Comparison of Soil Maps with Different Scales and Details Belonging to the Same Area

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Abstract: Two different soil maps prepared by different institutes at scales of 1:200 000 and 1:25 000 covering identical areas were compared to determine the accuracy of reconnaissance. These soil maps are widely used in land resources assessment studies in Turkey. For this purpose, the soil maps were digitised and performed a data set. Then the map layers were compared by using GIS technology in order to assess the soil properties and land characteristics. The reconnaissance soil map at the scale of 1:200 000 has the highest accuracy for the slope due to the fact that topographic maps have been used as basic maps for the field studies. The accuracy of other properties in descending order is as follows; slope > depth > salinity > texture > drainage > top soil texture. In addition, physiographic and topographic patterns of soils also affect the accuracy of maps. The reconnaissance soil map was found to be less accurate in flood plains where the slope does not affect other soil properties.

Keywords: detailed soil map; reconnaissance soil map; geographic information system

The aim of the soil surveys is to describe the soils and provide sufficient data about their distribution, behaviours, and properties of soils in a given area (Soil Survey Staff 1993; Dinç & Şenol 1997).

The soil surveys have traditionally overlooked spatial variability within the map units for a variety of reasons including scale limitations and inadequate quantitative data. Soil mapping typically partitions the soil in the landscape into more or less discrete entities using the map units. Soil surveyors map the soil with a conceptual model of soil variation in mind, based often on air photo interpretation and collated information on the soil and its relations with landform, geology, vegetation, and land use (Dijkerman 1974; Soil Survey Division Staff 1993; Lin *et al.* 2005). Field observations are made at a selected number of locations chosen by soil surveyors using formal knowledge and intuitive judgment. On a soil map, the map unit boundaries are clear lines across which the observed differences are deemed significant and within which the soil is relatively homogeneous. Variations within the soil map units are acknowledged, but described qualitatively in vague terms. Moreover, virtually every delineation of a map unit in all soil surveys includes other soil components or miscellaneous areas that are not identified in the name of the respective map unit. Many of these components are either too small to be delineated separately at the given soil survey scale or deliberately included in delineations of another map unit to avoid excessive detail in the map or the legend (Soil Survey Division Staff 1993; Lin *et al.* 2005). These inclusions reduce the homogeneity or purity of the map units and often affect the interpretation or modelling. However, soil surveys traditionally have lacked appropriate sampling designs to present quantitative estimates regarding spatial variability within and across the map units. Quantification of map unit purity for different scales of soil maps is an area needing improvement in modern soil surveys (Arnold & Wilding 1991; Lin *et al.* 2005).

Soil maps formed mapping units. The map units include the slope, micro relief, top soil texture, etc. phases. The quality of a soil map is a function of reliability, relevance, and presentation of the information. Purity and homogeneity can be characterised by the reliability of information in a map (Beckett & Webster 1971; Bie & Beckett 1973; Marsman & De Gruijter 1986; Salehi *et al.* 2003). Soil surveys vary greatly in the accuracy, detail, complexity, and the type of output. The purity of soils in mapping units heavily depends upon the mapping scale, intensity of sampling, quality of soil description, and the presence of soil landscape relationships. In addition, the purity of soils in the mapping units is a prerequisite for a rational land use and soil management (Oberthur *et. al.* 1996).

Hennings (2002) used GIS to determine the accuracy of coarse-scale land quality maps (1:200 000 and 1:1 000 000), and to evaluate possible improvements by applying different upscaling procedures on fine-scale soil data (1:5 000) in Northern Germany. He found that the taxonomic criterion of the upscaling procedure was irrelevant for the accuracy of the land quality maps at the 1:1 000 000 scales. Hennings (2002) reported that the validity of all these paper conclusions is limited to a certain land quality and a study area characterised mainly by glacial and fluvioglacial sediments. A similar investigation in another soil landscape or that focused on land qualities dependent on soil properties may show completely different results.

