Completion of a 1:5 Million Soil and Terrain Digital Database (SOTER) for Latin America and the Caribbean

(SOTERLAC)

1993 - 1997

Terminal Report

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1/ Preface

The United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO) and the International Soil Reference and Information Centre (ISRIC) have recognized the need for updating the existing soil and terrain information that is currently available at a global scale (FAO-Unesco Soil Map of the World). As a first step the Latin American continent was to be revised. In 1993 a Letter of Agreement was concluded between UNEP and FAO for the compilation of a soil and terrain database for Latin America, to which UNEP contributed US$ 100,000. This agreement can be seen as a follow-up of a recommendation of the Ad Hoc Expert Group meeting that discussed the Global Soil and Terrain Database (SOTER), (UNEP, Nairobi, 1992). At this meeting FAO expressed its full support for the SOTER programme. The objective of this Letter of Agreement between FAO and UNEP was to contribute to the development of a regional soil and terrain database for Latin America.

Late 1993, FAO and ISRIC concluded a Letter of Agreement (CMT 71178), which had as immediate objective to prepare an updated Soil and Terrain Database for a number of countries in Latin America (Argentina, Brazil, Cuba, Mexico, Uruguay and Venezuela) by June 1994, with the long-term objective to expand this product to the whole of Latin America.

The purpose of a subsequent Letter of Agreement (CMT 76299) between FAO and ISRIC, signed early 1994, was to prepare and edit material related to the preparation of a Soil and Terrain Database for Latin America. As the material provided in the first Letter of Agreement mainly consisted of raw digital soil and terrain databases, linked often to paper map information, the editing of this material should be considered to include the harmonization of data from six different data sources in uniform format. A final report on these activities was published in 1995 (van Engelen and Peters).

The next step was to cover the remaining part of the continent. A UNEP funded project of US$ 60,000 was formulated for Central America and the Caribbean, while additional financing for the not yet covered territory of South America was obtained from FAO (US$ 60,000) and from the International Potato Centre (CIP) in Lima, Peru (US$ 23,500). The UNEP project document was signed in August 1995. An additional US$ 10,000 was contributed by UNEP-GRID Arendal in December 1996. Two reports have been made that describe these separately funded activities, one for the UNEP and one for the CIP contribution. No separate report has been made for the FAO contribution.

This terminal report will review the activities undertaken by the project over the entire period (1993-1997) to achieve its goal. It will therefore repeat statements already formulated in earlier partial progress and terminal reports for the sake of completeness. The report describes to which extent the project activities were instrumental in realizing the outputs as listed in the project documents and Letters of Agreement. Conclusions drawn about the management of the project and principal factors, which determined success or failure in meeting the objectives of the project are given.

2/ Introduction

The major source of geo-referenced soil data of Latin America and the Caribbean at a scale of 1:5 M is the Soil Map of the World (SMW) of FAO/Unesco (1974-1981). For this part of the globe the information was collected before 1974, the year of publication of the Latin American map sheets. Collection of soil survey information by the national institutes responsible for soil survey continued after publication and a large amount of new data is available at the national level.

Since 1991 the FAO is actualizing the SMW information of Latin America with support from national soils institutes in the concerned countries. This has resulted in the acquisition of new 1:5 M soil maps of most Latin American countries. New soil maps with a revised soil classification legend (FAO, 1990) of Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela were obtained by FAO through subcontracts with the national soil institutes.

Since 1988 the World Soils and Terrain Database Programme (SOTER) is operational in various Latin American countries at a scale of 1:1 M, in particular in Argentina, Brazil and Uruguay with UNEP funding. The major objective of the SOTER methodology is to use information technology, like geographic information systems and database management systems, for the creation of a world soils and terrain database with digital maps and attributes and their interpretations. At the moment SOTER databases at scale 1:1 M are available for the whole of Uruguay, the northern part of Argentina (460,000 km^2) and the south of Brazil (100,000 km^2).

