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A SURVEY TO UPGRADE INFORMATION FOR SOIL MAPPING AND MANAGEMENT IN LEBANON

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Introduction

The first complete soil map of Lebanon at a scale of 1:200.000 appeared in the early fifties of the last century (Geze, 1956). It was the result of a French-Lebanese co-operation with the Lebanese Ministry of Agriculture. The mission established the Lebano-French station at Rayak-Tal Amara.

The map was based on fieldwork and on the earlier produced geological maps of Lebanon at 1:50,000 and 1:200,000 scales (Dubertret, 1945, 1955), as well as on aerial photos. Geze used the topographic maps of the country at 1:50,000 scale for geographical location, field validation, description and sampling. The results were presented in the "*notice explicative*" published in the mid fifties (Geze, 1956).

The "*notice*" contained detailed additional information on Lebanon's geomorphology, climate and soil characteristics. They were largely based upon the soil nomenclature reflecting early attempts of soil studies and classification in the Middle East region. In a sense it anticipated the old French classification of Aubert and Duchaufour proposed in 1956 at the VIth International Congress of Soil Science held in Paris. Geze's soil categorisation was also based on the works of other French soil scientists who worked in ORSTOM (Segalen, 1977).

The soil names used in Geze's Soil Map of Lebanon, considered soil colour, lithology and texture as the main criteria for soil identification. The map and its legend, however, were up to most recently the only complete soil map for the country, and thus could be considered as an initial national soil classification system. This is true despite the non-uniform basis for soil type identification and nomenclature used which characterises the early attempts of soil classification.

Lebanon's limited territory has a striking diversity of topography, geology, climate, hydrology and vegetation. Adding the human impact, they result in a remarkable mosaic of soil types that rarely can be found in comparable areas. This is why Geze's approach relied on applied pedology in a way to facilitate availing practical knowledge for soil management.

Geze rightly considered the map a reconnaissance soil map of Lebanon, and frame for future research on more detailed soil cartography. However, the progress made in soil studies and classification world-wide was not reflected in the production of new and updated Lebanese soil maps. This was partially due also to the civil war in the country (1975-1990).

Obviously, there was the need for upgrading that map, and the opportunity came though the support of the European Commission's Soil Bureau (ESB). Funding was provided within the framework of the EC's ResManMade project (ERBIC18CT970151; 1998-2000). The authors faced several problems during the upgrading and the re-classification process. This paper reviews the work carried out for creating the new digital soil map of Lebanon at a scale of 1:250,000 and updating existing soil information.

Materials and Methods

Going back to Geze's original work, he attributed a special role in soil genesis to the parent material and climate. To these fundamental factors of soil formation he added secondary factors like water influence, vegetation and human impact. He recommended paying attention to the second set of factors in a detailed mapping at 1:50,000 scale. The author associated particle migration and the conservation of oxidised or hydrated forms of iron as responsible for the red or yellow tint (hue in the Munsell Soil Colour Chart).

He also considered humus accumulation (black or grey tint) to the altitudinal climatic variation (vertical zonality). Based on these aspects, a simple observation of rocks and soil colour would allow distinguishing major soil types of the region. Consequently, parent material and soil colour served as basis for the reconnaissance soil map of Lebanon at 1:200,000 scale.

Geze recognises, however, that colour is not a classification criterion because often the same colour can characterise two different soil types. For instance, within the red soils can be grouped the clay and sandy soils as well as the calcareous and leached soils with different agronomic use. This remark of Geze could serve as an implication to use $CaCO_3$ content and texture for further soil subdivision into groups and types.

In general, the author used the parent material as separation criteria for higher soil classes. He identified 8 soil classes, which are: soils from hard limestone, soft marl, sandstone, basalt, mixture, black or grey soils and peat soils, step and subdesertic soils and alluvial soils.

Analysis of the main soil physical and chemical properties, presented in the “notice”, were limited to fifty-two point data (superficial soil samples) and eleven profiles (Fig. 1). Geze (1956) included only these data in his “*notice*” believing that they are the most characteristic. Among these, seven locations were indicated in stereoscopic projection while the other forty-five locations were given in Lambert projection.

Upgrading Geze's soil classification was essentially based on the initial soil name indicated in the map, which carries some indications on soil genesis and properties. Additional information like area of distribution and genesis in connection with the original material, depth, colour, texture, $CaCO_3$ content, SiO_2 and sesquioxides content and molecular ratio was gained from the description in the “*notice explicative*” (Table 1).

Table 1. Upgrading soil classification of Geze's 1956 reconnaissance map of Lebanon at 1:200,000*

