods was determined by using the kerosene method (Monnier and al., 1973). In order to separate the textural porosity, that result from the packing of the elementary particles in the groundmass, from the structural porosity, that result from the aggregate packing, wetting-drying cycles, biological activity (larger pores than former), clods were transformed into a paste by pugging wetted clods. Then the textural porosity was measured on a air-dried paste where the porosity resulting from the packing of the elementary particles remains alone (Fies and al., 1981 ; Bruand and Cousin, 1995).

3 Results and Discussion.

3.1. Macro-structure

The studied soils show a weak vertical differenciation, mainly expressed by structural changes and differences of pedogenic carbonates with depth. Horizons boundaries are hardly recognizable at the field level and most of soil profiles show gradual structure variations. The general trend of field aggregation is from crumby, sometimes massive (structural collapse), at the soil surface, polyedric at medium depth, to prismatic or massive with well expressed slickensides at around 2 or 3 meters. Biological activity, wetting-drying cycles and cementation effects by pedogenetic carbonates are the main factors of structuration. Locally, the presence of buried chronological indicators (archeological levels) indicates the importance of sedimentation processes, particularly eolian, in soil development. This provides the basis to approach the temporal dimension of the vertical succession of horizons and of their structure.

3.2. Porosity

The physical characterization of the centrimetric-sized samples shows a decrease in the porosity from soil surface to depth. The textural porosity was about 0.52 cm^3/g for all the soil material studied. This leads to attribute most of the porosity variation measured to structural porosity variation, which is considered to be under the dependence of material « histories » (Faure, 1981). For the AF.7 profile, the structural porosity decreases from about 0.10 cm^3/g at the surface to 0.02 cm^3/g at about 2 meters depth (fig. 2). AF.1 structural porosity profile, buried under undisturbed archeological sediments, presents broadly the same general shape, but shifted to 1.70 meter down.

The physico-chemical analysis (table 1) indicate that level 1, 2 and 3 of the AF.1 profile correspond to the same sedimentary phase than level 3 and 4 of the AF.7 profile, and are contemporaneous (3^{rd} millenium B.C., as attested by archeological data).

The significant difference of structural porosity shown for these two profiles (about 72 % between level 1of AF.1 profile and level 3 of AF.7 profile structural porosity) can be related to the different conditions and rhythms of burial processes : rapidly under archeological sediments for the AF.1 profile, progressively under eolian sediments for the AF .7 profile.

This suggests that, under particular conditions, these soils can register in their structure and physical properties, the succession in time of different stages of development.

3.3. Micro-structure.

Optical microscopy observations of thin sections enabled to better define this hypothesis by morphological argument. Under the 3rd millenium B.C. archeological level, the soil structure of the surface horizon shows the same characteristics than the present time surface structure as described for the level n° 1 of AF .7 profile (fluffy micro-structure / crumby to weak polyedric field structure). Soil of level n°3 of AF.7 profile shows the imbrication of two genetically different structures (relictual fluffy to massive micro-structure / polyedric to prismatic field structure) which indicates a superimpose of two stages of evolution: (i) a surface aggregation controlled, for a large part, by biological activity and wind action and (ii) a secondary aggregation, consequence of wetting-drying cycles that has been produced at depth, and which affect more or less the initial fluffy structure.

This suggests that soil structure of the AF.1 profile has been fossilized under archeological sediments of rapid deposition This isolation from environmental post-burial conditions, has allowed the effects of their first step of evolution to have remained intact. The level n°3 of AF.7 profile, progressively buried under eolian dust, has not been isolated from environmental post-burial conditions. Therefore, it has undergone a second step of aggregation as the result of wetting and drying cycles. Nevertheless, its structure has kept a signature of the firt step of aggregation.

4. Conclusion.

This study shows the persistance of the effects of successive stresses on soil structure (« soils structural memory »), morphologically (mainly at the micro and field level) as well as concerning physical properties. The importance of this « memory » should be related to the stability of the different structures under various environnemental conditions, particularly water regime, controlled by climate (semi-arid climate in Djezire) and sedimentation rate (of natural or anthropic origin).

A consequence of this « structural memory » is that a punctual modification of soil structure, if stable enough regarding later stresses, can durably affect the functionning of the soil. This can be paralleled to the « maximum energetic stress » of Tessier (1984) for clays particles.

Characterization of thresholds that takes in account parameters such as water content, mineral surface properties and cumulative effects, should be necessary to understand better the structure dynamic now identified through the physical and morphological study here presented.

Finally, the spatial variability of soil structures from the profile to the micro-region, and more particularly their steady or non-steady character, has to be related with the evolution in time of these soils.

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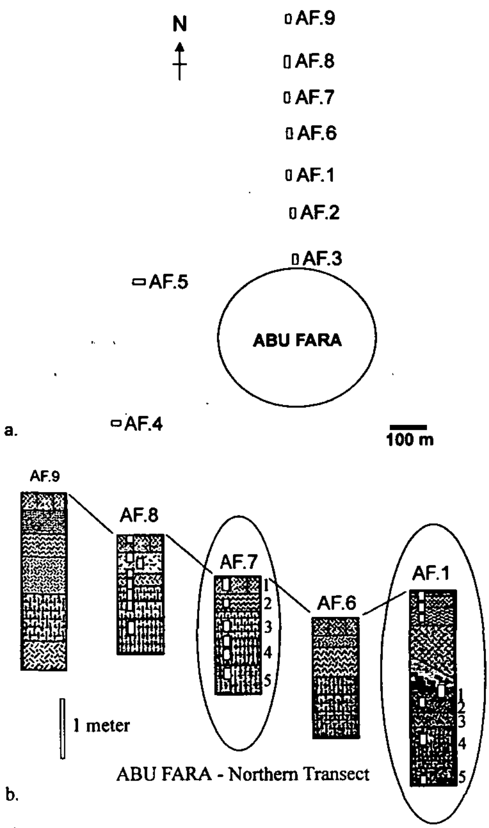

Fig. 1. ABU FARA
a. Archeological site and trenches localization.
b. Topography, horizons description and undisturbed samples localization.

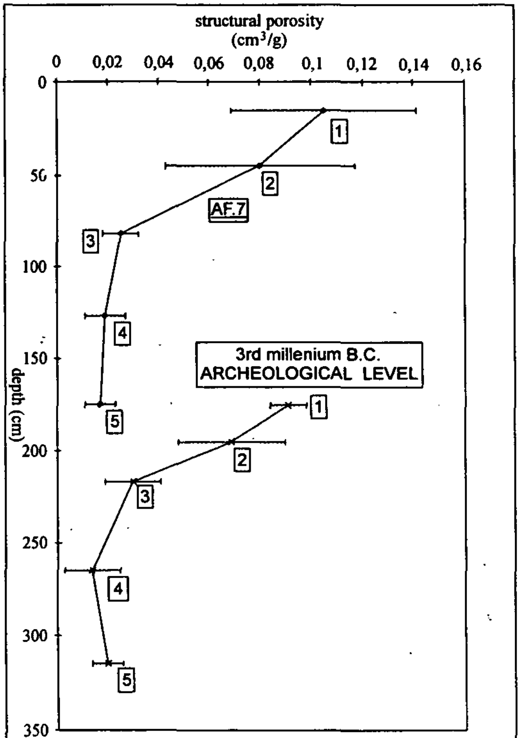

Fig. 2. ABU FARA – STRUCTURAL POROSITY (cm³/g)

Depth	Particle size distribution - after decarbonatation (g/kg)					Total	Organic	Cation exchangeable capacity				
cm	Clay	Fine silt	Coarse silt	Fine sand	Coarse sand	carbonates	matter	T	Exchangeable cations			
	< 2 µm	2 -	20 -	50 -	200 -				Ca	Na	Mg	K
		20 µm	50 µm	200 µm	2000 µm	(g/kg)	(g/kg)	(cmol.kg^{-1})				
<u>AF.1</u>												
170-185	34.9	21.1	5.7	1.4	0.3	34.3	0.4	15,1	41,9	0.77	3.24	5.39
185-205	32.1	21.3	4.4	0.9	0.2	38.4	0.29	15,2	42,4	0.74	4.04	4.56
205-230	30.6	24.3	4.5	0.8	0.2	37.4	0.24	16,9	45,1	0.81	4.90	4.07
230-300	40.7	16.8	3.8	1.0	0.2	34.8	0.21	18,3	44,6	0.97	6.43	3.96
300-330	33.5	21.4	3.7	0.9	0.2	38.1	0.17	18,6	44,2	1.11	7.22	2.81
<u>AF.7</u>												
0-30	37.2	21.8	7.4	1.5	0.2	30.6	1.1	17.3	46.8	0.06	2.89	0.99
30-60	40.6	17.6	6.0	1.4	0.2	32.4	0.64	17.2	46.7	0.07	3.22	0.75
60-105	32.6	21.3	4.4	0.9	0.1	38.0	0.29	16.1	44.3	0.14	6.35	0.28
105-150	31.8	20.7	4.6	1.0	0.1	39.2	0.24	17.0	43.3	0.23	8.41	0.25
150-200	44.0	11.3	3.5	0.8	0.1	37.5	0.19	18.5	43.1	0.33	9.72	0.25

Table 1. Physico-chemical analysis of soil profiles in Abu Fara 1 (AF.1) and 7 (AF.7) trenches.

USABLE EMPIRICAL MODEL OF THE SOILINTERNAL NITROGEN CYCLE

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Introduction

Nitrogen transformation in soil represents the most important part of global nitrogen cycle on the Earth. There are two essential processes of nitrogen cycle: mineralization of organic nitrogen and immobilization of mineral nitrogen. Both processes are resulting from biological activities (microorganisms mainly) with very high sensitivity from soil properties and climate condition, of course. Therefore, it is very difficult to determine exactly all data of this so called "continious internal nitrogen cycle" (C.I.N.C.). Nevertheless it is necessary to know it for all specific soil and ecological conditions (space variability) with aim to manage the soil nitrogen regimes in relation to sound agricultural production and environment protection, as well. A useful approach is to do it: to derive a valid models which are relevant to be used in theory and agricultural and/or environmental practices. This is also very important for succesful activities of all decission bodies on all levels of operation in agriculture and environment protection.

Material and methods

The bottom up target of the paper is to derive the specific models for the assessment and also the forecast of two main processes of the soil internal nitrogen cycle: nitrogen mineralization (N_{in} accumulation) in soil and nitrification ($N\text{-}NO_3^-$ accumulation) in soil. Both quantities we must define as a result not only N_{in} and N_{NO3}^- (separately) productions in soil but as residues after immobilization processes (net quantities).

The bottom up principles were used to derive the models. From 9 different soil-ecological agricultural conditions of Slovak Republic were 3 years (from each) collected data on net nitrogen mineralization and net nitrification processes. The following soils were investigated (named by World Reference Base for Soil Resources, 1994): Eutric Cambisols, Luvic Stagnosols, gleyic Eutric Fluvisols, albic Stagni-Haplic Luvisols, Eutric Fluvisols, calcaric Haplic Chernozem, calcaric Mollic Gleysols, Haplic Luvisols, Stagnic Glossisols.

Fifteen samplings were carried out from each experimental place at least. Incubation tests were used for all net nitrogen mineralization and net nitrification determinations. Soil monoliths (150 cm^3) were incubated 14 days at fresh moisture content and natural temperature (Bielek, 1980). Both non-fertilized and NPK fertilized (N 60-100, P 30-40, K 110-150) plots were sampled simultaneously.

For each experimental place the soil production potential was derived as a point value (from 1 to 100) with help of the method by Dzatko et al. (1976). Following parameters were taken into consideration: soil type/subtype, mineralogical substrate, soil texture and structure, soil gravelly and stones, slopeinclination exposition, climatic region. All point values of agricultural soils of Slovakia we can find in Geographical Information System about Agricultural Soils of Slovakia (Soil Fertility Research Institute, Bratislava).

Results and Discussion

Mean net nitrogen mineralization and nitrification intensities were derived from all collected data (Table 1).

Table 1 Net nitrogen mineralization and nitrification intensities in studied soils

Soil Type	Point values	Net Nitrogen Mineralization 1)	Net Nitrification 2)
(1) Eutric Cambisols	28	2.50	0.40
(2) Luvic Stagnosols	47	2.26	0.27
(3) gleyic Eutric Fluvisols	55	2.18	0.62
(4)albicStagni-Haplic Luvisols	64	2.29	0.80
(5) Eutric Fluvisols	90	4.86	2.03
(6) calcaric Haplic Chermozem	91	3.08	1.50
(7) calcaric Mollic Gleysols	95	2.90	1.55
(8) Haplic Luvisols	85	2.77	1.23
(9) Stagnic Glossisols	88	3.01	1.40

1) mg N_{in}/kg/ 14 days
2) mg N-NO_3^-/kg/ 14 days

Point values of non-fertilized soils were determined and related to relevant net nitrogen mineralization data (Tab. 1). The equation was derived as fallows:

(1) $$y_{Nin} = 2.01 * 2.7182^{0.0045\,x} \qquad (r = 0.9877)$$

where y_{Nin} = mean net nitrogen mineralization in soil (mg_{Nin}/ha/14 days);
x = point value of soil.

Using the data from NPK fertilized plots a second equation was derived, as well:

(2) $$y_{Nin} = (2.01 * 2.7182^{0.0045\,x}) + (143.5\,x^{1.1} * 10^{-6} * D_N)$$

where y_{Nin} = mean net nitrogen mineralization in soil (mg N_{in}/ha/14 days);
x = point value of soil;
D_N = dose of mineral nitrogen fertilizer (kg N/ha).

The relation between soil point values and net nitrification intensities was derived:

$$(3) \quad y_{N\text{-}NO_3^-} = 0.33 * 2.7182^{0.0151\,x} \qquad (r = 0.9654)$$

where $y_{N\text{-}NO_3^-}$ = mean net nitrification in soil (mg $N\text{-}NO_3$/kg/14 days);
x = point value of soil.

For fertilized NPK conditions was derived equation as follows:

$$(4) \quad y_{N\text{-}NO_3^-} = (0.33 * 2.7182^{0.0151\,x}) + (23.42\,x^{1.53} * 10^{-6} * D_N)$$

where $y_{N\text{-}NO_3^-}$ = mean net nitrification in soil (kg/ha/14 days);
x = point value of soil;
D_N = dose of mineral nitrogen fertilizer (kg N/ha).

Case-specific net nitrogen mineralization and nitrification rates can be calculated from the models (1,2,3,4) for any soil site when we know it's point value (which is available in Slovakia).

Using a Geographical Information System about Slovakian soils we created:

i) a data base of mean net nitrogen mineralization and nitrification rates with an accuracy of 3 ha of agricultural soils as minimum;
ii) maps of mean net nitrogen mineralization and nitrification activities (for each 5 categories of intensities, scale from 1 : 5 000 to other derived scales).

Besides, created data base and maps about territorial variability of nitrogen mineralization and nitrification in Slovakian soils the equations (1,2,3,4) we can use in many decision activities in agriculture and environment protection (for example: optimization of nitrogen fertilizer consumption, recommendations for farming in sensitive areas, etc.)

Conclusions

The following general conclusions can be made after the data collection and data processing on net nitrogen mineralization and net nitrification processes in soils:

1. Specific models (equations) were derived with the aim to calculate and/or predict the mean net nitrogen mineralization and nitrification intensities in arbitrary nonfertiized and NPK fertilized agricultural soils.

2. Using the entire Geographical Information System about Slovakian Agricultural Soils the national data base about mean net nitrogen mineralization and nitrification intensities was created for territory of agricultural land of Slovakia (resolution 3 ha as minimum).
3. Maps of mean net nitrogen mineralization and nitrification intensities were created on the level of Slovak Republic agricultural land (basic scale 1 : 5 000, digitalized). Printed maps (1 : 500 000) and also leaflet forms are available from the Soil Fertility Research Institute, Bratislava.
4. Nitrogen mineralization and nitrification were determined as very sensitive processes in soil. Generally from 70 to 210 kg of mineral nitrogen per 1 ha is produced in non-fertilized soils of Slovakia during the vegetation period. When we use N-fertilizers the net mineralization of nitrogen is accelerated almost in all territory of agricultural soils. Total nitrate production in Slovakian agricultural soils represents from 10 to 60-70 kg $N\text{-}NO_3^-$/ha during the vegetation period. In N-fertilized soils it is much more.
5. Higher intensities of both net nitrogen mineralization and nitrification processes we can find in more productive soils. Low intensities belong to the poor soils.
6. Acceleration effects of nitrogen fertilizers on nitrogen mineralization and nitrification processes is higher in more productive soils in comparison with poor soils.
7. Only 20-30 % of total mineral nitrogen production is represented by nitrates in poor soils. In most productive soils it is about 40-50 % (non-fertilized conditions).
8. When nitrogen is applied almost 50 % of nitrate is produced from the total mineral nitrogen production in poor soils. In most productive soils it is about 80-90 %.
9. A system of nitrogen fertilizers application was derived from the models (see in Soil Fertility Research Institute, Bratislava).

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Modells of Soil System Processes With Organmic Matter Turnover in arable Land on Sandy Soils

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Introduction

On the sandy soils of Central Europe, deep ploughing and sprink-ling is practised more and more (SCHWERDTFEGER, 1978). On this old arable land there is today an Ap-horizon between 30 to 35 cm with N-richness and also high values of all other nutrients. This soil-type is named Agrosol (SCHWERDTFEGER, 1994).

Materials and Methods

First the differences between Agrosol and the historic soil Plaggen(esch)(WRB, 1994) has to be explained.

A Plaggenesch has an Ap/E/II-profile with more than 5dm E-horizon. This horizon originates from sods of heath and grasses,which were strewed in the stable and rested there for several months. For one or two years this manure was in a clamp before it was brought into the field. By this Plaggenmanure the arable land was raised by 1 mm per year. This method was in use in the northwestern part of Europe on the light sandy soils since one thousand years ago.

But nowa-days nobody works in this way. The origin of Agrosols needs the horsepower of modern tractors. With horses the plough and his following aggregates can penetrate only a little over 20 cm. With the power of tractors most of the time every three years the plough is going down to 30 cm. Special aggregates work even 15 to 30 cm deeper. This loosening of the underground is also done by plants.

Nitrogen fixing plants benefit most from deep ploughing. Schultz-Lupitz, who had pioneered this technique on light sandy soils with different kinds of lupine and clover (GÄDE, 1989) was able to increase the yield of cereals and potatoes by a factor of three.

1885 he was one of the first members of the DLG (Deutsche Landwirtschafts Gesellschaft), which was founded in this year by MAXEYTH. The "soil genesis" in the mind of SCHULTZ-LUPITZ is a dynamic process of developing, which is carried out today by many farmers. In the last years also science is working more and more in this direction.

A very important step is the ascertainement of mineral fertilization. For the important nutrient N the basis is for springfertilization the Nmin-method. During the growing season the new method "Nitrachek" brings more security (NITSCH,1997). For this analysis a sample for 3-5 ha in cerealfields gives a good result. Thirty strongest stalkest from the whole area are to be cut at their basis in pieces of 1 cm. With the Nitrat-test in some minutes the result between 200 and 3000 ppm gives a clear answer. Plants are optimal supplied, if they have 800-1000 ppm Nitrat.

For soil fertility as described above the content of organic substance (OS) is an important characteristic. ALTERMANN and URBAN (1996) have presented the two profiles in table 1. In Kunrau the profile is going down to 200 cm, in Schmarbeck to 153. There was opened by URBAN an other profile only some meters away of 170 cm depth. It was never used as arable land. Nowadays it has a heathvegetation and serves for sheepgrazing. Its pH-values are between 3,3-4,7. Schmarbeck has not only intensive arable land but also a famous breedingherd of "Heidschnucken".

Table 1 Soilprofiles in Kunrau (K) und Schmarbeck (S) (from ALTERMANN and URBAN, 1996)

horizon		thickness		colour		OS %		pH-value	
K	S	K	S	K	S	K	S	K	S
Ap	Ap	35	30	10YR3/4	5YR2.5/2	2,2	4,94	5,8	5,6
Bv	B(s)v	15	24	10YR5/6	7,5YR4/6	0,5	0,5	4,7	5,9
IIBt +ilC	Bv(s)	40	25	10YR7/3	7,5YR5/6	--	0,07	4,8	5,9
ilC +Bt	BvCv	40	40	10YR5/6	10YR6/8	--	0,05	4,3	5,5
OilC	Cv1	20	26	10YR6/6	10YR6/6	--	--	4,8	--
IIIBt	Cv2	50	8	10YR6/6	10YR5/8	--	--	4,8	--

The quantity of OS is by these analyses only insufficient to de-termine,over the quality is nothing to say on this way.