Dent & Young (1981) suggested that the differences between the mapping units should be both statistically significant and relevant to the land use or the management. But this is not suitable because the variability differs for each soil property and the range of variability was often irregular (Beckett & Webster 1971; Baker 1978; Bouma *et al.* 1980; Breeuwsma *et al.* 1986). Robertus (1998) pointed out that the presence of short distance, spatially unpredictable variability in loess thickness, presents mapping difficulties that had not been adequately addressed in the published soil surveys and resulted in a low mapping accuracy.

Lin *et al.* (2005) investigated the variability of soil map units and soil properties at multiple scales using two case studies, and demonstrated that the soil spatial variability was a function of the map scale, spatial location, and specific soil properties. They found that the area-weighted mean purity Pm for Order II (1:24 000) soil map, when compared to Order I (1:7 920) delineations, was 51–99% for soil taxonomic units (soil series to order) and 65–85% for the soil properties important for the land management in the respective area (texture, structure, surface thickness, hydrologic group, and drainage class). The corresponding values of Pm for Order IV (1:250 000) map were 24–81% and 60–90% when compared to that of Order II (1:24 000) delineations. Most of the variability (over 50% in most cases) for all three soil properties was at the local point scale, suggesting that a careful examination of short-range soil property variability should not be overlooked. They report that the possible causes of variability ranged from the climate at the basin scale to localised effects of differential infiltration and runoff caused by the differences in the landscape positions and soil characteristics.

The detailed soil maps (1:18 000–1:25 000 scales) and reconnaissance soil maps (1:100 000–1:200 000 scale) are widely used in the land resources assessment studies in Turkey. Detailed soil maps are produced for agricultural applications such as land use planning, land and water management, irrigation, drainage, also non-agricultural applications such as forest management, selecting of urban, road, and dam areas and estimating the construction materials. This is also useful in relating areas of similar soils for transferring technology and exchanging the research results.

The quality of the soil maps and the accuracy of the output data depend on the methodological changes and mapping techniques. The smallest unit (polygon) of the reconnaissance soil maps is identified in more detail in detailed soil maps. Besides, a unit of, reconaissance soil map is divided into sub units as mapping unit in detailed soil maps.

In Turkey, all nationwide thematic maps based on the 1:200 000 scale were produced by the General Directorate of Rural Services. More detailed soil surveys and maps covered only limited areas that have a high agricultural potential. Therefore, the reconnaissance soil maps were used in many studies because of being obligatory though not suitable.

In this study, the quality was investigated of reconnaissance soil maps (1:200 000 scale) widely