Legend of Geze soil types	FAO Nomenclature	WRB Classification	Identification in the "notice explicative" of Geze map
Sols rouges (terra rossa, discontinu) sur calcaire compact (residu argilieux de decalcification, parfois sableux) passant quelquefois à des sols bruns forestiers.	Chromic Luvisols (LVx) could also be Ferric Luvisols (LVp) and calcic Luvisols (LVk).	Chromic Luvisols (LVcr) could also be Ferric Luvisols (LVfr) and calcic Luvisols (LVcc)	Spread in "karstic" Jurassic and Cretaceous depressions, decalcified Quaternary sand pockets (Ramleh) and colluvium in footslopes. Decalcified insitu (Ferric Luvisols) and can show subsoil "calcic" horizons in colluvium (Calcic Luvisols). pH is neutral, clay 30-50%, total Fe_20_3 in clay 13-18%, SiO_2/Al_2O_3 between 1 and 2 (analogy with tropical laterite clay), found in Southeast Tripoli and Central Beqaa.
Sols noirs ou gris (très argileux et generalement calcaires) et sols tourbeux	Association of Calcic Vertisols (VRk), Eutric Vertisols (VRe), Luvic Chernozems (CHl) and Gleyic Chernozems (CHg)	Association of Calcic Vertisols (VRcc), Eutric Vertisols (VReu), Luvic Chernozems (CHlv) and Gleyic Chernozems (CHgl)	Very dark colored soils developed on the coastal plains and in Central Beqaa. Similar to the Tirs plain in Morocco. Spread in the area of the Red soils although these develop on compact limestones under dry climate. They develop on alluvial or colluvial parent material originated from white marls, thus forming a toposequence in the lower area of marl outcrops. This results in a progressive transition of gray or black rendzinas (Calcic Vertisols) to the real black soils (Eutric Vertisols). The color is due to calcium humate, despite the low organic matter content. The real black soils develop on flat topography, in humid regions (or used to be humid), with temporal appearance of wetlands and peat behind the coastal sand belt and on the inundated Litani palin (Joub Jannine, Beqaa). The soils physical properties depend on local conditions. On the coastal areas (Chekka, part of Akkar) the clay content may be significant (30-55%). In Beqaa clay content decreases till 4-10%. The clay chemical composition is similar to the red soils, from which they differ by the $CaCO_3$ content, which varies from 3.5% to 87%, with an increase within the profile. But the decarbonation is never complete, therefore the pH is basic.

*. As the original work was only general and indicated by the author to need more detailed investigation (Geze, 1956), it is considered a "reconnaissance map"

The work on map upgrading consisted of four steps: the map was first digitised using GIS ArcInfo to produce the initial layer of soil types. Then the soil mapping units were analysed comparing Geze's classes, descriptions and characteristics to those of FAO and WRB classifications. The field verification of map homogeneity and suggested new classification covered a representative area in the central parts of the country (Figure 1).

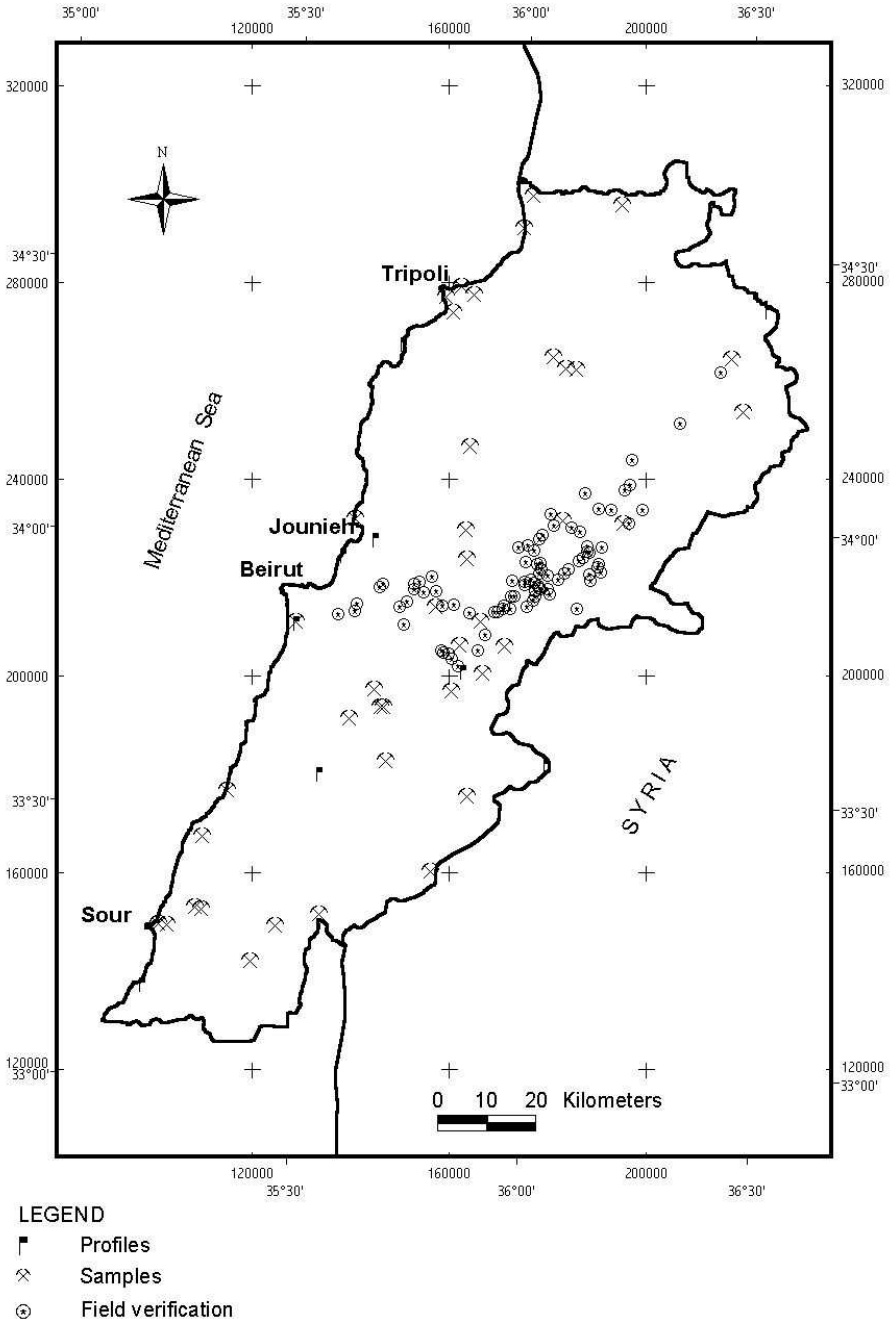

Figure 1. Geze's surface samples, profiles location, recent soil sampling and verification point.

