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Subject II: Ecological fundamentals of production systems

STUDY MATERIAL

elaborated by a team of authors under W. Bassus

Volume One

1. Biological fundamentals of production

   - Basic problems of the ecology of terrestrial ecosystems
   - Basic problems of the ecology of aquatic ecosystems
   - Fundamentals of primary production
   - Production of useable biomass and strategies for its utilization
   - Influencing the productivity of ecosystems

Volume Two

2. Soil as production factor

   - Soil genesis
   - Soil types and soil classification
   - Site characteristics
   - Soil fertility

Volume Three

3. Water as production factor

   - Climate and hydrological cycle
   - Groundwater
   - Surface water
   - Interrelations soil-water-plant
   - Irrigation and drainage
   - Water quality, water treatment, drinking water supply

Volume Four

4. Stability and protection of ecosystems

   - Economic, social and hygienic influences
   - Conditions for the regeneration and stability of ecosystems
   - Measures for the maintenance of stability
   - Management of nature and landscape protection, biosphere reserves and rational utilization and protection of natural resources

Volume Two

Soil as production factor
by H.J. Fiedler, W. Hunger, W. Nebe, W. Hofmann, W. Katzschner

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Introduction

The world soils policy is defined as follows:

In recognition of the fact that soil[1] is a finite resource, and that continuously increasing demands are being placed on this resource to feed, clothe, house and provide energy for a growing world population and to provide worldwide ecological balance, the governments of the nations of the world agree to use their soils on the basis of sound principles of resource management, to enhance soil productivity, to prevent soil erosion and degradation[2], and to reduce the less of good farmland to non-farm purposes.

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1) Soil - is that part of the earth's surface that is penetrated by plant roots and upon which the world depends for most of its food and fibre supply.

A soil type is a unit of soil classification which includes soils which are essentially alike in all major profile characteristics including the surface texture.

2) Soil degradation - The decline in soil quality caused through its use by humans. Soil degradation includes physical, biological and chemical deterioration such as decline in soil fertility, decline in structural condition, erosion, adverse changes in salinity, acidity or alkalinity, and the effects of toxic chemicals, pollutants or excessive inundation.

Its objectives are:

1) To increase and apply scientific knowledge of the soils of the world with a view to increasing their potential for production and undertaking their sound management;

2) To encourage and assist countries in improving the productivity and management of their soils and in reducing soil degradation;

3) To encourage the management and conservation of soil, reduce pollution, and improve the quality of water and air;

4) To develop and promote agricultural production systems that assure the use of the soil on a sustained basis;

5) To enlarge and improve the world's supply of arable agricultural land through irrigation, flood control, and reclamation;

6) To slow the loss of productive agricultural and forest land to other purposes;

7) To monitor changes in soil quantity and quality and in land use;

8) To bring to the attention of the people of the world, and their political leaders in particular, the extent of world soil degradation and its seriousness, its causes and its remedies.

All national governments should:

1) Commit themselves to the sound use of land and water resources;

2) Develop a land-use policy and the necessary legislative framework to implement it;

3) Increase awareness among all sections of the community of the problems caused by the loss of productive soil and of the need for prompt action;

4) Identify, map and assess the potentials and constraints of soil resources, map current land use, assess the present extent of soil degradation, predict foreseeable hazards and develop methods for their prevention;

5) Adapt soil capability classifications and methods of land evaluation to local conditions;

6) Develop programmes to ensure the availability and wise application of fertilizers and other actions appropriate to the improvement and sustained use of the soil;

7) Establish an adequate legislative and institutional framework for monitoring and supervising soil conservation development and management;

8) Impose obligations on users, with the aim of ensuring the most rational use of land, through the use of tax exemptions, subsidies, credit facilities and other types of financial devices;

9) Train an adequately paid professional cadre of extension workers to assist farmers in managing soil and water resources effectively;

10) Establish and fund programmes, where needed, for reafforestation, irrigation, and reclamation of saline, flooded or other land not presently productive;

11) Actively pursue research needed to develop systems of farming that combine adequate production with resource protection and are compatible with socio-economic and cultural conditions;

12) Help develop local institutions to secure the leadership, assistance and co-operation of farmers in applying soil and water improvement and conservation practices. Provide an adequate programme of environmental education in support of resource management activities.

Implementation of a national soils policy should foster maximum utilisation of the soil on a sustained basis without lowering its productivity, and without causing direct or indirect damage to the environment. The various elements of the soils policy should be taken into account when any aspect of national development is being considered.

Soils are fragile systems that may be severely affected by changes in patterns and modes of land use. Failure to integrate national soils policies fully with those concerned with the use of or conservation of other natural resources may have a profound influence on the quality and quantity of soil and land resources available for future use. Our aim has to be achievement of sustained use of each nation's and region's soils in harmony with the use and development.

Despite short-term improvements due to many factors including technology (such as advances in plant breeding, fertilizer use and soil management), the world's long-term capacity to grow food and fibre is being reduced by increasing loss and degradation of its soils.

There are many causes of soil degradation, ranging from those associated with agricultural and pastoral use to those resulting from mining and other "non-rural" uses. Similarly, in the past, there have been many effective soil improvement and protection programmes undertaken by national and international bodies which have led to substantial increases in world food production. However, these successes tend to obscure the deterioration in the over-all world soil situation.