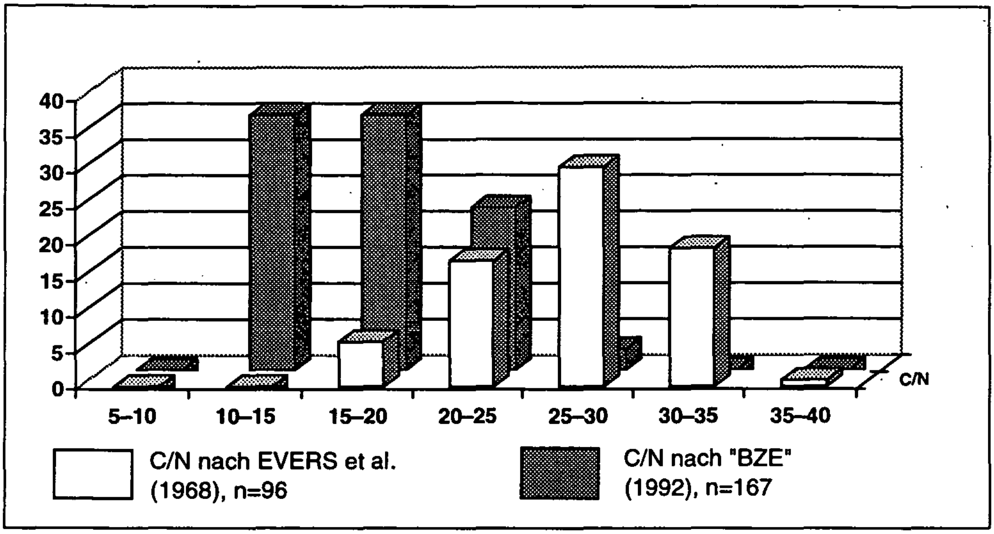

Figure 1 Relative frequency of C/N-values in Baden-Württemberg (Beyer, 1996 aus BUBERL e.a., page 13, 1994a)

Not everything can be found over the total N-bilanz. For that other methods are nessesary on arable land with profiles over 2 m. Some of our cultivated plants are gowing down with their roots to that depth.

The quality of OS has changed in the last 40 years. In figure 1 the relative frequency of C/N-values in Southwest-Germany (Baden-Württemberg) in the years 1968 and 1992 is pointed out (BEYER, 1996). The maximum of 25-30 is going down to 10-20. The reason for this development in forests is the higher airtransport of N.

On arable land only a small part of N comes out of the air; the most is given by the farmers with fertilizers. Therefore the C/N-value in the last years becames narrower and the colour of the A-horizon darker. WIECHMANN (1996) presented the following division of

Ackermull

disintegrated semiintegrated integrated

light dark very dark

little thick deep extended

The values of Munsell-Color-Charts are for light over 3,dark 3-2,5 and very dark under 2,5. This way the C-content and the C/N-value is determined directly in the field. Very dark soils have a high absorption for radiation and by that also effect to all pro-cesses regulated by the emperature. The total store of N in a soil can be used only during the growing season by plants. But this differs each year with changing soil moisture and temperature. Therefore the farmer needs the above described methods for N-investigations.

Results and Discussion

The turnover of organic matter is different in all soils. In sandy soils it changed much quicker than in other locations. So the farmer in this region needs a current information during the growing season. One of the most important is the plantavailable N. The new method "Nitrachek" brings this security. But the answer is only for growing plants.

The knowledge of the whole profile is necessary for longtime decisions. It must go down to 2 m. On light sandy soils some of OS is to find till that depth. The N in this OS is fixed in macromolecules, which release only a small part during each growing season. There the rootlets of deep growing cultivated plants can take it up. So the N is not leached into the groundwater.

Conclusions

1. In each national soil systematic a major soil group of Anthrosols is needed. In this unit several subdivions are all sealed soils (full and partly) and all anthropogeogenic soils (mining, Deposols,Reductosols).
2. Anthropopedogenic processes form the subdivision of Terrestric Kultosols.
3. In this subdivision the Agrosol may be on the first place. Other related soils are Plaggen, Hortisol, Treposol, Nekrosol.
4. The start of building up Agrosols was given by farmers. They needed higher yields also on the light sandy soils. One of the most important pioneers was SCHULTZ-LUPITZ.
5. Science commenced this work first in the last decade (GÄDE, 1989).

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World Reference Base for Soil Resources and Soil System Behaviour in Time and Space

Lectures

WRB, A DYNAMIC WORKING GROUP OF THE ISSS

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1. Introduction

This paper traces the history of World Reference Base for Soil Resources (WRB) since its inception with special attention to its evolution since Acapulco, 1994. WRB is elaborated upon as a dynamic working group under ISSS. Major conclusions of WRB meetings are reviewed and the rationale, principles, current issues, and publications of WRB are presented.

A common nomenclature is vital to the functioning of any society The credibility of soil science is suffering from the lack of a generally accepted system of soil classification. . This situation arises partly from the fact that soils constitute a continuum which, unlike using the species of plants and animals, and needs to be broken into classes based on subjective criteria. For many years the International Society of Soil Science has endeavored to develop this common language for naming the soils of the world.

2. History

In the early days of pedology the classification of soils was mainly based on soil genesis. The various schemes that were generated differed according to the concepts of soil formation held by the authors. The intensification of international communications and the expansion of soil surveys in the 1950s, both in temperate and in tropical areas, greatly enhanced the overall knowledge of the soil cover. Classification systems were developed which aimed at embracing the full spectrum of the soil continuum. It soon appeared that nomenclature, survey methods, legends and systems of classification varied so widely that inter-regional comparisons were difficult. Although a consensus had evolved as to the main soil bodies to be separated, major differences persisted with regard to the levels of generalization at which these soils were to be distinguished, the criteria to be used for their separation and the weight to be attached to different soil properties in a classification system. Differences in terminology and nomenclature were an additional constraint to international correlation. At the initiative of FAO, in cooperation with UNESCO, UNEP and the ISSS, a group of soil scientists, representing a broad range of soil institutions, met at Sofia in 1980 in order to enhance international involvement in a follow-up to the Soil Map of the World (Dudal, 1990). The Bulgarian hosts effectively contributed to overcoming some geopolitical issues which, at that time, were not entirely absent from scientific gatherings. The meeting decided to launch an International Reference Base for Soil Classification (IRB) with the aim of reaching international agreement on the major soil groupings to be recognized at a global scale as well as on the criteria to define and separate them. The group met a second time at Sofia, in 1981, and laid down the general principles of a joint programme toward the development of an International Reference Base (IRB). In 1982, at New Dehli, the 12th Congress of the International Society of Soil Science endorsed and adopted this programme and entrusted it to a Working Group at large. In 1986, at the 13th Congress of the ISSS at Hamburg, the IRB was taken in charge by a Working Group of Commission V itself (Soil genesis, classification and cartography). In 1990, the Commission devoted a Symposium to the IRB in the framework of the 14th Congress of the ISSS in Kyoto. The IRB scheme which was presented on this occasion comprised 20 major soil groups compared to the 28 first level units distinguished in the legend of the FAO/UNESCO Soil Map of the World (Dudal, 1990). At the meeting of the IRB Working Group, at Montpellier, in 1992, it was decided that the revised FAO/UNESCO legend would be used as the basis for the further development of the IRB and that efforts would be merged. It would be IRB's task to apply its general principles to the further revision of the FAO/UNESCO units and to provide them with the necessary depth and validation. The consolidated approach was renamed 'World Reference Base for Soil Resources' (WRB) reflecting the involvement of a wide range of soil scientists, rather than of representatives of 'national schools' only, and the attention being paid to soils as a resource rather than as mere taxonomic units. Progress in the preparation of the WRB was reported to the 15th Congress of the ISSS at Acapulco in 1994 (Spaargaren, 1994).

3. WRB goals

The World Reference base for Soil Resources (WRB) is designed as a standard nomencleture or taxonomy to identify, characterize and name major types of soils. It is not meant to replace national soil classification systems but will serve as a common denominator through which national systems can be compared and correlated. In addition to serving as a link between existing classification systems the WRB may also serve as a key tool for compiling global soil data bases for the inventory and monitoring of the world's soil resources. WRB intends to facilitate the exchange of information and experience, provide a common scientific language, strengthen the applications of soil science, and enhance communication with other disciplines.

4. WRB organization

To facilitate operations, WRB is structured in three tiers:

1. The WRB Task force is comprised of the Chairman, vice-Chairman and the Secretary. The mission of the task force is to initiate, chair and report WRB activities and to compile overviews for discussion in plenary WRB sessions.
2. WRB Steering Committee: sets the stage for WRB activities, discussing financing of WRB activities, policies and publications.
3. WRB Plenary Working Group, compiles reference databases, drafts WRB proposals and contributs to the discussions during plenary sessions.

5. WRB activity calendar since Acapulco, 1994

One Steering Committee meeting was convened at Leuven (1995). Plenary WRB meetings were held at Kiel (1996), Moscow (1996), South Africa (1996), Argentina (1997) and Vienna (1997). Each of these meetings were attended by a group of 15-30 participants and comprised indoor sessions as well as field testing of WRB on well-documented soil profiles.

6. Classification guidelines for WRB

The general principles on which the WRB is based were laid down at the early Sofia meetings and further elaborated upon by the Working Groups entrusted with its development (Dudal, 1996). These general principles can be summarized as follows :

1. The classification of soils is based on soil properties defined in terms of diagnostic horizons and characteristics, which to the greatest extent possible should be measurable and observable in the field;
2. The selection of diagnostic horizons and characteristics takes into account their relationship with primary soil forming processes. It is recognized that an understanding of soil forming processes contributes to a better characterization of soils but that they should not, as such, be used as differentiating criteria;
3. To the extent possible at a high level of generalization it is attempted to select diagnostic features which are of significance for management purposes;
4. Climatic parameters are not applied in the classification of soils. It is fully realized that they should be used for interpretation purposes, in dynamic combination with soil properties, but they should not be part of soil definitions;
5. WRB is meant to be a comprehensive classification system which enables people to accommodate their own national classification system. It comprises two tiers of categorical detail: (1) the "Reference Base" which is limited to the first level only, having 30 Reference Soil Groups; (2) the "WRB Classification System" consisting of combinations of a set of prefixes as unique qualifiers (or modifiers) added to the Reference Soil Groups, allowing precise characterization and classification of individual soil profiles.
6. The Reference soil units to be retained in WRB should be representative of major soil regions so as to provide a comprehensive overview of the world's soil cover.
7. The revised legend of FAO/UNESCO Soil Map of the World (FAO, 1990) was used as a basis for the development of the WRB in order to take advantage of the international soil correlation work which has already been conducted through this project;
8. An attempt is made for definitions and descriptions of soil units to reflect variations in soil characteristics both vertically and laterally so as to account for spatial linkages within the landscape;
9. The term 'Reference Base' is connotative of the common denominator function which the WRB will assume. Its units should have sufficient width to stimulate harmonization and correlation of existing national systems;
10. The nomenclature used to distinguish soil groups will retain terms which have been traditionally used or which can easily be introduced in current language. These terms need to be precisely defined in order to avoid the confusion which occurs when names are used with different connotations.
11. The Reference Base is not meant to substitute for national soil classification systems but rather serve as a common denominator for communication at an international level.

7. Major changes in the WRB system since Acapulco, 1994

(1) Changes at highest categoric level are: inclusion of the Durisols as a new Reference Soil Group; Sequisols were renamed to Plinthosols; Glossisols were defined more precisely as Albeluvisols; stagnic properties are referred to lower categoric level; (2) A system of qualifiers was introduced from the second categoric level downwards; (3) A number of new diagnostic horizons were defined in order to simplify the system e.g. Chernic, Albeluvic, Duric horizons; (4) Definitions were adjusted: e.g.. Plinthite now has made room for a soft variant, paraplinthite, which is common in South Africa.

8. WRB publications

WRB received due publicity in the scientific press, with a paper in Geoderma, 6 papers published in workshop proceedings.

Towards Montpellier 1998 two books have been prepared:

- Reference Soils of the World in a nutshell: illustrated overview of the 30 Major Reference Soils aiming at a wide readership, including non-soil scientists.
- Keys to Reference Soil Groups of the World: a technical key.

9. Conclusions

Soil science has suffered from the lack of a generally accepted system of soil classification which has resulted in a loss of credibility and in a limited interaction with other disciplines. It is hoped that the updating of the Soil Map of the World and the development of the WRB will remedy this situation and will progressively lead to a generally agreed identification of major soil groups and of the criteria to separate them at an international level. The great diversity of soils at country scales justifies national systems at the lower levels. This two-pronged approach will facilitate the establishment of an international consensus. It is a challenge for the WRB to remedy the widespread soil resource illiteracy which still prevails. As a result a great deal of incorrect information is being generated - about environmental hazards related to agriculture, dessertification, degradation - which often leads to decisions which are adverse to sound development. WRB should serve as a first entry, accessible to other disciplines and to a wider public, into the knowledge of soil diversity and soil distribution. It is imperative that soil science assert itself in the public debate and in the overall scientific community. A common WRB language could provide the means to do so.

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TRENDS IN SOIL TAXONOMY - A SHARED HERITAGE

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The task of developing a new soil classification system was initiated in 1950 as a response to the enhanced demands for soil information, a desire to organize our understanding of the genesis, properties and distribution of soils, and the need for a system that was adequate to meet the challenges of making and interpreting soil surveys. It took about 25 years for the system to evolve and its final publication (Soil Survey Staff, 1975) in 1975 served as a benchmark in the evolution of concepts and developments in pedology. It had a mixed reception and even strong criticisms in some parts of the international community which, in fact, became a challenge to the USDA Natural Resources Conservation Service (then the Soil Conservation Service) to mount an aggressive program of validation and improvement. The makers of the system recognized that more information on soils of other parts of the world, specifically the tropics, was needed to develop it into a system that could be used globally. In 1980, a program was initiated to obtain data and information from around the world and to draw on the experience and expertise of all soil scientists to enhance the system. This paper explores the basic traits of the system and elaborates on its evolution since 1980 (Soil Survey Staff, 1996).

Soil Taxonomy has a number of characteristics common to most international soil classification schemes today. They include: a formalized hierarchy with defined categories and criteria for class recognition, quantified soil properties, specified methods of determination, consistently applied nomenclature, prioritized keys of placement, a genetic thread as a basis for selection of soil properties, defined properties that can be used at different categorical levels, recognition of intergrades and extragrades, and defined units of classification and sampling. Of great importance has been the built-in flexibility that enabled the process of modifying the system to occur as additional information was considered. Soil Taxonomy was designed to facilitate an ongoing soil survey program in the United States which involved mapping on air-photos at scales of about 1:20,000, correlation of map units named for the dominant soil series or equivalent components, publishing surveys on photo mosaic backgrounds, and providing laboratory data and other information to support numerous interpretations of soils for planning and implementing appropriate practices associated with land use for agriculture, forestry, range, parks, wilderness areas, and urban and rural communities.

A basic unit of classification needed to be specified and after much debate and trials with definitions it was agreed that the unit was a geographic entity which was called the polypedon. The basic units did not have a specified size, only taxonomic limits, and they were those of the soil series being recognized. The pedon, as a sampling unit, was 1 meter square on the surface unless the soil exhibited cyclic or periodic horizonation whereby the pedon was to cover one-half of the cycle but not to exceed 3 1/2 meters in diameter.

Unlike previous systems, emphasis on measurable properties was a major requisite during its development. To maintain consistency in the placement of soils in the system the method of measurement was specified. A major departure from other systems was the recognition of soil temperatures and soil moisture states as bona fide soil properties which could be measured, or approximated with reasonable assurance, and which were compatible with the abstract definitions used for most of the categories. By quantifying soil properties and features, other soil properties could be added as needed. This flexibility has been exercised many times during the continuing evolution and refinement of Soil Taxonomy.

Because the genesis of soils was not emphasized in the descriptions of the soil categories and their classes, it was assumed by many readers that those underlying concepts had been abandoned. To some observers the system was a rigid, mechanical, technocratic marvel without the backbone of the logic that had given rise to soil science and pedology. As users became more familiar with the classification of their favorite soils, it became apparent that soil genesis had guided the selection of soil properties. The soil survey itself was founded on the recognition of landscape elements and patterns of soil profiles in those landscapes that could be consistently identified, described and delineated. For the most part, the recognition of functional relationships is the way of soil genesis and it undergirds the philosophy and structure of Soil Taxonomy.

The principles of hierarchical structures are rather widely known and used to formulate working models of soil classification. Hierarchy theory was used and a set of keys was devised to enable the user to not only navigate the system but also appreciate the linkages. The categories are arranged from the higher, more abstract groupings down to the lower, more detailed and less abstract groupings. The nomenclature of a hierarchical system is meaningful to the extent that there is consistent composition of the classes. The use of roots from Latin and Greek, whenever possible, has been an interesting experience. The mnemonics of a hierarchy were sometimes as challenging as defining the classes of the categories.

Though Soil Taxonomy was published in 1975, it was in its final form by 1970 and the decade of the seventies was used to apply and test the system in the US and by others around the world. A concerted effort towards international testing beginning in 1980 has led to major changes to the system. Initial steps weres to determine the weaknesses in the system, solicit ideas from the international community, and develop data bases to test the ideas and concepts. The willingness by NRCS to change, the flexibility of the system to undergo the changes without distortions to basic concepts and tenets, and the participation of the international community in this process were the hallmarks of the last two decades.

The changes introduced have been supported by:

- a clearer understanding of the role and intent of each of the six categories of the system;
- with a larger database and a wider experience of global soil resources, the relative importance of soil processes became clearer and the geography of soils, was better understood;
- systematic detailed soil surveys and other resource assessments in the US and other parts of the world provided the knowledge of landscape relationships; this provided a rational basis for defining criteria and hence categories in the hierarchical system;

- developments in the supporting sciences such as soil physics, chemistry, mineralogy and micromorphology became *defacto* tests of the relevance and utility of the system;
- the ability to predict soil behavior through taxonomic classes and the need to interpret consequences of management has placed additional requirements on the system;
- recent changes in land-related legislation affecting use and management which depend on refinements, particularly in the lowest category, for proper implementation.

Changes within the system are the result of recommendations from field parties and their state staff, other members of the National Cooperative Soil Survey of the U.S.; international committees established to address specific issues in Soil Taxonomy, and individual soil scientists from around the world. Over the years the Ultisols, Alfisols, Oxisols, Spodosols, Vertisols, and Aridisols were revised to incorporate the findings and recommendations of International Committees. The previous suborder of Andepts was expanded to an order and recently a Gelisol order class has been established, paralleling the Cryosols of the World Reference Base proposal.

Improvements of the features associated with wetness have been made including Endo-, Epi-, and Oxy- aquic conditions, and refined definitions of redoxymorphic features. Modifications of the definitions of soil moisture regimes and soil temperature regimes continue to be evaluated. The keys to family classes are being tried, a committee is working on proposals for an Anthrosol order and suggestions for modifying the Inceptisols are under review. An upcoming amendment will exclude the soil temperature related criteria for some suborder classes. Documenting the proposed changes is a very time consuming activity as it requires good descriptions, laboratory and other supporting data, estimates of the extent and significance, and then the impact or implications on all other taxa in the system.
We think that Soil Taxonomy remains a viable and useful system of soil classification because the tenets on which it was based were good ones that have stood the test of time.

- Use a hierarchical system because there are far too many individual soils to deal with.
- Apply the principles of hierarchical organization of knowledge of populations; that is, define categories with appropriate levels of abstraction and select properties to separate classes within the category that are consistent with the definition of the category.
- Provide a naming system that is a mnemonic aid to learn and use the system. Define soil, basic units of classification, soil properties and methods of measurement.
- Provide keys to assist in the placement of soils by competent scientists.
- Supplement the operational system with descriptions of the rationale for the decisions that have been made.
- Keep the process of change as open and flexible as possible, but have standards for making and implementing modifications and follow them. Try to keep flexible enough to accept the rapidly changing technology that enables the system to change.
- Know in your heart that someday the system will have the capability to destroy itself as it no longer is able to adapt to truly new paradigms of knowledge.

There is, and we suppose always has been, merit in having several major systems of soil classification available at the same time. The World Reference Base for Soils and its potential application for 1:1 M maps and databases supported by FAO and other UN organizations makes sense. It also makes sense to have a system like Soil Taxonomy that was developed and continues to be used for detailed examination and evaluation of soils at the farm and field level. As other countries, like China and Russia, continue to re-examine their systems and databases, scientists throughout the world will have more opportunities to learn and to contribute. There is such a great need to better understand soils and the ecosystems that they support that there is ample room for friendly competition, for cooperation, for mutual respect, and for carrying out our responsibilities to help people everywhere know and use soil resources as wisely as possible for a sustainable global habitat.

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ACTIVITIES OF THE EUROPEAN SOIL BUREAU AND STATE OF PROGRESS OF THE EUROPEAN SOIL INFORMATION SYSTEM

L. Montanarella, D. King, J. Daroussin, M. Jamagne, C. Le Bas and V. Souchère

Introduction

Numerous actions for the knowledge of soil resources had been made in Europe for many years, but without real harmonisation. A lot of them have been supported by the European Commission, but not sufficiently co-ordinated. A European Soil Bureau has been thus recently created for better co-ordinate the European activities on soil.