The correct co-ordinates of the sampled sites were established using Global Positioning System (GPS) equipment. A total of 86 soil samples were analysed for main physical and chemical characteristics according to the methods adopted for the region (Ryan *et al.*, 1996). The new soil classification was based on the FAO-UNESCO, Revised Legend (1997) and the World Reference Base for Soil Resources-WRB (1998). Geze's soil types were converted into the second level of FAO Soil Units, which correspond to the lower-level units of WRB reference soil groups.

Some soil polygons on Geze's map were neither represented by soil profiles nor by surface samples or analyses. Thus, for the sake of upgrading them in the new map, they were inferred depending on Geze's descriptive text and parent rock lithology, as well as from landforms that could be inferred from his description of locations on the topographic map.

Results and Discussion

Eighty-one soil units were identified on the old map compared to fifty-five units present on the new one. Geze identified thirty-eight soil types as pure types and forty-three as soil associations (Table 2). Among these, thirty-four represent association of two soil types, and nine are formed from association of three soil types.

Due to merging, the upgraded version contains a reduced number of total soil associations, seven of which contain four soil units. In Geze's map legend, for instance, he represents three patterns: rocks, sands and "*croûte calcaire*" as one soil type even though they show geographical variability. Thus in the upgraded map, the sands are named Arenosols, some of which are Calcaric (coastal area), while others are Eutric (mountain area).

Table 2. The old and new configuration of the "reconnaissance soil map of Lebanon" (Geze, 1956).

Soil classification	Total Units	Pure Units	Association of Soil Types			
			Total	Two types	Three types	Four types
Geze	81	38	43	34	9	-
Upgraded	55	33	22	8	7	7

In many cases soil colour reflects the organic matter and $CaCO_3$ content, as well as the oxidation-reduction status of iron and probably aluminium. However, most recent soil classifications are based on the soil horizons, epipedon and endopedon designation, as well as on soil-landscape functional relationships.

Geze indicated the presence of "*sols noires et sols tourbeux*" (peat soils) in Lebanon (Fig. 2a). But knowing that climatic conditions in the country are not favourable for forming such soils*, they were re-classified into Vertisols and possibly Chernozems (Fig. 2b). This is because peat soils develop under more wet and cold conditions, characteristic for northern Europe, in stead, the climate in Lebanon is typically Mediterranean with low seasonal precipitation.

