ELSEVIER

Agriculture, Ecosystems and Environment 95 (2003) 327–342

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: a case study in northwestern Syria

N. Cools [a,*], E. De Pauw [b], J. Deckers [a]

[a] *Institute for Land and Water Management, Katholieke Universiteit Leuven, Vital Decosterstraat 102, B-3000 Leuven, Belgium*
[b] *Natural Resource Management Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria*

Received 9 August 2001; received in revised form 2 April 2002; accepted 16 April 2002

Abstract

Adaptation of land use to the potentialities and constraints of local agroecologies is a key principle of sustainable land management. Farmers and land resource professionals assess the options that optimise the productivity and sustainable land use through different knowledge systems. Both systems have advantages and drawbacks. Through a case study in a village of northwestern Syria, an approach was developed to integrate the knowledge of both farmers and land resource experts in order to promote adoption of new land use systems. This was done by comparing a farmer-led land suitability assessment (FLSA) with the results of an expert-led land suitability assessment (ELSA) so as to evaluate respective comparative advantages and complementarities. The results of FLSA and ELSA were integrated in a geographical information system (GIS). The farmers compared the results of FLSA and ELSA and their input ELSA was upgraded to suit local circumstances.

Some striking differences came out between FLSA and ELSA, which could be explained by a participatory land evaluation. The farmers' knowledge provided a better understanding of the impact of microclimatic variations on crop productivity. This is an important bonus of the participatory approach because detailed climatic data for long periods are rarely available in most rural communities. The FLSA procedure explained adequately the overriding weight of socio-economic constraints over biophysical opportunities. A constraint in the participatory approach is that useful and interesting indigenous knowledge is often scarce. GIS was instrumental in the correlation of indigenous and expert land units and in the farmers' validation of land suitability. The benefits of this approach to the researchers were clear. The farmers on the other hand highly appreciated the improved communication with the scientists. The better interaction with the farmers will eventually pay off when it comes to adoption of improved management recommendations.

Keywords: Land evaluation; Indigenous knowledge; Soil suitability; Farmer participatory research; GIS; Northwestern Syria

1. Introduction

By experience, often going back for generations, farmers have developed land use systems that are well adapted to the potentials and constraints of their land. To achieve this adaptation they have developed informal systems of land quality appraisal based on

---

[*] Corresponding author. Tel.: +32-16-329721; fax: +32-16-329760.
E-mail address: nathalie.cools@agr.kuleuven.ac.be (N. Cools).

PII: S0167-8809(02)00045-2

observation and experimentation both of which are often very sophisticated and accurate (Chambers et al., 1989). This knowledge that people in a given community have developed over time and continue to develop is defined in literature as ‘indigenous’ or ‘local’ or ‘traditional’ or ‘indigenous technical’ knowledge.

In contrast, resource professionals use methods for land quality evaluation that often perform poorly when it comes to predicting land productivity at parcel level because their approach is largely deductive. Having limited experience of land use sensu strictu, land productivity is assessed on the basis of diagnostic soil properties which are considered to act as limitations to crop growth. Usually this assessment is based on conceptual models of relationships between land characteristics, land qualities and land productivity. These models are often too simple to capture complex relationships (Nordblom et al., 1993). An additional constraint is the high cost of conventional soil surveys and land evaluation to assess land quality at the detailed scales required for land use planning at community level. For this reason land resource professionals and land use planners usually do not fully understand the micro-scale variations within farmer environments and are therefore unable to fine-tune their recommendations to a specific environment.

It is thus quite clear that farmers are the best experts in understanding local environments. They certainly have a comparative advantage to assess land use systems they are familiar with. However, when it comes to adopting new technologies or new management practices, they have few reference points to guide their decisions. It is here that farmers need advice from outsiders. Land resource professionals have the advantage of standardised and systematic methods for characterisation and extrapolation, which are vital to assess where new technologies, developed in one area, are likely to perform well in other locations of comparable ecological setting.

An improved understanding of local variations in land characteristics within the farmers’ environment will allow a more efficient assessment of farming systems constraints and opportunities. Henceforth improved management options will be defined more clearly, which should, in theory, lead to a more rapid and wider adoption. For this to happen, there is an urgent need to develop a language in which farmers and land resource professionals understand each other (Habarurema and Steiner, 1997; Steiner, 1998).

Studies on linking local and scientific soil knowledge have been done by Kundiri et al. (1997) in Nigeria, Sandor and Furbee (1996) and Guillet et al. (1996) in Peru, and Norton et al. (1998) in New Mexico. Little work has been done in west Asia and north Africa. Briggs et al. (1998) studied the choice and management of cultivation sites by Bedouin in upper Egypt. Recently Zurayk et al. (2001) carried out a participatory land capability classification and a land use analysis in a semi-arid mountainous village in Lebanon. All these studies make an attempt to link both farmers’ and expert knowledge. In the Middle East, however no attempt has been made so far to establish a systematic and quantitative link.

In this paper the results of an indigenous land suitability assessment, undertaken by farmers, are compared with those of a conventional land evaluation exercise, undertaken by ‘experts’, in a Kurdish village in northwest Syria. The objectives of the study were to judge to what extent the two approaches are complementary or conflicting, and to explain deviations in results. Another important objective was to use the increased knowledge about local agroecologies, obtained through a participatory approach, for fine-tuning land management recommendations. A third objective was to explore the possibilities of spatial analyses within a geographical information system (GIS) for integrating indigenous and expert knowledge about land resources.

2. Methods and materials

2.1. Environment and agricultural setting

The village Karababa is situated on the foot slopes of rounded limestone hills, on the eastern side of the Kara Su (Black River) valley, which is a graben that can be considered as a northern extension of the Dead Sea Complex (Fig. 1). Thick sheets of quaternary basalts cover most parts of the valley (Protasevich and Maksimov, 1966). The deeper soils in the calcareous hills are mainly Calcaric Cambisols, while the shallower soils are classified as Hypersceletic Leptosols