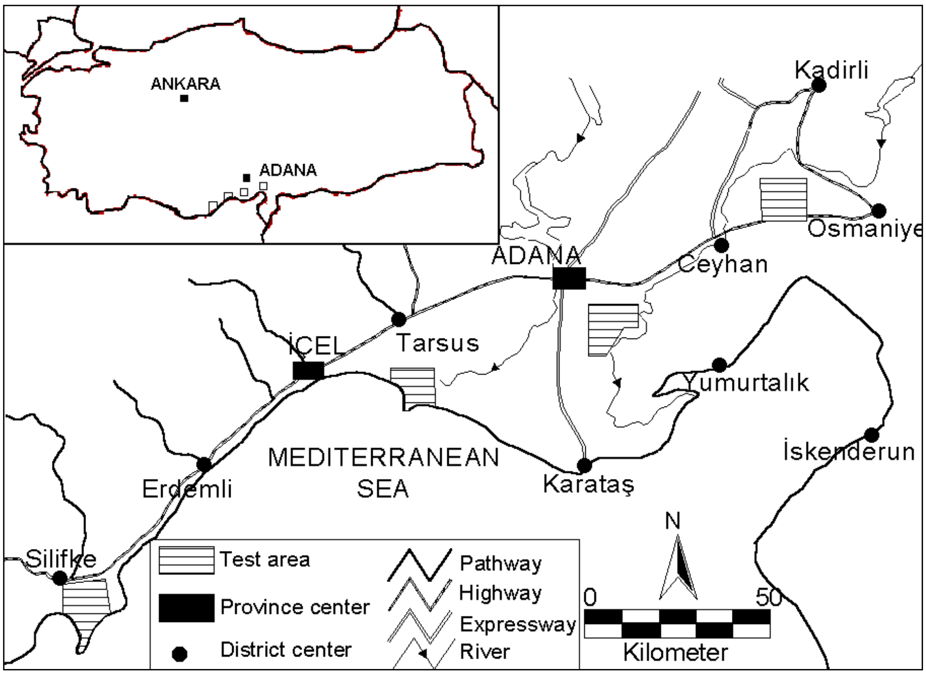

Figure 1. Location of the study area and the test area

used as basic maps in many studies including the land use planning assessment in Turkey. For this purpose, two different soil maps at the scale of 1:200 000 and of 1:25 000 belonging to the same areas were compared to determine the accuracy of the reconnaissance soil maps for boundaries and homogeneities.

Alluvial soils include 590 million ha in the earth. This is not very much but all of them are used as agricultural necessity (Kellog & Ordeval 1969). Alluvial soils are also very important for Turkey. Therefore a specific evaluation of alluvial, soils is explained in this article.

MATERIAL AND METHOD

In this study, two different soil maps prepared by different institutes at the scales of 1:200 000 and 1:25 000 covering identical areas, were compared with the aim to determine the accuracy of reconnaissance by using GIS technology.

The reconnaissance soil maps (1:200 000 scale) of the Soils of Ceyhan Basin (Anonymous 1973) and the Soils of East Mediterranean Basin (Anonymous 1974), and detailed soil maps of Ceyhan Plain (Özbek *et al.* 1981), Çukurova Plain (Dinç *et al.* 1990), and Silifke Plain (Özus 1988) were used

Table 1. Geographic positions and main soil types of the test areas

Test area	Location	Geographic position	Total area (ha)	Soil types
A1	Silifke plain	36°16'00"–36°24'30" N. latitude 33°52'30"–34°04'30" W. longitude	26.573	Alluvial plain, coastal dune, reddish brown mediterranean soil
A2	between Mersin Tarsus	36°48'00"–37°00'00" N. latitude 34°50'00"–35°00'00" W. longitude	13.650	Alluvial, coastal dune, lake
A3	southeast of Adana 20 km	36°50'00"–36°54'00" N. latitude 35°20'00"–35°30'00" W. longitude	21.226	Alluvial, reddish brown mediterranean soil
A4	northwest of Osmaniye 30 km	37°05'00"–37°13'00" N. latitude 35°55'00"–36°10'00" W. longitude	14.605	Alluvial, brown forest soil

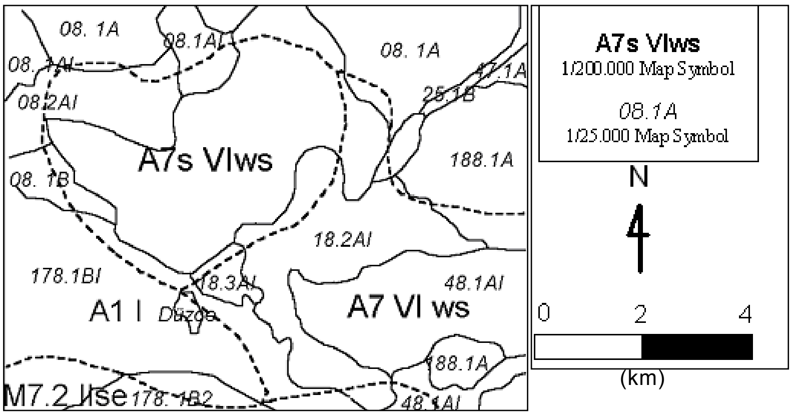

Figure 2. Reconnaissance and detailed soil map of a part of A4 test area

as the basic cartographic material. To compare these maps, four test areas (A1, A2, A3, and A4) were selected from the reconnaissance maps. The locations and soil types of the test areas are given in Table 1. Each test area is formed by different soil units and landscape (Figure 1).