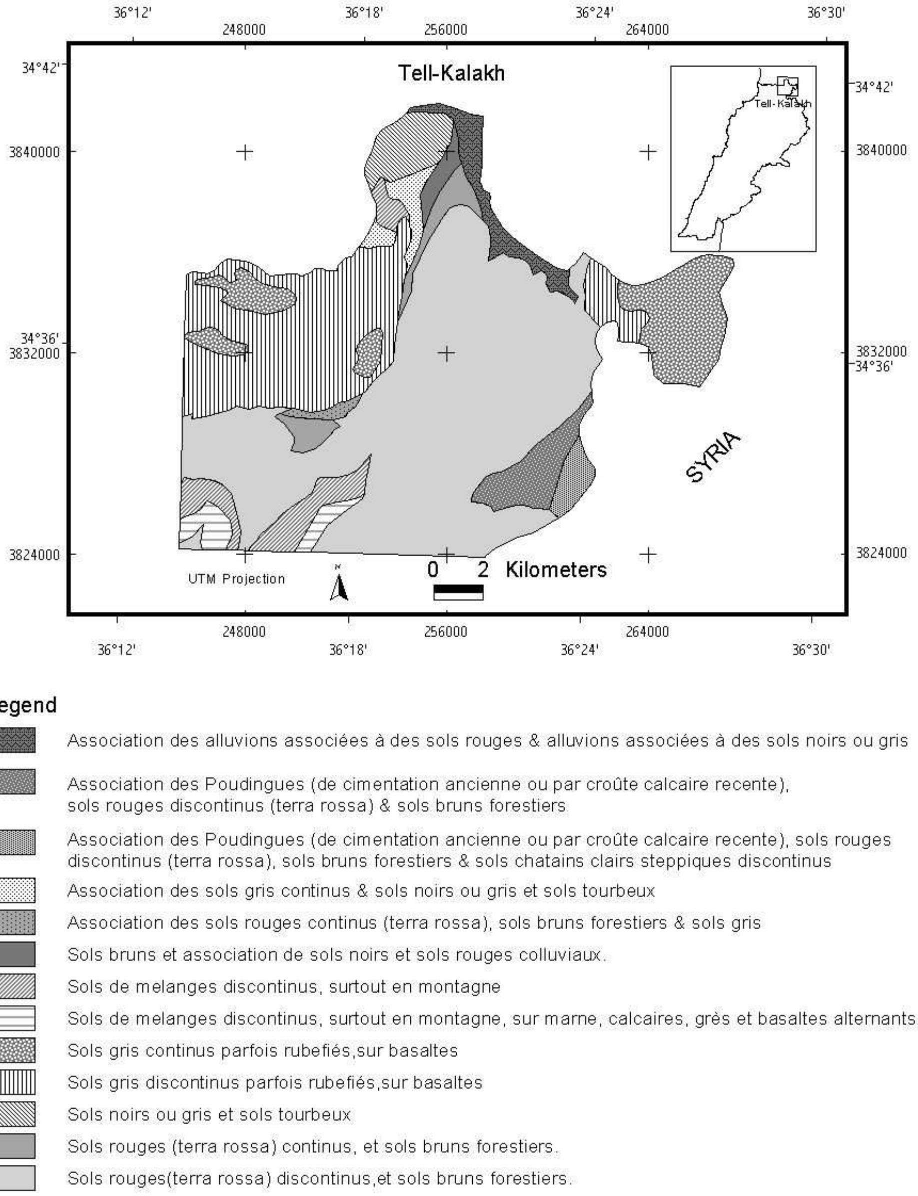

Figure 2a. Geze (1956) classification of peat soils and soil types developed from hard limestones and basalt in north Lebanon.

According to E. Servat, who assisted Geze and examined in detail the black soils of the Beqaa, and whose results contributed to Geze map, two subtypes can be distinguished: calcareous and decalcified. The first soils represent a calcareous surface layer, which has a loose consistency when dry (could be classified as Mollic horizon). This subtype has more clayey subsoil with prismatic structure, which can be considered as Bt horizon and thus was classified as Luvic Kastanozems (Kslv).

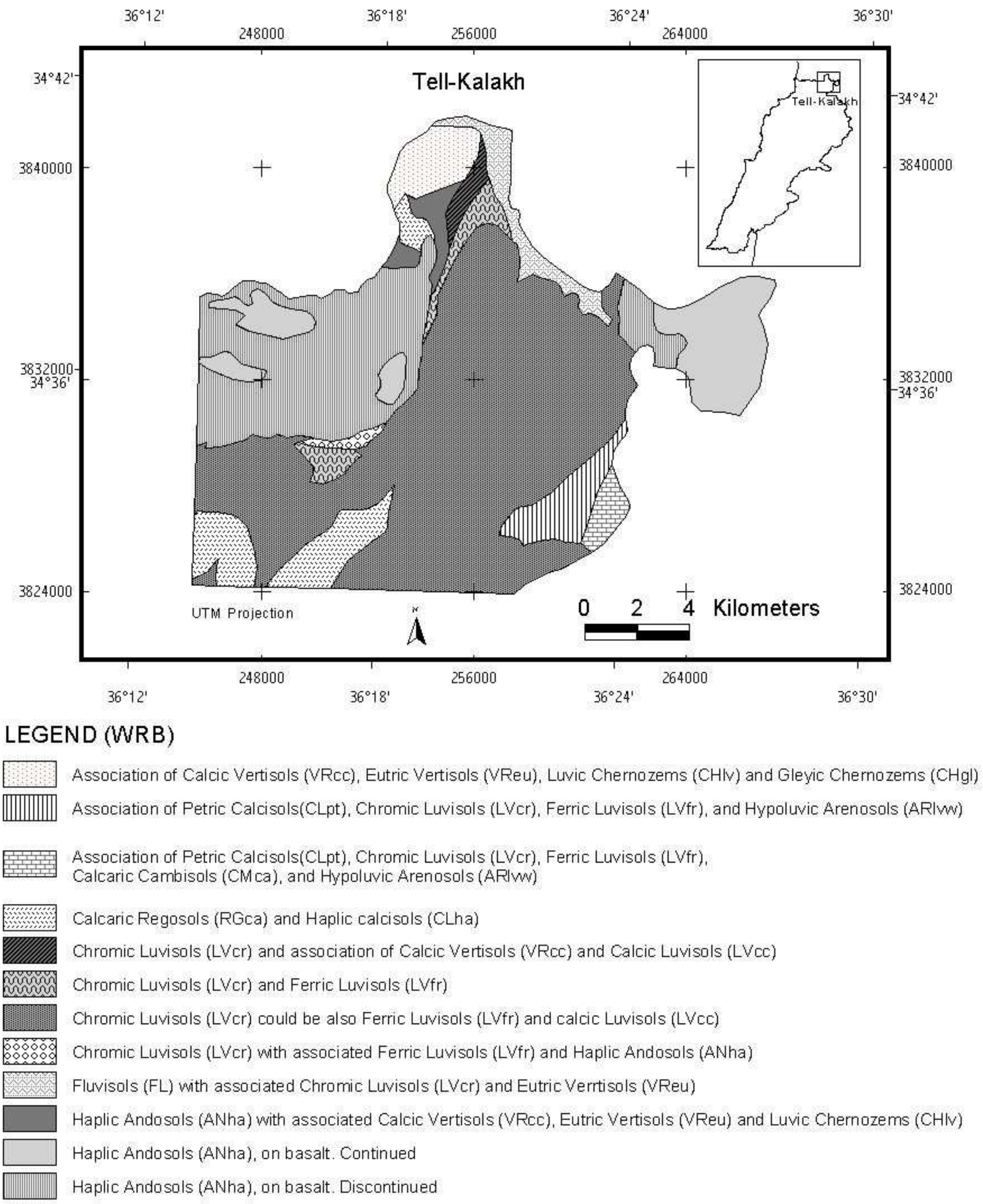

Figure 2b. The suggested new classification of the soils derived from Tertiary and Quaternary deposits in North Lebanon.