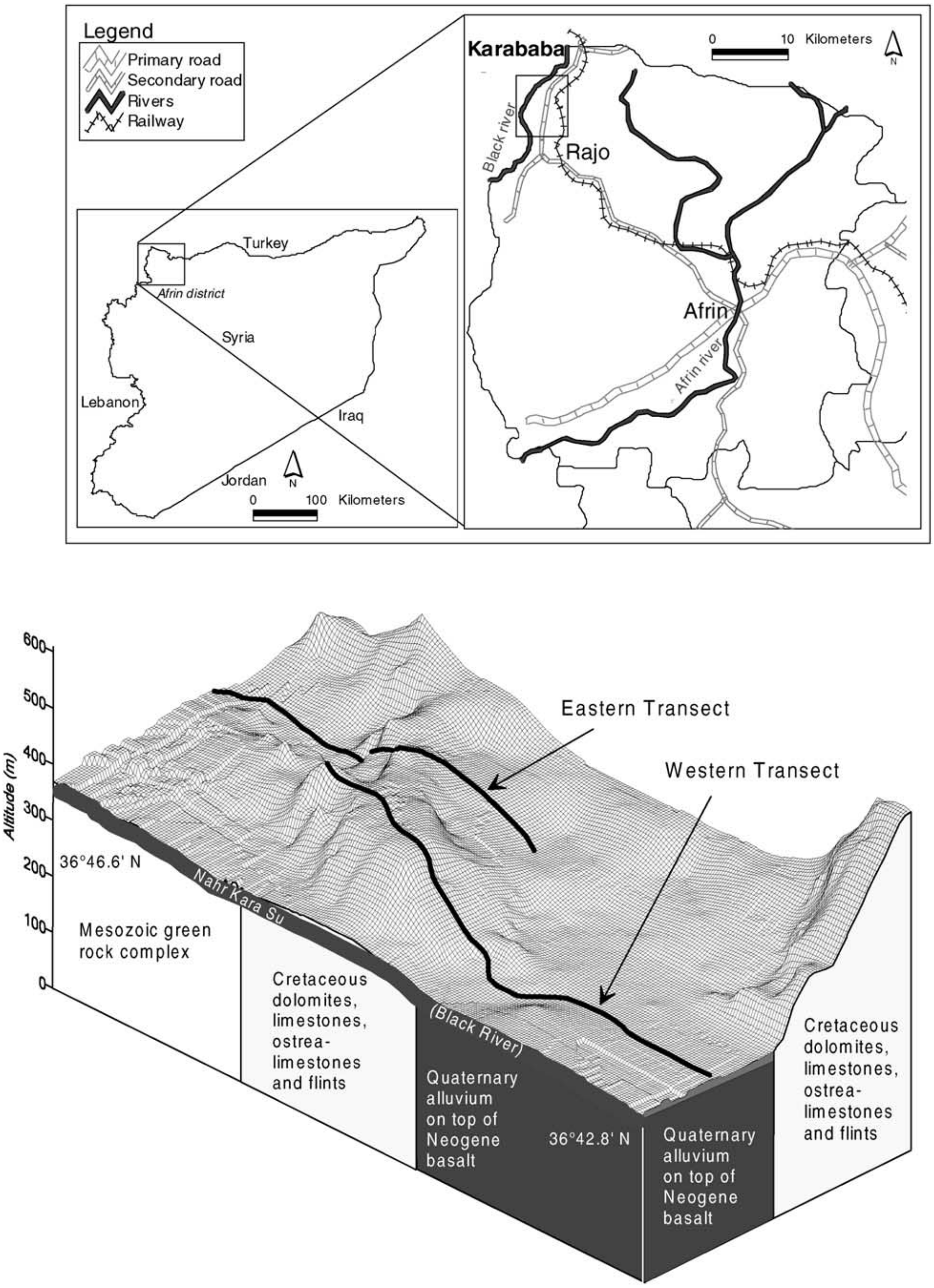


Fig. 1. Location of Karababa and a block diagram showing the topography, geology and the location of the participatory transect walks.

and Leptic Regosols. In the valley Vertic or Chromic Cambisols and Eutric Vertisols are found (FAO et al., 1998). The agricultural land of the village is located on the lower slopes of the limestone hills and in the valley of the Black River. Farmers irrigate the fields in the valley by diverting river water into surface channels. Strategic irrigation is used for some winter crops [especially wheat (*Triticum* spp.)]. Summer

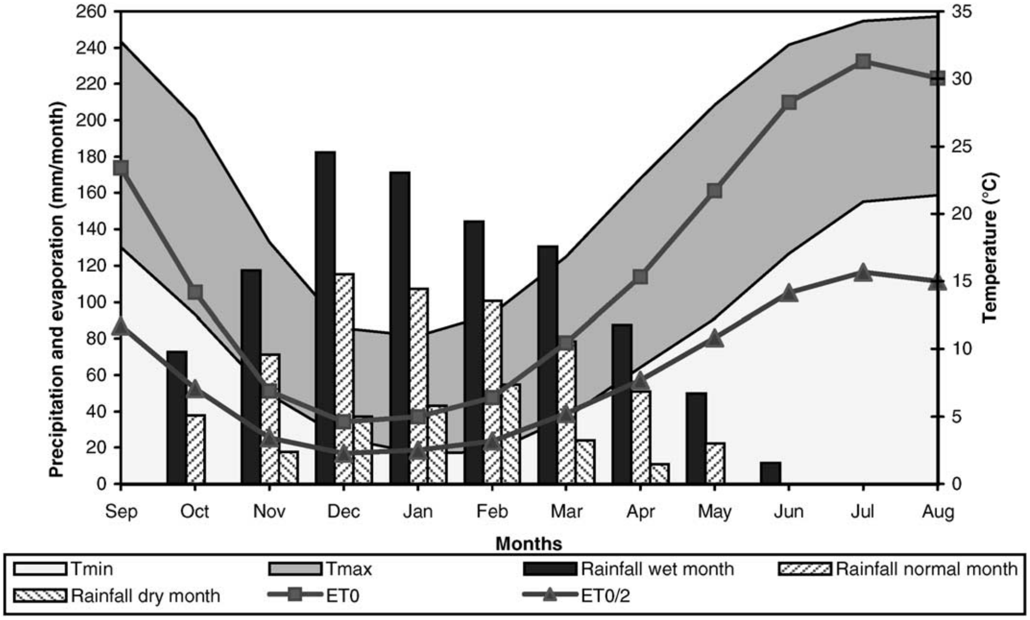


Fig. 2. Climatic diagram.

crops are grown under full irrigation. The lower hill slopes are used for olive (*Olea europaea* L.) orchards while the upper hill slopes are covered by natural forest dominated by evergreen oak (*Quercus coccifera* subsp. calliprinos). Rainfed crops comprise cereals [wheat and barley (*Hordeum vulgare* L.)] and legumes [lentils (*Lens culinaris medikus*) and chickpea (*Cicer arietinum* L.)]. Irrigated areas have a great diversity of winter and summer crops where watermelon (*Citrullus lanatus* (T) Mansf), yellow melon (*Cucumis melo* L.) and sunflower (*Helianthus annuus* L. var. macro) are of great importance. The climate diagram of Fig. 2 illustrates the typical Mediterranean climate with rainy winters and hot dry summers. Interannual variability of precipitation is high.

