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TOWARDS A GLOBAL SOIL RESOURCES INVENTORY AT SCALE 1 : 1 MILLION

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INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

Towards a global soil resources inventory at scale 1:1 million

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(first draft of a discussion paper)

1. Aim

To produce a digitized soil (or physical land resources) map at accuracy 1:1 million, in first instance of Latin America, Africa, the Middle East and Asia, serving as an international soil geographic information system as well as a soil data base management system for regular updating; preferably to be synchronized with similar-level information bases on other natural resources like (agro)climates, vegetation/land use, surface hydrology, in a global resources information data base.

2. Background

The only available document on the geography of the world's soil resources is the FAO/Unesco/ISSS Soil Map of the World at scale 1:5 million (1 cm^2 on the map representing 250.000 ha.), as prepared by conventional cartographic means (though recently digitized). It was the result of a major international action programme and it succeeded to aggregate all soils information as available about 15-20 years ago. In the meantime - and often stimulated by the FAO/Unesco effort - many countries in all continents have embarked upon systematic soil resources mapping at national scale, combining new ground truth with remote sensing imagery of several kinds, resulting in maps often at scale 1:500,000 to 1:1 million. These national soil geographical data sets give not only much more detail, but in a number of cases also modify earlier estimates as occurring on the 1:5 m. FAO/Unesco map (the Amazon region being a case in point). The national soil maps are however being produced with different level of ground truth, in different languages, with different legend structures, and with different systems of soil classification and land capability evaluation.

The same applies to recent efforts to produce regional soil resources maps at such or smaller scales (e.g. CIAT for tropical South America; ACSAD for the Arab Countries; EEG for Western Europe; FAO for West Africa; etc.). In order to take full advantage of the various efforts and to stimulate international cooperation, there is an urgent need to collate and correlate these national and regional geographical soil data bases, and to bring them under a common denominator that can serve as a legend for a new and more precise soil map of the world. Only in this way it will be possible to use this information on the world's soil geography for a number of applications (see 4).

3. Approach

The geographic density of the new soils information now becoming available at national level; the availability of satellite imagery of ever larger resolution and frequency; and the advance of new, computer-aided cartographic techniques, make a global soil mapping effort at substantially larger scale than before a feasible proposition. A 1:1 million level (1 cm^2 on representing 10,000 ha.) would normally imply about 350 printed sheets for Latin America, Africa and (sub)tropical Asia, at astronomic costs. Initial costs of digitized mapping may be relatively high, too, especially as regards base map preparation. One can however produce computer-printed sheets on demand only. Moreover, once all data has been duly processed and fed into the computer system, a continuous or periodic updating by incorporation of new national mapping data is far cheaper than updating by conventional cartographic printing techniques. Using interactive graphical systems of digitized mapping also opens the prospect of combining information on other elements of the physical environment in one geographic information system - available to all scientists, all countries and all international institutions/organizations concerned with natural resources and their use.

4. Use

A digitized map at accuracy 1:1 million of the soil resources of the world, and of the developing countries in particular, will serve a number of purposes, especially when accompanied by a soil data base management system:

- It will provide the necessary land resource data for international agricultural research centres of the CGIAR system at their efforts to extrapolate their research findings on site-dependent agricultural production factors to areas of similar physical land conditions. Factual information on the geography, the characteristics and the properties of the soils and other physical land parameters like agro-climate will also allow these centres to better formulate guidelines for complementing their basically crop-oriented research programmes to soil-related constraints, especially in marginal land zones (areas of acid red and yellow tropical soils, tropical wetland soils, tropical black clays, semi-arid zone soils; shallow mountain soils, etc.). Networks that are to study soil-related constraints specifically, will need to avail of as precise data as possible on geography of such soils, and their average and variation in characteristics and properties.

- It will also allow a more precise estimate to be made of the agricultural production potential at different levels of input and management - and thereby the future population carrying capacity per country and per state/province. This, in turn, would provide guidelines for (re)orientation of bilateral and international Food Programmes, especially those that are directed to increasing the food, fuel and fodder production as a longer-term means to prevent chronic hunger situations in developing countries.

  In combination with a climatic and surface hydrological data base at the same level it will for instance allow the assessment of irrigation potential per country and state/province, and hence the direction of funds for its development in relation to expected population growth.

  These country-level estimates and assessments could also be made on the basis of a national map, but then one has to study time and again the particulars of each different national approach to resources mapping.

- It will provide the soils part of an integrated updatable global resources information base, as required for a monitoring of the earth's life supporting systems, signalling trends in land transformation/degradation, and providing clues for sustainable use of the land resources, while safeguarding essential nature reserves and particularly fragile ecosystems.