This paper will present briefly the organisation of the projects of the European Soil Bureau, then the state of progress of one of those projects resulting from an important and fruitful effort of consultations: the European Soil Information System.

The European Soil Bureau

The European Soil Bureau (ESB) has been created in 1996 as a new body within the European Commission. It is located at the Joint Research Centre (JRC), Ispra, Italy, and is part of the Agricultural Information Systems Unit of the Space Applications Institute. Its aim is to carry out scientific and technical duties in order to collect and harmonise soil information relevant to Community policies, to its relevant General Directorates (DG's), to the European Environment Agency and to concerned Institutions of the EU Member States (Montanarella, 1996).

The activities of the ESB are essentially driven by the demands on soil information by the EU Member States and the European Commission. The needs of these two large user communities are gathered through two committees, the Advisory Committee and the Inter-DG Co-ordination Group on Soil Information.

The Advisory Committee is formed by official delegates from the 15 EU Member States and from the EFTA countries. Observers with no voting rights are also admitted from the major International organisations (FAO, UNEP, etc.) and from the EU neighbouring countries. The committee insures the necessary link between the activities of the ESB and the relevant policies and activities concerning soil in the single EU Member States.

The Inter-DG Co-ordination Group on Soil Information is an inter-service working group with participants of all the relevant services of the European Commission involved in directly or indirectly with soil related issues. Particularly DG VI (Agriculture) and DG XI (Environment) are heavily involved in soil related policies. Recently a surge of interest in soil information has been observed also by other Commission services: DG XVI (Regional policy) in relation to the European Spatial Planning Perspective, DG I (External relations) and DG VIII (Development) in relation to soil information in non-EU countries. The extension of the European soil databases to non-EU countries has indeed been stimulated by the needs of these General Directorates. Recently, the United Nations Convention to Combat Desertification entered into force, and the European Union, as one of the parties of the Convention, will have to strengthen its support to adequate soil information systems in the affected regions.

The needs identified by the two bodies, the Advisory Committee and the inter-DG Group, are collected by the Secretariat of the ESB and transmitted to the Scientific Committee.

The Scientific Committee is in charge of implementing the necessary activities in response to the needs for soil information. It is formed by relevant European experts in soil science and operates through small *ad hoc* working groups in charge of performing the single tasks requested by the soil information users. Currently there are four working groups active within the ESB:

• The **1:1,000,000-scale European Soil Database Working Group** is operating already since many years, well before the creation of the ESB. It has been the driving force of a European joint effort of many soil scientists from different countries. Chairman of the group is Dr. M. Jamagne (INRA - SESCPF). A more detailed presentation is done in chapter 3.

It is expected that the development of this soil information system will continue well beyond 1998 with the extension of the coverage to the Commonwealth of Independent States and to the Mediterranean basin.

• The **Information Access Working Group (IAWG)** turned out to be one of the most important within the ESB, as it is in charge of the development of a European policy for the access to soil databases. The general aim of the group has been to develop guidelines that insure the maximum protection of the data ownership together with regulated access for all the potential data users, with conformity to the EU policy regarding the access to relevant environmental information in Europe. Chairman of the IAWG is Dr. R.J.A. Jones (Silsoe College, Cranfield University).

The Information Access working group developed the guidelines that are a major breakthrough in European data access policy. The key statement is that data ownership and copyright remain with the Contributor. This means that the data supplied to the ESB by the Contributors for the creation of the European soil database are owned by the Contributors and not by the Commission. On the other hand, the principle of regulated access to the data by everybody is reinforced. The combination of these two statements produces a data access policy that maximises database access and use and safeguards the intellectual property by the Contributors. Licenser of all the soil data is the European Commission through its European Soil Bureau that becomes focal point for data licensing and distribution.

Data are leased for a limited time and not sold. Charging is according to a price matrix. The adopted price matrix differentiates the cost of lease of data according to the use. Minimum charge (cost of handling) is applied to Contributors and non-profit organisations for internal use. Charging is required in the case of external use by these organisations. Maximum charging is applied to full commercial uses by private organisations.

• The **1:250,000-scale Working Group** represents the future of the ESB. It works at the design and construction of the new European soil database at scale 1:250,000. Chairman of the group is Dr. P. Finke (SC-DLO, Wageningen).

The 1:250,000 Georeferenced Soil database of Europe project started after a feasibility study by the Directorate General XI (Environment) prepared by R. Dudal, A. Bregt and P. Finke in 1993 (Dudal and al., 1993). This study was commissioned to meet the still growing demand for soil parameters in environmental context - for which assessment on levels of regions or watersheds seems most appropriate - and to support the databases already developed by CORINE, e.g. on land cover and biotopes at scale 1:100,000. Direct contact to national soil surveys and land research centres of the former 12 EU Member States demonstrated that the national coverage of soil mapping at scale appropriate for a more detailed soil map ranged from 10% to 100%. However in all countries, some areas where found with coverage sufficient to be converted into a 1:250,000-scale soil map through generalisation, eventually complemented with some additional fieldwork. Special attention was paid to soil and terrain attributes which need to be recorded in term of environmental protection.

Given the low availability of soil data suitable for preparing a more detailed soil map of Europe, it was determined that " a wall to wall soil map" or soil database could be accomplished only in the long term, but a recommendation was made to carry out studies in small pilot areas with a high coverage of data, with the aim to develop a methodology, a common legend and a common database useful for the final database at scale 1:250,000. This principle was endorsed also by the European Environment Agency (Scoping study on establishing a European topic Centre for Soil, DGGU Service Report no. 47, 1995). In order to start the project, a working group was created within the ESB. It is charged with the preparation of the Manual of Procedures, the delineation of the pilot areas and the overall scientific supervision of the project. From the operational point of view the database will be created in selected pilot areas co-ordinated by regional co-ordinators for territorial correlation of each project . The selection of the first pilot area already started with the delineation of an area covering the North-Italian Quaternary plains. Project leader for that area is R. Rasio (ERSAL-Lombardia).

• The **Soil Hydraulic Parameters Working Group** has been established independently of the ESB, financed through a Human Capital and Mobility Network. Only during its second year of work it applied for being included in the activities of the ESB, as it is concerned with a soil hydraulic parameters database linked to the 1:1,000,000-scale soil database of Europe. The database has the acronym HYPRES which stands for Hydraulic Properties of European Soils. It will be distributed in its final version through the ESB according to the same data access procedures. Chairman of the group is Dr. H. Wosten (SC-DLO, Wageningen).

The European Soil Information System (EUSIS)

This system is developed in the framework of the European Soil Bureau, as described above through scope of the 1:1,000,000-scale European Soil Database Working Group. Before presenting the state of progress of EUSIS, the different stages which allowed to reach its present status will be quickly described.

History

European programmes of the European Communities Commission on soil knowledge and management have been included since many years in two wider-ranging programmes as:

- in agricultural production domain (DG VI), by means of the Soil Map of the European Communities (EC) at scale 1:1,000,000 .
- in environment domain (DG XI), by means of CORINE programme.

Action of FAO and EU General Directorate VI (Agriculture)

From 1952, studies were made about the different soil classification systems in Europe, with a view to eventual harmonisation and common work. The first result was the publication of the FAO Soil Map of Europe at scale 1:2,500,000 in 1965 (FAO, 1965). During the seventies, work continued under the auspices of FAO on the Soil Map of Europe at scale 1:1,000,000. The legend was designed at the same time as that of the Soil Map of the World at scale 1:5,000,000, which was published in 1974 (FAO, 1974). Because of financial problems, the work was stopped by FAO and the map has never been published. In 1978, the European Commission decided, with agreement of the FAO, to revive the work for the countries of the European Communities (EC). The final Soil Map of EC was published at scale 1:1,000,000 in 1985 (CEC, 1985). In 1986, the territories of Austria and Switzerland were added to the map at the initiative of UNESCO and the International Soil Science Society (CEC - ISSS, 1986).

During this time, agronomic research was organised by DG VI in different Programme Committees with precise objectives, co-ordinated by the Permanent Committee of Agronomic Research (PCAR). The Programme Committee for Soil Science first was called "Land Use" and later became "Land and Water Use and Management". Between 1972 and 1985, it worked successively on the following points: 1) inquiries in EC countries to define the main problems affecting land management ; 2) drafting of the EC Soil Map at scale 1:1,000,000 ; 3) organisation of "Workshops" where soil conservation took an increasingly important place ; 4) introduction of computerisation in data processing ; 5) research into land evaluation, land degradation and conservation.

The publication of the 1:1,000,000-scale EC Soil Map was certainly the most powerful stimulus but we have to keep in mind that it was the fruit of more than 30 years of works and many regional and national soil survey staffs.

Action of EU General directorate XI (Environment)

The main objective of the CORINE programme (DG XI) was the creation of a Co-ordinated Information System on the state of the Environment and Natural Resources of the European Communities. This implied setting up a homogeneous framework for collecting, storage, presentation and interpretation of environmental data on the EC countries (Briggs and Martin, 1988).

The CORINE programme resulted in the computerisation of the EC Soil Map in 1986, constituting the first spatialised soil database (version 1.0). This work consisted in digitising contours and indicating, for each polygon, the number of the corresponding soil association and the nature of the possible phases (Platou and Norr, 1989). No more data were used than those which were drawn on the map.

This database thus was created as part of research into, and the storage and handling of soil parameters that must be considered for both agricultural production and land protection. The first version of the database was rapidly applied to two major problems that required the use of multi-parameter combinations: a map of the buffering capacity (Chadwick and Kuilenstierna, 1990) and a zoning of the southern part of EC in term of susceptibility of soil to erosion, associated with another zoning dealing with land quality (Giordano and al, 1995). Other uses of this information were attempted and were not necessarily published but the number of studies remained weak (Jamagne and al., 1993 ; King and al., 1994).

Structure of the present European Soil Information System.

The soil information system has presently four parts: (1) the meta-database, (2) the soil geographical database at scale 1:1,000,000, (3) the soil profile database, and (4) the knowledge database (King and al., 1996).

• The **Meta-database** is chronologically the last stage and it is still in progress. The objective is to gather information on the references about pedological studies in Europe. The expected meta-database should provide a catalogue where users could find more information in detailed national maps. An earlier programme was carried out but no update has been made for ten years.

• The **1:1,000,000-scale Soil Geographical Database** is the heart of the system. It includes the list of the Soil Typological Units (STU) i.e. all soil types within the European Union which were mainly identified with the FAO-UNESCO legend (FAO, 1974), revised by the CEC (1985). From a semantic point of view (non spatial attributes), STUs are described by attributes with a harmonised coding: FAO soil name, parental material, slope, phase, topsoil and subsoil texture classes, subsoil texture depth, depth to an obstacle to roots, presence of an impermeable layer, water regime, water management. From a geometric point of view, STUs generally are too small to be drawn on a map at scale 1:1,000,000. They are clustered in Soil Mapping Units (SMU) which are defined by contour lines and polygons. The "object SMU" is clearly related to the concept of soil association (Simonson, 1971).

• The **Soil Profile Database** contains soil profiles with physical and chemical analyses. For each dominant STU, a representative soil profile was collected with main analytical data. Standard formats were developed for harmonising the various analytical methods in Europe (Madsen and Jones, 1995).

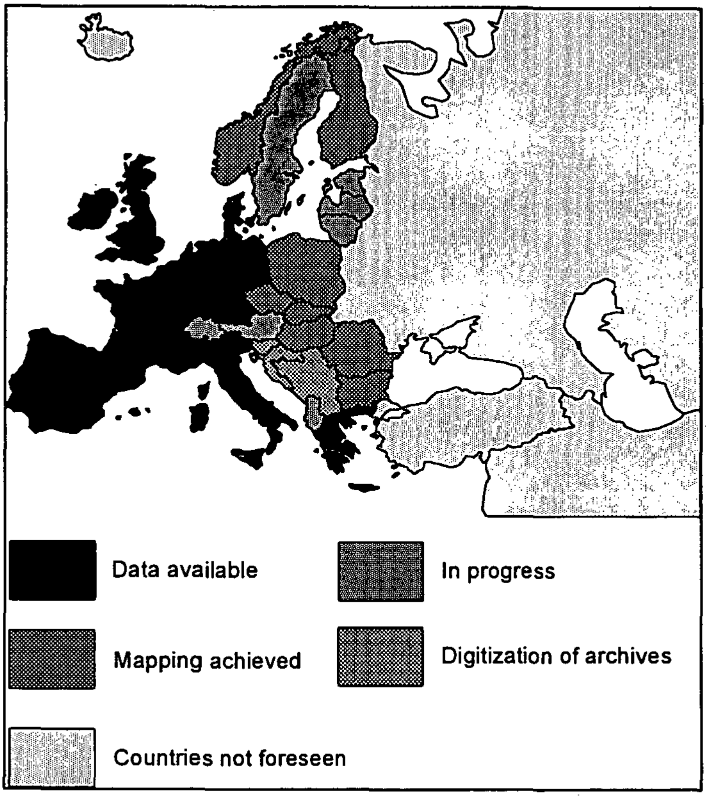
The difficulties to harmonise all the various analytical methods led to the adoption of two data formats. The first is for measured data which come directly from real georeferenced profiles. A code enables storage of the analytical methods used and missing values are accepted. The second format stores estimated data. The analytical methods are fixed for comparison of the values throughout the various countries of Europe. In this second format, the attributes must be fully completed by using guesstimation. About 500 soil profiles are available, but more are expected in the near future.

• The aim of the **Knowledge Database** is to provide interpreted variables for agricultural or environmental purposes, for helping non-expert users, or for giving analytical parameters for modelling. The interpretation is done using pedotransfer rules, elaborated by several experts, for estimating the needed parameters through logical relationships. The way of building the rules tries to formalize how the soil expert interprets the soil data stored in the Geographical Data Base. The rules can also use data from other sources e.g. climatic, land use or elevation data.

State of progress

The map shows the state of progress of the different databases over Europe. For the European Union of the twelve countries, the geographical database version 3.2 is achieved. A knowledge database and an analytical database are being updated. For the Central European countries, the geographical database is nearly achieved and an analytical database is in development. For the new countries, the geographical database is in development. The other countries are not foreseen for the moment.

State of progress of the 1:1,000,000-scale Soil Geographical Database of Europe (September 1997)



Conclusion

A usable Soil Geographical Database at scale 1:1,000,000 is available at the EU level and several projects are asking for using it. Information in such a database is regularly updated due to new knowledge or adding of new territories. Management of this information is taken in charge by the European Soil Bureau. It should ensure the quality control of the updates and should deliver licenses for users.

The 1:1,000,000-scale Soil Map, and then the several versions of the 1:1,000,000-scale Geographical Database allowed the use of harmonised data by diverse European projects, such as study of erosion risks, monitoring of agricultural production or mapping of water holding capacity. But considering the more and more precise demands, quantitative information at more detailed scales are needed. One of the priorities is to elaborate a 1:250,000-scale soil database. This project is not really an improvement of the 1:1,000,000-scale database but it should use new methods in order to develop a more flexible and reliable information.

Moreover it is needed to go from basic information to necessary indicators for sustainable management of rural areas and more widely for resources protection (water, air, landscape). Development of methodological research on those indicators is thus an important objective: data combinations, remote sensing use, development of models to formalise the processes, combinations with monitoring networks.

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SOILS OF AUSTRIA IN THE WORLD REFERENCE BASE FOR SOIL RESOURCES

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1. Introduction. The current Austrian soil classification system was published almost 30 years ago (Fink, 1969), and has never been revised since then. Currently, efforts are underway by the Austrian Society of Soil Science to revise the national classification system, but a very limited number of soil scientists with experience in soil classification makes it a difficult task to update and maintain a classification system in a small country such as Austria.

National classification systems, in particular those developed in small countries have the disadvantage that they are not adopted for use in other regions of the world. Facing the increasing need for cross-border cooperation, e.g. in UN and EU programs, or with developing countries, we question the rationale for the maintenance of national soil classification.

Based on these considerations we identify an urgent need for harmonization of soil classification at an international level. This need has partly been addressed by the legend for the soil map of the world (FAO-Unesco, 1988). Based on classification frameworks adopted from the US Soil Taxonomy and various other national (merely European) classification systems, this legend represents the fundament of the latest efforts to establish a soil classification at a global level, i.e., to develop a World Reference Base for Soil Resources (WRB). A draft has been jointly proposed by the International Society of Soil Science (ISSS), the International Soil Reference and Information Center (ISRIC) and the Food and Agriculture Organization of the United Nations (FAO) (Spaargaren, 1994).

This novel classification system provides a chance for the harmonization of national systems if the upper two levels of WRB are carefully defined with respect to:

- consistency: criteria used to define diagnostic horizons, materials and properties, as well as for soil groups and soil units should be theoretically sound and based on soil properties only;
- completeness: all known major features of the world's soil cover have to be properly described;
- compatibility with the national classification systems.

While the first two requirements can likely be accomplished to a high extent, the latter may be useful to support the acceptance and use of WRB by national organizations concerned with mapping and monitoring of soil resources. Its feasibility will depend on the national system in consideration, and on the availability of comparative studies.

In this paper we check the draft for WRB (Spaargaren, 1994) for general consistency, as well as for completeness, and compatibility from our national view by applying WRB to soil data available for major soil types defined in the Austrian classification system (Fink, 1969). Based on this procedure, we identify and discuss advantages and problems associated with WRB.

2. Materials & Methods. Both field and laboratory data on Austrian soils available from previous studies and soil mapping exercises were used to classify these soils according to WRB and the Austrian system to correlate these systems. Spatial and temporal relationships, in particular intergrades between major soil groups of soil units according to WRB were compared to those described in the Austrian classification system to identify gaps in WRB. Classification exercises along with theoretical considerations were used to identify inconsistencies and potential pitfalls of WRB.
Based on these considerations, we propose modifications of WRB at the first two hierarchical levels of the system, and specify subunits required for proper assessment of Austrian soils.

3. Results & Discussion

3.1. Consistency of WRB. According to FAO-Unesco (1988) Cambisols key out as the last soil group, being defined as "other soils having a cambic B horizon". The new concept of Cambisols in WRB defines Cambisols as "other soils having a cambic horizon or a mollic horizon overlying a subsoil which has a base saturation (by 1 M NH_4OAc) of less than 50 percent in some part within 125 cm of the surface" (Spaargaren, 1994). These soils key out prior to Arenosols and Regosols.
The revised definition is inconsistent or at least problematic simply because soils typically weather from the surface downwards; therefore, the subsoil is usually less acidic than the topsoil. This is representative of most brown soils ("Braunerden") under agricultural landuse and/or on parent materials rich in bases: these soils are typically calcaric, eutric, or only slightly acidified, displaying BS>50% throughout 125 cm depth. These soils are excluded from Cambisols in WRB, and the soil units: chromic, eutric and calcaric Cambisol become obsolet, since these soils do not match the criteria set for Cambisols. Brown soils with BS < 50% in the subsoil will key out latest as dystric Cambisols, since the cambic B will typically display even lower BS than in the horizons below. Since there is no other equivalent in WRB for brown soils that have BS > 50% throughout the upper 125 cm, these soils key out at the end of the WRB key as Regosols; this is in contradiction to the definition of Regosols, since soils having cambic horizons are excluded from this group.
It is important to resolve this problem, because Eutric, Calcaric and Chromic Cambisols represent a dominant proportion of the soil cover in Austria and other countries throughout the temperate climate belt. It is proposed to cancel the criterium "overlying a subsoil which has a base saturation of less than 50% in some part within 125 cm of the surface".
On page 3, WRB, it is stated that „it was decided, however, not to introduce separations on account of climatic characteristics..". However, the concept underlying the definition of Chernozems, Phaeozems and Kastanozems is based on tradictional zonal and climatic considerations. These are appreciated in the detailed description of these soils in WRB, but not in the key, which is only based on soil properties. This is contradictory in theory, and gives raise to confusion and inconsistent classification when applied to soil data. Soils outside the climate and vegetation zones in which Chernozems, Phaeozems and Kastanozems typically occur, fall in these soil groups when the WRB key is employed. Moreover, all three soil groups may be found in close spatial neighbourhood, although they should be representative of clearly separated climate and vegetation zones. As an example, we found Kastanozems, Chernozems and Phaeozems closely associated with each other in the River Inn Valley, Tirol.

This problem could be resolved by clearly defining these soils either by morphological / analytical characteristics or by climate / vegetation in both the key and the detailed description. Since, according to the introductory statement cited above, classification should be based on soil properties, the latter option is not appropriate.