2.2. Land suitability assessment by farmers and by scientists

A double track approach was followed to compare land suitability as perceived by farmers and through expert judgement. The approach is outlined in Fig. 3, which shows the main steps in both the farmer-led land suitability assessment (FLSA) and the expert-led land suitability assessment (ELSA).

2.2.1. FLSA

During spring 1999, an FLSA was recorded by means of participatory mapping and transect walks, field visits, individual interviews and ranking exercises. Arabic was the communication language. Initially, with the help of a few farmers, a map of the ‘indigenous’ land units was drawn and geo-referenced, based on an enlargement of the topographical map at 1:50,000 scale (Ministry of Land Registration, 1992). Gradually, during visits of other farmers’ fields, the map was completed and reviewed several times together with the farmers. Eventually these ‘indigenous’ land units served as a basis for detailed discussion on soils. Sixteen farmers, between the age of 30 and 82 years, participated in detailed individual interviews which varied in style and format. Both formal (structured questionnaire) and informal (semi-structured and unstructured) interview techniques were used to collect information about soil types within the farmers’ land-holding and farmers’ decision making with regard to crop and soil management. A ranking exercise of local soil types according to their suitability for agriculture was conducted. During transect walks farmers marked the boundaries between different soil types, described each soil type and discussed land

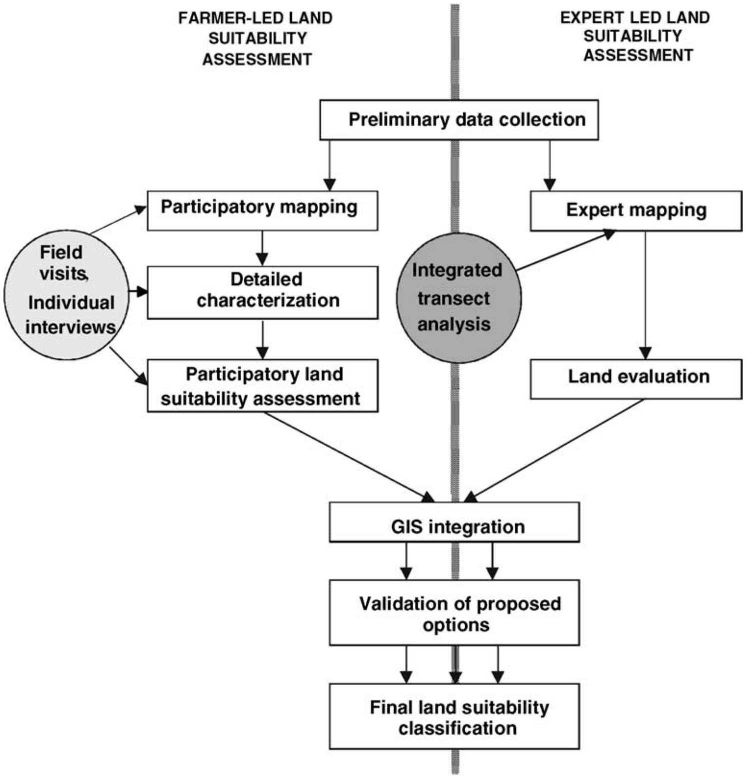


Fig. 3. Steps in farmer-led and expert-led land suitability assessment.

use, land cover and physiography. Boundary positions were measured with a Trimble-Scoutmaster GPS to enable a link between the farmers' knowledge and the soil survey that was conducted in a subsequent phase.

An important tool in both FLSA and ELSA for understanding the variations of soil properties across landscapes and for capturing the perceptions of farmers about land quality and management properties is the integrated transect analysis (ITA). This tool (Gobin et al., 1998) combines biophysical surveying techniques and participatory research methods along toposequences. Seven sites were described along two participatory transects, which went across the main slope gradients of the landscape (Fig. 1).

2.2.2. ELSA

The ELSA included two main steps: formal land unit delineation and land evaluation. An 'expert' land unit map was compiled by combining the geological map of Aleppo (V.O. Technoexport, 1963), the topographical map of Rajo (Ministry of Land Registration, 1992), and data collected in the ITA. The toposequences were measured using a clinometer, altimeter, compass and a GPS. The representative positions of the soil profiles along the toposequences were selected based on locations indicated by farmers during the transect walk. The limits of the soil units were determined by means of additional augerings between the soil profile pits. The profiles were described according to a slightly modified version of the FAO guidelines for soil description (FAO, 1990) and soil colours were determined using the Munsell soil color chart (Munsell, 1954). From each horizon, soil samples were taken, air-dried, ground and passed through a 2 mm sieve. Soil sample analyses were done on the fine earth fraction (<2 mm) according to the standards used at International Center for Agricultural Research in the Dry Areas (ICARDA) (Ryan et al., 1996). The soil profiles were classified according to the world reference base (WRB) for soil resources classification system (FAO et al., 1998).

The methodology for land evaluation developed by Sys et al. (1991) was applied, including a separate climatic and soil suitability assessment for important current or potential crops to be grown in the area. This method assesses the fitness of land for a defined use in terms of comparative suitability and passes through three stages.

The first stage is the establishment of climatic and soil requirements for the relevant crops. This is done by means of a crop requirements table, which translates climatic and soil characteristics into rankings, indicating the degree of limitation for a particular crop. An example of a soil requirements table for olive is given in Table 1. Crop requirement tables are established by combining information sources from literature. The main sources used in this study are Duke et al. (1993), Ecocrop (FAO, 1994), Katsoyannos (1992), Landon (1991), Sys et al. (1993) and personal communications with specialists of ICARDA. A similar requirement table is made for the climatic requirements regrouped in four groups according to their relation to radiation, temperature, rainfall and relative air humidity.

Table 1
Soil requirements of olive (*O. europaea* L.) ordered according to five limitation levels (0–4)[a]

Land characteristics	Degree of limitation				
	0	1	2	3	4
Topography (t)					
Slope[b] (%)					
(1)	0–1	1–2	2–4	4–6	>6
(2)	0–4	4–8	8–16	16–25	>25
(3)	0–8	8–16	16–30	30–50	>50
Wetness (w)					
Flooding[c]	F0	–	–	–	F1+
Drainage	Good, groundw. >150 cm	Good, groundw. 100–150 cm	Moderate	Imperfect	Poor
Physical soil characteristics (s)					
Texture/structure[d]	L, SCL, SL	SC, SiL, SiCL, Si, CL, LfS, LS, Si	C<60s, LfS, C>60s, fS	Cm, SiCm, cS	–
Coarse fragments (vol.%)	0–15	15–35	35–55	55–75	>75
Soil depth (cm)	>150	150–120	120–100	100–80	<80
$CaCO_3$(g/kg)	Any				
Gypsum (g/kg)	0–100	100–150	150–200	200–250	>250
Soil fertility characteristics (f)					
Apparent CEC (cmol(+)/kg clay)	>24	24–16	<16 (−)	<16 (+)	–
Base saturation (%)	>80	80–50	50–35	<35	–
Sum of basic cations (cmol(+)/kg soil)	>8	8–5	5–3.5	3.5–2	<2
pH (H_2O)	7.2–7.0	7.0–6.2	6.2–5.8	5.8–5.5	<5.5
	7.2–7.5	7.5–8.0	8.0–8.2	8.2–8.5	>8.5
Organic carbon (g/kg)	>15	15–8	8–4	<4	–
Salinity and alkalinity (n)					
ECe (dS/m)	0–2.7	2.7–3.8	3.8–5.5	5.5–8.4	>8.4
ESP (%)	0–15	15–25	25–35	35–45	>45

[a] Limitation level: 0: no limitations; 1: slight, 2: moderate, 3: severe and 4: very severe limitations.