The second soil reveals an epipedon with grey-bluish colour and contains iron and $CaCO_3$ concretions, therefore, it was named Calcic Kastanozems (KScc). Both subtypes could be classed into one unit: Luvic Chernozems (CHlv). The second soil is very clayey throughout and develops cracks in the dry season (the real Vertisols). Gley formation is also frequent in the subsoil with shallow water table, therefore, a new unit was derived: the Gleyic Chernozems (Chgl).

On the other hand, under primitive Oak Forest Luvisols develop into "*sols bruns*". The dark colour of the surface horizon is due to the hydrated iron and organic matter. The same iron content and $SiO_2/A1_20_3$ ratio as in red soils reveals similar origin of these two soils that differ only by their late evolutionary stage. The red soil is the truncated relative part of this soil unit. It is never decalcified (decarbonated) but it has a weakly basic pH. Some times $CaCO_3$ increases in the subsoil (20-40%) with concretions. For this reason, the "sols bruns" were subdivided into two soil units Chromic Luvisols and Calcic Luvisols. They are spread in Southwest Jabal Aamel, Kesrouane, Southeast Akkar and Harmon surroundings.

Other mountain soils that attract attention are the "*Les sols jaunâtres des montagnes*", which are equivalent to the "terra-rossa" formed on hard limestone. They are found in high altitude areas, covered with snow for several months, thus showing some characteristics of cold regions like "*solifluction*" and "*striation*". Derived from hard limestone, they show similarities with other red soils (*i.e.* Luvisols), even though their geo-morphological position is in the "*fente de lapiaz*" and colluvium. However, they contain more coarse particles, which are due to rock segregation and less clay fraction.

They are not completely decarbonated (3-10% $CaCO_3$) with neutral and rarely basic pH. In comparison with red soils, the clay contains less Fe_20_3 (10-13%), to which Geze attributed the yellow tint of the soil matrix. The $SiO_2/A1_2O_3$ ratio varies between 2 and 3 and reaches 4.5, a trend that distinguishes them from the tropical soils. On the high Mount Lebanon or western chain, cedars and pines may grow such soils. On the eastern anti-Lebanon chain, wheat is cultivated on such soils on elevations as high as 2,200 m above sea level.

The "*sols chatains clairs et sols jaunâtres subdesertiques à croûtes calcaires*" presented in Fig. 3a were classified as Calcaric Cambisols and Petric Calcisols, as shown in respectively in Fig. 3b. Geze explained the appearance of saline soils as a result of fertilisation and irrigation in the semi-arid area of the country. Therefore, a new soil unit in the upgraded map (Haplic Solonchaks) was added to the association of soils developed in the steppic zone under subdesertic conditions.

Geze also distinguished in that area old and recent petrocalcic layers, and proposed methods for the exploitation of the soil buried under the old layer. He also discussed the prevention of the formation of new petrocalcic layers by managing the input of acid fertiliser and irrigation to prevent the encrustation of calcium carbonate. It is interesting to mention that 30 years later scientists adapted similar management techniques through fertigation, for a combined application of nutrients with the acidified irrigation water (Papadopoulos, 1985).

Some new and old alluvial soil types were merged in the upgraded map version, except where some profile differentiation was found necessary. This is the case of alluvial soils on few left old terraces of the Litani River near Qaraoune Lake where the soil has been completely decarbonated.