In 1992 FAO formally endorsed SOTER and decided to use the methodology to store and update soils and terrain data at a global level. The SOTER Procedures Manual was published jointly by FAO, ISRIC, ISSS and UNEP in 1993 and in the following year also as No. 74 in the series of World Soil Resources Bulletins. During the same year an agreement was signed between FAO and UNEP to develop a soils and terrain database of Latin America at scale 1:5 M, jointly with the updating of the SMW. ISRIC was asked to coordinate the activities of the SOTERLAC 1:5 M project in the countries to be included.

ISRIC concluded an external collaboration contract with Prof. W.L. Peters, residing at the Universidad del Zulia, Maracaibo, Venezuela, already involved since 1988 with the Latin American SOTER activities, to establish contacts with the national institutes and to coordinate and execute activities in the framework of SOTERLAC. Letters of Agreement were signed with Argentina, Brazil, Cuba, Mexico, Uruguay and Venezuela. The first preliminary results were displayed at the XVth World Soil Science Congress in Acapulco, Mexico in July 1994.

The SOTER methodology and the objectives of the SOTERLAC 1:5 M project were explained during a workshop, organized jointly with a training course in the framework of the SOTER 1:1 M activities in Argentina and Uruguay, in Buenos Aires in April 1994 in which representatives of Argentina, Brazil, Colombia, Cuba, Ecuador, Mexico, Paraguay, Peru and Uruguay participated.

The first six countries involved in SOTERLAC collected the data (Argentina, Brazil (30%), Cuba, Mexico, Uruguay and Venezuela) and the other S-American countries participating in the workshop expressed their interest to participate in the project pending necessary external funding (ISSS, 1994).

After a period of stagnation, new funding became available through regional funds of UNEP for Central America and the Caribbean during 1995. At the same time, CIP indicated ISRIC its interest in SOTER information for their mandate area in the Andes Mountains in relation to the CGIAR Global Mountain Initiative. It made a financial contribution to SOTERLAC. The remaining part of the continent was covered by an FAO contribution in late 1994 and late 1996. ISRIC observed difficulties in applying the SOTER methodology in countries where no formal training had been given. Moreover, major discrepancies between the mapping units in the border areas of countries existed.

A listing of participating institutes is given in the box below.

Contributing institutes to SOTERLAC

Argentina: Instituto Nacional de Technologia Agropecuaria-Centro de Investigaciones de Recursos Naturales-Instituto de Suelos
Bolivia: Proyecto Zonificación Agro-ecológia y Establecimiento de una Base de Datos y Red de Sistema de Información Geográfica en Bolivia
Brazil: Empresa Brasileira de Pesquisa Agropecuária-Centro Nacional de Pesquisa de Solos
Chile: Universidad de Chile-Faculdad de Ciencias Agrarias y Forestales-Departamento de Ingenieria y Suelos
Central America: Centro Internacional de Agricultura Tropical, ISRIC
Colombia: Instituto Geográfico Augustin Codazzi
Cuba: Instituto Nacional de Investigaciones de la Caña de Azucar
Ecuador: Centro Panamericano de Estudios e Investigaciones Geográficas
Mexico: Colegio de Postgraduados-Centro de Edofología
Paraguay: FAO, Instituto Nacional de Technologia Agropecuaria-Centro de Investigaciones de Recursos Naturales-Instituto de Suelos
Peru: Instituto Nacional de Recursos Naturales
Trinidad and Tobago: Ministry of Agriculture-Soil and Land Capability Unit-Central Experiment Station
Uruguay: Dirección de Suelos y Aguas
Venezuela: Ministerio del Ambiente y de los Recursos Naturales Renovables
Other countries: FAO and ISRIC

3/ Methodology

SOTER uses the concept that land (in which terrain and soils occur) incorporates processes and systems of interrelations between physical, biological and social phenomena evolving through time. This idea was developed initially in Russia and Germany (landscape science) and became gradually accepted throughout the world. SOTER has continued this development by viewing land as being made up of natural entities consisting of combinations of terrain and soil individuals (van Engelen and Wen, 1995).