[b] (1): Irrigated agriculture basin furrow irrigation; (2): high level of management, full mechanisation; (3): low level of management, animal traction or handwork.

[c] F0: no flooding; F1+: 5 cm water or more for at least 2–3 days a year.

[d] L: loam; SCL: sandy clay loam; SL: sandy loam; SC: sandy clay; SiL: silt loam; SiCL: silty clay loam; Si: silt; LfS: loamy fine sand; LS: loamy sand; C<60s: clay <600 g/kg, well-structured; C>60s: clay >600 g/kg, well-structured; fS: fine sand; Cm: massive clay; SiCm: massive silty clay; cS: coarse sand.

The second stage is exploring the match between selected land requirements per crop with corresponding land characteristics as defined during the scientific land survey. The sufficiency of each land characteristic is expressed in a limitation rating (0–4).

In a third stage, the various limitations are converted to a qualitative indication (land classes) of the suitability of the land for the defined use, which is the final output of the land evaluation procedure. Land classes are defined according to the number and the intensity of the limitations. For each group of climatic characteristics, the most severe limitation is considered to determine the climatic suitability class.

Using this approach the suitability of 22 crops, six rainfed [olive, chickpea, barley, wheat, lentil and grape (*Vitis vinifera* L.)] and 16 irrigated crops [citrus (*Citrus* ssp.), cotton (*Gossipium hirsutum* L.), green beans (*Phaseolus vulgaris* L.), green pepper (*Capsium annuum* L.), groundnut (*Arachis hypogaea* L.), maize (*Zea mays* L.), onion (*Allium cepa* L.), potato (*Solanum tuberosum* L.), safflower (*Carthamus tinctorius* L.), sesame (*Sesamum indicum* L.), sorghum (*Sorghum bicolor* (L.) Moench), sugar beet (*Beta vulgaris* L.), sunflower, tobacco (*Nicotiana tabacum* L.), tomato (*Lycopersicon esculentum* M.), and watermelon] was assessed.

2.3. Practical implementation of a GIS and validation by the farmers

From the investigations outlined above, products arose which were spatial and non-spatial in character. The maps produced during the indigenous knowledge studies and soil surveys were digitised, labelled and linked with tabular data and recorded soil data within the GIS.

A spatial map overlay of the 'indigenous' and 'expert' land unit maps was carried out using the software package Arcview GIS version 3.1 (Environmental Systems Research Institute, 1998). The dominant 'indigenous' and 'expert' soil type in each of the land units were compared. In each 'indigenous' land unit, the relative areas of the prevailing 'expert' soil types were calculated. Through the link established by the integrated transect analysis between the 'expert' and 'indigenous' soil types, the 'indigenous' land unit map was validated with the information obtained from the individual interviews. Experts explained to the farmers what suitable options were identified for each major local land unit and farmers commented. This step led to the revision of the classification and necessitated changes in the final recommendations.

3. Results

3.1. FLSA

The different areas within the village have their local names, often Kurdish or Turkish in origin, which are used on a daily basis by all the villagers, including the children. The farmers mapped 63 local land units and distinguished three major soil types on their fields: red (*Turba hamra*), black (*Turba soda*) and white (*Turba byda*) soils based on soil colour. The red soil is the best type, especially to grow olives. On the black soils near the river, all crops grow well but irrigation is needed. The white soils retain less water than the black and the red soils, are easy to cultivate, dry fast after rain but become very smooth and easily erodable when wet. They are often located on steep slopes and consequently difficult to work and are only suitable for trees like olives and grapes. Next to these three main soils, there is a soil type called '*Kraaj*' which is gravely and does not retain much water, is often stony and is rated poorly for agriculture.

3.2. ELSA

A map with the 'expert' land units was compiled by combining data from transect surveys with topographical and geological coverages (V.O. Technoexport, 1963) and with field observations in other parts of the village (Fig. 4). In total nine land units were separated on the basis of geology, landform and broad soil types. A division was made in landforms that originate from sedimentary cretaceous and in igneous parent material. On the limestone hills three land units were differentiated: upper hill slopes (Hc1), mid slopes (Hc2), colluvial foot slopes (Hc3) and steep hill slopes (Hc4). Soils developed in these land units know a large variation in soil depth. Another set of hills consists of ultrabasic rocks, mainly peridotites and serpentinites, that give origin to different soil types on three land units: undulating hill slopes (Hv1), steep hill slopes (Hv2) and slightly sloping foot slopes (Hcv). The