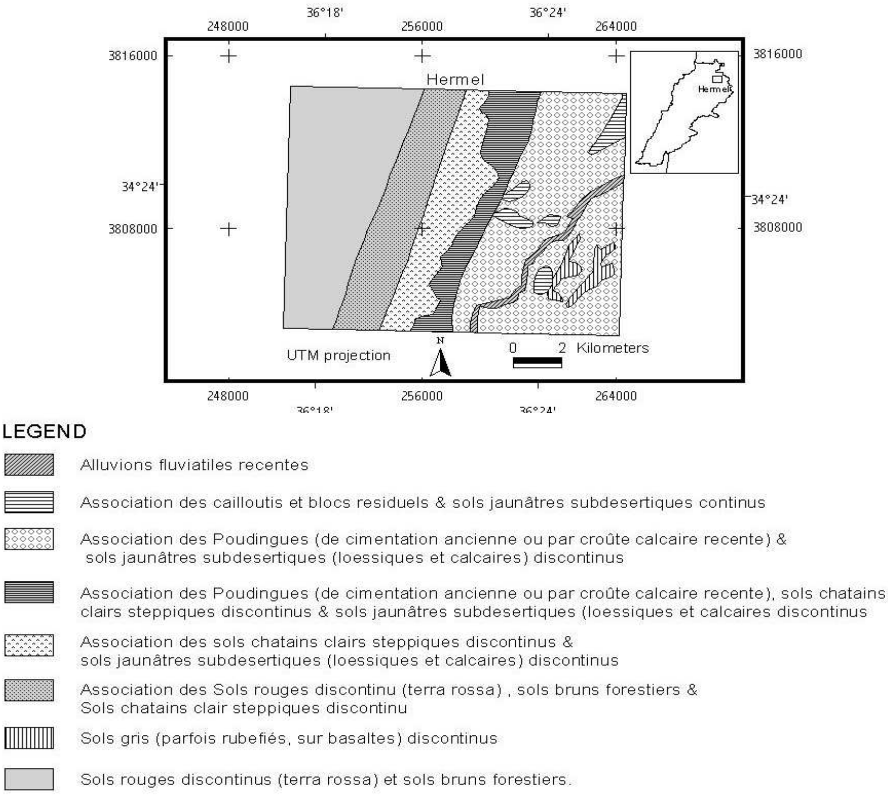

Figure 3a. Geze (1956) classification of the soils developed under subdesertic conditions in Qaa-Hermel area, Northeastern part of Lebanon.

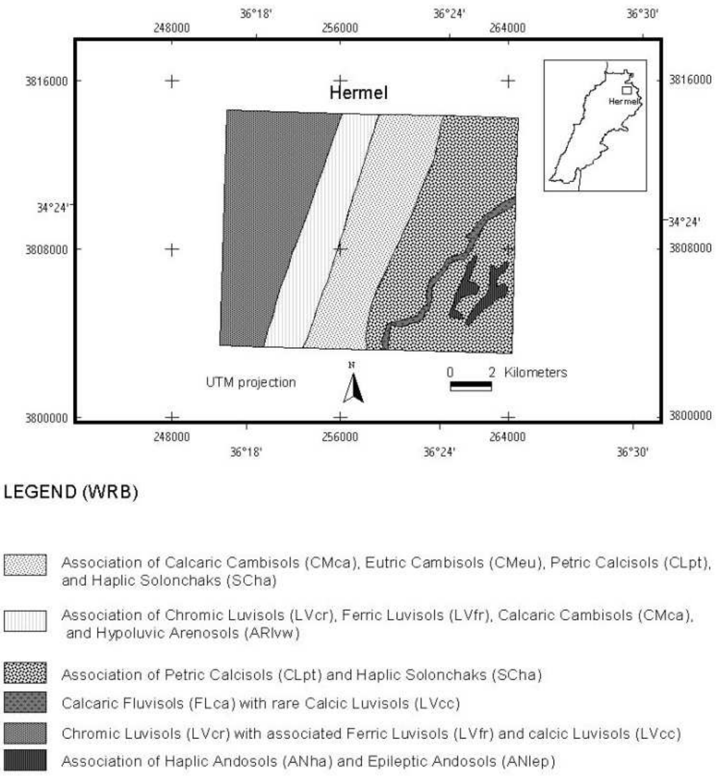

Figure 3b. The new proposed classification of the soil of Qaa-hermel area along the Orontes River, Northeast Lebanon.

Ten soil types identified in the old map as “alluvions” are now classified as Fluvisols (Fig. 4a). For example, the "*alluvions associés a des sols rouges fersialitiques*" are now reclassified as Association of Fluvisols and Luvisols (Fig. 4b). They could also be named Fluvisols with associated Luvisols. However, the most appropriate classification seems to divide the Fluvisols associated to calcareous and non-calcareous soils in two major Units: Calcaric and Eutric Fluvisols, respectively. Other types indicated in the old map as "*Sols Chatains clairs*" and *"Sols chatains foncés*" are now grouped together in one soil unit and named collectively Cambisols.

Field verification (with GPS) to reveal soil homogeneity was done over representative areas of Lebanon covering the coastal hills, the mountains and inland Beqaa valley. A total of 165 points/polygons were checked (Fig. 1), from which 120 locations, constituting 73% of the observed and analysed soil units matched Geze's description and classification (Table 3). Mismatching was mainly due to the soil type and partly to soil properties (texture and $CaCO_3$ content).

Information included in the upgraded soil map of Lebanon at 1:250,000 scale is useful to infer a new national soil classification system. This could be significant for assessing and managing soil resources and establishing plans for appropriate regional land use. The authors have used the data from the new map to produce the unified soil map of Lebanon at 1:50,000 scale and to build the relevant SOTER database. The digital map and the Soil Geographical Database for Lebanon at 1:1 Million scale, which is included on the Euro-Mediterranean Database was prepared mainly using the information described in this paper.

The new soil map at 1:250,000 scale is under revision and probation for further publication and dissemination. The correspondence between soil types and soil units is being reviewed by INRA (France). Lebanese ministries and institutions will receive this updated map. The Ministry of Agriculture and the FAO office in Beirut have already requested and received an adapted digital version of the old map. In addition, international organisations and countries offering assistance to Lebanon as well as the Lebanese private sector, subcontracting projects on reconstruction, are interested in receiving a copy of the new map.

The information will also be used in a future project, which aims the creation of the Georeferenced Soil Database for Lebanon, at scale of 1:250,000 within the framework of a project that could be supported by the European Soil Bureau. Moreover, this product would also be useful for the activities of the Euro-Mediterranean network on soil information established in December 1999 on a Regional Meeting held at CIHEAM-Mediterranean Agronomic Institute of Bari-Italy, with the participation of 12 Mediterranean countries.

Conclusions

The paper reflects on the work carried out to upgrade an old 1:200,000 scale soil map of Lebanon that existed in the fifties (Geze, 1956). This is a topic that came as a by-product of a European Commission funded ResManMed project No ERBIC18CT970151.