3.2 Compatibility of WRB and the Austrian system and completeness of WRB. We correlated soil types / subtypes defined in the Austrian system and soil groups / units in WRB. Most of the soils recognized in the Austrian systems are reflected reasonably well by soil groups or soil units of WRB. Major problems identified yet are:

- Histosols: the subunits folic, fibric and haplic are only weakly correlated with those used in the Austrian classification;
- Anthrosols: the subunits proposed for Anthrosols are not appropriate and should be revised according to the German system, since these soils are weakly described by the Austrian system as well;

Based on a systematic comparison of occurence of intergrades between major soil groups in Austria and their recognition in the WRB at the second (or third) level we have identified the following major problems:

- Cambisol - Stagnosol: intergrades are abundant and should be recognized at the second level by introducing Cambic Stagnosols, and at the third level by defining gley- and stagni- subunits of other soil units for Cambisols;
- Cambisols - Luvisols: intergrades should be recognized by creating a soil unit: Luvic Cambisols;
- Cambisols - Phaeozems: intergrades are partly addressed by Mollic Cambisols; however, because Phaeozems are allowed for having a cambic horizon, a Cambic Phaeozem should be defined;
- Gleysol - Histosol: a histic soil unit should be defined for Gleysols; intergrades are common in many Austrian landscapes;
- Gleysols - Stagnosols: a stagnic soil unit should be introduced for Gleysols;
- Fluvisols - Stagnosols: a stagnic soil unit should be introduced for Fluvisols;
- Stagnosols - Ferralsols: although Ferralsols occur in Austria only as paleosols, a ferric soil unit for Stagnosols is required to adequately describe intergrades;
- Colluvial accumulation of topsoil material is abundant, e.g. at lower slope positions; it would be useful to address this process by introducing Colluvial soil units especially for Cambisols, Umbrisols and Regosols. If not, this process must be addressed at the third level.

4. Conclusions. The WRB system is considered as an important step towards an international soil classification system. We identified some problems that should be resolved before the draft is accepted for publication. The WRB system is relatively compatible with the Austrian classification system. However, we identified several gaps in WRB and proposed solutions to make WRB a system that adequately and completely describes the soils occurring in Austria without any changes at the first level of classification.

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SOILS OF SOUTH AFRICA IN A WRB FRAMEWORK

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1. Introduction

All major international soil classification systems make inadequate provision for the classification of some of the most important soils of Southern Africa and Australia. This is due to lack of appreciation that this is a different soil zone (Laker and Samadi, 1996), differing from both the temperate zone in the northern hemisphere and the tropics.

Dudal (1996) stated that this "different soil zone" is due to the fact that "the main soil forming factors (time, climate, relief and parent materials) in South Africa vary from those in the northern hemisphere". He added that it appears that the specificity of the South African soilscape resides mainly in the composition and the great variability of the soil associations. These variations over short distances are not random variations in soil properties, but systematic variations in major soil features, requiring the soils to be classified differently (Laker and Samadi, 1996).

2. Factors of soil formation

South Africa's **climate** can generally be described as hot and dry with erratic rainfall. Evapotranspiration is very high. Distinct wet and dry seasons alternate. Occasional prolonged droughts occur, followed by periods of torrential rain. Some areas are subject to scorching, desiccating "berg winds".

South Africa and the major part of Australia lie between about 20° and 35° southern latitude. The corresponding zone in the northern hemisphere is dominated by deserts. The big land masses of North America, Europe and Central and Northern Asia are beyond 35° northern latitude.

Parent material is a dominant factor determining the features of South African soils and causing differences between them and the soils of North America, Europe and Central and Northern Asia. South African soils are mainly formed from in situ weathering of solid rock or in local colluvium. The solid geology consists of a variety of mudstones, shales, sandstones, granites, basic igneous rocks, etc. Loess is **totally** absent in South Africa.

The undulating **topography**, characteristic of the higher rainfall areas, causes the **systematic** variations in soil features over short distances. Distinctive repetitive toposequences, such as the so-called "Highveld catena" or "plinthic catena" result.

Time is a distinctive factor since the landscapes are much older than in North America and Europe. Due to the low and inefficient rainfall the advanced stages of pedogenesis of the humid tropics have not been reached, however. In moister areas (>600 mm annual rainfall) very active pedogenesis is taking place, most notably in the "plinthic catenas".

3. Accommodation of South African soils in a WRB framework

Any soil can probably be classified in any classification system, but this does not necessarily mean that its classification is logical or useful. Very important properties of the soil may be ignored and/or the class in which it is grouped may not make sense. The question then is not whether all important South African soils (representing the "southern mid-latitude soil zone") are accommodated by the WRB framework, but whether they are accommodated in a **logical** and **useful** way. I came to the conclusion that the latter was not the case for **some** of the most important soils of this soil zone. The WRB workshop in South Africa, described by Deckers as "a turning point in soil classification" (SSSSA, 1996), convinced some "northern" pedologists of some of these. Three major unresolved issues, are:

3.1 "Soft plinthite"

About 5 million hectares in South Africa are covered by soils with "Soft Plinthic B" horizons. These horizons have abundant **high chroma** mottles (usually bright red and more clayey than the surrounding matrix), with grey matrix colours due to gleying in or directly below the horizon. They are non-indurated, i.e. they can be cut with a spade when wet, but do **not** harden **irreversibly** upon alternative wetting and drying, i.e., they do not qualify as plinthite. They form "in a zone of periodic saturation with water, for example between the limits of a fluctuating water table" (Soil Classification Working Group, 1991). Both the genesis and properties of "soft plinthite" are identical to what the Soil Survey Staff (1996) describe as the initial stages of plinthite formation, before it qualifies as plinthite. It undoubtedly represents the first significant stage in the pedogenetic sequence: "soft plinthite"- plinthite-petroplinthite.

Spatially soils with soft plinthite usually occupy the middle section of plinthic catenas, between the drier soils with no signs of wetness upslope and excessively wet gleyed soils (usually Planosols) downslope. In some cases they occupy the whole upper part of the catena, above the "wet" soils. The central part of the catena, where soft plinthite is classically found, is a zone of very active pedogenesis. During wet periods there is intensive lateral movement of water through this zone, transporting dissolved reduced iron, suspended clay, etc. through it. This causes the lack of accumulation of cementing materials that would enable it to harden into plinthite.

Many soils with soft plinthite have high crop production potential. Their higher water storage capacity enable crops to survive droughts better on them than on the drier soils. On the other hand they do not have the limitations of excessively wet soils, like the Planosols, which have no, or at the best very low, cropping potential.

WRB has decided that provision must be made for this "intermediate stage" between gleyic properties and plinthite "at a lower level of classification" (Nachtergaele and Deckers, 1996). "Soft plinthite" seems to be an unacceptable term internationally and terms such as "paraplinthite" and "protoplinthite" are being considered.

3.2 "Lithocutanic B horizons"

Soils with ochric horizons underlain by "Lithocutanic B" horizons (Soil Classification Working Group, 1991) are the most widespread soils in South Africa. Smaller areas with Lithocutanic B horizons underlying mollic, umbric or albic horizons are also found. A Lithocutanic B horizon is one with minimal development of an illuvial B horizon into weathering rock. Its main feature is cutanic character, expressed as prominent tongues caused by residual clay formation and illuviation. "Peds" consisting of rock fragments covered by cutans are common in the tongues. An international name and definition are required for these special pedogenetic horizons.

Because of the favourable water storage capacities of lithocutanic horizons it is important to distinguish between these soils and those with epipedons directly on solid materials such as hard rock. The ochric/lithocutanic soils do not fit the concept of Leptosols (Dudal, 1996), nor of Regosols. They are probably a special type of Cambisols. It is interesting to note that only under Phaeozems WRB makes provision for "Glossic Phaeozems", i.e. Phaeozems "showing tonguing of the mollic horizon ... **or into the underlying substratum**." An example of such Glossic Phaeozem was seen during the South African WRB workshop. Classification guidelines for **all** soils with "lithocutanic" horizons are required.

3.3 Solonetz and "solonetzic" soils

The South African WRB workshop highlighted the widespread occurrence of "solonetzic" soils, in addition to perfect Solonetzes. Solonetzic soils have Solonetz morphology (a huge abrupt increase in clay content and columnar or prismatic structure in the subsoil) **and** Solonetz behaviour (extremely high dispersivity and erodibility), but without Solonetz chemistry. These phenomena have repeatedly been observed worldwide for many decades, but have been ignored in both the USDA's Soil Taxonomy and the WRB/FAO system.

In contrast to the generally accepted ESP of 15, the new Australian soil classification system uses a minimum ESP of 6 as indicative of sodic properties (Isbell,1996), whilst a minimum ESP of 4 has been suggested for Zimbabwean soils (Nyamapfene, 1991). In South Africa perfect "Solonetzes" with ESP's as low as 3 are found. The vast majority of our non-sodic Solonetzes have very high exchangeable Mg:Ca ratios (>1.5:1). These include the most unstable and erodable solonetzic soils. "Magnesium solonetzes" have been reported from all over the world. WRB makes provision for a horizon to be classified as "Natric" (the key Solonetz horizon) if it has ≥50% (Na + Mg) in the upper 40 cm, **but** on condition that it must have an ESP of at least 15 "in some subhorizon within 200 cm from the surface". The latter is an unacceptable co-requisite.

Many of our most unstable "non-sodic Solonetzes" have red subsoils. Failure to recognize these as highly erodable Solonetzes has often led to agricultural and environmental disasters. Red solonetzic soils are found worldwide.

It is clear that soils with Solonetz morphology behave like Solonetzes, irrespective of their chemistry. It seems that morphology should be the overriding criterion for defining Solonetzes (as in the South African system), using chemistry only for their subdivision at lower levels.

In South Africa a very large region, including large proportions of the Free State and Eastern Cape provinces and the major part of Lesotho's lowlands, is dominated by solonetzic soils. In this region solonetzic soils are not confined to footslopes. The parent material, mudstones and shales of the Beaufort Group, is the main factor causing the widespread occurrence of solonetzic soils in this region. These mudstones and shales are rich in illite and magnesium. Purple-red mudstones, from which the red solonetzic soils inherit their colour, occur extensively. The region is a summer rainfall area of which the major part receives an average of between 500 and 700 mm rain annually. Elsewhere in the country solonetzic soils are mainly associated with toposequences having sandy soils on crests and middle slopes and Planosols and Solonetzes on footslopes.

4. General

Most initial problems with the classification of South African soils in WRB have been solved successfully between 1993 and 1996, including creation of a "Durisol" major group for the shallow soils on duripans in extreme aridic environments. The outstanding issues will probably be resolved soon. Deckers (WRB chairman) believes that as a consequence of the South African WRB workshop "... we have now come to a better understanding of global soil geography and genesis" (SSSSA, 1996).

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WELL DRAINED SOILS WITH REDOXIMORPHIC PROPERTIES: MORPHOLOGY, GENESIS, DYNAMICS, ECOLOGY AND CLASSIFICATION

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Introduction

The formation of redoximorphic soil properties is normally caused by a lack of oxygen and a surplus of water, associated with high groundwater levels in Gleysols. Effects of permanent water saturation are reductomorphic properties like a black to bluegreen colour, and oximorphic properties e.g. rusty mottles in the groundwater capillary fringe (Fig. 1a). In Planosols or Stagnosols (in compacted soils) water surplus is caused by imperfect drainage, which leads to wet bleaching, concretions and/or marbling (Fig. 1d-f).

Besides these classical soils with redoximorphic properties there are soils which have other reasons of oxygen lack, e.g., soil oxygen may have been displaced by rising carbondioxide of postvolcanic mofettes or by methane in sanitary landfills, i.e., oxygen deficiency may occur not only in consolidated, but also in unconsolidated soils (Fig. 1b). Furthermore, a lack of oxygene causing redoximorphism can occur in unsaturated soils, if they contain or receive easily-decomposable organic matter in large quantities. These soils with redoximorphic properties, having no aquatic moisture regime, are defined as „**Reduktosole**" (Reductosols) in the German soil classification. Their morphology, genesis and concepts are discussed in this contribution.

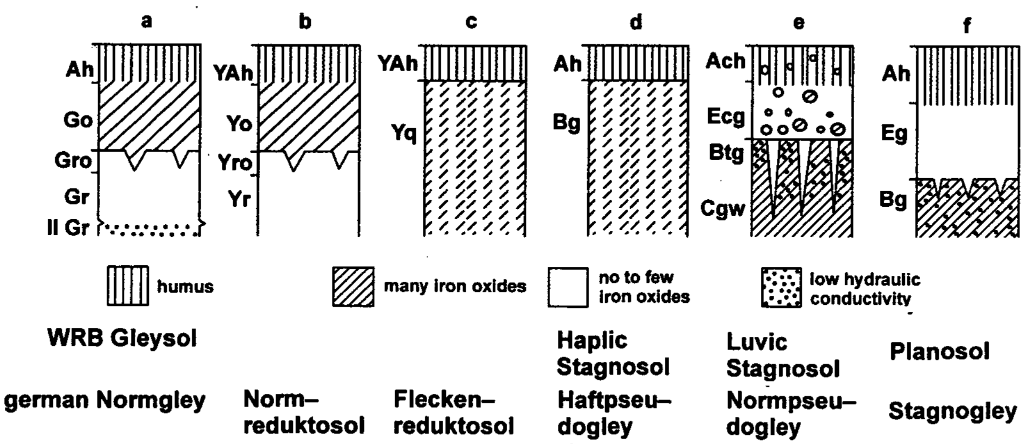

Fig. 1: Archetypes of soils with redoximorphic properties (WRB: Spaargaren 1994; German: AG Boden 1994; a-c German, d-f WRB horizon symbols)

Morphology

Soils on or beside sanitary landfills (Table 1b) as well as soils from sewage sludge (Table 1c) often have a black coloured subsoil, caused by metal sulphides. The top soil, however, is coloured red-brown by enriched ferrihydrite, especially on aggregate surfaces and along root channels. In soils above postvolcanic mofettes the subsoil is typically bleached and impoverished of sesquioxides, while the topsoil is enriched with red-brown iron oxides (Table 1a). In many cases the reductomorphic features reach up to the soil surface. So the morphology of these soils correspond to that of groundwater influenced soils, i.e., Gleysols (Fig. 1b). Soils having been infiltrated by easily-decomposable matter, by benzine or sewage, often are mottled. Rusty mottles mainly occur inside the peds, while the surfaces often appear bleached (Table 1d, YgBw). In this case the morphological properties of these soils are in accordance with those of Stagnosols (Fig. 1c).

Table 1: Reduktosols of Germany (after Blume 1996); a) with heath, above postvolcanic mofette, b) with ruderal vegetation of a 7 years old sanitary landfill, c) with nettle, elder growing on a 7 years old sludge deposit.

horizon	depth	colour		water	OC	stone content	pH	silt	clay	carbonate	Fe_d
	cm	matrix	pedface	regime	%	%	$CaCl_2$	%	%	%	%
a) Dystric Ockerreduktosol from solifluction deposits, Rengen, Eifel											
Ah	0-10	2.5Y3/2		moist	11	10	4.1	36	37	0	1.6
Yo	18-50	5Y5/1	5YR4.5/6	moist	2.4	0	4.1	18	74	0	7.5
Yr	50-70	5Y6.5/1		wet	1.5	0	4.0	29	70	0	0.2
b) Eutric Normreduktosol from rubbish/bricks/soilm., Berlin-Wannsee											
YoAh	0-20	7.5Yr4/2	5YR3/3	moist	1.0	16	7.0	11	6	2.2	3.0
Yo	20-38	7.5YR5/2	5YR3/3	moist	1.0	12	7.0	19	10	3.0	3.3
Yr	52-110	2.5Y4/2		moist	0.6	11	7.2	13	11	0.9	3.2
c) Eutric Normreduktosol from sewage sludge (w. lime, $FeCl_2$), Kiel-Bülk											
YoAh	0-38	8YR3/4	5YR3/4	sl. moist	6.5	4	7.6	23	26	32	2.9
Yr1	-55	N2/O		moist	14	11	7.9	42	36	35	4.0
Yr2	-147	5Y4/1		moist	14	3	9.6	35	30	29	3.1
d) Redukto-Braunerde of a waste water irrigation field, Berlin-Satow											
Ap	0-37	10YR3/2	10YR6/3	moist	2.8	1	5.2	12	9	0	0.3
Bhw	-52	10YR5/4		moist	0.2	1	5.5	13	8	0	0.1
YgBw	-70	7.5YR6/7	10YR6/4	moist	0.1	1	5.6	14	8	0	0.1

Genesis

In waste deposits methane and carbon dioxide evolve upon strong microbial activity. These reductive gases displace the air from the soil of an uncovered or insufficiently covered deposit. Sometimes the same may occur to soils beside a waste deposit placed in a former sand pit. In this situation microbial reduction is causing mineralization of organically bound sulphur and reduction of Fe/Mn-oxides, and of (rainwater-) sulphate, resulting in (black) metal sulphides (Yr in Fig. 1b). A part of reductive Fe^{2+}- and Mn^{2+}-ions can rise even in dry periods and then get oxidized and enriched in a very loose upper soil by oxygen supply from the air (Yo in Fig. 1b). In sludge or harbour mud-deposits high in protein-containing organic matter, reductive gases as well as metal sulphides develop, colouring the soil black. With decreasing microbial decomposition oxidation of sulphides is starting from the top. A similar process can be associated with leaking gas pipes and with postvolcanic mofettes. If a soil hardly contains sulphur compounds, the subsoil is bleached rather than black.

Repeated infiltration of soils with organic liquid like benzine or oil - often occurring below petrol stations - may cause strong microbial activity associated with reduction and redistribution of iron and manganese . Similar processes are observed were soils are infiltrated by leachates from manure heaps or by waste water used for irrigation. In any of this situations described above, redoximorphic features may occur even in well drained soils.

Dynamics

Fig. 2 shows the dynamics of soil moisture, gas chemistry and redox potential in an uncovered waste deposit. During the whole year the topsoil was moist to dry. The air volume of the subsoil was > 2% and in the upper soil >10%. The air of the subsoil at a depth of 30 to 80 cm contained 10-60% methane and below 80 cm 40-60% methane througout the year, corresponding with a black soil colour. In the upper soil the methane content varied between 0 and 10%, corresponding with a reddish-brown soil colour. The redox potentials of this (calcareous) soil were about 50-200 mV in the moist topsoil, otherwise always above 200 mV. The moist subsoil, however, showed negative soil potentials, the fresh subsoil had values between 50 and 400 mV.