Objective criteria and uniform methodology are required to assess the status of land resources and to monitor changes in the quantity and quality of soil and land resources. These will enable detection of changes in the world's capacity to produce food and fibre, to focus attention on critical areas, and to target scarce funds to those areas where they can be used most effectively.

To provide a theoretical framework within which the influence of man on soils may be more fully understood, it is necessary to develop a general theory of soil changes under the influence of man. Such changes will often proceed slowly, although at times accelerated erosion may occur through injudicious use of certain crop production techniques. The science of pedology should be further developed to cover anthropogenic (man-stimulated) influences.

The objectives are:

1) To assemble and assess available information relating to the influence of man on the soil both in the past and at the present time;

2) To develop a general theory of anthropogenic soil forming, soil-improving, and soil-degrading processes, which can describe, explain and predict the changes in the major soil types likely to arise from man's activities in different environments;

3) To assess the dynamics of these processes in the major soil types and to predict rates of change likely to arise from their use by man;

4) To formulate criteria relating to the establishment of desirable equilibria between the soil, the environment and man's activities;

5) To develop the pedology of anthropogenic soil processes as an important and necessary part of general pedology, and to provide a fundamental basis for world and national soil policies.

Literature

Extract from United Nations Environment Programme (1982). World soils policy and draft plan of action for its implementation.Nairobi.

1. Soil genesis

A soil is a three-dimensional body. It is examined by exposing it in vertical cross-section. Such a vertical cut of a soil body is a profile. It consists of a vertical sequence of horizons. The horizons located above the geological material (not-soil) make up the solum. In any soil profile a sequence of an eluvial (A) and illuvial (B) horizon is termed a sequum. The nature and properties of the profil form the basis for soil classification. The unit of soil for which a soil profile de - scription is usually made is termed a pedon. It has the smallest area for which we should describe and sample the soil. The area of a pedon ranges from 1 to 10 m^2, depending on the variability in the soil. Its lower limit is the somewhat vague limit between the soil and the "not-soil" below. The minimum width of the soil profile face of a pedon is one metre.

1.1. Soil horizon designations

A soil horizon may be defined as a zone of soil, approximately parallel to the soil surface, with characteristics produced by soil-forming processes. A soil horizon is commonly differentiated from the one adjacent by characteristics that can be seen or measured in the field - such as colour, texture, structure, consistence - and sometimes also in laboratory tests. In addition to genetic soil horizons soils may show stratification due to variations in parent material or lithological discontinuities. A succession of different substrata should not be differentiated as "horizons" but as "layers". The symbols used to designate soil horizons are as follows:

Capital letters H, O, A, E and B indicate master horizons. A combination of capital letters is used for transitional horizons. Lower case letters are used as suffixes to qualify the master horizons. The lower case letters immediately follow the capital letter. Two lower case letters may be used to indicate two features which occur concurrently.

Arabic figures are used as suffixes to indicate vertical subdivision of a soil horizon. For A and B horizons the suffix figure is always preceded by a lower case letter suffix. Arabic figures are used as prefixes to mark lithological discontinuities..

1.2. Master horizons

H: An organic horizon formed or forming from accumulations of organic material deposited on the surface, that is saturated with water for prolonged periods (unless artificially drained) and contains 30 percent or more organic matter if the mineral fraction contains more than 60 percent of clay, 20 percent or more organic matter if the mineral fraction contains no clay, or intermediate proportions or organic matter for intermediate contents of clay.

H Horizons formed at the surface of wet soils, either as thick cumulative layers in organic soils or as thin layers of peat or muck over mineral soils. Even when ploughed the surface soil keeps a high content of organic matter following the mixing of peat with mineral material. The formation of the H horizon is related to prolonged waterlogging, unless soils are artificially drained.

O: An organic horizon formed or forming from accumulations of organic material deposited on the surface, that is not saturated with water for more than a few days a year and contains 35 percent or more organic matter.

O horizons are the organic horizons that develop on top of some mineral soils - for example, the "raw humus" mat which covers certain acid soils. The organic material in O horizons is generally poorly decomposed and occurs under naturally well-drained conditions.

A: A mineral horizon formed or forming at or adjacent to the surface. The organic matter in A horizons is well decomposed and is either distributed as fine particles or is present as coatings on the mineral particles. As a result A horizons are normally darker than the adjacent underlying horizons. The organic material is derived from plant and animal remains and incorporated in the soil through biological activity rather than by translocation.

E: A mineral horizon showing a concentration of sand and silt fractions high in resistent minerals, resulting from a loss of silicate clay, iron or aluminium or some combination of them.

E horizons are eluvial horizons which generally underlie an H, O or A horizon from which they are normally differentiated by a lower content of organic matter and a lighter colour. From an underlying B horizon an E horizon is commonly differentiated by colours of higher value or lower chroma, or by coarser texture, or both.

B: A mineral horizon in which rock structure is obliterated or is but faintly evident, characterized by one or more of the following features:

1) an illuvial concentration of silicate clay, iron, aluminium, or humus, alone or in combinations;

2) a residual concentration of sesquioxides relative to source materials;

3) an alteration of material from its original condition to the extent that silicate clays are formed, oxides are liberated, or both, or granular, blocky, or prismatic structure is formed.