Table 3. Field validation and verification of map homogeneity

Number of observation points Geze map	Number of matched points	Geze legend	Aspects of mismatching*	
			Soil Type	CaCO3, texture
10	8	Sols de melanges (discontinus, surtout en montagne) sur marne, calcaires, grès et basaltes alternants.	+	
8	8	Sols sableux (sur grès silicieux friables), sols lessivés et parfois prodzoliques	--	--
4	0	Sols de melanges (discontinus, surtout en montagne) sur marne, calcaires et grès silicieux alternants	+	+
13	11	Sols blancs grisatres (sur marnes blanches), souvent rendzines blanches ou grises	+	+
19	13	Sols rouges discontinu (terra rossa) sur calcaire compact (residu argileux de decalcification, parfois sableux)	+	
5	5	Sols rouges discontinu (terra-rossa), residu argileux de decalcification, parfois sableux, passant quelque fois à des sols bruns forestiers et sols chatains clairs steppiques (argileux a limono-sableux, generalement calcaires, parfois decalcifiés), discontinu (on poudingues de sedimentation ancienne ou par croûte calcaire recente)	--	--
14	9	Sols chatains clairs steppiques continu (argileux à limono-sableux, generalement calcaires, parfois decalcifies)	+	
13	8	Sols rouges (terra rossa), continu, sur calcaire compact (residu argileux de decalcification, parfois sableux)		+
4	2	Cailloutis et bloc residuels et Sols rouges discontinu (terra-rossa), sur calcaire compact (residu argileux de decalcification, parfois sableux), passant quelque fois à des sols bruns forestiers.	+	

*. Only two aspects are given as they are found to constitute the basic difference between old and new classification.

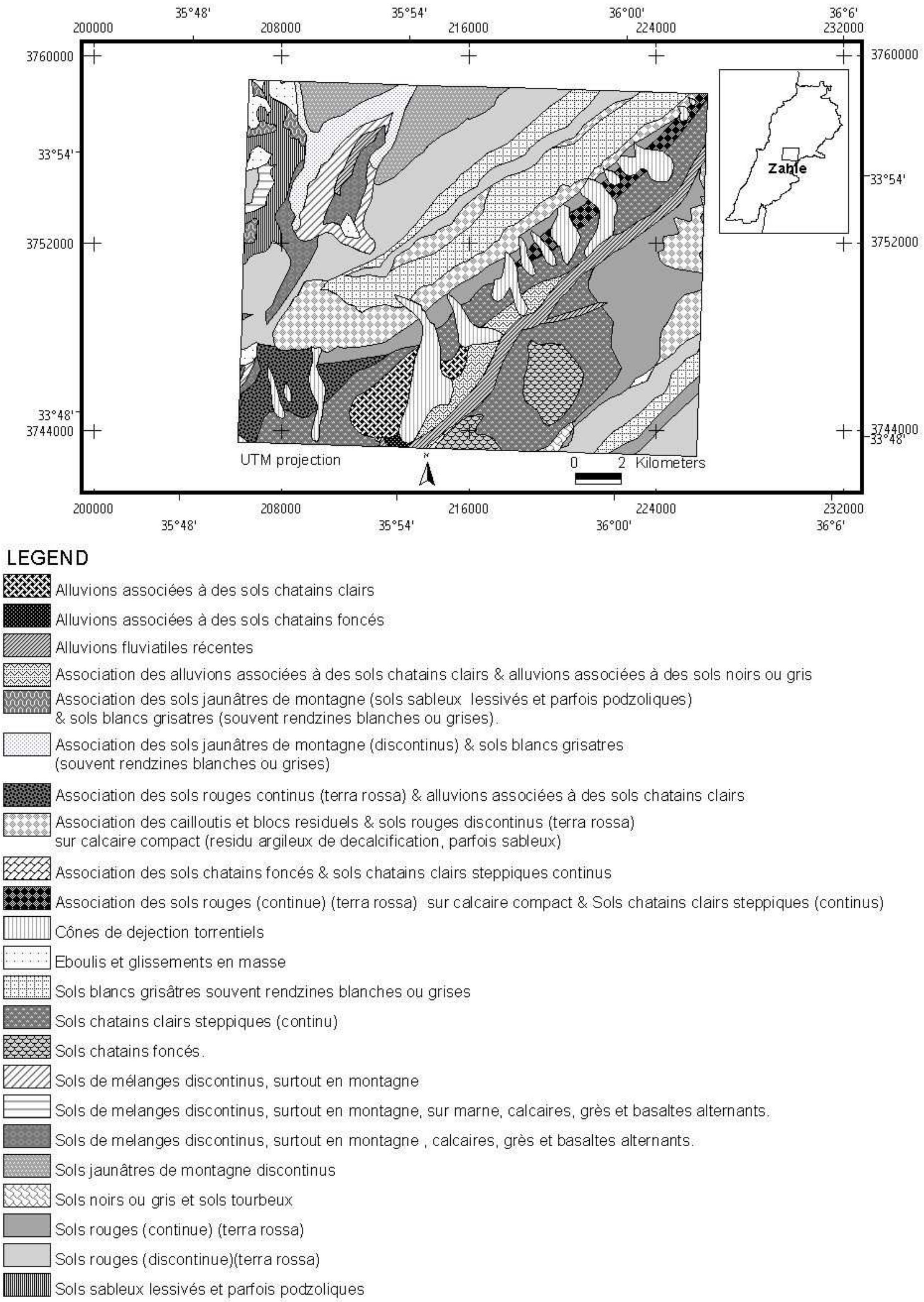

Figure 4a. The main area of alluvial and colluvial soils along Litani River in Central Beqa'a, Lebanon.