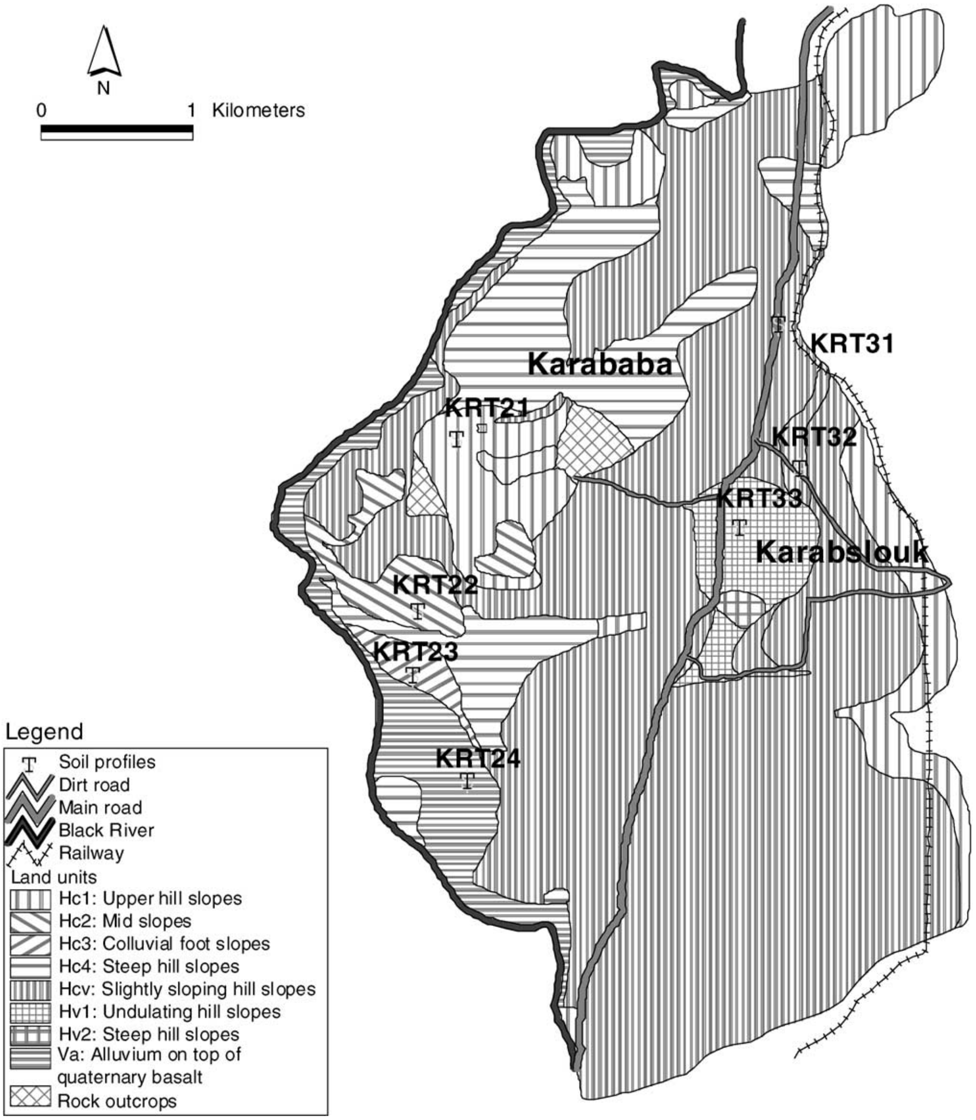
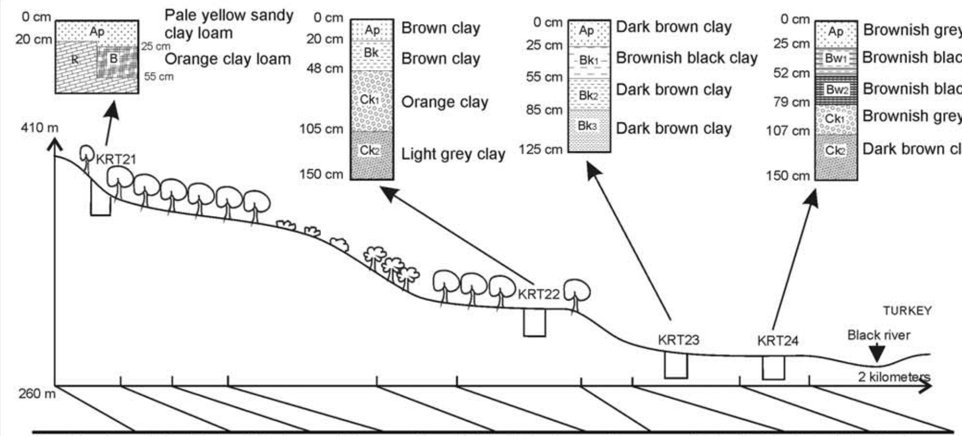


Fig. 4. 'Expert' land units in Karababa.

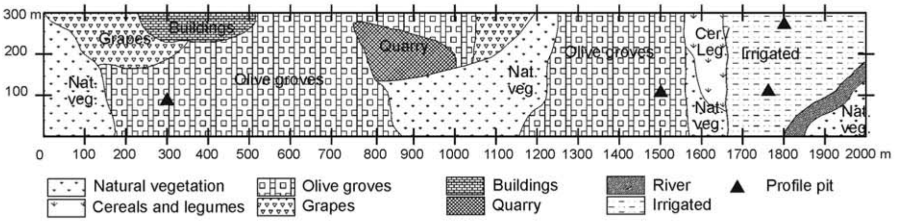
valley floor consists of alluvium on top of quaternary basalts (Va).

The integrated transect analysis was the basis for understanding the position of different soil types in the landscape. The agro-ecosystem diagrams of the two transects with the 'indigenous' soil names, their english translation and the corresponding scientific soil classification following WRB (FAO et al., 1998) are presented in Figs. 5 and 6. Textural and chemical properties of the topsoil of the seven profiles (Table 2) are all very similar except for profiles KRT21 and KRT33, which are shallow, eroded and rather sandy.

The result of the land suitability classification is presented in Tables 3 and 4. The 'expert' climatic evaluation indicates that rainfall during critical months may be a slight to moderate limitation, and therefore rainfed crops, with the exception of barley, will benefit from extra rainfall during well-defined growth stages. However, often temperature is below the optimal range, resulting in a moderate to severe limitation. Low