The study has three main steps; digitising-creating a database, converting to the data and comparing to the map layer. In the first step, all soil boundaries in each test area were digitised using ARC/INFO (GIS software) by A0 digitised. This digital layer was the projection in the UTM, WGS 84, zone number 36.

This data set includes the slope, depth, top soil texture, subsurface texture, drainage, and salinity. In the second step, some data of the detailed map were associated to compare as much as the level of the reconnaissance soil map in this data set. For example, the units of clay, sandy clay, and silty clay identified in the detailed soil map were associated in a border called fine texture in the reconnaissance map. In the third step, these layers were compared by using GIS technology (ARC/MAP) in the mean of the mapped soil properties and land characteristics such as the slope, depth, texture, topsoil texture, salinity and drainage. Thus the conformity of the soil maps for the soil properties investigated was determined. The analysis of variants was performed on the slope, depth, texture, topsoil texture, salinity, and drainage data using the SAS software (1998). The means were compared using LSD test at the 0.05 probability level. The overlapped maps layers for a part of A4 test area is shown in Figure 2 (for the purpose of comparison, both maps have been overlapped).

RESULTS AND DISCUSSION

When the reconnaissance soil map (1:200 000) is compared to the detailed soil map (1:25 000) as to the selected soil properties and land characteristics in a four-test area, the slope is the least variable characteristic. On the other hand, the reconnaissance soil map at the scale of 1:200 000 has the

Table 2. The conformity of maps for soil properties in test area

Compared properties	Conformity of maps for test areas (%)				
	A1	A2	A3	A4	average values
Slope	98	90	95	98	95.3 a*
Depth	72	89	93	90	86.0 a
Salinity	56	57	84	61	64.5 b
Texture	77	26	65	77	61.3 bc
Drainage	67	47	71	55	60.0 bc
Top s. texture	57	26	56	46	46.3 c
Average	71.2	55.8	77.3	71.2	68.9

*Means followed by the same columns are not significantly different at the $P = 0.05$ level.

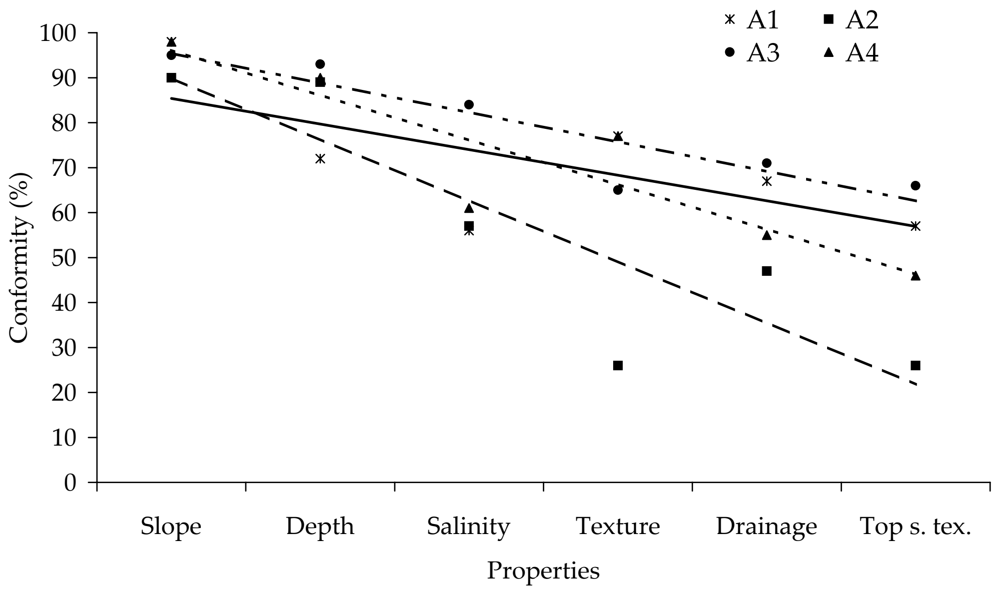

Figure 3. The conformity ratios of maps for selected properties in A1, A2, A3 and A4 test area

highest accuracy in the slope. The accuracy of other properties is followed in the descending order of: slope > depth > salinity > subsurface texture > drainage > top soil texture. The conformity ratio of the properties investigated is given in Figure 3.