B horizons generally need to be qualified by a suffix to have sufficient connotation in a profile description. A "humus B" horizon is designated as Bh, an "iron B" as Bs, and a "textural B" as Bt.

Letter suffixes

The suffix letters used to qualify the master horizons are as follows (extract):

c. Accumulation in concretionary form; this suffix is commonly used in combination with another which indicates the nature of the concretionary material (for example, Bck).

g. Mottling reflecting variations in oxidation and reduction (for example, Bg, Btg).

h. Accumulation of organic matter in mineral horizons (for example, Ah, Bh); for the A horizon, the h suffix is applied only where there has been no disturbance or mixing from ploughing, pasturing or other activities of man (h and p suffixes are thus mutually exclusive).

k. Accumulation of calcium carbonate

n. Accumulation of sodium (for example, Btn).

p. Disturbed by ploughing or other tillage practices (for example, Ap).

r. Strong reduction as a result of groundwater influence (for example, Br).

s. Accumulation of sesquioxides (for example, Bs).

t. Illuvial accumulation of clay (for example, Bt).

1.3. Diagnostic horizons

Soil horizons that have a set of quantitatively defined properties which are used for identifying soil units are called "diagnostic horizons". Since the characteristics of soil horizons are produced by soil-forming processes, the use of diagnostic horizons for separating soil units ensures that the classification system is based on general principles of soil genesis.

Histic H horizon

The histic H horizon is an H horizon which is more than 20 cm but less than 40 cm thick. It can be more than 40 cm but less than 60 cm thick if it consists of 75 percent or more, by volume, of sphagnum fibres or has a bulk density when moist of less than 0.1.

Mollic A horizon

The mollic A horizon is an A horizon which, after the surface 18 cm are mixed, as in ploughing, has the following properties (extract):

1. The soil structure is sufficiently strong, so that the horizon is not both massive and hard or very hard when dry.

2. The base saturation is 50 percent or more (by the NH_4 OAc method).

3. The organic matter content is at least 1 percent throughout the thickness of mixed soil.

Umbric A horizon

The requirements of the umbric A horizon are comparable to those of the mollic A horizon in colour, organic matter and phosphorus content, consistency, structure and thickness. The umbric A horizon, however, has a base saturation of less than 50 percent (by the NH_4 OAc method).

Ochric A horizon

An ochric A horizon is one that is too light in colour, has too high a chroma, too little organic matter, or is too thin to be mollic or umbric, or is both hard and massive when dry.

Argillic B horizon

An argillic B horizon is one that contains illuvial layer-lattice clays. This horizon forms below an eluvial horizon, but it may be at the surface if the soil has been partially truncated. The argillic B horizon has the following properties (extract):

1. If an eluvial horizon remains, the argillic B horizon contains more total and more fine clay than the eluvial horizon, exclusive of differences which may result from a lithological discontinuity. The increase in clay occurs within a vertical distance of 30 cm or less.

2. If peds are present, an argillic B horizon either shows clayskins on some of both the vertical and horizontal ped surface and in the pores, or shows oriented clays in 1 percent or more of the cross-section.

Natric B horizon

The natric B horizon has the properties of the argillic B horizon. In addition, it has a columnar or prismatic structure in some part of the B horizon, or a blocky structure with tongues of an eluvial horizon in which there are uncoated silt or sand grains extending more than 2,5 cm into the horizon. The natric B horizon has a saturation with exchangeable sodium of more than 15 percent within the upper 40 cm of the horizon.

Cambic B horizon

A cambic B horizon is an altered horizon lacking properties that meet the requirements of an argillic, natric or spodic B horizon; lacking the dark colours, organic matter content and stucture of the histic H, or the mollic and umbric A horizons; showing no cementation, induration or brittle consistence when moist, having the following properties:

1. Texture that is very fine sand, loamy very fine sand, or finer.

2. Soil structure or absence of rock structure in at least half the volume of the horizon.

3. Significant amounts of weatherable minerals reflected by a cation exchange capacity (by NH_4 OAc) of more than 16 me per 100 g clay, or by a content of more than 3 percent weatherable minerals other than muscovite, or by more than 6 percent muscovite.

4. Evidence of alteration in one of the following forms:
   a) higher clay content than the underlying horizon;
   b) stronger chroma or redder hue than the underlying horizon;
   c) evidence of removal of carbonates (when carbonates are present in the parent material or in the dust that falls on the soil).

5. Enough thickness that its base is at least 25 cm below the soil surface.

Spodic B horizon

Spodic B horizon meets one or more of the following requirements below a depth of 12,5 cm, or, when present, below an Ap horizon:

1. A subhorizon more than 2,5 cm thick that is continuously cemented by combination of organic matter with iron or aluminium or with both.

2. A sandy or coarse-loamy texture with distinct dark pellets of coarse silt size or with sand grains covered with cracked coatings.