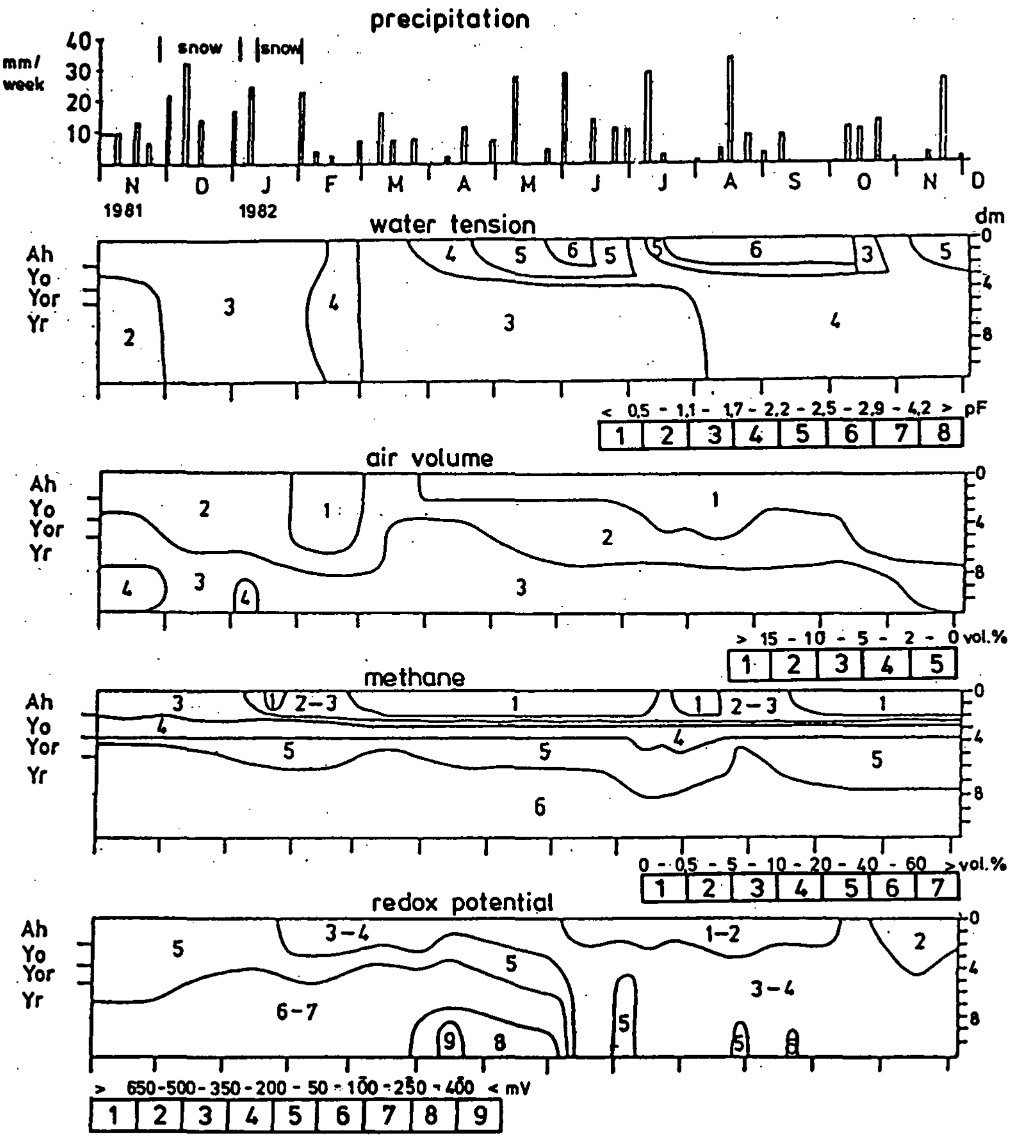

Fig. 2: Precipitation (in mm), water tension (pF values), air volume (%), methane content of soil air (%) and redox potentials (mV) of a Reduktosol from a mixture of rubbish, bricks, mortar and soil substrate of a (4 years old) sanitary landfill in Berlin-Wannsee (after Mouimou 1983)

Classisfication

Recently the described soils has been named „Reduktosole“ in Germany. Diagnostic horizons (Y) are formed by reductive gases (CO_2, CH_4, H_2S) with at least temporarily increased (>10vol%) CH_4- and/or CO_2-contents in the soil air, introduced from the earth's interior, gas leakage or microbial activity in well-drained soils. A Yr horizon is defined by reduction colours, i.e. Munsell value N1 (black) to N8 (white) or 5G (greenish), 5GY (grey green) or 5B (bluish grey), and a chroma beneath 1.5 (at 5G 2.5); its air contains no oxygen, but is rich of CH_4 and/or CO_2; its rH-value[x)] is <19. It is often composed with an overlying Yo-horizon, which is coloured redish-brown by Fe-oxides (i.e., mostly on aggregate surfaces) and has only temporarily increased CH_4- and/or CO_2-contents. Instead of a Yr- and Yo-horizon a Yg-horizon can develop, which is mottled in such a way that the surfaces of the peds (or parts of the soil matrix if structure is absent) are lighter (by one value or more) and paler (by one chroma unit or more), and the interior of the peds (or parts of the soil matrix) are more reddish (by one hue unit or more) and brighter (one chroma unit or more), compared to the non-redoximorphic parts of the layer, or of its average when mixed. If reducing conditions are apparent, its rH-value is below 19, or Fe^{2+}-ions are proved (i.e., according to a test with a 1% ($K_3Fe(III)(CN)_6$)-solution).

x)

$$rH = \frac{2\,Eh}{59\,mV} + 2pH$$

In the German soil classification "Reduktosols" are established as an own suborder within the order of terrestric soils. Subunits under discussion are:

- Normreduktosol (Haplic or Typic Reductosol): Ah/Yo/Yr-profile; Yo<4dm depth
  (Ah means mollic, umbric or histic epipedon)
- Rohreduktosol (initial stage of Reductosol development): (Y)Ai/(Yo)/Yr-profile
  (Ai means ochric epipedon)
- Ockerreduktosol (Chromic Reductosol): Ah/Yo/Yr-profile; Yo>4dm depth
- Bleichreduktosol (Bleached Reductosol): Ah/Yr-profile; Yo is missing
- Fleckenreduktosol (Mottled Reductosol): Ah/Yg-profile

Occurrence and Ecology

Reduktosols occur mainly in urban-industrial areas and have developed under anthropogenic influence. As natural formations they have been observed in the Eifel area, a formerly volcanic district of Germany, where they consist of an only narrow stripe above fissures of the terrestrial crust with an emergence of CO_2.

Reduktosols are redoximorphic sites. As a consequence, plants with deep-reaching roots are being damaged or die. Reductosols of sewage or harbour mud normally are rich in base and nutrients; toxic heavy metal concentrations may occur as a consequence of increased mobility at low redox potentials. Reductosols of postvolcanic mofettes can be extremely acid, caused by long-term CO_2-emergence and formation of carbonic acid (Table 1a). Reductosols of former gasworks often are acid, too: towngas was sent through Fe-oxide-filters in order to bind H_2S; the sulphide containing filter residues have been dumped to soils and caused acidification upon oxidation of the sulphides.

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WRB CRYOSOLS: DEFINITIONS, CONCEPTS AND CLASSIFICATION

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1. Introduction. Cryosols are perennially frozen mineral and organic soils that contain cryic horizons within 100 cm of the soil surface. Worldwide, Cryosols occupy approximately 17.7 x 10^6 km^2, and occur in the Arctic, Antarctic, Subarctic and Boreal regions under cold continental, subhumid, semiarid or arid climatic conditions and at high elevations at low latitudes (the Andes and the Tibetan Plateau). They support unvegetated to continuously vegetated tundra (Antarctic and Arctic), open-canopy lichen or moss coniferous forest (subarctic forest), closed-canopy coniferous forest (boreal forest), or mixed coniferous and deciduous forest (boreal forest).

Permafrost soils have previously been described in the USSR as Peaty Frozen and Taiga Frozen soils (Zol'nikov *et al.*, 1962; Zol'nikov, 1965; Yelovskaya, 1987), as Frozen Tundra Cryoturbated and Frozen Gley soils (Yelovskaya, 1987), and as Homogenous (or Peaty-Duff) and Thixotropic Cryozems (Naumov, 1973; Sokolov 1980a, 1980b). In the Canadian soil classification permafrost soils are classified as Cryosols and are recognized as a group of mineral and organic soils in which cryogenic processes dominate the soil genesis (Agriculture Canada Expert Committee on Soil Survey, 1987; Tarnocai, 1994). The Canadian Cryosolic Order encompasses the Turbic, Static and Organic subgroups (Agriculture Canada Expert Committee on Soil Survey 1987; Tarnocai, 1993). In the United States permafrost soils are classified in Soil Taxonomy as Gelisols (ICOMPAS, 1996). The Gelisol Order encompasses the Histel, Turbel and Haplel suborders, which generally correspond to the Organic, Turbic and Static subgroups in the Canadian system.

This extended abstract focusses on the definitions and concepts associated with these soils, and on their classification in the World Reference Base for Soil Resources (WRB).

2. Materials. The classification presented in this abstract is the result of work by members of both the International Society of Soil Science and International Permafrost Association Cryosol Working Groups and by other experts from the field of cryopedology. This work was coordinated by the author.

3. Discussion. Cryosols are dominated by cryogenic processes (Tarnocai, 1994), including the freeze–thaw process, cryoturbation, frost heave, cryogenic sorting, thermal cracking, and ice segregation. These processes are driven by the presence and mobility of unfrozen soil water as it migrates towards the frozen front along the thermal gradient in the frozen system.

Cryosols have a perennially frozen (permafrost) subsoil, and their genesis and properties are the result of cryogenic processes. Cryogenic soil properties include perennial segregated ice, cryoturbated soil horizons, and macrostructures and microstructures resulting from cryogenic processes. These soils, or portions of the soil, are generally saturated during the early part of the thaw season as a result of the melting of seasonally frozen soil water. They are often associated with both a significant accumulation of organic matter at the surface and cryoturbated organic matter in the subsoil. Patterned ground is commonly associated with Cryosols. The patterned ground types associated with mineral Cryosols are earth hummocks, and sorted and nonsorted circles, nets, stripes, steps and polygons and with Histic Cryosols are palsas, peat plateaus, peat hummocks, polygonal peat plateaus, and low- and high-centred lowland polygons.

Other soil-forming processes can also leave an imprint on these soils. One of these, the gleyic process, is caused by temporary saturation of Cryosols with water (during the thaw period) or permanent saturation with ground waters, leading to reduced grayish colours and redoximorphic features. Another soil-forming process, weak podzolization, is associated with Haplic Cryosols developed on coarser textured materials (Mazhitova, 1987). These soils can also have a thin eluvial horizon. Important soil-forming processes in Cryosols occurring in cold desert environments are salinization–alkalization (the accumulation of soluble salts in the absence of a water table) and rubification (staining of the profile by oxidation of iron-bearing minerals) (Bockheim, 1990; Bockheim and Ugolini, 1990).

Histic Cryosols have developed on undecomposed (fibric) to well decomposed (humic) peat materials. Some of these Cryosols developed on shallow peat materials are cryoturbated. These Cryosols typically contain ground ice.

3.1. Description and definitions. Cryosols are defined as mineral or organic soils that contain one or more cryic horizon(s) within 100 cm of the soil surface. This definition is based on the following properties:

1. The presence of cryic (perennially frozen) horizon(s) within 100 cm of the soil surface.
2. Soil water in the cryic horizon occurs in the form of ice (molecular water remains unfrozen) except for cryic horizons associated with dry permafrost.
3. Cryogenic processes are the dominant soil-forming processes.

3.2. Cryic Horizon. The definition of cryic soil horizon is as follows: All cryic horizons are perennially frozen (for at least two consecutive years) mineral or organic soil materials that have soil temperatures at or below 0°C.

The vast majority of cryic horizons contain varying amounts of soil moisture. Cryogenic processes are driven by the presence and mobility of the unfrozen soil water (solution) as it migrates towards the frozen front along the thermal gradient in the frozen system, which is then responsible for the increase of ice volume in the soil and, thus, the increase of soil volume. Volume changes are also caused by the conversion of water to ice and by the thermal contraction of frozen material as a result of continued rapid cooling. The resulting cryic horizons show evidence of perennial ice segregation and/or cryoturbation and/or other macrostructures and microstructures resulting from cryogenic processes. Ice segregation is manifested by ice lenses, vein ice, ice crystals, and some ground ice. Although cryoturbation is not always present in a cryic horizon, where it is present it is manifested by irregular and broken soil horizons, involutions, organic intrusions, oriented rock fragments, and silt-enriched layers. The characteristic soil structures include platy, blocky and vesicular macrostructures resulting from vein ice development, and orbiculic, conglomeric and banded microstructures resulting from sorting of coarse matrix.

While nearly all cryic horizons contain some soil moisture, if there is insufficient interstitial water, the resulting cryic horizons are dry. These dry cryic horizons are subject to thermal contraction of the frozen soil materials as a result of continued rapid cooling. This thermal contraction, however, is weaker than that associated with soil horizons of higher moisture content.

3.3. Proposed soils units. The Cryosol major soil group has been subdivided into three subgroups. Histic Cryosols are dominated by organic horizons within 100 cm of the surface, Turbic Cryosols are mineral soils having cryoturbated soil horizons, and Haplic Cryosols are other mineral Cryosols without significant cryoturbation. The soil units included in these three groups are listed in Table 1.

Table 1. The soil units in the Histic, Turbic and Haplic Cryosol soil subgroups.

Histic Cryosols	Turbic Cryosols	Haplic Cryosols
Glacic Histic Cryosols	Glacic Turbic Cryosols	Glacic Haplic Cryosols
Leptic Histic Cryosols	Leptic Turbic Cryosols	Leptic Haplic Cryosols
Folic Histic Cryosols	Thionic Turbic Cryosols	Thionic Haplic Cryosols
Fibric Histic Cryosols	Andic Turbic Cryosols	Andic Haplic Cryosols
Mesic Histic Cryosols	Tephric Turbic Cryosols	Tephric Haplic Cryosols
Humic Histic Cryosols	Salic Turbic Cryosols	Salic Haplic Cryosols
	Gypsic Turbic Cryosols	Gypsic Haplic Cryosols
	Calcic Turbic Cryosols	Calcic Haplic Cryosols
	Spodic Turbic Cryosols	Fluvic Haplic Cryosols
	Mollic Turbic Cryosols	Spodic Haplic Cryosols
	Umbric Turbic Cryosols	Mollic Haplic Cryosols
	Gleyic Turbic Cryosols	Umbric Haplic Cryosols
	Stagnic Turbic Cryosols	Gleyic Haplic Cryosols
	Orthic Turbic Cryosols	Stagnic Haplic Cryosols
	Regic Turbic Cryosols	Orthic Haplic Cryosols
		Regic Haplic Cryosols

Eutric, dystric and thixotropic subunits could form the fourth level of the classification and can be applied to both the Turbic and Haplic subgroups. Typic (terric contact below 1 m) and Terric (terric contact within 1 m) could form the third level for the Histic subgroup.

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PALEOSOLS AND REJUVENATED SOILS REFLECTED IN WRB - EXAMPLES FROM SOUTH INDIA, SW-USA AND PAMPA HUMIDA, ARGENTINA.

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Non-buried paleosols - former called relict soils - are broadly defined by the Comission on Paleopedology as soils formed on a landscape or environment of the geologic past (Catt 1997), which means a changed constellation of the soil forming factors notably climate and associated vegetation.

In India, the so-called „Red Soils" cover an area of about 720.000 km² (Krantz et al. 1978), mainly in the southern part. Most of them are classified as *Lixisols* in the revised legend of the Soil Map of the World or the WRB (FAO-UNESCO-ISRIC 1990, ISSS-ISRIC-FAO 1994) or as *Udic*, *Typic* and *Aridic Rhodustalfs* according to Soil Taxonomy, which reflects, however, the *present day* climate, notably rainfall. Most Lixisols from South India are formed on saprolitically weathered „peninsular gneiss". - In a climatic sequence from ten to one humid month per year (2500mm to 590mm /a) nine surface derived soils were examined for recent and relict soil features (Bronger & Bruhn 1988). Besides soil chemical properties the studies were focussed on the mineralogy of sand, silt and clay fractions as well as on micromorphological features of the soils and its parent material.

Above a threshold of 2000 mm (6 humid months) in a Lixisol (close to an Acrisol) deep weathering is a recent process leading to formation of kaolinites. Above 2500 mm in 900 m a.s.l. (10 humid months) in a Haplic Acrisol and a Haplic Oxisol it leads also to the formation of gibbsite. These soils are considered according to the Paleopedology Commission (Catt 1997) to be *Vetusols*, old non-buried soils which underwent the same or very similar processes of soil formation over at least several 100 ka under a similar constellation of soil forming factors. In lee of the Westghats under decreasing rainfall (1500 - 1000 mm) the base saturation of the saprolite increases and so do the amounts of 2:1-clay minerals in the saprolite and the soils (example in Fig. 1). Despite the decreased weathering intensity, a broad spectrum of relict weathering features is present in the Lixisols, e.g. kaolinized biotit flakes, boxwork of strongly weathered hypersthene, garnet and hornblende and single quartz grains with hematite infillings („runiquartz"). In even drier climates below 800 mm e.g. in two Lixisols near Hyderabad the pedogenic kaolinites are still dominant, however, with increasing amounts of smectites, illite-smectite intergrades and illites (example in Fig. 2). This succession of clay minerals seems to reflect a process of climatic dessication in the past, perhaps as a consequence of the increasing distance of the Indian plate from the equator fortified by the uplift of the West Ghats since the late Tertiary. In the *present day climate* illites are being formed, but smectites and mixed-layer minerals are apparently relict features. In three soils *secondary calcite* has accumulated in the saprolite and lower B horizons. In contrast to the pedogenic kaolinites this carbonate accumulation is a good evidence of the significant change of the soil environment. We conclude that most Lixisols in now seasonal semiarid India are *relict soils* or *non-buried paleosols* formed in an earlier period of much more moist climate than the present. - The classification as Lixisols for these polygenetic soils seems to be very appropriate because of the two sets of properties: the subsurface accumulation of low activity clays especially of pedogenic kaolinites on the one hand and a moderate to high base saturation on the other hand seem to reflect the changed environmental conditions. We propose the soil unit *Chromic Lixisols* for these soils, having a reddish brown to red argic horizon (a Munsell hue of 5 YR or redder).

Our results including the conclusion that the efficiency of weathering in the seasonal semiarid tropics has been overestimated by far in many cases especially in the geomorphological literature are supported by the (clay) mineralogical results from a Phaeozem in Southern Gujarat (about 900 mm rainfall) derived from late Pleistocene sandy loessical material: only a small increase of 2:1 minerals, mainly smectites could be found (Fig. 3). - For further confirmation of the conclusions six selected „Red Soils" in two intramontane basins of hyperthermic SW-Nepal at the border to India with 1600 - 1800 mm rainfall/year (5-6 humid months) were investigated by the same methods for comparison. In some of these soils respectively in the underlying material traces of late paleolithic cultures have been found; first TL-dates give ages of 10-30 ka (Fig. 4). Surprisingly little pedogenic clay mineral formation could be identified. The illites in the soils are predominantly *inherited* as well as the (small amounts of) kaolinites. The few non-regular mixed layered minerals in the fine clay fraction (<0,2 μm) are regarded as a possible initial stage of silicate weathering. In contrast the *hematites* are proved to be of *pedogenic* origin (DXRD, supported by Moessbauer spectroscopy). Therefore the *rubefication* is an autochthonous and recent process; rubefication of soils alone is not a reliable indicator for strong pedogenic weathering.

In contrast to South India in larger parts of the High Plains of Texas soils are „growing" : several widespread soil series are formed under considerable dust input rich in CaCO3 alternating with prevailing pedogenesis since Middle Pleistocene (Aandahl 1982, Nettleton et al. 1989). Locally these soils include several thick argillic and calcic horizons; other pedons are developed as relict soils or unburied paleosols containing, however, several maxima of silicate clay accumulation. Several soils have only one welded argillic horizon with carbonate accumulation only in its lower part. If these soils have a mollic horizon they are to be classified as Chernozems or Kastanozems according to the colour; without a mollic horizon they are Chromic Luvisols. The classification as Aridic or Calciorthidic Paleustolls respectively Paleustalfs better reflects the paleopedological aspect.

Some Phaeozems in the *Pampa humida* recently studied during a WRB meeting in the Buenos Aires Province, Argentina show white spots or even larger parts of distinct white CaCO3 concentrations in the solum. This very recent rejuvenation is the result of an accelerated dust input probably due to vegetation degradation because of overgrazing in large parts of Patagonia with an aridic soil moisture regime. These rejuvenated soils must now be classified as *Chernozems*.