- It will allow a better insight to be obtained on the geography of the different physical, biological and socio-economic elements of the land, and thereby provide guidelines for more basic multi- and interdisciplinary scientific research on their interactions (biomass production; biological processes and nutrient cycling per major resource-geographic region; global Carbon cycling; climatic changes, etc.). Detailed studies on sites chosen carefully in relation to the soil-geographic pattern will then permit more quantified and reliable spatial assessments of rates of soil formation and forms of degradation.

5. Materials and Expertise

The hardware and software system(s) to be chosen should be factory-type independent, and compatibility with simple systems in individual countries should receive major attention.

The hardware for a computer-aided 1:1 m. soil resources should consist of a centrally located main computer of at least 2 megabites, with a number of subsystems in a network configuration (located at major cooperating international institutions and/or main geographic regions). The connection can be on-line, which is very expensive, or by magnetic tapes or floppy disk transmittal.

At the output side of the central processing unit (and of the terminals?) a number of specialistic supporting devices will be necessary, e.g. a tabular data output system (screen + printer of standard alphanumeric terminal facilities), and a cartographic data output with a plotter.

At the intake side a powerful interactive graphics system with a layer structure will be required. It should preferably contain a high-resolution scanning device for half-toning. There are basically two possibilities for an interactive graphics system: a raster-based system and a polygon vector based system. The vector-based one would probably facilitate links with national Geographical Information Systems in developing countries, and is relatively simple to operate if only one set of geographical data, like soils, is to be dealt with. If however several thematic sets are involved, that in the end need to be combined for interpretative purposes, then the merging of different thematic lines is cumbersome. The latter is easier with a raster-based system, which can also accommodate remote sensing data without transfer gadgetry. The raster technology is however expected to be further developed in the forthcoming 10-20 years, especially as regards denseness of the grid, hence presentday equipment may soon become outmoded. Tape transfer from one system to the other is possible in principle, but in practice there are many problems. Therefore an early decision on the type may be required.

The total costs of hardware and auxiliary apparatus will be in the order of US$ 1.0 million or more, depending on the number of input and output subsystems and the mode of transmittal. One possibility is to avail of the services of the equipment that is to be acquired by UNEP-GEMS for development of its Global Resources Information Base (GRID). It is understood that such an equipment has been offered to UNEP by NASA, but that the actual siting is still under discussion (UK, Geneve, Nairobi or elsewhere). This equipment will be reportedly "open for anybody to use". If the centre for soil data collating and software development is not at the same site as this GRID computer, then at least one on-line connection will be required.

It is also understood that the management expertise for the GRID system, which normally would require $ 1.5 m. or so, is being offered by several European and American donor countries.

The software development for computer-aided 1:1 m. soil resources mapping is composed of two elements. A cartographic base map will have to be prepared and digitized, in such detail as required for adequate orientation at 1:1 m. thematic sheet output. There is no ready-made convential cartographic base-map at that scale with complete global coverage (an International/UN series of 1:1 m. topomapping was started already in 1910, but covers only 60-70% of the world's land surface, at different quality). Therefore both the projection and the detail have to be prepared specifically, by matching between existing 1:2.5 m. and 1:0.5 m. maps. The mode of this matching, and the decision on the minimum and maximum detail at digitizing itself, best be decided by cartographic specialists that are in regular contact with representatives of different thematic disciplines.

This can for instance be the existing joint Working Group on environmental atlasses and maps of the International Geographical Union (IGU) and the International Cartographic Association (ICA); and/or a working group of ICSU's CODATA Commission.

A digitized base map for all developing countries at accuracy 1:1 m. will imply about 350 sheets, and the costs of preparation will be about $ 1.0 m.. It may be carried out at one or more well-equipped Geographical institutes, like the German Institute for Applied Geo-Sciences (IFG, Frankfurt), the Institut Geographique Nationale (IGN, Paris), the Ordnance Survey (UK), the International Training Centre for Aerial Survey and Earth Sciences (ITC, Enschede), The Canadian Surveys and Mapping Branch (Ottawa), the Mapping Division of the US Geological Survey, the National Atlas & Thematic Mapping Organisation of India, etc.

For the soils part of the software development, advise can be obtained by the standing Working Group on Soil Information Systems of the International Society of Soil Science (ISSS). Guidance on the collection, quality control, and the collation into a suitable legend of the soils ground truth can be given by ISSS Commission V (which deals with soil genesis, classification and cartography).

ISSS, with its 7000 individual members (about 2000 of them Commission V adherents) in all countries of the world, and its 60 affiliated national soil science societies, is in fact in a unique position to obtain the effective cooperation of soil cartographic institutes and individuals everywhere.