Oxic B horizon

The oxic B horizon is a horizon that is not argillic or natric and that:

1. Is at least 30 cm thick.
2. Has a fine-earth fraction that retains 10 me or less ammonium ions per 100 g clay from an unbuffered N NH_4Cl solution or has less than 10 me of base extractable with N NH_4 OAc plus aluminium extractable with N KCl per 100 g clay.
3. Has an apparent cation-exchange capacity of the fine earth fraction of 16 me or less per 100 g clay by NH_4OAc unless there is an appreciable content of aluminium-interlayered chlorite.
4. Does not have more than traces of primary aluminosilicates such as feldspars, micas, glasses, and ferromagnesian minerals.
5. Has texture of sandy loam or finer in the fine earth fraction and has more than 15 percent clay.

6. Has mostly gradual or diffuse boundaries between its sub-horizons.

7. Has less than 5 percent by volume showing rock structure.

Calcic horizon
The calcic horizon is a horizon of accumulation of calcium carbonate. The accumulation may be in the C horizon, but it may also occur in a B or in an A horizon.

Gypsic horizon
The gypsic horizon is a horizon of secondary calcium sulfate enrichment that is more than 15 cm thick, has at least 5 percent more gypsum than the underlying C horizon, and in which the product of the thickness in centimetres and the percent of gypsum is 150 or more.

Sulfuric horizon
The sulfuric horizon forms as a result of artificial drainage and oxidation of mineral or organic materials which are rich in sulfides. It is characterized by a pH less than 3.5 (H_2O) and jarosite mottles with a hue of 2.5 Y or more and a chroma of 6 or more.

Albic E horizon
The albic E horizon is one from which clay and free iron oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the primary sand and silt particles rather than by coatings on these particles.

If the properties and natural processes occuring in a soil are known and understood, then intelligent, non-destructive practices are more likely to be employed than if soil is viewed as a static inanimate part of the earth which can be used or misused at will. If the soils or the vegetation they support are altered or manipulated by man, then many of the soil processes change. If the use or alteration is superficial, then the natural soil-vegetation system will rebound easily to its original state, but if the exploitation is great or if intensive cultural practices are introduced, then the soil itself will be modified.

Literature

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2. Soil types and soil classification

2.1. International reference base for soil classification

The major soils of the world are duly recognized in the main soil classification systems. However, they are defined to different degrees of refinement and by different criteria, so that many individual units overlap and differ in their range of variability. Differences in terminology and nomenclature further add to the difficulties of establishing correlations and international understanding. There is a strong need for a global soil resources assessment, as well as for a transfer of knowledge and an international agreement on soil classification.

The legend of the FAO/UNESCO Soil Map of the World can be used as a basis for discussion. It is now widely recognized that FAO/UNESCO Soil Map of the World on the scale 1 : 5 000 000 is a base for global and regional soil resources assessment. The project was initiated more than 15 years ago.

To support the efforts which are being made to establish an internationally accepted system for soil classification, it is essential to establish a reference collection of soils and data related to their characterization. The international Soil Museum based in the Netherlands has already established the nucleus of such a collection.

2.2. Definitions of soil units

FLUVISOLS

Soils developed from recent alluvial deposits having no diagnostic horizons other than (unless buried by 50 cm or more new material) an ochric or an umbric A horizon, a histic H horizon, or a sulfuric horizon. As used in this definition, recent alluvial deposits are fluviatile, marine, lacustrine, or colluvial sediments characterized by one or more of the following properties:

a) having an organic matter content that decreases irregularly with depth or that remains above 0.35 percent to a depth of 125 cm (thin strata of sand may have less organic matter if the finer sediment below meets the requirements);

b) receiving fresh material at regular intervals and/or showing fine stratification;

c) having sulfidic material within 125 cm of the surface.

GLEYSOLS

Soils formed from unconsolidated material exclusive of recent alluvial deposits, showing hydromorphic properties within 50 cm of the surface; having no diagnostic horizon other than (unless buried by 50 cm or more new material) an A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking bleached coatings on structural ped surfaces when a mollic A horizon is present which has a chroma of 2 or less to a depth of at least 15 cm.

REGOSOLS

Soils from unconsolidated materials, exclusive of recent alluvial deposits, having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon; lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols and Andosols; lacking high salinity; when coarse textured, lacking lamellae of clay accumulation, features of cambic or oxic B horizon or albic material which are characteristic of Arenosols.

LITHOSOLS

Soils which are limited in depth by continuous coherent hard rock within 10 cm of the surface.

ARENOSOLS

Soils from coarse-textured unconsolidated materials, exclusive of recent alluvial deposits, consisting of albic material occurring over a depth of at least 50 cm from the surface or showing characteristics of argillic, cambic or oxic B horizons which, however, do not qualify as diagnostic horizons because of textural requirements; having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon; lacking hydromorphic properties within 50 cm of the surface; lacking high salinity.

RENDZINAS

Soils having a mollic A horizon which contains or immediately overlies calcareous material with a calcium carbonate equivalent of more than 40 percent; lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity.

RANKERS

Soils, exclusive of those formed from recent alluvial deposits, having an umbric A horizon which ist not more than 25 cm thick; having no other diagnostic horizons (unless buried by 50 cm or more new material); lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Andosols.

ANDOSOLS

Soils having a mollic or an umbric A horizon possibly overlying a cambic B horizon; having no other diagnostic horizons (unless buried by 50 cm or more new material); having to a depth of 35 cm or more one or both of:

a) a bulk density (at 1/3-bar water retention) of the fine earth (less than 2 mm) fraction of the soil of less than 0.85 g/cm^3 and an exchange complex dominated by amorphous material;

b) 60 percent or more vitric volcanic ash, cinders, or other vitric pyroclastic material are silt, sand and gravel;

lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity.