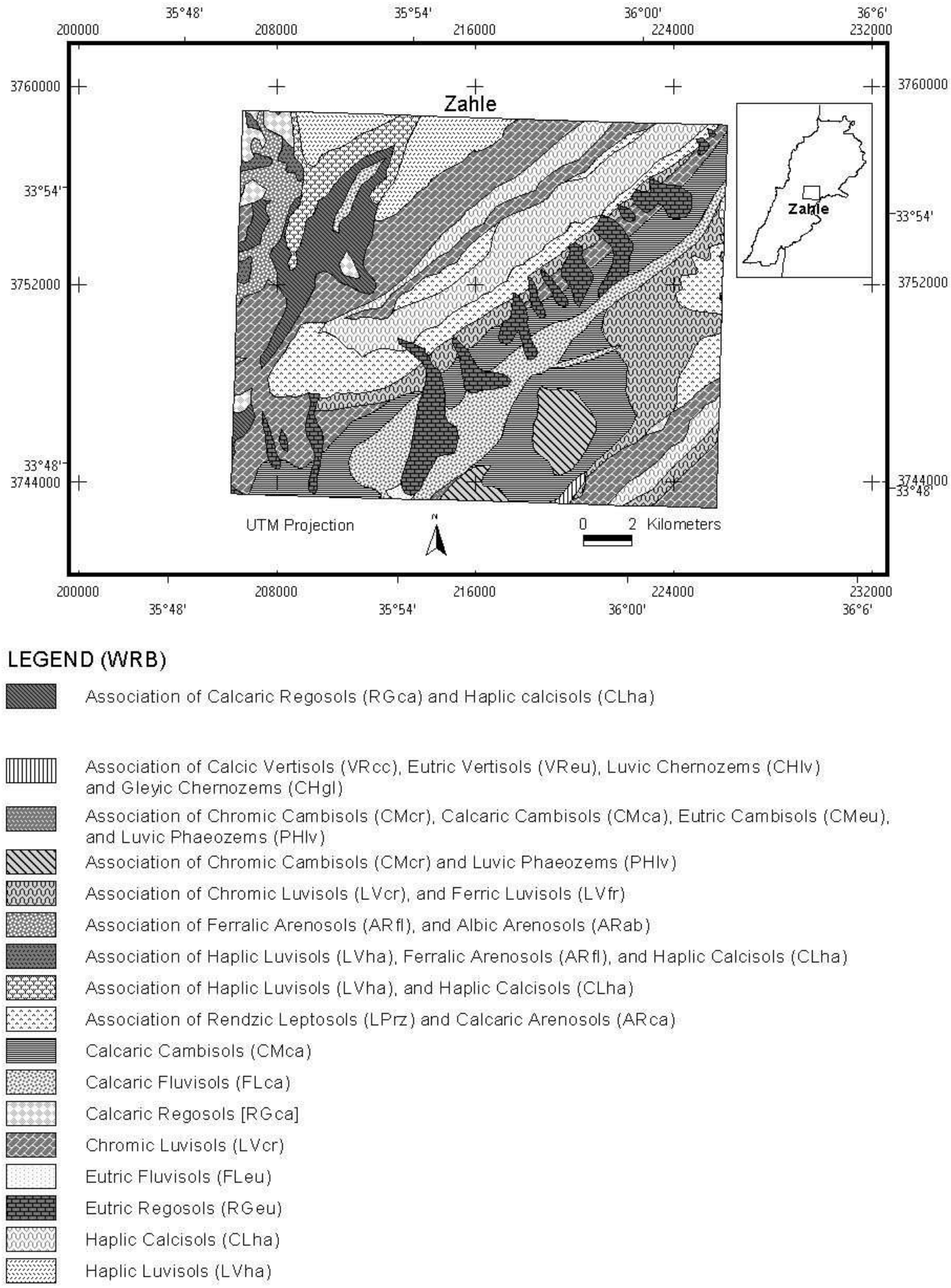

Figure 4b. Upgrading of the soil classification of Central Beqa'a area and surrounding mountains.

It is important to point out that Geze's map served as a reliable reconnaissance document, but it needed upgrading for improving the soil database in Lebanon and producing a digital 1:250,000 new version. This is based on FAO and WRB classification.

The upgrading process covered verification of field locations and soil descriptions as exposed in the old map and its accompanying "*notice explicative*". Large areas of Lebanon were covered for complete representation of the multi-diversity of soil types. Although some old classes were retained, with 73% of the original being matched, several areas revealed discrepancies. The major differences turned out to be the soil type and less on soil properties, mostly $CaCO_3$ and texture.

The total number of soil types in the old map was 81 reflecting a large soil phenotypic variability. In the upgraded map, apparent differences in soil characteristics gave place to a genetic soil classification inferred from Geze's description. Thus, 55 soil units replaced the old classes. The new map would serve to infer a new national soil classification system. This could be significant for assessing and managing soil resources and establishing plans for appropriate regional land use.

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