The conformity ratio of the arithmetic mean and the associated value of four-test area is followed in the descending order as in (Figure 4). The conformity ratios of the maps for the slope in A1, A2, A3 and A4 test areas were found, respectively, to be 98, 90, 95, and 98%. The conformity ratios of the maps for the depths in same test areas were found to be 72, 89, 93, and 90%, respectively. However, the conformity ratios of other soil properties were not as high as the ratios of the slope and depth. Especially the conformity ratio of the maps for the top soil texture was of minimal value. The conformity ratio of the soil properties investigated is shown in Table 2.

Some properties of the soil in the test area affected the accuracy of the reconnaissance soil map (1:200 000 scales). The accuracy of the reconnaissance soil map (1:200 000 scale) increased with the increasing amount of fine aggregates in the

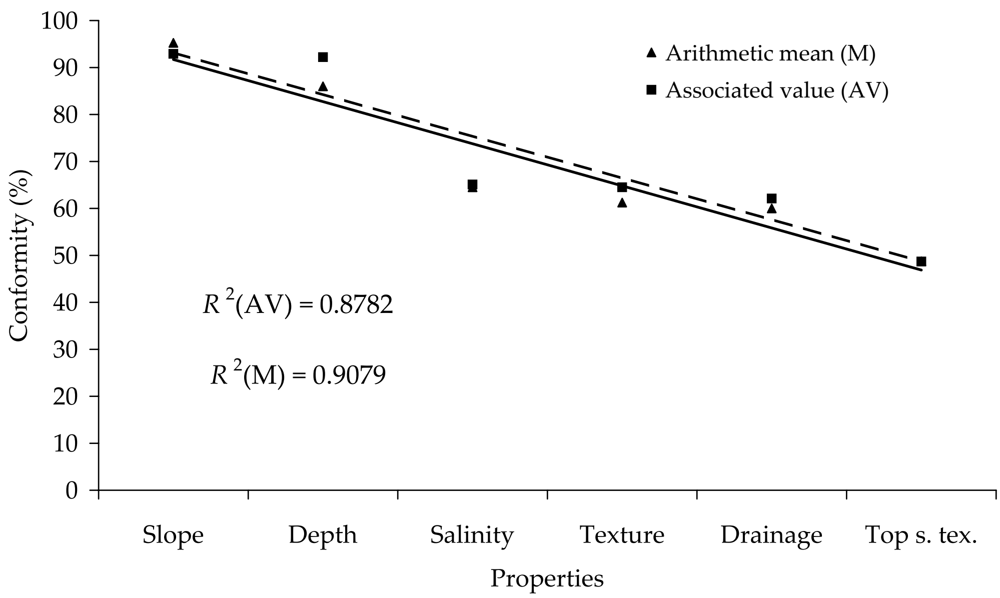

Figure 4. The conformity ratio of arithmetic mean and associated value for four-test area for selected properties

Table 3. The accuracy percentage of the reconnaissance soil map due to the detailed soil map in the mean of the subsurface texture, topsoil texture, salinity classes, drainage classes, soil depth and soil slope