VERTISOLS

Soils having, after the upper 20 cm have been mixed, 30 percent or more clay in all horizons to a depth of at least 50 cm; developing cracks from the soil surface downward which at some period in most years (unless the soil is irrigated) are at least 1 cm wide to a depth of 50 cm; having one or more of the following: gilgai microrelief, intersecting slickensides, or wedge-shaped or parallelepiped structural aggregates at some depth between 25 and 100 cm from the surface.

SOLONCHAKS

Soils, exclusive of those formed from recent alluvial deposits, having a high salinity and having no diagnostic horizons other than (unless buried by 50 cm or more new material) an A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon.

SOLONETZ

Soils having a natric B horizon; lacking an albic E horizon which shows hydromorphic properties in at least a part of the horizon and an abrupt textural change.

YERMOSOLS

Soils occurring under an aridic moisture regime; having a very weak ochric A horizon and one or more of the following: a cambic B horizon, an argillic B horizon, a calcic, a gypsic horizon; lacking other diagnostic horizons; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking permafrost within 200 cm of the surface.

XEROSOLS

Soils occurring under an aride moisture regime; having a weak ochric A horizon and one or more of the following: a cambic B horizon, an argillic B horizon, a calcic horizon, a gypsic horizon; lacking other diagnostic horizons; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking permafrost within 200 cm of the surface.

KASTANOZEMS

Soils having a mollic A horizon with a moist chroma of more than 2 to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon or concentrations of soft powdery lime within 125 cm of the surface; lacking a natric B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties within 50 cm of the surface when no argillic B horizon is present.

CHERNOZEMS

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon or concentrations of soft powdery lime within 125 cm of the surface; lacking a natric B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties within 50 cm of the surface when no argillic B horizon is present; lacking bleached coatings on structural ped surfaces.

PHAEOZEMS

Soils having a mollic A horizon; lacking a calcic horizon, a gypsic horizon and concentrations of soft powdery lime within 125 cm of the surface; lacking a natric and an oxic horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties within 50 cm of the surface when no argillic B horizon is present; lacking bleached coatings on structural ped surfaces when the mollic A horizon has a moist chroma of 2 or less to a depth of at least 15 cm.

GREYZEMS

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm an showing bleached coatings on structural ped surfaces, lacking a natric and oxic B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity.

CAMBISOLS

Soils having a cambic B horizon and (unless buried by more than 50 cm or more new material) no diagnostic horizons other than an ochric or an umbric A horizon, a calcic or a gypsic horizon; the cambic B horizon may be lacking when an umbric

A horizon is present which is thicker than 25 cm; lacking high salinity; lacking the characteristics diagnostic for Vertisols or Andosols; lacking an aridic moisture regime; lacking hydromorphic properties within 50 cm of the surface.

LUVISOLS

Soils having an argillic horizon which has a base saturation of 50 percent or more (by NH_4OAc) at least in the lower part of the B horizon within 125 cm of the surface; lacking a mollic A horizon; lacking the albic E horizon overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitosols and Podzoluvisols respectively; lacking an aridic moisture regime.

PODZOLS

Podzols having a spodic B horizon which in all subhorizons has a ratio of percentage of free iron to percentage of carbon of less than 6, but which contains sufficient free iron to turn redder on ignition; having one or both of the following: an albic E horizon that is thicker than 2 cm and is continuous, and a distinct separation within the spodic B horizon of a subhorizon which is visibly more enriched with organic carbon; lacking a thin iron pan in or over the spodic B horizon; lacking hydromorphic properties within 50 cm of the surface.

PLANOSOLS

Soils having an albic E horizon overlying a slowly permeable horizon within 125 cm of the surface (for example, an argillic or natric B horizon showing an abrupt textural change, a heavy clay, a fragipan), exclusive of a spodic B horizon; showing hydromorphic properties at least in a part of the E horizon.

ACRISOLS

Soils having an argillic B horizon with a base saturation of less than 50 percent (by NH_4OAc) at least in the lower part of the B horizon within 125 cm of the surface; lacking a mollic A horizon; lacking an albic E horizon overlying a slowly permeable horizon; the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitosols and Podzoluvisols respectively; lacking an aridic moisture regime.

NITOSOLS

Soils having an argillic B horizon with a clay distribution where the percentage or clay does not decrease from its maximum amount by as much as 20 percent within 150 cm of the surface; lacking a mollic A horizon; lacking an albic E horizon; lacking the tonguing which is diagnostic for the Podzoluvisols; lacking ferric and vertic properties; lacking plinthite within 125 cm of the surface; lacking an aridic moisture regime.

FERRALSOLS

Ferralsols having an oxic B horizon that is neither red to dusky red nor yellow to pale yellow; lacking an umbric A horizon and lacking a high organic matter content in the B horizon when the base saturation is less than 50 percent (by NH_4OAc) in at least a part of the B horizon within 100 cm of the surface; having a cation exchange capacity (from NH_4Cl) of more than 1.5 me per 100 g of clay throughout the oxic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

HISTOSOLS

Soils having an H horizon of 40 cm or more (60 cm or more if the organic material consists mainly of sphagnum or moss or has a bulk density of less than 0,1) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil; the thickness of the H horizon may be less when it rests on rocks or on fragmental material of which the interstices are filled with organic matter.