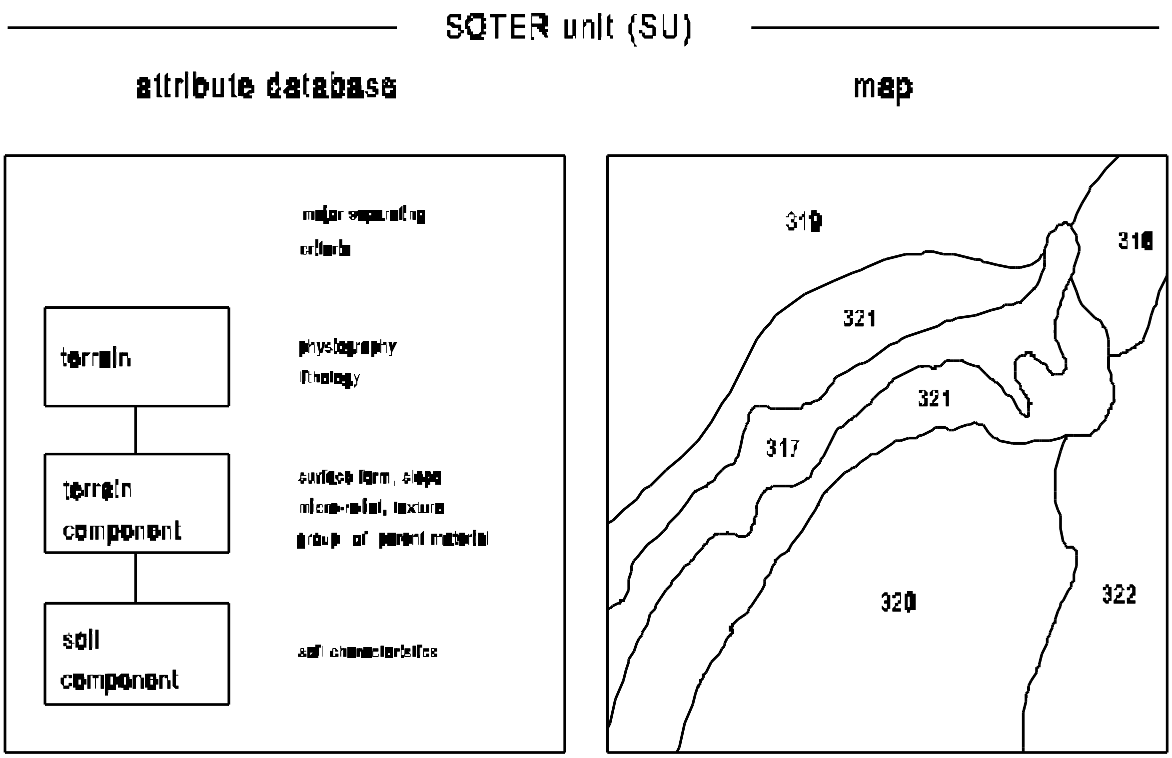

Figure 1. Relations between a SOTER unit and their composing parts and major separating criteria.

Underlying the SOTER methodology is the identificationof areas with a distinctive, often repetitive, pattern of landform, lithology, surface form, slope, parent material and soil. Tracts of land distinguished in this manner are named SOTER units. Each SOTER unit thus represents one unique combination of terrain and soil characteristics. Figure 1 shows the representation of a SOTER unit