Properties	Classes	% area				
		A1	A2	A3	A4	average
Texture	fine	65.19	13.26	69.22	70.91	54.64
	medium	16.87	57.29	17.96	28.97	30.27
	coarse	17.94	29.45	12.83	0.11	15.08
	conformity (%)	77.00	26.00	65.00	77.00	61.25
Topsoil texture	fine	43.43	17.75	55.39	54.30	42.72
	medium	43.77	56.50	40.76	45.54	46.64
	coarse	12.80	25.75	3.86	0.16	10.60
	conformity (%)	57.00	26.00	56.00	46.00	46.25
Salinity	non	75.54	69.26	100.00	77.06	80.47
	slightly	18.52	14.42	0.00	6.16	43.10
	strongly	5.93	16.32	0.00	16.78	9.76
	conformity (%)	56.00	57.00	84.00	61.00	64.50
Drainage	well drained	36.71	37.27	78.07	45.12	49.29
	moderately well drained	49.05	21.70	20.31	49.11	35.04
	poorly drained	12.70	20.91	1.61	5.76	10.25
	high water table	1.53	20.12	0.00	0.00	5.41
	conformity (%)	67.00	47.00	71.00	55.00	60.0
Depth	shallow	0.03	0.09	6.89	2.40	2.35
	moderately shallow	0.86	0.67	4.00	3.43	2.24
	moderately depth	1.24	0.58	1.40	5.02	2.06
	depth	97.88	98.66	87.71	89.24	93.37
	conformity (%)	72.00	89.00	93.00	90.00	86.0
Slope	nearly level	87.00	97.60	91.38	88.15	91.03
	gently	12.97	1.77	7.96	9.11	7.95
	moderately	0.03	0.63	0.22	2.61	0.87
	strongly	0.00	0.00	0.43	0.13	0.14
	conformity (%)	98.00	90.00	95.00	98.00	95.25

profile and surface in the test area. The accuracy of the reconnaissance soil map (1:200 000 scale) decreased when the amount of salty soil in the test area increased. It was found that the changes in the amount of drainage, depth, and slope in the test areas did not affect the conformity of the soil maps. The conformity ratio of all properties investigated are given in Table 3.

Although the soils of the test area selected in this study are formed by alluvial plain, coastal dune, reddish brown Mediterranean soil, and brown forest soil, the dominant soil type is alluvial.

As to the soil properties investigated, a relationship exists between the accuracy of the reconnaissance soil map and the soil type (Table 4). The accuracy of the reconnaissance soil map (1:200 000 scale) increased when the amount of alluvial soils in the test area increased.

When the accuracy of the reconnaissance soil map (1:200 000 scale) was investigated using only

Table 4. Soil types and amounts in test areas

Test area	Total area (ha)	Soil order and amount			Conformity (%)
		soil types	area (Da)	area(%)	
Area 1	26.573	Alluvial plain	21.560	81	71.2
		coastal dune	3.467	13	
		reddish brown mediterranean	1.546	6	
Area 2	13.650	Alluvial	10.740	79	55.8
		coastal dune	1.682	12	
		lake	1.229	9	
Area 3	21.226	Alluvial	20.366	96	77.3
		reddish brown mediterranean	0.861	4	
Area 4	14.605	Alluvial	14.111	97	71.2
		brown forest soil	0.494	3	

alluvial soils, the conformity ratios of the maps for the slope in A1, A2, A3, and A4 test areas (including, respectively, 81, 79, 96, and 97% alluvial soil) were found to be, respectively, 100.0, 99.2, 95.2, and 92.8%. The conformity ratios of the maps for the depth in A1, A2, A3, and A4 test areas were found to be, respectively, 72.0, 98.3, 92.7, and 92.3%. The conformity ratios of the soil properties investigated, using only alluvial soils, are given in Table 5.

As a result, it has been found that the accuracy of the reconnaissance soil map (1:200 000) with increasing amounts of alluvial soils is related to the slope only, while other properties do not have any effect.

All the results obtained by means of the detailed soil map were more accurate and provided more detailed information than the reconnaissance soil map (1:200 000 scale). The accuracy of the other characteristics followed in the descending order of; slope > depth > salinity > subsurface texture > drainage > top soil texture for A1, A2, A3, and A4 test area, (A1 + A2 + A3 + A4)/4 also ∑(A1 + A2 + A3 + A4). On the other hand, it was found that the reconnaissance soil map at the scale of 1:200 000 revealed the highest accuracy in the slope but lower accuracy in the top soil texture.