Table II.2.

Approximate correlation between the FAO legend and the U.S. Soil Taxonomy with special reference for the tropics (Aubert and Tavernier, 1972)

FAO Legend	U.S. Soil Taxonomy
Fluvisols	Fluvents
Regosols	Psamments
Arenosols	
Ferralic	Oxic Quartzipsamments
Gleysols	
Eutric and Dystric	Tropaquepts
Humic	Humaquepts
Plinthic	Plinthaquepts
Andosols	Andepts
Planosols	Paleudalfs and Paleustalfs
Cambisols	
Dystric	Dystropepts
Eutric	Eutropepts
Humic	Humitropepts
Luvisols	Alfisols
Acrisols	Ultisols
Ferralsols	Oxisols
Lithosols	Lithic subgroups

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3. Site characteristics

3.1. Land and soil inventory and assessment

Taxonomic soil classifications are related to soil properties. Interpretation of such properties in terms of land-use suitability requires consideration of other environmental factors (including climate, topography, parent rock, etc.), with particular reference to hazards of irreversible degradation. This subject is dealt with in the FAO Bulletin Framework for Land Evaluation, which outlines the basic guidelines for the application of these principles to a wide range of situations, which can be grouped broadly as rainfed agriculture, irrigated agriculture, forestry and ranching.

In the context of a national soil policy, soil capability classification can be useful in interpreting technical soils data and in making available advice on the appropriate use of particular soils to policy-makers. This interpretation should recognize that some soil properties can be manipulated more easily than others, and also that some soil properties are inherent while others are the result of current land use.

Land productivity evaluation is broader than soil capability classification, since land productivity evaluation considers not only the soil but other attributes and qualities of the land, including agroclimatic, social and economic factors.

Soil survey, land evaluation and land classification are a key element in identifying land development projects. Appropriate planning and execution of development projects is necessary to minimise the risk of project failure and/or damage to the environment. Efforts should be made to ensure that the basic elements of planning are carried out before any development project is implemented. It is now widely recognised that many projects for land development and even land rehabilitation have not only failed to yield the desired results, but have often resulted in damage to the soil/land resource.

Attempts to transfer technology without due consideration on soil and other environmental factors may be hazardous. Therefore we have to aim at tested conservation practices for defined soil and climatic environments and farming systems.

3.2. Content, tasks and significance of site science

The site of a plant combines the entirety of factors and processes outside this plant which make its existence possible or which permanently influence it (Vater,1925). The interaction of the site factors "climate" and "soil" is of special importance for the plant growth. Forest sites are locations with properties which promote the forest growth.

Site science is an applied natural-scientific discipline. It is based on geosciences (geology and soil science, meteorol - ogy and climatology) and biosciences (plant physiology, vegetation science). In its modern form it deals with the environment of forest plants, comprising the correlation between the different site factors and the mutual relations between sites and their communities of organisms.

Sukatchev (1951) describes the mutual relations between site and the community of organisms as "biogeocenosis", and Ellenberg (1973) calls it "ecosystem". Both terms go beyond Vater's traditional definition of the site. Hence, the ecosystem is understood, with respect to its structure, as a three-dimensional section of the biosphere with a clearly defined space of soil, air and water, which is inhabited by characteristic organisms. Functionally, the ecosystem constitutes a system of mutual relations between the environment and biological communities. Any interference into the mutual relations has, on principle, impacts on the whole system. Therefore ecology deals with the structure and functions of ecosystems under natural conditions or conditions that have been changed by man.

3.3. Concept of natural site

The growth of plants depends on the site factors climate and soil and the biological genotype. The harmonious interaction of the site factors is indispensable if the living conditions needed by each plant species are to be guaranteed.

The conditions caused by these factors for the production of organic substance by vegetation may vary between a minimum and a maximum. If the minimum prevails, one of the site factors is too weak, and if the maximum prevails, it is too strong. An optimal development of a plant is guaranteed when all site factors become effective within their optimal range. If it is not optimal the fertility of the site will be limited by the most unfavourable factor.

Before man entered the scene in Central Europe the land surface had (with the exception of so-called "open spaces") been covered with forests. The composition of these virgin forests differed in various places. Only those tree species and soil plants were able to settle and survive on the individual sites which adapted themselves to the respective site conditions in the best possible manner and succeeded in forming a stable symbiosis with their neighbours. Consequently, any natural site is characterized by a certain plant association (or forest association) which is optimally adapted to its abiotic status.

In these natural plant associations the complex interaction of site factors has found its adequate expression. In landscapes where man has not yet interfered, plant-geographical and site-geographical boundaries and areal units coincide. Hence, a cartographic description of the natural site units could most quickly and exactly be given by determining the natural plant associations, by classifying them and then by mapping the areas where they occur.