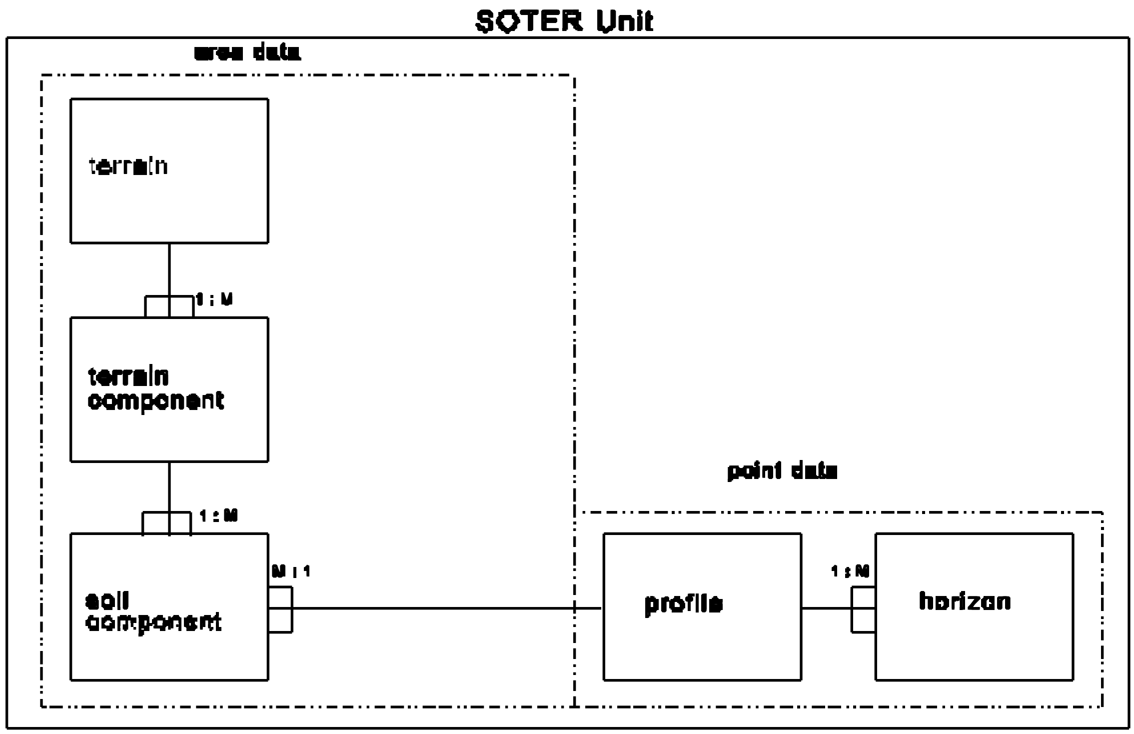

Figure 2. SOTER database structure with area and point data (1:M = one to many, M:1 = many to one).

in the database and gives an example of a SOTER map, with polygons that have been mapped at various levels of differentiation. The organization in a database structure is displayed in Figure 2.

The SOTER approach in many aspects resembles physiographic soil mapping. Its main difference lies in the stronger emphasis SOTER puts on the terrain-soil relationship as compared to what is commonly done in traditional soil mapping. At a scale of 1:5 M this is of particular importance. At the same time SOTER adheres to rigorous data entry formats necessary for the construction of a universal terrain and soil database. As a result of this approach the data accepted by the database will be standardized and will have the highest achievable degree of reliability (van Engelen and Wen, 1995).

The structures of the SOTER 1:1 M and the 1:5 M databases have many similarities. However the 1:5 M has the following differences:

1. The number of attributes is lower (57 in stead of 118).
2. The attributes of the terrain component are stored in a single relation (table), see Figure 2.
3. The maximum number of terrain components is restricted to 3.

The list of attributes holds a total of 58, less than half the number used by the 1:1 M SOTER database according to the Procedures Manual. The list of attributes is shown in Table 1.