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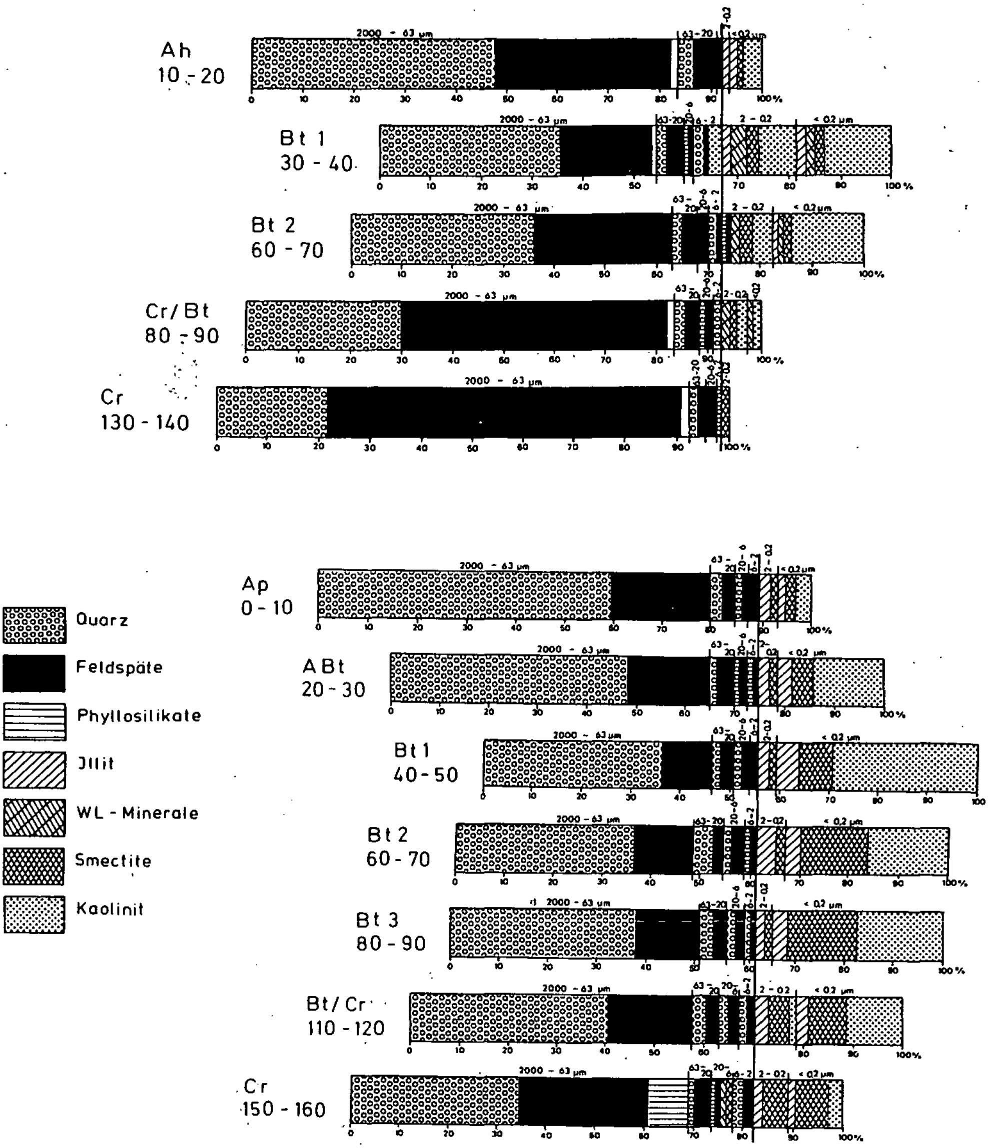
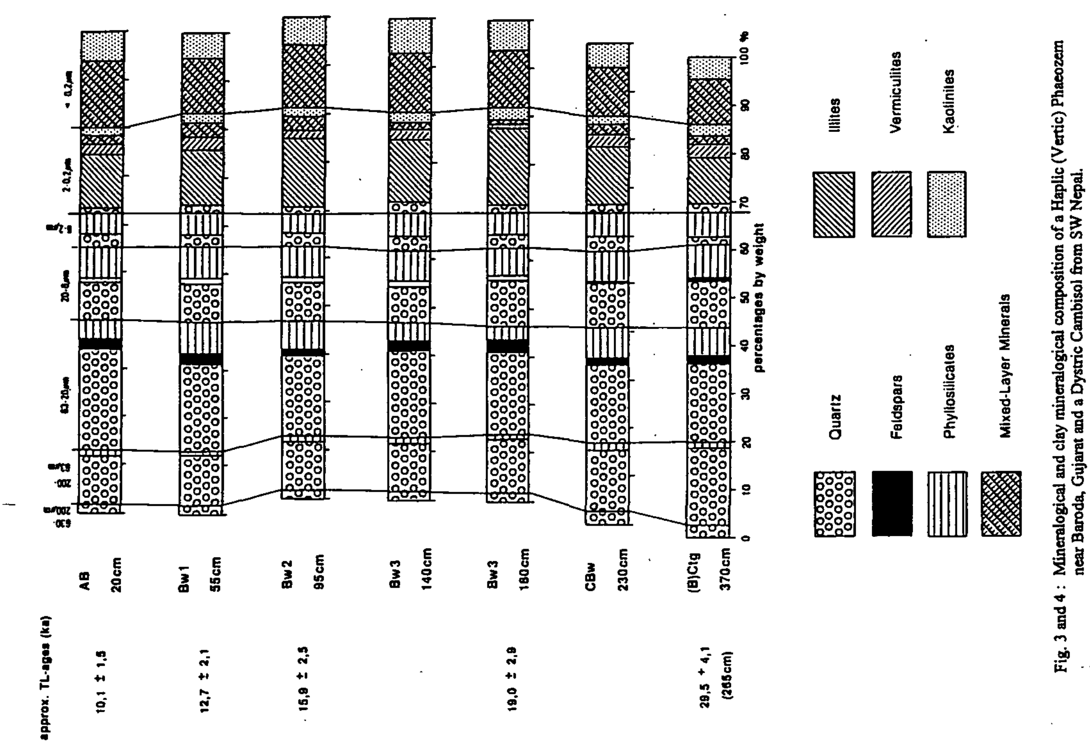


Fig.1 and 2 : Mineralogical and clay mineralogical composition of two Chromic Lixisols (Anakatti Soil, upper part and Patancheru Soil, lower part).



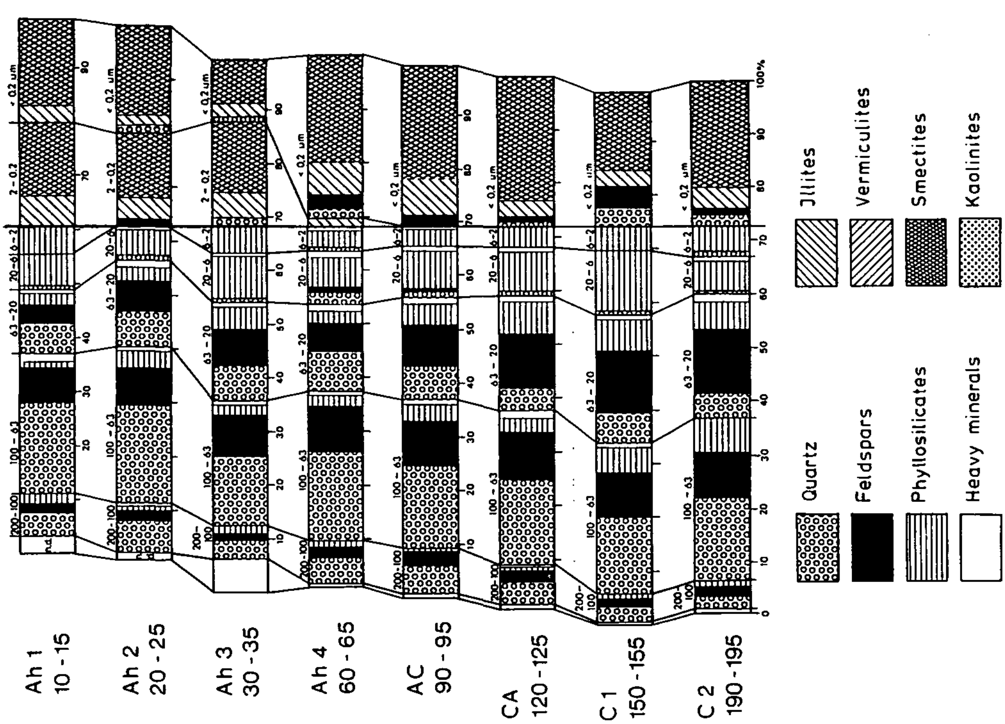


Fig. 3 and 4 : Mineralogical and clay mineralogical composition of a Haplic (Vertic) Phaeozem near Baroda, Gujarat and a Dystric Cambisol from SW Nepal.

CURRENT SOIL PROCESSES IN A HAPLIC ALISOL-DYSTRIC CAMBISOL LOESS DERIVED TOPOSEQUENCE

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1. Introduction

Soil morphology is the reflection not only of current soil-forming processes but also of earlier stages of soil development. The distinction between currently active and former pedogenesis is generally not possible by the characterization of basic soil properties. The analysis of soil solutions (Ugolini et al.,1988) and the test mineral method (Ranger et al.,1991) were both used in a Haplic Alisol - Dystric Cambisol toposequence of the Belgian loess belt in order to provide information on current pedogenetic processes. These data are compared with basic morphological, physico-chemical and mineralogical characteristics of the soils.

2. Materials and Methods

2.1 Environment and soils

The toposequence is located in a dry flat-bottomed valley of the Forest of Bertem, approximatively 20 km east of Brussels (Belgium). The parent material is a loess deposited at the end of the Weichsel glaciation. Six profiles (P1-P6) have been selected to represent this toposequence. The vegetation is mainly dominated by beech (*Fagus sylvatica*) and oak (*Quercus robur*).The mean annual rainfall is 835 mm and the mean annual temperature is 9.4°C. The soils distincly differ according to their topographic position: Haplic Alisols (or Dystric Luvisol according to the recent WRB proposal) occur on slopes while Dystric Cambisols are observed in the lower topographic positions of the valley. Cambisols developed in probably old colluvial sediments after the erosion of the sloping soil material exposed to the SW (Langohr,1997, personnal communication).

The main analytical data for three representative profiles are given in Table 1. P2 (Alisol) is located on the slope exposed to the NE, P5 (Alisol) on the slope exposed to the SW and P4 (Cambisol) is located downslope. The Ah horizon of the Cambisol covers a dark coloured B horizon with a very low macroporosity that we have morphologically described in the field as a Bh horizon. In the surface horizons of all the selected soils, soil acidity is invariably very strong and the exchange complex is dominated by Al (Al/ECEC = 70-80 %). Lower clay content, base saturation and TRB point to a more weathered environment in the Cambisol. Are also to be noted in the surface horizons of the Cambisol the occurence of 2:1 swelling clays (*Degra-dation smectites*) and a higher Fe_e content (Brahy et al.,1996) both suggesting an "incipient podzolisation process"(Herbauts,1982).

Table 1: Main analytical data of the Alisols and the Cambisol of the toposequence.

Soils	Horizon	Depth (cm)	pH_{H2O}	Clay (%) <2µm	C (%)	Σ exch.bases cmolc(+)/Kg	Al exch. cmolc(+)/Kg	CEC cmolc(+)/Kg	TRB[1] cmolc(+)/Kg	Fe_e[2] (mg/g)
P2	Ah	0-7	3.77	9.71	10.05	2.38	4.37	28.21	80.36	2.9
Alisol	E	7-32	4.25	13.22	0.6	0.43	4.49	7.01	93.81	0.52
	Bt	32-89	4.96	16.97		2.61	4.3	9.16	111.89	0.35
P5	Ah	0-6	3.98	8.48	13.69	3.45	5.15	32.63	87.03	2.94
Alisol	E	6-23	4.2	13.8	2.75	0.83	6	11.73	101.51	2.27
	Bt	23-75	4.42	19.59		1.12	7.6	10.97	124.89	0.49
P4	Ah	0-4	3.53	7.26	9.83	2.1	3.87	25.66	77.97	3.67
Cambisol	Bh	4-13	3.78	9.23	3.09	0.95	4.13	11.31	85.17	3.34
	Bw	13-40	4.35	9.03	0.6	0.46	3.22	4.88	95.19	0.56
	Cg	40-86	4.32	8.69		0.36	2.84	4.08	95.46	0.17

(1) TRB = Total Reserve in Basis is an estimation of the content in weatherable minerals in the fine earth.

(2) Fe_e = EDTA extractable iron (pH7) is an estimation of the content in Fe bound with organic matter.

2.2 The soil solution collection and analysis

Since november 1995 soil solutions are collected in permanent zero tension lysimeters (little gutters inserted under the Ah horizons) and in capillary wicks lysimeters (inserted within E, Bh and Bw horizons). Fiberglass wicks act as a hanging water column, drawing soil solution from the soil without external application of suction (Boll et al.,1992). The soil solutions were passed through a 0.45 µm filter and the absorbances measured at 465 ηm and 665 ηm to determine the E4/E6 ratios. Samples were analysed for Na^+ K^+, Ca^{2+}, Mg^{2+}, Fe^{3+}, Al^{3+}, Si, NH_4^+, NO_3^-, SO_4^{2-}, Cl^- and Dissolved Organic Carbon (DOC).

2.3 The resin and test-mineral bags

Small bags of 20 µm mesh polyamide containing either a test-mineral or a cationic exchange resin (Amberlite IRN 77) were carefully introduced into the main horizons of the soils (Ah, E, Bt, Bh, Bw, Cg) in three replicates. The test mineral is a high-charge trioctaedral vermiculite (0.8 per half cell) with a high CEC (160 cmolc(+)/Kg) from Santa Ollala, Spain. At the end of the experiments, the following determinations were performed on the test-mineral : (1) KCl and NH_4Cl extractable cations and Na citrate extractable Al and Fe (2) X-ray analysis.

3. Results and Discussion

3.1 Soil solution study

Selected data (Table 2) confirm the general trends observed during the 1995-1997 period. In the Alisols, stronger acidity and higher contents in Al, NO_3^- and SO_4^{2-} characterize the solutions extracted from P2. A similar trend is observed in the Cambisol soil solution (P4-Bh), but to a lesser extent, likely due to a lower TRB. Lower DOC concentrations characterize the Ah solutions extracted from the Cambisol. However these solutions have a higher E4/E6value, indicating a higher FA/HA ratio (Gressel et al.,1995).

Table 2 : Soil solution data for the summer period (07/06/1996-31/08/1996)

Soils	Lysimeters location	Depth (cm)	pH	DOC (mg/l)	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	K^{+} (meq/l)	Fe^{3+} (µeq/l)	Al^{3+}tot. (meq/l)	NO_3^- (meq/l)	SO_4^{2-} (meq/l)	E4/E6
P2	under Ah	7	3.5	77.14	1.31	0.44	0.62	43.8	0.38	2.21	1.1	9.9
Alisol	in E	25	4.39	36.61	0.79	0.54	0.32	12.3	1.24	2.3	1.13	
P5	under Ah	6	5.3	77.82	1.15	0.37	0.44	33.8	0.14	0.87	0.71	8.84
Alisol	in E	25	5.49	23.68	0.33	0.18	0.09	11.7	0.06	0.14	0.47	
P4	under Ah	3	3.91	50.67	0.63	0.16	0.31	24.2	0.03	1.16	0.31	10.63
Cambisol	in Bh	5	3.78	53.43	1.13	2.37	0.4	27.9	0.264	2.3	0.73	12.38
	under Bh	11	4.04	30.25	0.92	0.41	0.43	16.2	0.487	2.23	0.55	7.83
	in Bw	24	4.41	19.21	1.03	0.59	0.33	4.2	0.156	2.3	0.66	

3.2 Cationic garniture of the resin and evolution of the test mineral

After 6 months experiment, higher amounts of Ca, Mg and Al were fixed by the cation exchange resin inserted in P2 Alisol (especially in Bt horizon) (Figure 1) as expected from the composition of the soil solutions. The proportion of K fixed by the resin is higher in the Cambisol. It probably reflects the current weathering of less weatherable primary minerals.

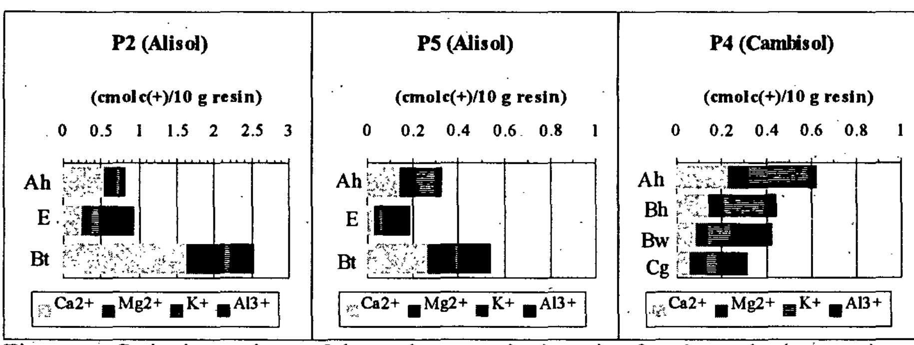

Figure 1 : Cationic garniture of the exchange cationic resin after 6 months (summer)

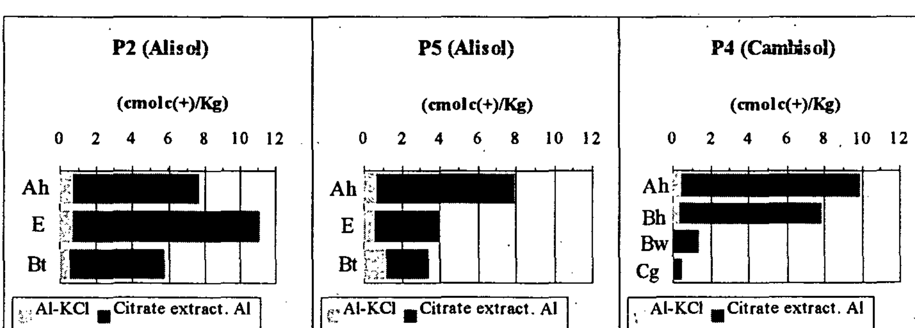

Figure 2 : KCl and Na-citrate extractable Al fixed by the test mineral after the summer.

After the summer period, the transformation of the test mineral (Fig.2 & 3) is characterized by (1) the fixation of Al, mostly citrate extractable, the largest amount corresponding to E horizon of P2 Alisol (2) the formation of stable 1.4 ηm *d* (001) spacings, providing strong evidence for aluminization of the vermiculite interlayers, especially in the P2 E horizon.
This process is related to "acidolysis" and seems to be current in both soil types during the summer period."Acidocomplexolysis" process seems not to be operating in the surface horizons of the Cambisol though morphological and other basic data suggest "incipient podzolisation". It is however consistent with the seasonnal functioning of podzolic soils (Ranger et al.,1991)

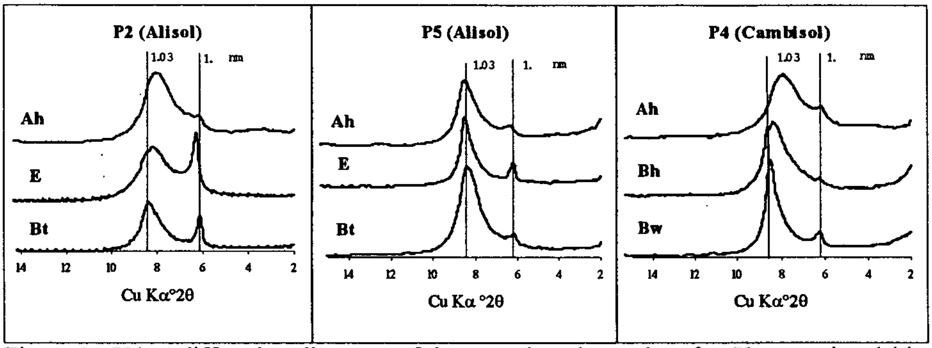

Figure 3 : X-ray diffraction diagrams of the test mineral samples after K saturation (air)

4.1 Conclusions

Two in situ experimental methods are used to determine currently active soil processes in a Haplic Alisol - Dystric Cambisol toposequence derived from loess. Consistency between the soil morphology, the analysis of the soil solid phase and experimental results is obtained for both Alisols and the Cambisol in wich organic complexation is not expected to play an important role during the summer period. Our results also indicates clear differences in the soil acidolysis process intensities even for the same Major Soil Grouping (Alisol) under similar climatic conditions. These differences mainly result from distinct inputs in nitric and/or sulfuric acids largely responsible for the current weathering processes observed.

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THE HUMAN FACTOR IN WRB: SOIL AS AN ARTEFACT

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1. Introduction

In the early years of the twentieth century, pedologists concentrated their studies upon fully developed soils under natural conditions, where genesis had taken place without the disturbing influence of human beings. Whilst it was accepted that many soils had been modified by agriculture and other land uses, no particular emphasis was given to the study of the changes which had taken place in cultivated soils. Gradually, it became appreciated that the influence of human beings was increasing and that their impact upon soils could not be ignored. In the UK, Robinson (1949) acknowledged that fully developed profiles are not everywhere in evidence and he draws attention to immature profiles, profiles truncated by erosion and adds *the natural profile may be disturbed by cultivation which results in a confounding of all horizons within reach of the implements of tillage*. There was also an implicit acceptance by Russell (1950) that soils were changed by various management techniques in order to increase their productivity, but despite the manipulation of physical and chemical properties of soils, the impact of human activities upon soils was not given much prominence. Soil scientists in many other countries have experienced a similar evolution of ideas concerning the impact of human beings on soils.

In the second half of the twentieth century evidence has accumulated that many soils have been profoundly changed by human activities, and gradually in the last twenty years this has been reflected in systems used to describe and classify soils. At first, certain horizons were recognized as man-made. More recently, a category of Anthrosols was created to cater for soils with profound modification brought about by human actions (FAO-Unesco, 1988). The theme of this article isthat many soils have been so changed that they have become **artefacts** of human workmanship. This necessitates that careful attention be paid to the human element in WRB; anthropic influences are no longer of marginal interest.

2. Man and soil formation

Jenny (1941) in *Factors of Soil Formation* included human beings as only one of the many organisms which, with climate, relief, parent material and time determine the nature of soil formation. Whilst Jenny recognized the role of human beings at the time he wrote his book, it is evident that the human impact on soils was not seen to merit more than a small section of his chapter on the role of organisms. In subsequent publications, this position was rectified as Jenny sought to bring human beings and their impact on soils into the ecosystem concept. Bidwell and Hole (1965) summarized the influence of human beings upon the soil under the headings of beneficial or detrimental actions.

3. Materials and Methods

The process of change in soils, diverging from their natural process of development through human intervention, has been referred to as metapedogenesis by Yaalon and Yaron (1966). The increasingly important impact of human influence on soil development has been traced by Bridges (1978) and Davidson (1980). Therefore, an historical approach is appropriate for this study. Information has been drawn from literary sources and archaeological research which throws light upon the interaction of human beings and the soil.

4. Recognizable Properties of Man-made Soils

The effect of human activities is to modify soils, giving them a deeper, dark-coloured topsoil which is neutral or slightly acid and which has an increased fertility. Soils in which human activities have resulted in a profound modification of the profile currently are referred to as **Anthrosols** (FAO-Unesco, 1988). The definition of Anthrosols does not include the many millions of hectares of soils only slightly modified by normal agricultural practice. As a result of human activities, both site characteristics and profile features may be changed. The sites of anthrosols have usually been altered physically by levelling, terracing, embanking, raising or lowering of the land surface compared with the adjacent natural or semi-natural soils and their water relationships changed. The profile features have been changed by deepening, enrichment with organic matter, mixing of horizons, burial, and changes to the chemical, physical and biological nature of the soil.