Major collections of small-scale soil maps and related thematic maps are already present at FAO in Rome (the former World Soil Resources Office), and at the International Soil Reference and Information Centre (ISRIC) in Wageningen. Sizeable collections, often with regional emphasis, exist at CIAT (Cali-Colombia), the Bureau Interafricain des Sols (BIS, Bangui-Central African Republic), The Asian Institute of Technology (AIT, Bangkok), at ORSTOM (Paris), the Land Resources Division (LRD, London), the World Soil Geography Office of the USDA (Lanham, USA), etc..

To organize the soils input the functioning of a multilingual group of (tropical) soil-cartography specialists will be required. These can be drawn, or seconded from a number of major national soil cartographic institutes with experience in small-scale mapping of (tropical) soils and its machine processing. As a first estimate 6 specialists over a period of 5 years may do the job. Together with active soil map data gathering in countries of difficult contact, and the organizing of several regional workshops, the total costs will be in the order of $ 1.0-1.5 million.

Because the members of this group will have to work very closely together, they should be stationed together at one place during the project period, e.g. at one of the major soil map collection centres (see above), with easy access to the central computer outfit.

One may want to start, also for testing purposes, with one or more subregions where the need for organising an over-all soil geographic data base is felt most urgently, e.g. Southern Africa (through SADCC?), Western Africa (through FAO?), South-East Asia (through ASEAN?), the Amazon region (through REDINAA?) or Western Europe (through EEC?).

On the basis of such pilot processing, also methods can be tested for combining the geographic information with non-graphic data (e.g. the results of agrotechnological experiments) leading to the production of single-purpose interpretative maps.

6. Structure of the soil data base

It is suggested not to use soil classification proper as major entry of the map legend that will have to be developed. This not only because as yet there is not one such a system that is universally accepted, but also because it may obscure other useful information on the physical aspects of the land units, and thereby reduce interchangeability with other thematic mapping efforts that would use the same computer outfit (whether or not with the same 1:1 m. accuracy). Priority to soil classification aspects would also imply a less than maximum use of information that can be extracted from remote sensing imagery (satellites, radar).

The first entry (main headings) of the legend preferably be on landforms (the physiography); the second level on (soil parent) materials (surface lithology), and only the third one on soils information proper. The latter best be done by a system of coding of diagnostic surface and subsoil characteristics and features - on which there is already a large degree of agreement the world over. The combinations of these coded diagnostics, with texture, slope and drainage classes as additional characteristics, can then be "translated" optionally into any particular soil classification system by the user of the computer print-outs.

Much attention should be given to the quantification of the composition of mapping units (associations, complexes, or inclusions of soils), through a system of major and referral coding. A separate file of extended legend information can contain the properties of each coded unit in relation to plantgrowth, to engineering use, to hazard of degradation, etc.. For interpretative purposes these properties should be as estimates within a limited number of classes, rather than as actual figures of field- and laboratory analysis (though representative example pedons should be available for consultation in a computerized "pedon file").

Major altitudinal zoning, overhead (eco)climatic conditions and flooding conditions, which usually have less detailed patterns than that of the landforms and soils proper, can be fed into the computer as an overlay (in consultation with climatologists and hydrologists; c.f. the agroclimatic zonification approach of FAO at 1:5 m. world level and at 1:1 m for some countries; the moisture and temperature regimes as calculated with the Newhall method of Cornell University).

A number of examples at national level exist as to the approach sketched above. They are the 1:1 m. Canadian land resources mapping; the Northcote approach of the CSIRO Division of Soils in Australia; the life system zoning of Holdridge as in use in Central America; the "cartes morpho-pédologiques" of the Institut de Recherches Agronomiques Tropicales (IRAT) in France, using the geomorphology-lithology concepts of Tricart; the physiographic soil mapping of the Kenya Soil Survey, etc.. Also the legend of the USDA World Soil Geography Office at Lanham uses the sequence landform-materials-soils.

7. Organisational aspects and Funding

In view of the likely use of the digitized 1:1 m. map as outlined in section 4, it may be expected that major institutional and bilateral donors as already cooperating in the CGIAR system will be found prepared to provide the necessary funding ($ 2.0-3.0 m., assuming that the hardware and its management is not costed). Also institutes like the World Resources Institute in Washington, the International Institute for Applied System Analysis (IIASA) in Vienna, and the International Institute for Environment and Development (IIED) in London, may be prepared to participate in the funding.

A logical umbrella for receiving and administering such funds would be the recently created International Board for Soil Research and Management (IBSRAM), which already receives funds for its networking activities from some of the donors of the CG group. This board may want to carry out the programme under its own direction, or to delegate it to a UN organization like FAO, an international soil resource information centre like ISRIC, a major national soil cartography institute, or a consortium of these.

An alternative is to tie the project to the International Geosphere-Biosphere Programme (IGBP) as proposed by the International Council of Scientific Unions (ICSU) at its recent "Global Change" symposium in Ottawa, September '84.