The level of generalization has reduced the number of attributes in the terrain, terrain component, soil component, profile and horizon tables with about 50% compared to the 1:1 M approach. The possibilities for the use of the SOTERLAC 1:5 M database are therefore limited to continental applications with the most important attributes. The major changes occur in the terrain component relation (or table) of which all attributes that are of minor importance or that could be deducted from others are eliminated. All attributes that describe in detail the chemical and physical properties and characteristics that cannot be considered relevant at this level of generalization were not included in the horizon relation (or table) like sand sub-fractions, exchangeable cations, phosphorus and aluminium.

Table 1. Non-spatial attributes of a SOTER unit and their occurrence in % in the database

TERRAIN	%
1 ISO country code	100
2 SOTER unit_ID	100
3 year of data collection	95
4 map_ID	60
5 slope gradient	100
6 relief intensity	95
7 major landform	100
8 regional slope	100
9 hypsometry	100
10 general lithology	100

TERRAIN COMPONENT	%
11 ISO country code	100
12 SOTER unit_ID	100
13 terrain component number	100
14 proportion of SOTER unit	100
15 length of slope	84
16 local surface form	70

SOIL COMPONENT	%
17 ISO country code	100
18 SOTER unit_ID	100
19 terrain component number	100
20 soil component number	100
21 proportion of SOTER unit	100
22 profile_ID	88
23 position in terrain component	88
24 surface rockiness	83
25 surface stoniness	83
26 rootable depth	87

PROFILE	%
27 profile_ID	100
28 profile database_ID	58
29 latitude	77
30 longitude	76
31 elevation	74
32 sampling date	66
33 lab_ID	51
34 drainage	86
35 classification FAO	100
36 classification version	100
37 national classification	48
38 Soil Taxonomy	50
39 phase	18

HORIZON	%
40 profile_ID	100
41 horizon number	100
42 diagnostic horizon	68
43 diagnostic property	39
44 horizon designation	100
45 lower depth	100
46 moist colour	
47 type of structure	95
48 abundance of coarse fragments	88
49 total sand	95
50 silt	95
51 clay	95
52 particle size class	95
53 bulk density	37
54 pH H_2O	96
55 ECEC soil	32
56 CEC soil	61
57 total carbon	92
58 total nitrogen	75

In SOTERLAC 1:5 M only measured or estimated values of representative profiles were included and not the minimum or maximum values. Data on land use, vegetation, source map, laboratory and information on climate has been entered in the database according to the rules of the 1:1 M SOTER Procedures Manual.

An explanatory text, issued by ISRIC (Peters and van Engelen, 1993) for the compilation, organizing and coding of soils and terrain information at a scale of 1:5 M was used by the soils institutes of the participating countries. The SOTERLAC philosophy is identical to the one of the 1:1 M project: existing information was used for the creation of the database and SOTERLAC was not involved in any new survey activity.

The topographic base for SOTERLAC 1:5 M has been taken from the digital version of the FAO-Unesco Soil Map of the World (FAO-Unesco 1974-1981). On this map physiographic units have been defined according to the landform definitions of the SOTER Procedures Manual. Hardcopy prints have been send to the cooperating organizations with the request to modify the units when required and to add the missing information on terrain components and soils.

An attribute data input programme, running under dBase 4, has been developed to allow for direct creation of the SOTER files. For those institutes where no dBase was used, only a hard copy version of the datasheets was created which were later entered into the database by ISRIC. Extensive checking of the integrity of the database and the consistency of the data has been taken place but it is not guaranteed that all data are correct.

SOTER units have been defined on a national basis and remitted to ISRIC in various formats. Converting the various files into a correct ARC/Info coverage was done at ISRIC. Especially, connections of units at the borders created problems and required a correlation trip to a number of countries.

An effort has been made to indicate the resolution/reliability of the database by means of a rating of the scale of the source data of physiography and soils (the greater the scale of a source map, the higher the reliability of the delineation of the SOTER unit). The highest reliability is reached when all tables could be filled with data from mapped and described sources, e.g. terrain and soils information is derived from map s with scales larger than 1:1 M and soil profile data come from fully described and analysed samples. The lowest reliability is the case when information is taken from small scale maps (< 1:5M) or from schematic maps, with only partial description and incomplete analysis of soil samples.