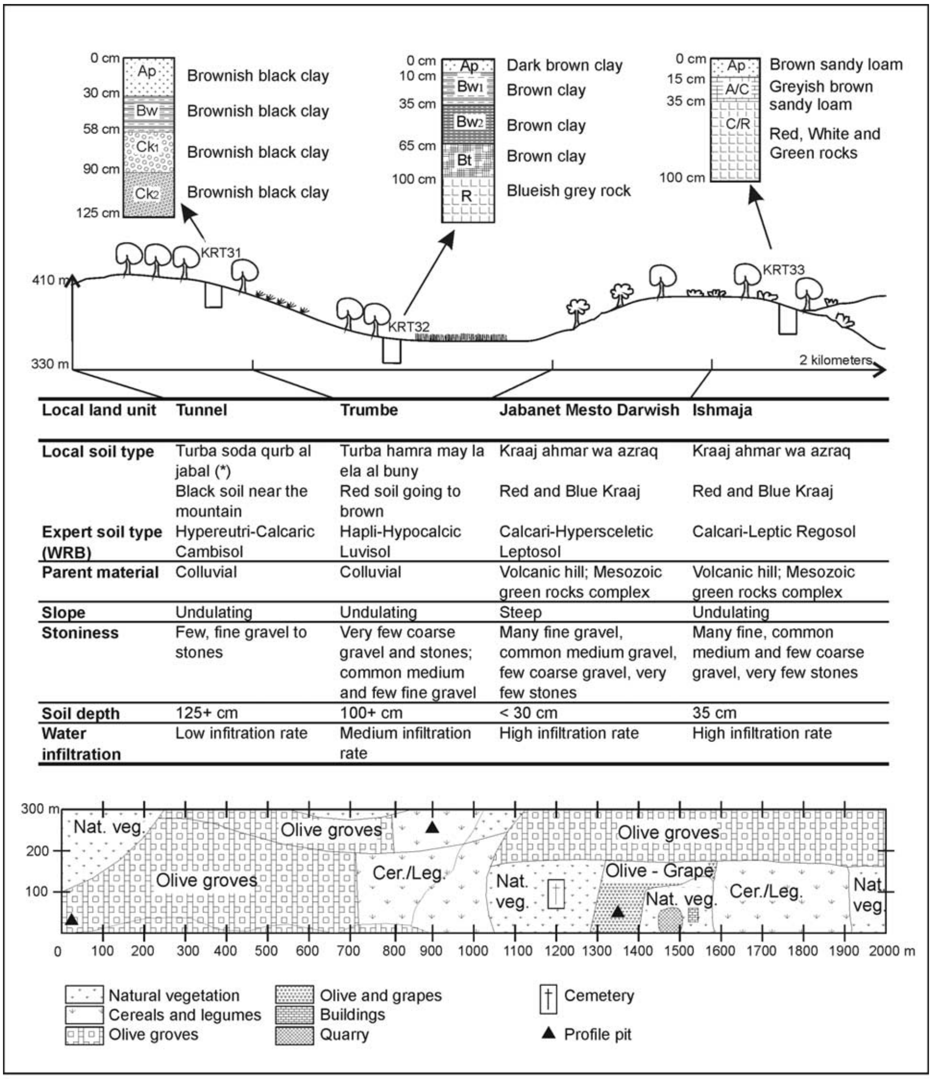
Local land unit	Sultan Soite	Chorbe Korte	Heir	Kane Hatch Bilil	Riche Jenta	Sara Koske	Koche Gulek	Arde Kojo	Koch Botoon
Local soil type	Turba byda (*)	Turba byda wa hamra	Turba byda wa hamra	Turba hamra may la ela al buny	Kraaj asfar	Turba hamra	Kraaj asfar	Turba biniyya ghamiqa	Turba soda qurb al nahr
	White soil	White with red soil	White with red soil	Red soil going to brown	Yellow Kraaj	Red soil	Yellow Kraaj	Dark brown soil	Black soil near the river
Expert soil type (WRB)	Calcari-Hypersceletic Leptosol	Calcaric Regosol	Chromi-Calcaric Cambisol	Hypereutri-Calcaric Cambisol	Calcari-Hyperskeletic Leptosol	Chromi-Calcaric Cambisol	Calcari-Hyperskeletic Leptosol	Hypereutri-Calcaric Cambisol	Hypereutri-Calcaric Cambisol
Parent material	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Colluvium	Alluvium on top of basalts
Slope	Steep	Very steep	Undulating	Undulating	Steep	Undulating	Steep	Almost flat	Almost flat
Stoniness	Few, fine gravel and stones, many medium and coarse gravel	Few rock outcrops, common stones	Many stones and gravel	Very few medium and few coarse gravel, common stones	15% rock outcrops, many coarse fragments	Very few medium and few coarse gravel, common stones	Many coarse fragments	Very few boulders, few fine and common medium gravel and stones	Very few coarse, few medium gravel and stones
Soil depth	20 to 55 cm	50 cm	90 cm	85 cm	15 cm	150+cm	20 à 25 cm	125+ cm	150+cm
Water infiltration	Very high infiltration rate	Rapid runoff	Humidity increases with depth	High infiltration rate	Rapid runoff	High infiltration rate	Rapid runoff	Medium infiltration rate	Low infiltration rate



(*) Transliteration: Modified Encyclopedia of Islam (Brill, 1999)

Fig. 5. Agro-ecosystem diagram of transect in west Karababa (Brill, 1999).

temperatures are more serious for chickpea and wheat than for barley. Lentil prefers higher temperatures at germination and the absolute minimum temperature may cause frost damage to olive trees. For all the irrigated crops considered in the climatic suitability assessment, additional water during the growing season is essential and assumed to be available. Temperatures outside the optimal range pose very severe limitations to watermelon and citrus and severe limitations to tomato and onion. Relative humidity is



Local land unit	Tunnel	Trumbe	Jabanet Mesto Darwish	Ishmaja
Local soil type	Turba soda qurb al jabal (*) Black soil near the mountain	Turba hamra may la ela al buny Red soil going to brown	Kraaj ahmar wa azraq Red and Blue Kraaj	Kraaj ahmar wa azraq Red and Blue Kraaj
Expert soil type (WRB)	Hypereutri-Calcaric Cambisol	Hapli-Hypocalcic Luvisol	Calcari-Hyperesceletic Leptosol	Calcari-Leptic Regosol
Parent material	Colluvial	Colluvial	Volcanic hill; Mesozoic green rocks complex	Volcanic hill; Mesozoic green rocks complex
Slope	Undulating	Undulating	Steep	Undulating
Stoniness	Few, fine gravel to stones	Very few coarse gravel and stones; common medium and few fine gravel	Many fine gravel, common medium gravel, few coarse gravel, very few stones	Many fine, common medium and few coarse gravel, very few stones
Soil depth	125+ cm	100+ cm	< 30 cm	35 cm
Water infiltration	Low infitration rate	Medium infiltration rate	High infiltration rate	High infiltration rate

(*) Transliteration: Modified Encyclopedia of Islam (Brill, 1999)

Fig. 6. Agro-ecosystem diagram of transect in east Karababa (Brill, 1999).

often above optimal, which poses moderate limitations to the production of citrus. The day length is below optimum for autumn potato and sugar beet.