5. Classification and WRB

Soils in which human activities have resulted in a profound modification of the profile currently are referred to as **Anthrosols**. The extent of these soils has been estimated by FAO (1993) as occupying about 0.5 million hectares in Europe alone, with areas present in all continents, but their scattered nature does not enable them to be shown on a small scale map. Anthrosols are defined as *soils in which human activities have resulted in profound modification or burial of the original soil horizons through removal or disturbance of surface horizons, cuts and fills, secular additions of organic and mineral materials, long continued irrigation etc* (FAO-Unesco, 1988). The definition of Anthrosols does not include the many millions of hectares of soils only slightly modified by normal agricultural practice by human beings.

Discussion is still taking place about the definition of soil units within the Anthrosols, and will continue in the foreseeable future. As in all systems of classification, the successive narrowing-down of criteria for the lower orders should be logical and these criteria should be applied in a consistent manner. In subdividing the major soil grouping of Anthrosols, there is agreement that the visible evidence of the modified soil is the primary criterion which should be used for units and sub-units (Kosse, 1989; 1990; Rozanov, 1990; Zitong, 1990). The possibility exists for soils to be degraded and polluted, but equally, the existence of many highly productive Anthrosols reveals that mankind has learnt how to modify soils so they become a useful artefact. This artefact is one that will become increasingly significant and of inestimable value in the 21st century.

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SHARING OUR INTELLECTUAL LEGACIES

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The Lure of Technology. We say to each other that the world is a pretty good place to live. Our age of information, delivered in its myriad of electronic formats, lulls us into the realm of "happy campers". We watch a current event on television then move on to another part of the world gazing at the marvels of a far away wilderness. We fly into space or explore the ocean floor; we observe the re-enactment of more history than we were aware of and then tune in to an analysis of the day's news. And all the while we, as "happy campers" enjoy the marvels of modern food processing, marketing, and the joys of international trade all within the warm, comfortable domain of our homes.

In our short life spans we have been deluged, surrounded and likely "brain washed" into the driving desire for more - more and more of products and services that someone thinks is good for us, or more likely , is good for their pocket book - and for faster, quicker delivery of products and services. Instantaneous gratification - the mind boggling achievements of humankind racing from the industrial revolution to the technological advancements of information management. It is no wonder that sometimes we stop for a moment, sit on a bench, and bask in the warming rays of sunshine. They are soothing and convey a sense of healing to our runaway passions of living the good life.

One Earth in Space. Now what does this have to do with this conference? Actually - everything. A few decades ago scientists everywhere began sharing their information, building models, trying to unravel more of the mysteries of how our earth system behaves. They knew that part of the answer lies in the records of the past - from the birth of our solar system and throughout the earth's fantastic journey in space and time. I cannot readily comprehend a billion dollars, neither can I grasp a billion earth years - nevertheless, they both seem to occur. Whether one deals with rocks and geology, air and the atmosphere, water and the oceans, or with bugs and plants and the biological systems there is always a strange feeling of commonality. How can that be? They seem like night and day, hot and cold, or alive and dead. Well, they all involve processes that take place in space and time, and each is characterized by events and happenings -- things that change, have been changed, or are changing. As the pieces begin to fit together there emerges the notion that everything is connected - that actions and events do not occur or exist in isolation. From space we see only one earth - it is traveling at a phenomenal rate and it even turns at 1000 mph. Wow! And this is the world we say is a pretty good place in which to live.

The earth system has a marvelous carbon-based existence that pervades our lives in ways to many to number. We are realizing that the build up of certain gases enhances the warming of our global habitat and that soils are important as both sinks and sources of carbon. The details of how, where, and when carbon exists in soils is nearly as interesting as it is significant to mitigating strategies related to global change (Arnold, 1997). The carbon atoms in your body are recycled ones. Where they were before - and before that - is not known with any degree of certainty. And some day , some time, they will be re-cycled again. Although we are part of the grand scheme of things, our bodies are not very good means for sequestering carbon to help stabilize the world's climate. There are far too many conflicting situations that accompany an increasing population to make any solution a simple one.

Noology and You. Your mind is another story. Noology is the study of the mind and you are part of the noosphere, that realm beyond the bio-geo-chemical components of our geosphere-atmosphere-hydrosphere-cryosphere-lithosphere-biosphere - and even that special one - the pedosphere. The uniqueness of the noosphere is that it enables us to imagine all the things that are being discussed here.

I do not know about the recycling of minds. The products of mental activities, such as the formation of ideas and concepts, the discovery of relationships - both functional and empirical, and the explanations ascribed to phenomena can certainly be passed on from generation to generation. Are you trying to make a difference? - or are you merely passing through? You have to learn an idea to recycle it. You can put ideas together in novel ways thereby creating new insights and levels of understanding. You can change the future through the actions initiated within the noosphere.

And that brings us to the relevance of this conference on soil system behavior in time and space. As soil scientists we have a responsibility - and obligation - to help people understand soils. It is the sharing of your intellectual legacy that I'm referring to. As people come to know more about the wonderful world of the pedosphere, their decisions about the care and use of the soils resources become wiser.

The Pedosphere. The main functions of the pedosphere tend to be obvious to the observant (GACGC, 1995). The pedosphere is the geomembrane that helps sustain life. It provides habitat to all the terrestrial biota whose metabolism is crucial for regulation and production aspects. The soil habitat is what conditions and modifies the ebb and flow of energy. Regulation is a function of healthy ecosystems - providing clean water, clean air, and mitigating fluxes of water, heat, pollutants and so forth. One part of the utilization function of soils refers to the transformation of biomass - whether used for food, fiber, building materials, feed, or pleasure. Another part refers to the use of soil to support infrastructures of society - cities, roads, dams, and so forth. Our reliance on food and water for survival has generally made us more aware of these functions of soils.

The pedosphere is the aggregate of natural, three-dimensional segments of the earth's terrestrial cover called soils. It is the combination of properties of soils that enable them to provide meaningful functions. Well functioning soils provide and promote healthy, harmonious ecosystems. which can be modified and maintained for environmental sustainability. Soil science strives to elicit the basics of the pedosphere - the whats, the hows, the whens and wheres - and then to whys of this soil cover - this pedosphere that guards and guides the behavior of the constantly interacting spheres.

All too often the cultural function of soil is brushed aside, even though it has been the basis for human civilization as we know it. Man has had intimate interactions with soils throughout history - especially those related to food and water. Mother Earth is not a myth - she is a root of teleological belief in the frailty of humans to create, to care for, and to sustain a Garden of Eden for all things. In the search for meaning we commonly recognize the foundation of our forefathers which was based on reverence of natural resources and the utter interdependence that existed in the natural world around them. The lesson learned is that we must take care of the world. Stewardship of resources, including soils, is the social acceptance of sustainability. It is the noosphere interfacing with all of the other spheres. It is the social acceptance of sustainability.

Food Scarcity: A Bellwether? We appear to be confronted with sufficient environmental deterioration to disrupt the economic progress of our world. Making sure that the next generation has enough food is no longer merely an agricultural matter(Brown, 1997). Decisions made in the ministries of energy that will affect future climate stability may have as much effect on the food security of the next generation as those made in agricultural ministries. To secure future food supplies and build an environmentally sustainable economy we will need a stabilized population and climate. In addition, a sustainable environment will depend on reversing deforestation, arresting the loss of plant and animal species, and stabilizing fisheries, aquifers, and soils. Surpluses have become scarcities.

The replacement of surpluses with scarcity argues for a much greater commitment of both private and public funds in agriculture. Every new technology that would lead to even a small expansion in food output is valuable. The shift to scarcity will affect land use and water use policies (Postel, 1996). In a world of food scarcity, land use suddenly emerges as a central issue and soil science has an intellectual responsibility to be involved. Designing, building, and improving a reference system for global soils is, therefore, a good undertaking.

The Path Ahead. To quote Lester Brown, " ... if political leaders do manage to secure food supplies for the next generation, it will be because they have moved the world economy off the current path of environmental deterioration and eventual economic disruption and onto an economic and demographic path that is environmentally sustainable" (Brown, 1997, p.64). As scientists concerned with the behavior of soil systems in time and space, we must sharpen our skills, consolidate our understanding, and effectively market our knowledge of soils. To stand on the shoulders of giants and not reach out to others would be a tragedy.

Soil for you and me is also an acronym - a reminder of our heritage and of the professional responsibility we have to reach out and help people understand soils and the many lessons that they offer us..

SOIL

Sharing Our Intellectual Legacies because

Serving Others Is Logical knowing that

Soils Offer Important Lessons

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World Reference Base for Soil Resources and Soil System Behaviour in Time and Space

<u>Posters</u>

DEFINITION AND CLASSIFICATION OF SOLONETZ

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1. Introduction

Solonetz soils occur widespread throughout the world, especially in semi-arid and sub-humid regions. Solonetz soils are problem soils with extremely unfavourable qualities for agricultural land use. Most important are their high dispersivity and extreme vulnerability to erosion. In view of the land use problems of these soils, their vulnerability to mismanagement and their low resilience, it is important to define and classify Solonetz soils correctly. Kust (1985) already stated that: "The problem of identifying solonetzic soils is now particularly urgent".

Khitrov (1984) highlighted that Solonetzes are "extremely complex natural formations". Consequently many different criteria have been proposed for their identification. Kust (1985) lists exchangeable sodium, exchangeable magnesium, content of water-peptizable clay, hydrophilic silica, alumina and iron gels and the mineral composition of the soils as having been identified as *some* of the factors being responsible for the unfavourable properties of Solonetzes.

One can obviously not use all above properties (plus others not even listed) as criteria for the definition and classification of Solonetzes. On the other hand the criteria selected should not create such a narrow range that a significant number of soils which fit the Solonetz concept are excluded. An important decision would be whether all soils with Solonetz morphology and behaviour should be classified as Solonetzes or whether provision for solonetzic units should be made under other major groups (e.g. Luvisols and Planosols) to accommodate some of these.

2. The Solonetz concept

Kust (1985) states that the many definitions of solonetz in literature " all have one point in common: they are soils with an eluvial-illuvial differentiated profile, with the illuvial horizon having a columnar structure and an alkaline reaction". In Russia the identification of Solonetzes "is based on the structure of the soil profile as a whole (its textural differentiation) and on the characteristics of its component genetic horizons, primarily the properties of the solonetzic horizon. Most of the specific properties of Solonetzes are confined to the latter." (Khitrov, 1984). Khitrov (1984) states that the "main and decisive criteria" are morphological and that chemical and physical properties are of secondary importance.

The typical Solonetz morphology can be summarized as (i) a very big abrupt increase in clay content from the horizon above the solonetzic horizon to the solonetzic horizon and (ii) columnar (or sometimes prismatic) structure of the solonetzic horizon. Two main types of Solonetzes are recognized, viz. (a) ordinary Solonetzes, where the solonetzic B horizon is overlain by an A horizon, and (b) solodized Solonetzes, which have an E (albic) horizon or an albic capping between the A and B horizons.

3. The natric horizon as key Solonetz horizon

In the USDA's Soil Taxonomy the "natric horizon" is the key horizon for the indentification of soils with solonetzic properties (Soil Survey Staff, 1975). This horizon was also adopted for the identification of the Solonetz major group in the FAO-Unesco Soil Map of the World and is still used in the WRB reference base (Spaargaren,1994). The use of the natric horizon as key horizon for the identification of Solonetzes has several implications which can lead to major classification problems. Firstly, the main morphological characteristics of Solonetzes are no longer prerequisites for identification, viz:

a. The big abrupt textural differentiation, characteristic of Solonetzes, is not a prerequisite. The natric horizon is simply seen as a special type of agric horizon, i.e. the minimum clay increase required is insignificantly small and the distance over which it must be reached quite large (30 cm).
b. The natric horizon as defined by the Soil Survey Staff (1975) and used by FAO (1974) does not necessarily need to have columnar or prismatic structure. Horizons having blocky structure with tongues of an eluvial horizon can also qualify as natric horizons. Fortunately the WRB reference base (Spaargaren, 1994) no longer mentions the latter, thus making columnar or prismatic structure a prerequisite for Solonetzes.

Secondly, sodicity (specifically an ESP >15) is a prerequisite in the definition of natric horizons, and in the identification of Solonetzes. Even where a natric horizon can be identified because it has more exchangeable (Na + Mg) than (Ca + exchangeable acid) in the top 40 cm the soil must still have an ESP >15 in some subhorizon within 200 cm from the surface. The name "natric" indicates the overriding position accorded to sodicity in the definition of the horizon.

Due to the overriding emphasis on an ESP >15 and the ignoring of all other physico-chemical factors many soils with typical Solonetz morphology and (most importantly) Solonetz behaviour cannot be classified as Solonetzes in WRB. These include, inter alia, the "low-sodic Solonetzes" which are "common" in parts of Russia (e.g. Tyul'panov and Manukov, 1981) and the "solonetzic" soils of South Africa. The situation is aggravated by the fact that no provision is made for solonetzic units in other major soil groups such as Luvisols and Planosols.

The pre-occupation with an ESP >15 is difficult to understand. In Australia an ESP of 6 or higher has been found to indicate "sodicity" in dispersive soils (Isbell, 1996). In Zimbabwe soils with ESP's as low as 4 are found which "still show all the major morphological properties associated with sodic soils" (Nyamapfene, 1991). In South Africa soils with perfect Solonetz morphology **and** behaviour are found with ESP's as low as 3 or less.

4. Magnesium Solonetzes

Most "low-sodic Solonetzes" are characterized by high levels of exchangeable magnesium in the solonetzic horizon. This has been reported by many Russain researchers and is also the case in South Africa, and other parts of the world. The terms "magnesium Solonetz" or "slitonetz" are used for such soils (Spaargaren, 1994).

For magnesium to bring about solonetzicity it must substantially exceed the amount of calcium. As a rule of thumb I have observed that in South African "magnesium solonetzes" the exchangeable Mg:Ca ratio in the solonetzic horizon usually is in the order of 1.7:1 or more.

Various researchers have studied the effects of magnesium in soils and the mechanisms of these effects. Amongst the findings are that a little sodium greatly aggravates the effects of magnesium; that the effects of magnesium are greater on micaceous clays than on smectites; that magnesium not only disperses clay, but also mobilizes iron oxides and changes the composition of the soil's humus fraction (the two main structure stabilizing agents). Yet there is an inexplicable reluctance to accept magnesium as a major factor in solonetzicity.

5. Low-sodic, low-magnesic solonetzic soils

In addition to the sodic and magnesic Solonetzes, soils with typical Solonetz morphology **and behaviour**, but with low exchangeable sodium and magnesium contents are found.

6. Suggested approach to the definition and classification of Solonetzes

The solonetzic horizon is the key to the definition and classification of Solonetz soils. The first requirement is to develop an acceptable definition for a solonetzic horizon. (The term "solonetzic horizon" is widely used in Russian soil science literature and it is suggested that this term is used. This is the same principle as having the "nitic horizon" as key horizon for Nitisols). The following definition is suggested for the solonetzic horizon:

A solonetzic horizon:

1. Has an abrupt textural transition from the overlying horizon. An abrupt textural transition requires a doubling of the clay content within 7.5 cm if the overlying horizon has less than 20 percent clay, or an absolute increase of at least 20 percent clay within 7.5 cm if the overlying horizon contains more than 20 percent clay, **and**
2. Has prismatic or columnar structure (usually coarse); occasionally primary blocky structure is more pronounced than secondary prismatic or columnar structure. (Blocky structure without prismatic or columnar tendency under an abrupt transition or prismatic structure under a transition which is not abrupt are not permitted), **and**
3. Has a water-dispersible clay (WDC) content comprising at least 30% of the total clay (TC) content of the soil. It is calculated as $\frac{WDC}{TC} \times 100\%$

Remarks:

1. The criteria for an abrupt textural transition are identical to those for the "Prismacutanic B horizon", the South African version of the solonetzic horizon (Soil Classification Working Group, 1991) and for Planosols in WRB (Spaargaren, 1994).
2. High dispersivity is an important characteristic of solonetzic horizons. Khitrov (1984) found that the ratio of "water peptized" to "aggregated" clay in the solonetzic horizon is the most suitable criterion for the classification of Solonetzes. The minimum value of 30% for water-dispersible clay is based on results for South African "solonetzic

soils". Water-dispersible clay is already an important criterion for the identification of Nitisols in WRB. (In that case it is to determine stability, i.e. lack of water-dispersibility). The Australians have some strange soils with typical Solonetz morphology and even high sodicity (ESP's up to over 25), but which do not disperse (Isbell, 1996). Consequently they do not want to include them under "Sodosols". A water-dispersibility criterion will exclude them from the Solonetz major group.

At the second (soil unit) level it is proposed that only two units are distinguished, viz. Solodized Solonetz and Haplic Solonetz. There are major differences between these two types of Solonetz. Furthermore most properties presently used at soil unit level in WRB (salic, mollic, gypsic, calcic) can be associated with both types and should be used to sub-divide each at the third level. The following definitions are proposed:

Solodized Solonetz. Solonetz having an albic horizon or albic capping on the solonetzic horizon.
Haplic Solonetz. Other Solonetz.

7. Linkages

Ironically the two most important linkages, conceptually and spatially, between Solonetzes and other major soil groups are not mentioned in WRB (Spaargaren, 1994). The first is the linkage between Solodized Solonetzes and Planosols. Presently some typical Solodized Solonetzes (morphologically and behaviourally) are classified as Planosols, because of low sodicity. The proposal will correct this. Solodized Solonetzes and Planosols often occupy the same footslopes, with the Planosols on the slightly higher topographical positions. The second is the linkage between Haplic Solonetzes and Luvisols. Some morphologically and behaviourally typical Haplic Solonetzes are presently classified as Luvisols, because of low sodicity. The new proposal will correct this. Haplic Solonetzes and Luvisols often occupy adjacent landscape positions.

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TAXONOMIC CONSIDERATIONS OF PERMAFROST-AFFECTED SOILS

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Introduction. Soils of permafrost regions have gained considerably more attention than in the past due to anticipated global climate change and the particular vulnerability of these soils to warming (thaw instability). This interest has brought renewed attention to long-recognized problems with the classification of these soils (Tedrow 1977; Claridge and Campbell 1982; Tarnocai et al. 1993; Ahrens et al. 1994; Kimble and Ahrens 1994; Moore et al. 1995). In an attempt to remedy this situation, a new soil order has been proposed in *Soil Taxonomy* (ST) (Bockheim et al. 1994) and a new soil group for the *World Reference Base for Soil Resources* (WRB) that will eventually replace FAO-Unesco (FAO 1988; Spaargaren 1994). The proposed new soil order is *Gelisols* and the new soil group is *Cryosols*. The merits of establishing a new order or group for permafrost-affected soils versus classifying these soils within existing orders is considered here. Here, soil order and soil group are used interchangeably, both refer the highest level of classification in ST or WRB, respectively. The essential classification criteria defining these proposed soil orders is similar: the presence of permafrost throughout the year at ≤1 or ≤2 m. Permafrost is defined as soil temperature ≤0°C throughout the year.

2. Results and Discussion. The presence of permafrost and associated cryogenic processes tend to create unique conditions in these soils and leads to two basis questions that should be addressed regarding their classification.

1. Should the presence of permafrost take precedence over all other soil characteristics, including as organic or other diagnostic soil horizons, in soil taxonomy?
2. Is cryoturbation a soil-forming process; or a soil-disrupting process?

The first question is central to classification hierarchy. It is pertinent to note that permafrost and cryoturbation are often assumed to occur together but this is not necessarily the case. The occurrence of cryoturbation is primarily due to frost heave, which requires three conditions in order to occur: (1) thermal gradients induced by freeze-thaw cycles; (2) frost-susceptible materials, particularly silt-rich soils; and (3) water. While frost heave is common in permafrost-affected soils, it is neither a universal nor unique feature of these soils since soils without permafrost may undergo frost heave as well. In fact, some of the most intense frost heave occurs in soil of alpine areas that experience steep thermal gradients and numerous freeze-thaw cycles. Soil with permafrost may also not be disturbed if they may not meet the 3 conditions stated above, e.g. they may be dry or they may remain frozen and therefore be stable.

The second question can be answered that cryoturbation both contributes to and disrupts processes that are the classical hallmarks of soil formation. Cryoturbation may be somewhat of a misnomer since it implies that all cryogenic processes are disruptive. Cryogenic soil-forming processes include development of platy and other structure, and textural segregation of soil material on scales from millimeters to ten's of meter. On the other hand, cryogenic processes may attenuate horizon formation by bulk mixing of soil material and slow rates of weathering.