It was considered impossible to evaluate the quality of the data as such. For terrain and terrain component data, which can be derived from topographic and geological maps, a reasonable quality check is possible. However, soil profile data can only be evaluated properly during the laboratory analysis procedures. Checking of existing data concerns cross-checking only.

4/ Outputs

The outputs for the project were formulated as follows:

1. A generalized, digital, 1:5 million Soil and Terrain Database for Latin America and the Caribbean (SOTERLAC).

For the entire project area a map at scale 1:5 million with SOTER units has been compiled. It has a total of 1490 mapping units, divided over 2823 polygons. The 1490 SOTER units are further defined by 2008 terrain components. Every terrain component consists of one or more soil components, amounting to a total of 3580 Representative soil profiles have been selected for all soil components from a wide range of sources. A total of 1828 soil profiles can be found in the database. The total number of horizons of these profiles is 6525.

Table 2. Details per country on SOTER units and their components

Country	area (1000km^2)	SOTER units	terrain components	soil components	Profiles
Antilles*	8.5	9	12	23	16
Argentina	3113.8	105	120	290	217
Bahamas	15.5	2	2	4	0
Belize	22.8	14	18	36	0
Bolivia	952.3	58	67	128	73
Brazil	7425.8	298	455	832	584
Chile	924.1	68	81	130	21
Colombia	1000.1	62	66	118	92
Costa Rica	48.3	48	55	72	18
Cuba	123.8	30	49	104	26
Dominican Rep. & Haiti	81.7	12	16	36	7
Ecuador	224.2	44	64	105	44
El Salvador	20.3	14	15	28	4
Falkland Islands	18.2	1	1	2	2
French Guyana	74.3	11	20	35	31
Guatemala	110.3	52	60	104	7
Guyana	192.7	20	35	58	50
Honduras	112.6	40	41	58	8
Jamaica	111.3	5	10	15	11
Mexico	2301.0	323	513	797	53
Nicaragua	125.4	48	50	66	16
Panama	69.5	32	37	56	15
Paraguay	364.3	27	40	89	44
Peru	1100.7	80	85	191	73
Puerto Rico	9.6	9	14	22	17
Surinam	129.8	17	25	46	40
Trinidad/Tobago	5.0	6	10	17	17
Uruguay	187.0	16	23	37	36
Venezuela	839.7	96	102	180	141

- Antilles include: Antigua & Barbuda, Barbados, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, St. Croix, St Kitts-Nevis, St. Lucia, St. Vincent, Turks & Caicos Islands and Virgin Islands.
- Area calculations based on Lambert Conformal Conic projection (central meridian 70 W, standard parallels 15 N and 30 S).

For 12% of the soil components no newer information on soils than that could be extracted from the FAO-Unesco SMW was available. These components do not have a profile. This is e.g. the case in a larger part of Chile.

Most attributes in the various tables are complete or nearly so with the exception of bulk density in the horizon table. With only 40% measured, this attribute has the lowest occurrence. Another gap exists in the coordinates of the location of the profiles. In some countries such information could not be found (e.g. Argentina). Other attributes missing are elevation and date of description/sampling.

The map has been drawn on the topography of the original FAO-Unesco Soil Map of the World as available in digital and hardcopy form. Mapping units (SOTER units have been digitized in ARC/Info and the attribute data stored in a relational database system (compatible with most commercial software). A special input software package was compiled for entering attribute data and creating the appropriate tables.

Although the current dataset consisting of the ARC/Info and dBase files can be considered as the published material, it was thought better to develop software that can display the data without relying on GIS software that is often not available for most users. In this respect ISRIC has developed a Viewer programme that runs under Windows (3.1 or 95) and that displays thematic maps and attribute data for the non-GIS user.