Radiation is above optimum for onion and for maize during the second month (development stage). The land suitability was assessed for nine ‘expert’ land units of Fig. 4. The shallow and rocky areas of the upper hill slopes (Hc4 and ‘rock outcrops’) are considered unsuitable for most types of agricultural activities or only marginally suitable for lentil or grape. For the rainfed crops the climatic factors are often more limiting than the soil factors. The foot slopes of the calcareous hills (Hc3) and the hill slopes with mixed limestone and volcanic parent material (Hcv) would be moderately suitable for olive if the risk for frost damage was lower. The land unit Hc3 would be very suitable and Hcv and the valley floor (Va) moderately suitable for wheat but irrigation is needed for optimal production. Based on limits posed by the slope, the

Table 2
Textural and chemical properties of the topsoil of the seven ELSA profiles

Profile Id[a]	Depth (cm)	Clay (g/kg)	Silt (g/kg)	Sand (g/kg)	pH (H_2O)	EC (1:1) (dS/m)	Olsen-P (mg/kg)	Total-N (mg/kg)	OC (g/kg)	$CaCO_3$ (g/kg)	Na^+ (10^{-2} cmol/kg)	K^+ (10^{-2} cmol/kg)	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)	TEB (cmol/kg)	CEC clay (cmol(+)/kg)
KRT21	0–20	280	210	520	8.4	0.16	4.0	635	5	480	0.17	13	13.9	0.01	14.0	79
KRT22	0–20	560	250	180	8.4	0.21	8.8	1115	12	330	2.8	129	22.6	0.29	24.2	72
KRT23	0–25	640	210	150	8.1	0.36	7.7	1110	11	100	18	74	24.4	5.21	30.4	63
KRT24	0–25	610	190	210	7.6	0.44	28.6	1122	11	80	33	74	13.1	13.3	27.1	80
KRT31	0–30	550	200	250	7.9	0.27	4.9	796	7	20	13	62	20.6	3.75	25.0	89
KRT32	0–10	590	260	150	7.2	0.20	4.0	1018	11	30	6.0	87	14.8	7.10	22.7	70
KRT33	0–15	170	200	630	8.4	0.18	9.8	529	5	130	2.8	46	21.3	0.41	22.2	219

[a] See Fig. 4 for profile location.

Table 3
'Expert' suitability assessment of the climate in Karababa for rainfed crops[a]

	Climatic suitability class
Olive trees	S3: climate with one moderate (monthly rainfall during sclerification of stone) and one severe limitation (average absolute minimum temperature of coldest month)
Chickpea	S2: climate with one slight (temperature) and one moderate limitation (rainfall) but crop can make use of stored water in soil profile, built up in winter
Barley	S2: climate with one slight (rainfall above optimum) and one moderate (temperature of flowering stage) limitation
Wheat	S3: climate with one slight (mean temperature of growing cycle) and one severe limitation (rainfall at ripening stage). Irrigation is desirable
Lentil	S2: climate with three moderate limitations (annual rainfall, temperature at germination and radiation)
Grape	S2: climate with two moderate limitations (annual rainfall and radiation)

[a] S2: moderately suitable; S3: marginally suitable.

evaluation for irrigated crops was only carried out for the mid and foot slopes of the calcareous hills (Hc2 and Hc3), the valley floor (Va), and the hill slopes with mixed limestone and volcanic parent material (Hcv). The latter pose severe limitations to irrigation and make this land only marginally suitable for irrigation. On the calcareous mid slope (Hc2), the slope poses moderate limitations for irrigation, though there are no wells in this land unit and abstraction of water from the river is impossible in view of the relative higher altitude.

The evaluation is more important for the land in the valley. The main limitation on the colluvial foot slopes (Hc3) is the soil pH (8.1), which was considered to make the land unsuitable for tobacco and only marginally suitable for most of the other crops. Maize and cotton are more tolerant of high pH and are moderately suitable in this land. Wheat and sorghum are found to be very suitable. The valley floor (Va) is moderately suitable for wheat because of the flood risk in winter, especially close to the river. It is highly suitable for maize and sorghum and moderately suitable for sunflower, onion, cotton, green beans, tomato and sugar beet.

3.3. Use of GIS for correlating 'indigenous' and 'expert' land units

The overlay of the 'indigenous' land units map and the 'expert' map within the GIS brought an overall understanding of how local and scientific knowledge are linked spatially. Often there was a clear correlation but in many cases the correlation was indirect. A clear correlation means that farmers and the experts are referring to the same soil type. An indirect correlation means that farmers and experts distinguished different soil types in a particular land unit, or that one indigenous soil type relates to more than one 'expert' soil type. Through this spatial link, it was possible to return to the farmer with the output of the biophysical soil suitability assessment in order to generate discussion and enhance comprehension and/or adaptation by the farmers.

3.4. Validation of ELSA

Farmers largely agreed with the suitability classes but still came up with some striking differences of which two examples are given (Table 4).

The most prominent difference is related to suitability for olives. According to the 'expert' land evaluation, the area is due to low temperature constraints, only marginally suitable for olives, although it is the dominant crop in the area. The farmers agreed that there is indeed a frost risk, however severe frosts only happen once every 50 years and even then the damage is confined to pruned trees in large valleys. Postponing pruning till spring instead of pruning immediately after harvest can largely reduce the risk for frost damage. A simple adaptation to reduce frost even further is to grow olives on hillsides, and this is widely practised, also for other beneficial microclimate effects. Among the latter, in years with good rainfall the presence of fresh air and wind on the hillsides is beneficial for olive trees, compared to valleys where it is hot and warm. This important detail on site-specific effects could never be captured in the expert land evaluation.

Table 4
Combined (climate and soils) land suitability classification for 'expert' land units and its revision by the farmers[a]

Recommended land use	Recommended crops	'Expert' land unit	Recommended crops after corrections made by the farmers
Rainfed agriculture, low level of management	S3: grapes	Hc1	S3: grapes[b], lentil, chickpea; S2: olive[c], grapes[c]
Rainfed agriculture	S2: grapes; S3: wheat, barley, olive	Hc2	S2: grapes; S3: wheat, barley, olive
Irrigated or rainfed agriculture	*Rainfed*: S2: barley, lentil and grape and S3: olive; *irrigated*: S1: sorghum, wheat; and S2: cotton, maize	Hc3	*Irrigated*: S1: wheat; sorghum; S2: cotton, maize[b]
Natural vegetation and grazing area	If agriculture, S3: lentil and grape	Hc4	S3: lentil and grape
Rainfed agriculture	S2: barley and lentil; S3: olive and wheat	Hcv	S2: barley, wheat[c], lentil[b], olive[c]; S3: lentil[c];
Rainfed agriculture	S3: grape	Hv1	S3: grape
Natural vegetation and grazing area	S3: grape	Hv2	Natural vegetation or grapes
Irrigated or rainfed agriculture	*Irrigated*: S1: sorghum; S2: maize, cotton, onion, tomato, green bean, sunflower, wheat, sugar beet; *rainfed*: S2: barley, lentil, chickpea and S3: wheat	Va	*Irrigated*: S1: cotton[c], sugar beet[c], sorghum; S2: maize[b], cotton[b], onion, tomato, green bean, sunflower, wheat, sugar beet[b]

[a] S1: very suitable; S2: moderately suitable; S3: marginally suitable.

[b] Crops deleted by farmers.

[c] Crops added by farmers.

Olives were evaluated as not suitable in Hc1 (upper hill slopes, 'white' soils) because of limited soil depth, steep slopes and high erosion risk. However, farmers claim that these lands with the white soils are good for trees. White soils are cool and contain more moisture at depths that can be exploited by trees like olives and grapes. The farmers speculate that the evaporation from white soils is less than from other soil types or that roots penetrate cavities in the chalk which have a higher water holding capacity. According to them this translates in better quality of the olive oil, but trees stay smaller and give lower yield compared to trees in red soils.