2.1. Proposals for a new soil order for Permafrost-affected soils. Currently, soils of cold regions are classified in ST based on temperature and no indication is specifically made for the presence of permafrost, and descriptions of cryoturbation are inadequate (Soil Survey Staff 1992). In the current FAO classification, soils with permafrost are designated at the *Gelic* subgroup level. Permafrost occupies 13% of the world's soils and establishment of the *Gelisol* order will create the second largest soil order after *Aridisols* in ST (ICOMPAS 1994). This is a result of reclassifying soils that are currently primarily classified as *Inceptisols, Histosols,* and *Entisols.* The implications of this are that barren soils devoid of vegetation and containing virtually no organic carbon will be classified in the same order as tundra soils containing lush plant cover and some of the largest stores of organic carbon of any soil. Defining soils on the basis of permafrost at the order level supersedes the presence of most diagnostic horizons, and in order to describe the presence of these horizons a more complex nomenclature must be used that essentially defines other soil orders within the *Gelisol* order. For example, for the three proposed new suborders: *Histels* are essentially *Histosols* underlain by permafrost, and *Turbels* and *Haplels* include great groups for soils previously classified in several other orders. This provides a detailed description for these soils, but it also brings in more complicated, and possibly unnecessary, additional nomenclature. The danger of bring in extraneous complexity in soil nomenclature by using a single, apparently simple criteria for group soils at a high level was identified early on by Guy Smith (Smith 1986).

It appeals to a great many people to use one property in one category throughout the system. However, this leads to an enormous multiplication in the number of categories that we must form.

Soils grouped by the occurrence of permafrost would essentially being classified by climate. Using climatic definitions to determine soil order has been debated for *Aridisols* in ST since these soils are delineated primarily by climate. Considering that discussions whether to abandon the *Aridisols* order in ST have occurred on numerous occasions, it is rather surprising that we may be adding another soil order defined primarily by climate without considering this aspect more carefully. *Gelisols* would be the second largest order in ST after *Aridisols.*

The effect of classifying all soils underlain by permafrost into a single group, the *Cryosols,* would have even more greater implications for the WRB than for ST since only two levels of differentiation are defined in this system (Some additional information may be conveyed by using 2 descriptors from the second level as defined in FAO (1988)). The lack of additional levels of differentiation in WRB is compensated by recognizing 30 soil groups compared to 11 soil orders in ST. If all soils underlain by permafrost were reclassified as *Cryosols,* this likely would form the largest soil group in WRB, potentially grouping together soils currently classified as *Histosols, Leptosols, Solonchaks, Gleysols, Arenosols, Regosols, Planosols, Cambisols, Podzoluvisols,* and possibly *Andosols, Chernozems,* and *Podzols.* The actual extent of soils that are reclassified would depend on the depth to which the permafrost is recognized. Limiting the depth of the active layer to ≤1 m would possibly eliminate some soil groups from being reclassified as *Cryosols*, such as *Andosols, Chernozems, and Podzols*. But even with this change in permafrost depth criteria, many organic, mineral, salt-affected, and gleyed soils would be classified into a single group. The essential features of these soils may be defined within the existing orders such as is currently done in the FAO system; soils with permafrost are defined at the *Gelic* subgroup level.

Another potential problem with defining soils based on thickness of the active layer is that this may change over short periods and may vary for soils that are virtually identical in areas of sporadic permafrost. There is mounting evidence that the distribution of permafrost is changing. (Anisimov and Nelson 1996; Fitzharris 1996). Simply by deepening of the active layer, soils previously classified as *Cryosols* or *Gelisols* may no longer meet this criteria; this would likely be less problematic if it resulted in reclassification at a level lower than the order.

2.2. Suggestions for Soil Taxonomy. Bockheim et al. (1994) presented two alternatives to creating a new order for *Gelisols*. It is apparent that virtually equivalent information can be conveyed in the soil nomenclature by accounting for permafrost at the great group level with substantially simpler nomenclature. It is suggested here that permafrost be noted at the great group level; cryoturbation described at the family or subgroup level; and inclusion of the desert soils of Antarctica in the *Aridisols*. The last suggestion would require modification of the soil temperature classes for *Aridisols*.

2.3. WRB alternative classifications. There are at least 3 apparent possibilities for defining *Cryosols*: (1) Analogous to the *Gelisol* proposal - establish a new soil group that will encompass all soils underlain by permafrost with an active layer depth of either ≤1 or ≤2 m; (2) The *status quo* - do not establish a new soil group and continue note the presence of permafrost at ≤2 m at the *Gelic* subgroup. Cryoturbation could be noted by establishing a *Turbic* subgroup for soils underlain by permafrost and exhibiting cryoturbation. (3) Current, or slightly modified, WRB draft proposal - establish a new soil group for soils underlain by permafrost that lack other diagnostic horizons and display cryoturbation; other soil groups that are underlain by permafrost would continue to be noted at the *Gelic* subgroup. The arguments presented here favor the 2nd and 3rd possibilities.

3. Summary. It is asserted here that soil taxonomy should follow the guidelines of classifying the intrinsic material properties at the highest level and noting modifying properties, such as those primarily mediated by climate, at a lower level of classification. The definition of *Gelisols* or *Cryosols* based simply on the presence of permafrost within 1 or 2 m of the soil's surface would seem to be an uncomplicated system for classifying these soils. But this is essentially a climatic criteria and does not account for the diversity of soils that may occur under these climatic conditions. In order to describe the varieties of soils occurring in permafrost-affected regions, the nomenclature becomes significantly more complex, particularly for ST. Permafrost or cryoturbation may be recognized below the order level and convey equivalent information to establishing a new order using simpler, more consistent nomenclature.

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CRYOSOLS: HOW THEIR PROPERTIES, PROCESSES AND SPATIAL DISTRIBUTION CHANGE OVER TIME

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1. Introduction. Cryosols are perennially frozen mineral and organic soils that contain cryic horizons (Cryosol Working Group, 1997) within 100 cm of the soil surface. Worldwide, Cryosols occupy approximately 18 x 10^6 km^2, and occur in the Arctic, Antarctic, Subarctic and Boreal regions under cold continental, subhumid, semiarid or arid climatic conditions and at high elevations at low latitudes (the Andes and the Tibetan Plateau). They support unvegetated to continuously vegetated tundra (Antarctic and Arctic), open-canopy lichen or moss coniferous forest (Subarctic forest), closed-canopy coniferous forest (Boreal forest), or mixed coniferous and deciduous forest (Boreal forest).

Cryosols have a perennially frozen (permafrost) subsoil, and their genesis and properties are the result of cryogenic processes. Cryogenic soil properties include segregated ice, cryoturbated soil horizons, and macrostructures and microstructures resulting from cryogenic processes. These soils often have both a significant accumulation of organic matter at the surface and cryoturbated organic matter in the subsoil. They are also carbon sinks; large amounts of organic carbon are stored in both Turbic (cryoturbated) and Histic (organic) Cryosols. Soil water occurs in the form of ice in the perennially frozen soil layer. The presence of this ice is not only a unique characteristic of these soils, but it also has a great influence on their genesis and management. This ice occurs in the form of ice crystals, ice lenses, vein ice, ice wedges and massive ground ice.

The patterned ground types associated with mineral Cryosols are earth hummocks, and sorted and nonsorted circles, nets, stripes, steps and polygons (Washburn, 1980). Organic Cryosols (Histic Cryosols) are commonly associated with palsas, peat plateaus, peat hummocks, polygonal peat plateaus, and low- and high-centred lowland polygons (Seppälä, 1988).

Cryosols are a very dynamic group of soils whose spatial distribution has changed over time. This extended abstract focuses on both this spatial distribution and the effect the interaction of the physical and biospheric components have had on soil processes operating over time.

2. Materials and Methods. Most of the information presented in this extended abstract is drawn from Canadian sources. For the changes in the spatial distribution of Cryosols, European data was used in addition to that from Canada. The soil classification terminology used is according to the World Reference Base for Soil Resources (to be published in 1998). The soil terminology is according to Agriculture Canada Expert Committee on Soil Survey (1987) and International Society of Soil Science (1994), while the laboratory analysis methods are those of Sheldrick (1984).

3. Discussion. Permafrost-affected soils (Cryosols) are a component of a dynamic, ever-changing system, so their processes, properties, and spatial distribution also change over time. These changes can be short term, due mainly to the interaction between biospheric and physical factors, or long term, resulting from major climate changes.

3.1. *Short-term Model.* The short-term processes are driven mainly by the interactions between the soil, biosphere, microclimate and hydrology components. An increase in surface organic matter build-up and a well-established vegetation cover provide favourable conditions (cold soil climate) for the operation of cryogenic processes. As a result, the active layer thickness decreases, ice build-up in the subsoil increases, and cryogenic processes, especially cryoturbation, accelerate or begin to operate. These changes in Cryosols take place slowly and can be measured in terms of hundreds of years. The result of this process, however, is not a steady state. Removal of the surface organic layer and the vegetation cover by fires, or a change in the hydrology by flooding, can occur periodically. These changes increase the thermal regime of the soil, increasing the soil temperature. As a result, cryogenic processes slow down, the active layer depth increases, and a large part of the near-surface ice melts. These changes can very quickly lead to severe subsidence or flow slide development, usually within a few years.

3.2. *Long-term Model.* The dominant forcing factor for long-term processes is a major change in climate. Soil features derived from these long-term processes include cryoturbated macro- and microfeatures, sorted and oriented coarse fragments, cryogenic microrelief (patterned ground) and redoximorphic features. Fossil cryogenic features suggest that, during the glacial portions of the Quaternary period, Cryosols extended much farther south than they do now, with their distribution reaching mid-central and mid-western Europe and mid North America.

3.3. *Paleo Cryosols.* There is no evidence that Cryosols existed during the middle Tertiary period (in the Eocene epoch) even on the High Arctic islands of Canada (Tarnocai and Smith, 1991). In addition, there is no evidence that Cryosols occurred in the continental areas of Canada during the late Tertiary (Tarnocai, 1997; Tarnocai and Schweger, 1991; Tarnocai and Valentine, 1989). Although no supporting data is currently available, it is possible that Cryosolic soil development occurred during the late Tertiary period on the High Arctic islands of Canada.

The widespread distribution of Cryosols occurred during the glacial periods of the Pleistocene epoch. During these periods rubified Luvisols in the unglaciated areas of Canada and the northern United States (south of Canada) became Cryosols. Although they are not now Cryosols, they maintain the soil properties resulting from cryogenic processes (Tarnocai and Smith, 1989; Tarnocai and Valentine, 1989; Tarnocai, 1997). There is no evidence that Cryosols occurred in continental Canada during the early and middle Pleistocene (Tarnocai, 1997). Since the climate during the Sangamonian interglacial stage was similar to, or slightly warmer than, the present climate, Cryosols probably occurred in Canada at that time, although there is currently no data available to support this statement. Tarnocai (1997) compared the northern limits of various soils during the Tertiary period and the interglacial periods of the Quaternary period and found that none of the interglacial periods before the Holocene epoch were associated with Cryosols to such an extent as during the Holocene. Even though the spatial distribution of Cryosols has fluctuated during the Holocene, they are the dominant soils in Canada, covering approximately 35% of the land area.

3.4. *Contemporary Cryosols.* In the Holocene epoch contemporary Cryosols have been affected primarily by the processes described under the short-term model although, in some cases, long-term processes have also operated. Throughout the Holocene both the processes and spatial extent of Cryosols have changed. During the Hypsithermal interval the climate was warmer than at present so the southern boundary of Histic Cryosols in Canada was farther north (Tarnocai, 1978; Tarnocai and Zoltai, 1988). On the other hand, the occurrence of fossil cryogenic features and patterned ground on the northern fringe of the Cambisols and Luvisols (Tarnocai, 1973) suggests that Cryosols extended farther south during the cooler periods of the Holocene. The presence of collapse scars on the northern fringe of the Histosols in Canada indicates that the southern limit of the Histic Cryosols was about 100 km farther south during the Little Ice Age than it is now (Zoltai, 1971).

Cryogenic processes also varied during this period. Radiocarbon dating of cryoturbated organic materials from contemporary Cryosols suggests that most of the cryogenic processes began when the climate began cooling about 3.5 Ka BP. These processes subsequently fluctuated according to changes in climate and the environment (Zoltai et al., 1978).

3.5. *Effect of Climate Warming.* It is predicted that climate warming will cause a significant temperature increase in northern areas. Woo et al. (1992) suggested a surface temperature increase of 4°–5°C in permafrost regions. This warming will have a great impact on Cryosols, which cover an area of approximately 2.5 x 10^6 km^2 in Canada.

Calculations made by Kettles et al. (in press) indicate that climate warming (2x CO_2) would reduce the area of permafrost in Canada from 42% of the total land area at the present time to 23%. This suggests that climate warming would halve the area of permafrost in Canada.

4. Summary.

1. Cryosols are defined as mineral or organic soils that contain one or more cryic horizon(s) within 100 cm of the soil surface. Cryogenic processes are the dominant soil-forming processes. Soil water in the cryic horizon occurs in the form of ice.
2. The properties and spatial extent of Cryosols are affected by both short-term and long-term changes.
3. Soil properties that respond quickly to short-term processes are organic matter, ice content, soil temperature and active layer depth. Soil properties that result from long-term processes are cryoturbated macro- and microfeatures, sorted and oriented coarse fragments, cryogenic microrelief and redoximorphic features.
4. No Cryosols occurred in Canada during the middle Tertiary period, but they probably existed on the High Arctic islands of Canada during the late Tertiary.
5. Cryosols were widespread in both North America and Europe during the glacial periods of the Quaternary. During the interglacial periods, they reached their maximum spatial extent during the Holocene epoch.
6. Processes affecting the development of Cryosols fluctuate and represent a non-steady state system. Some of the cryogenic processes can slow down or become dormant before being reactivated.

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Buchbesprechung

Gerd Hintermaier-Erhard und Wolfgang Zech: ***Wörterbuch der Bodenkunde.*** 1997
Ferdinand Enke Verlag, Stuttgart. 338 Seiten, 273 Abbildungen, 43 Tabellen, 8 Farbtafeln, 15,5 x 23 cm, kartoniert.
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Die Bodenkunde mit ihren verschiedenen Themenschwerpunkten hat in der letzten Zeit wesentlich an Bedeutung gewonnen. Der Boden wird nun in zunehmendem Maße als eines der wichtigsten Kompartimente unserer Umwelt erkannt, von verschiedenen verwandten Disziplinen bearbeitet und diesbezügliche Vorschriften in Gesetzes- und Regelwerken aufgenommen. Diese Entwicklungen rechtfertigen aus meiner Sicht die Herausgabe eines Wörterbuches der Bodenkunde, wobei im Falle des vorliegenden Buches der Begriff „Wörterbuch" etwas zu tief gegriffen ist. Die zahlreichen Abbildungen und Tabellen lassen vom Charakter, wenn auch nicht vom Umfang her eher ein Lexikon entstehen. Die Abgrenzung bodenkundlicher Begriffe von jenen verwandter Disziplinen ist natürlich nicht leicht. Im vorliegenden Buch wurden Stichworte insbesondere aus der Geologie und Biologie zum Teil zusätzlich berücksichtigt. Weniger vertreten sind Begriffe aus der modernen Bodenanalytik (z.B. NMR, ESR, FTIR); die ökologischen Bodenfunktionen werden zufriedenstellend berücksichtigt, wenn vielleicht auch der eine oder andere Begriff (z.B. K_d-Wert), der in der Ökologie zur Beschreibung von Prozessen im Boden verwendet wird, nicht repräsentiert ist. Es kann aber meiner Ansicht nach nicht Aufgabe eines allgemein gehaltenen Wörterbuches für Bodenkunde sein, alle Randgebiete vollständig abzudecken. Die bodenkundlichen Begriffe sind klar und verständlich beschrieben. Ein gewisses naturwissenschaftliches Grundwissen kann und muß natürlich vorausgesetzt werden, was mit dem Adressatenkreis - Studierende und Lehrende an Hochschulen und Universitäten und Referenten in Fachbehörden - übereinstimmt.
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Heft 44 1991, 162 Seiten
STRITAR, A.: Pedoökologische Kartierung als Grundlage für die Raumplanung.
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Kurzfassungen der Vorträge.

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Kurzfassungen der Vorträge.

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Role of invertebrate and microorganisms in decomposition and soils organic matter formation.
KLAGHOFER, E.: Othmar Nestroy - Ehrenmitglied der ÖBG.
INSAM, H.: Vorwort.
BERG, G., C. McCLAUGHERT, A.V. de SANTO, M.B. JOHANSSON and G. EKBOHM: Decomposition of litter and soil organic matter - can we distinguish a mechanism for soil organic matter buildup?
COUTEAÛX, M.M.: Decomposition and soil fauna.
JOERGENSEN, R.G.: The C:N ratio of the soil microbial biomass in soilsof deciduous forests.
KJØLLER, A. and S. STRUWE: Decomposition of organic matter in terrestrial ecosystems. Microbial communities in soil.
MERCKX, R., S. KACHAKA,M. VAN GESTEL and B. ANLAUWE: Decomposition of organic residues in soils: Litter quality and spatial distribution of decomposition procducts and microbial components.
SMITH, J.U.: Calculating the amount of carbon returned to the soil each year from measurement of soil organic matter.
VALLEJO, R.: Evaluation of C:N ratio as a parameter of N-mineralization.
VERHOEF, H.A., F.G. DOREL, H.R. ZOOMER and S. MEINTSER: Effects of anthropogenic N-deposition on soil fauna-microbe interactions and the impact on decomposition pathways.
ZSOLNAY, A.: The relationship between resolved organic carbon and basal metabolism in soil.
CHEN, P. and L. LI: Sulphur deposition distribution and sulphur balance in Sichuan Basin, China.
Kurzfassungen der Vorträge.

Heft 48/49 1994, 442 Seiten
Bodenbiologie in Österreich.
SCHINNER, F.: Bodenmikrobiolgie in Österreich.
SCHALLER, F.: Bodenzoologie in Österreich.
OTTOW, J.C.G.: Bodenmikrobiologie in Deutschland.
DUNGER, W.: Bodenzoologie in Deutschland.
ILLMER, P.: Mikrobielle, nicht enzymatische Phosphormobilisierung aus unlöslichen Calciumphosphaten.
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BÖHM, K., E. KANDELER, W.E.H. BLUM: Jahreszeitlicher Verlauf mikrobiologischer Aktivitäten einer Schwarzerde mit unterschiedlicher Bodenbearbeitung.
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LUMMERSTORFER, E., E. KANDELER, O. HORAK: Einfluß leicht mobilisierter Schwermetalle auf die Aktivität von Bodenmikroorganismen.

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BAUERNFEIND, G., F. SCHINNER: Einfluß von Stickstoffeintrag aus der Atmosphäre auf bodenmikrobiologische Prozesse in Waldböden.

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CHRISTIAN, E.: Die Dipluren Wiens (Kurzfassung).

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SMEJKAL, G.: Bodentyp, Bewirtschaftungsweise und bodenbiologische Parameter: Ursprung-Elixhausen.

STANA, J., T. SEVCIK, S. MALY: Bodenbiologische Untersuchungen an Dauerbeobachtungsflächen in der Tschechischen Republik (Kurzfassung).
v. MERSI, W., F. SCHINNER: Bakterielle Kalium-Mobilisierung aus illitischen Tonmineralien.
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WIESHOFER, I.: Bodenmikrobiologische Parameter zur begleitenden Untersuchung des Umstellungsbetriebes Lobau.
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Heft 50 1994, 190 Seiten
Symposium: State of the ecological research on soil science and land use in Slovak Republic and in Austria.
AICHBERGER, K, G. HOFER and U. GRUBER: Heavy metals in soil - an aspect of the Upper Austrian soil monitoring program.
BIELEK, P.: Soil science in Slovak Republic, present state and perspectives.
BIZÍK, J.: Plant nutrition ecological aspects.
DUBLINEC, E. and J. KUKLA: Natural edaphic-ecological conditions and influence of polluted air on state of forest soils.
ÇURLÍK, J and L. MATÚSKOVÁ: Natural and man-induced factors of soil pollution (and hygiene).
DANNEBERG, O.H., I. POVOLNY, H. GOTTSCHLING and O. NESTROY: Soil Units and their Distribution in the Agricultural Area of Lower Austria.
DZATKO, M. and J. VILCEK: Pedo-ecological aspects of the land evaluation and land use planning.
FULAJTÁR, E.: Assessment of soil water regime.
FULAJTÁR, E.: Soil monitoring on the territory influenced by construction of the hydro-system Gabcíkovo.
JAMBOR, P.: To the relationships between Austrian and Slovakian soil scientists.
LINKEŠ, V.: Slovak Republic soils monitoring system.
NESTROY, O.: The position of soil ecology in the scope of the ecology.
RAMPAZZO, N., W.E.H. BLUM and J. CURLÍK: Soil structure assessment - the importance of mineralogical and micromorphological investigations.
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Heft 51 1995, 175 Seiten
NESTROY, O.: Ergebnisse bodenökologischer Studien im Raume Obertauern (Radstädter Tauernpaß, Land Salzburg).
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Der Autor trägt für den Inhalt seines Beitrages die Verantwortung.

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