Such an approach is, however, rarely possible because man has largely restrained original or natural plant associations. Their place has been taken by secondary forests where the economically less valuable pioneer species are prevailing, and by man made forests. The man made forests consist of arbitrarily selected plant species (monocultures) which often do not correspond to the natural site. These man made forests do no longer reflect the natural site differences; therefore, they are unsuitable for the pure vegetation-scientific, indirect evaluation of sites. In spite of this fact, the correlation between individual site factors and the occurrence of certain plant species remains so close that the plant species can serve as indicators for the impact of certain climatic factors (e. g. light, heat, continentality) and edaphic factors (e. g. soil fertility, pH value, N status).

As regards the soil conditions, the physiological amplitude of most higher plant species is relatively large. Under natural conditions, the edaphic competitive effect of other plant species, however, strongly limits the distribution area of the different plant species. Thus for instance, many "acidity indicators", are found mainly on acidic soils, but in small number they can also survive on soils belonging to the neutral range. If the forest site investigator cannot evaluate the site indirectly (floristically), he has to describe directly the individual site factors, a task which is much more complicated.

As regards their effect on plant life, the site factors stemming from the atmosphere (e. g. radiation, heat, precipitation, air motion) are classed under the site factor complex "climate", the factors stemming from the litho- and pedosphere (e. g. mineral composition, granulation, nutrients) under the site factor complex "soil". The effect of the complexes of climate and soil is modified by the position. That is why the position is referred to as the third site factor complex after climate and soil. The indication of the "position" allows conclusions to be drawn about certain properties of soil and climate.

Between the individual site features exists a relation system. It is the dominant task in the field of soil and site protection to preserve this relation system in a harmonious balance.

Definitions:

Site

An area considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can carry. Sites are classified either qualitatively, by their climate, soil and vegetation, into site types, or quantitatively (e. g. in forestry) by their potential wood production, into site classes.

Site class

A measure of the relative productive capacity of a site for the crop or stand under study, based e. g. on volume or height (dominant, co-dominant or mean) or the maximum mean annual increment that is attained or attainable at a given age.

Site index

A particular measure of site class, based on the height of a defined number of dominant trees per ha in a stand at an arbitrarily chosen age (normally age of harvest).

Site map

A map showing the distribution of site classes through out an area.

3.4. Site survey

A site survey involves the systematic examination, description, classification, and mapping of soils in an area. The scale of mapping must be decided before a survey can proceed. The most commonly used scale at which sites (soils, landforms) are mapped in the field is 1 : 5 000 to 1 : 10,000. For general planning, small scales of 1 : 250,000 are usually sufficient. A survey is an inventory of site informations and its use depends basically on two features. The first is the nature of the data in the inventory. The second feature is a knowledge of relationships between sets of site information and between site information and plant growth. A site survey must provide objectively determined quantitative and qualitative information about sites and their distributions in a given area. The type and amount of data and the scale at which the information is available are important factors when use is to be made of a site survey. It may provide certain interpretative information in relation to various uses, for instance interferences may be drawn about certain aspects of soil fertility in relation to a particular plant species and cultural treatments such as fertilization.

One of the common interpretations is that for capability. Capability classes have been established primarily on the basis of limitations that a site (soil) may have for agricultural use. Each capability class may contain sites (soils) of quite different kinds, and management practices and treatments may be quite dissimilar. Class I lands are those with sites (soils) that have no significant limitations for agricultural use. They are productive soils, level or with only gentle slopes, relatively free from erosion hazards. Limitations and erosion hazards increase with rising capability class number. Classes with higher numbers are unsuitable for agriculture, but may be suitable for forestry, limited grazing or wildlife purposes.

The interpretations of sites information vary considerably from region to region and the types of correlations which are established and function well in one area may not be useful in another. In some countries mathematical relations were developed for the estimation of site index values in relation to soil and climatic data.

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4. Soil fertility

The term soil fertility means capacity of a soil for plant production. Furthermore, the plant yield depends upon location, climate, vegetation, ecosystem management and time. When considering all these factors in their effect on plant growth we speak of site productivity.

Soil fertility is conditioned by a complex of physical, mineralogical, chemical, and biological soil properties. Consequently, besides the supply of nutrients, water, and oxygen to the plant essential features of soil fertility are likewise transformation and storage of these elements. The supply of plants with nutrients, which originate from natural soil or are fed to it by fertilization, is regarded the main point of soil fertility. For this reason the agricultural and ameliorative measures, which are designed to induce soil fertility, concentrate upon the promotion of these properties.

In developing countries the interest concentrates on suitable techniques for the evaluation of soil fertility.

4.1. Soil conservation

While it is recognized that erosion is the major cause of soil degradation and loss of land resources, sufficient work to meet the challenges posed by this problem is not being done globally to characterize the soils with respect to their sensitivity to erosion, to characterize the climate with respect to its erosive power and to identify the conservation aspects or otherwise of various tillage practices and land uses. Further, in the absence of such information in tropical and sub-tropical areas, the on-going soil conservation development programmes tend to be designed on an empirical or ad hoc basis, often with results far from those which were hoped for.

Specific studies on characterizing the erodibility of soils, erosivity of rainfall and beneficial or harmful effects of various land management practices and vegetation covers are required to establish guidelines for soil conservation practices for various environments.

Through UNEP/FAO project FP 1106-75-05, Phase I, a provisional methodology for assessing soil degradation criteria has been developed.