These conclusions can be explained by the following:

(1) The standard topographic map was used as the basic map for both the reconnaissance soil map and the detailed soil map,

(2) About 92% of the area under study is formed by nearly level slope,

Table 5. The conformity ratio of investigated soil properties using only alluvial soils

Compared properties	Conformity of maps for Alluvial soils in test area (%)					
	A1	A2	A3	A4	(A1 + A2 + A3 + A4)/4	Value of associated area
Slope	100.0*	99.2*	95.2*	92.8^	96.8* a+	98.0*
Depth	72.0^{-}	98.3*	92.7*	92.3*	88.8* a	95.7*
Salinity	49.0^	57.5*	83.8^	62.0*	63.1^ b	63.7^
Texture	72.5^	16.8^	63.6^	80.1*	58.3^ b	62.4^
Drainage	62.9^	45.5^	69.6^	54.5^	58.1^ b	60.3^
Top s. texture	53.1^	22.5^	54.6^	45.3^	43.9^ b	47.0^
Average	68.3^	56.6^	76.6^	71.2^{-}	68.2^	77.8*

*Increasing value, ^Decreasing value, $^{-}$Not changing value

+Means followed by the same columns are not significantly different at the $P = 0.05$ level.

(3) The slope in the study area is a separated homogenous part.

Two conclusions given above ((2) and (3)) can be related to the accuracy of the depth, because about 92% of the study area is formed by deep soil, and the soil depth of the study area is a separated uniform unit.

The reason for increasing accuracy as determined using only alluvial soil can be referred to alluvial soils formed on homogeny slope and depth (Özbek *et al.* 1981). However, the lower accuracy of A2 test area as compared to other test areas is the result of lakes. There are two small lakes in this test area but these were not plotted as a unit in the reconnaissance soil map (1:200 000 scale). The accuracy of the soil texture and topsoil texture using only alluvial soils is very small.

These findings can be explained by the following:

– Spatial variability of the subsurface texture and top soil texture cannot be defined in sufficient detail for the reconnaissance soil map (1:200 000 scale),
– Moreover, the distance between two auger drillings was 1500 m in the soil survey (Anonymous 1973, 1974),
– Topsoil texture is not defined as a characteristic in the reconnaissance soil map.

Lower accuracy of drainage and salinity in the reconnaissance soil map (1:200 000 scale) is caused by the distance of two auger drillings in the field survey and the basic map. For most properties, the reconnaissance soil map requires much more samples, and the number of samples must increase severely to provide a high degree of precision (Obertur *et al.* 1996; Salehi *et al.* 2003). However, there is no information about drainage and salinity on the topographic map used to produce the reconnaissance soil map (1:200 000 scale). However, the aerial photo used to make a detailed soil map contains the information about drainage and salinity.

This study shows that not only methodological changes and mapping techniques affect the accuracy of the map, but also detailed physiographic and topographic patterns of soils and the basic maps affect the conformity of maps. As a consequence, the reconnaissance soil map (1:200 000 scale) can be used to obtain general information about the respective area but this information is not available as the basic material for planning. In addition, if it is necessary to provide general information from the reconnaissance soil map (1:200 000 scale) for planning, this map can be used to provide information about alluvial soil depth in a nearly level slope. However, it is not suitable to give information on other soil properties and the land characteristics.

As a result, 1:200 000 land quality maps can be improved if based on new or alternative soil maps created by using the soil profiles typical for the respective region or by direct aggregation of finer-scale map units.