5/ The Use of Outputs

A part of the output has been used in a study in the framework of the Global Environment Outlook project of UNEP. For an area covering Argentina, Brazil and Uruguay, the water erosion risk has been modelled. (Batjes, 1996).

6/ Follow-up Action

1. Making the database more accessible

One of the major bottlenecks for the use of GIS databases is the necessity to use/own the appropriate software/hardware. As many potential users will not have this opportunity the idea took ground to develop software for SOTER that will allow displaying of the maps and data.

An additional activity that was not envisaged by the project document, was the development of a Viewer programme by ISRIC that enables the visualization of the map and database in a Windows environment. The user can display predefined thematic maps and execute simple searches in the database with this programme. A prototype has been developed.

2. Filling of the data gaps

It is hoped that the release of the database will incite national soil survey organizations to fill data gaps that still exists in their mandate area. From Table 2 it can been seen which territories need most urgently additional information on all levels of the database, and which countries need extra profile data to characterize the soil components.

A point of concern is the lack of soil physical data in SOTERLAC. About 60% of the horizons lack bulk density data which is considered essential for many interpretations. Ways are studied to replace the empty field with data derived through pedo-transfer functions.

3. Interpretation of the data

Various interpretations of the data are planned for the coming period: land evaluation for major kinds of land use, potential production analysis, carbon stocks in the Amazon region, etc.

7/ Conclusions and Recommendations

This section does not deal with conclusions related to the technical achievements. These are covered in the preceding sections of this terminal report.

Nevertheless, some conclusions can be made. They are grouped as follows:

1. Difficulties in applying the SOTER methodology for new participants:
In countries where no earlier SOTER activities have been taken place, either in the form of database compilation or as general workshops, it was sometimes very difficult for the participants to apply the SOTER methodology. Lack of funding prevented on the spot training by SOTER staff. Moreover, the scale of the study made it less interesting for smaller countries to participate. They are more interested in larger scale applications.

2. Not all countries participated:
It was not possible to ask each individual Central American and Caribbean country to participate in the compilation of the database due to two reasons:
1) absence of soil survey organizations in various countries or no response on requests;
2) lack of sufficient funds for subcontracting.
Therefore, CIAT was requested to compile under a subcontract the database for Central America, while soil profile information was assembled by ISRIC.
- For the smaller Caribbean islands the same reasons are valid. Here ISRIC created the full database.

3. Border correlation problems:
Correlation between the countries was often non-existent resulting in discontinuities of SOTER units at their common borders. Part of these problems has been solved by an additional mission to six countries (Brazil, Bolivia, Colombia, Ecuador, Peru and Venezuela.

4. Limited checking of data:
The varied sources of data have required extensive checking, while some uncertainties could not be solved. It was difficult to obtain revised data sets from the countries once the data were delivered.

5. Value for money
With the limited amount of funds available for sub-contacting soil institutes, the SOTERLAC activity did not always get the priority in their working programme. Some institutes requested a too large part of the total budget which forced ISRIC to look for other opportunities, meaning doing the job in-house. The limited financial remunerating possibilities made it sometimes difficult to put pressure on data compiling actors. Most of the cooperation was based on scientific interest mainly, which was fortunately well represented within the continent.

Resuming it can be stated that most problems were related to the limited financial possibilities of the project, limiting training, participation and involvement of the national partners. The overall database was therefore delayed substantially.

The following recommendations are made:

1. Training
As lack of knowledge in applying SOTER was the major constraint in the activities, it is recommended that in similar projects in the future provisions will be made to train participating institutions in the SOTER methodology and for across-border correlation. These aims could be reached by organizing some regional workshops at the start of the activities, while at a concluding meeting data quality issues could be handled.

2. Funding

Sufficient funds are needed to include the participation of all soil institutes that have a national mandate, assuring the involvement of the soils community at the national level in the SOTER methodology, the timely delivery of the data, quality control and border correlation.

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