While much research has been conducted on means for estimating erodibility of soil and the erosiveness of wind and water, relatively little attention has been directed to the quantitative prediction of the impact of erosion on the productivity of soils. Yet, soils differ greatly in this respect. A given amount of erosion may have little impact on the productivity in one soil and may completely destroy the productive capacity of another soil. Such knowledge is urgently needed to assess the impact of erosion and to designate areas in which scarce resources for erosion control should be concentrated. Some information on this topic is included in the FAO/UNEP report on "Global Assessment of Soil Degradation".

Fragile ecosystems (for example, humid and semi-arid tropical lowlands, steeplands, irrigation areas, unstable sandy areas) require special attention in relation to the introduction of farming systems that combine productivity with safeguarding of environmental quality. Research on appropriate farming systems and land utilization types has been carried out by various national and international institutions and organizations (e. g. the CGIAR farming systems programme, UNESCO's MAP programme agroforestry research, etc.), and the results of this research should be applied where possible.

4.2. Soil fertility evaluation

Soil fertility evaluation is the process by which nutritional problems are diagnosed and fertilizer recommendations made. A soil fertility evaluating program involves the following parts: Sampling (soil and plant), laboratory analyses (soil and plant), correlation between analysis and yield response, interpretation and recommendations, putting informations to use, research.

4.2.1. Fertility evaluation based on soil analysis

Taking a representative soil sample is the first step. It is composed of at least 10 to 20 subsamples from the rooting zone of a site. In the case of deep-rooted crops additional subsoil samples should be taken. For average management intensity sampling once every 5 years is recommended. The samples are sent to a soil-testing laboratory. There, the available forms of nutrients (P, K, Mg, Ca, Cu, Fe, Mn, Zn) in soils are extracted by different methods (e. g. the "modified Olsen method"). The lime requirements of acid soils are determined by measuring pH and exchangeable aluminium extracted by 1 N KCl. Electrical conductivity on a saturated soil paste is the best method for salinity determinations.

Soil test values become useful only when they are correlated with crop responses. The "critical level", which is specific to certain soils-crop situations, seperates soils with high probabilities of fertilizer response from soils with low probabilities. Plant growth and yields are dependent on many variables (soil, crop, climate, management) beyond the single nutrient under determination. Fertilizer recommendations are obtained only through field trials. Trials should be run in soils testing below the critical value. The purpose of soil test interpretation is to establish how much of each nutrient must be applied to bring about a given yield response within a predictable crop soil category. The most commonly used functions are the quadratic $y = b_0 + b_1x + b_2x^2$ and Mitscherlich $y = A\ (1 - e^{cx})$ with y = relative yield, A = maximal yield and x = soil factor, e. g. nutrient content. If more than one element is deficient, multifarious regression models must be used. The interactions between these elements have also to be clarified.

4.2.2. Fertility evaluation based on plant analysis

Plant analysis is used in very intensively managed agricultural areas with effective soil-testing systems as an additional method. In this case the analyses have to be performed rapidly. However, plant analysis is used mainly for permanent crops (e. g. tea plantations, forests) where soil tests are less meaningful because of the high proportion of roots in the subsoil. Plant analysis integrates the effects of the soil, plant, climate and management variables. It is used to identify nutritional problems and quantify their correction through the establishment of "critical levels", to compute nutrient uptake values as a key for fertilizer use and to monitor the nutrition of permanent crops. Samples have to be taken from the same anatomical part and at the same growth stage of the plant. Above the critical level the plant is sufficiently supplied with the nutrient in question (e. g. N, P, K, Mg). A second critical level is needed, if nutrients occur in excessive amounts that cause yield decreases. The critical levels obtained in plant analysis are less site-specific than those obtained from soil tests. Crop logging gives good measure of crop growth and increases the efficiency of fertilizers and irrigation. In the case of extreme nutrient deficiency, plants show visual deficiency symptoms.

4.2.3. Fertility evaluation based on missing element techniques

In this case nutrient deficiencies are identified by growing indicator plants (e. g. cereal plants) in the greenhouse or in the field on a soil to which a "complete" fertilization (e. g. NPK Ca Mg) is applied, and a series of treatments in which one element is not added. Pot experiments with the missing element technique give informations about elements, which are deficient and about the relative importance of the deficiencies. Missing element techniques are used in many tropical countries. The amount of work and time involved limits their use for routine purposes.

4.3. Soil fertility and soil classification

Fertilizer recommendations are site-specific. Therefore a soil fertility evaluation programme should be closely related to a soil survey and classification programme. However, the immediate goals of soil classification and soil fertility groups are different. Soil classification systems (e. g. the US-System) stress subsoil features as major diagnostic criteria. Soil fertility evaluation in agriculture is mostly interested in the plowed layer. Thus the two groups really see two different soils while examining the same pedon. Soil surveyors attempt to provide information that will serve the needs of all potential land users over several decades, while the soil fertility specialist attempts to evaluate the fertility needs of a given crop for one or at most a few years, after which he will then reevaluate the soil. Efforts must be increased to bring soil and site survey data into soil fertility evaluation projects (an example is given for forest sites in Central Europe). The development of such systems for grouping soils with similar fertility limitations will improve the effectiveness of soil fertility evaluation programmes.

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