References

Anonymous (1973): The Soils of Ceyhan Basin. Report Series No. 69, General Directorate of Rural Services, Ankara. (in Turkish)

Anonymous (1974): Soils of East Mediterranean Basin. Report Series No. 68, General Directorate of Rural Services, Ankara. (in Turkish)

Arnold R.W., Wilding L.P. (1991): The need to quantify spatial variability. In: Mausbach M.j., Wilding L.P. (eds): Spatial Variabilities of Soils and Landforms. SSSA Special Publication 28, Soil Science Society of America, Inc., Madison, 1–8.

Baker F.G. (1978): Variability of hydraulic conductivity within and between nine Wisconsin soil series. Water Resources Research, **14**: 103–108.

Becket P.H.T., Webster R. (1971): Soil variability: a review. Soil Fertility, **34**: 1–15.

Bie S.W., Becket P.H.T. (1973): Comparison of four independent soil series by air photo interpretation, Paphos Area (Cyprus). Photogrammetria, **29**: 189–202.

Bouma J., De Loat P.J.M., Van Holst A.F., Van De Nes Th.J. (1980): Predicting the effect of changing water table levels and associated soil moisture regimes for soil survey interpretations. Soil Science Society of America Journal, **44**: 797–802.

Breeuwsma A., Vleeshoumer J.J., Van Slobbe A.M., Bouma J. (1986): Derivation of land qualities to asses environmental problems from soil survey. Soil Science Society of America Journal, **50**: 186–190.

Dent D., Young A. (1981): Soil Survey and Land Evaluation. George Allen and Unwin, Boston.

Dijkerman J.C. (1974): Pedology as a science: the role of data, models and theories in the study of natural soil systems. Geoderma, **11**: 73.

Dinç U., Şenol S. (1997): Soil Survey and Mapping. Cukurova University Agriculture Faculty No.50, Adana. (in Turkish)

Dinç U., Sari M., Şenol S., Kapur S., Sayin M., Derici M.R., Çavuşgil V., Gök S., Aydin M., Ekinci H., Ağca N., Schlichting E. (1990): The Soils of Cukurova

Region. Cukurova University Agriculture Faculty No. 26, Adana. (in Turkish)

Hennings V. (2002): Accuracy of coarse-scale land quality maps as a function of the upscaling procedure used for soil data. Geoderma, **107**: 177–196.

Kellog C.E., Ordeval A.C. (1969): Potentially arable soils of the world and critical measures for their uses. Advanced Agronomy, **21**: 109–170.

Lin H., Wheeler D., Bell J., Wilding L. (2005): Assessment of soil spatial variability at multiple scales. Ecological Modelling, **182**: 271–290.

Marsman B.A., De Gruijter J.J. (1986): Quality of Soil Maps: a Comparison of Survey Methods in a Sandy Area. Soil Survey Pub. 15, Stiboka, Wageningen.

Oberthur T., Dobermann A., Neue H.U. (1996): How good is a reconnaissance soil map for argonomic purposes. Soil Use Manage, **12**: 33–43.

Özbek H., Şenol S., Dinç U., Kapur S., Güzel N. (1981): The study of Genesis, Physical and Chemical Properties and Classification of Ceyhan Plain Soils, Tubitak-Toag Subunit No. 6 Report, Adana. (in Turkish)

Özus A. (1988): The study of Genesis, Physical, Chemical and Mineralogical Properties and Classification of Silifke Plain Soils. [Ph. Thesis.] Department of Soil Science, Institute of Natural and Applied Sciences, University of Cukurova, Adana. (in Turkish)

Robertus R.A. (1998): Loessial of Delaware: taxonomy and map-unit assessment. Soil Science Society of America Journal, **62**: 412–422.

Salehi M.H., Eghbal M.K., Khademi H. (2003): Comparison of soil variability in a detailed and a reconnaissance map in central Iran. Geoderma, **111**: 45–56.

SAS Institute (1998): INC SAS/STAT Users' Guide Release 7.0. Cary.

Soil Survey Staff (1993): Soil Survey Manual. United States Dept. of Agriculture, Handbook No. 18. Washington.

Received for publication March 13, 2007
Accepted after corrections February 2, 2008

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