A second example concerns chickpea. Agronomists recommend sowing chickpea in winter because of its high water demand and its exhaustive effect on the soil moisture. Even though spring-sown chickpea has to rely on residual soil moisture, which could restrict moisture availability and create late-season drought stress, farmers prefer it. They will sow at the beginning of March because of labour availability and the related costs when labourers have to be hired. If chickpea is sown in winter (December) there will be an abundant weed population and this needs to be weeded by hand. Use of herbicides demands less labourers but is more expensive.

4. Discussion

Participatory mapping provided an in-depth and holistic overview of farmers' knowledge on the whole village area. At the same time, mapping was absolutely necessary to allow up-scaling from field-level information to village level. However, although the map of the local land units is highly valuable in its own right, its depth of interpretation and correlation with a scientific classification is obtained from the individual interviews on the farmers' own land holdings. This information is highly location-specific and detailed.

The equivalent scientific soil names according to WRB (FAO et al., 1998) for the major local soil categories were easy to establish because detailed profile descriptions were available for each local soil type. The selection of the pits was afterall based on the locations indicated by the farmers themselves during the participatory transect walk. A large portion of the indirect relationships in the map overlay can be directly explained by the scale difference between the two maps. The most important reason for indirect correlations was that farmers considered, in their discussion of 'soils', only that part of the land unit that was cultivated. They tend to see soils mainly as a medium for cultivation. As a result, soils that are not cultivated, such as poor sandy soils under forest cover, are not recognised as such. These areas lack the farmers' attention and consequently farmers' knowledge on these areas is limited. Other reasons for limited correlation may be explained by inaccuracies in the mapping of local land units or in less intensive field surveys in the land units along the border with Turkey for geo-political reasons.

There are some outstanding differences between farmer and expert land suitability assessment. For the expert each tract of land may be valuable in its own right: if it does not support wheat, it might be good for barley or forest, etc. With farmers the weights are not the same for different land uses. Since olive is the most important rainfed crop, farmers will value the land according to its scope for olive oil production. Red soil is considered the best, the white soil gives good quality oil but total production is less, black soil is only suitable under irrigation. What is striking is that farmers are much more positive about the performance of white soils than the land resource experts.

As demonstrated by the case of suitability for olive, the participatory land evaluation is able to explain flagrant discrepancies between suitability prognosis provided by the land evaluation method and actual land use. Often the assumptions used in the expert evaluation are wrong. In the expert evaluation for irrigated crops, it was assumed that down in the valley there is unlimited access to irrigation water. However, in reality, water flow is regulated by the Turks who force the farmers to grow exactly the same summer crop as the Turkish farmers.

Thanks to the farmers' knowledge it was possible to understand better the impact of microclimatic variations on crop productivity. This is an important bonus of the participatory approach because detailed climatic data for long periods are often not available in most rural communities. Extrapolating climatic conditions from meteorological stations is invariably difficult, especially in complex terrain, but often necessary due to the high cost of meteorological data. In such circumstances, the experience-based perceptions of farmers of risk of frost, hailstorms, high temperatures and other climatic parameters are invaluable. Farmers have additional tools to overcome temperature limitations. They plant for instance wheat later than barley and sow chickpea in spring. Farmers will still plant barley early in the rainy season to be able to take profit from early rains (if any) for grazing. Sheep and goats graze on the barley in the field once before winter. After winter, the barley resumes its growing cycle.

The case of spring-sown chickpea demonstrates the overriding weight of socio-economic constraints over biophysical possibilities. Farmers know the biophysical constraints of spring-sown chickpea but consider labour availability and costs related to winter-sown chickpea as more important limitations. Farmers have a more holistic view whereas land resource experts need a multidisciplinary team to come to the same conclusions, especially in the fast changing socio-economic conditions of Syria. A constraint in the participatory approach is that useful and interesting indigenous knowledge is often scarce and may even be declining with the trend towards urbanisation. Not every community possesses a worthwhile local knowledge but this is not known in advance and will only be revealed in the course of the survey. This is a potential risk when starting up a survey. Some researchers try to overcome this problem by carrying out rapid rural appraisals but these are not always capable to reveal the significance and scope of farmers' knowledge. It always requires time to find the right people, the so-called 'key-informants' or 'indigenous specialists'. Key-informants have special knowledge on a given topic but are not necessarily the 'leaders' (Mikkelsen, 1995). To understand the local knowledge on village level, one has to start from the individual farmers and then come to a synthesis. The village map was an important output at village level but would have been useless in the absence of individual detailed interviews.

5. Conclusions

This study has demonstrated that farmers have an excellent understanding of their biophysical environment, which is nearly impossible to be captured by land resource professionals owing to the time involved. In this way local knowledge is complementary to scientific knowledge.

Tools for communication on local-level land resources and land suitability between the land resource experts and the farmers, as the development of the map with the local land units combined with field visits, proved to be extremely useful. The results of a conventional land evaluation were formulated in a way that farmers could understand and respond to and validate. The land resource professionals benefited from this common language by gaining a better understanding of the local conditions. Farmers were able to draw the attention of the land resource professional to issues that would have been overlooked otherwise. On the other hand, they still showed a sharp interest in expert opinion. Because of the fast changing socio-economic conditions in Syria, farmers and land resource professionals need each other's support to keep pace with the new developments.

The benefits to the farmer lie in the introduction of new land use alternatives through the conventional land evaluation approach. However, few alternatives could be defined in this specific environment because farmers were already trying out and evaluating most likely options. Benefits can also rest in management recommendations, e.g. optimal fertiliser application. The participatory approach is a good starting point for developing such recommendations. The challenge for the scientists will be to guarantee these more direct benefits to the farmers in future interactions that are absolutely necessary for sustaining a fair and stable relationship.

References

Briggs, J., Pulford, I.D., Badri, M., Shaheen, A.S., 1998. Indigenous and scientific knowledge: the choice and management of cultivation sites by Bedouin in Upper Egypt. Soil Use Manage. 14, 240–245.

Brill, E.J., 1999. The Encyclopaedia of Islam. CD-ROM edition v.1.0. Koninklijke Brill NV, Leiden.

Chambers, R., Pacey, A., Thrupp, L.A., 1989. Farmer First. Farmer Innovation and Agricultural Research. Intermediate Technology Publications, London.

Duke, James, A., du Cellier, Judith, L., 1993. CRC Handbook of Alternative Cash Crops. CRC Press, Boca Raton, FL.

Environmental Systems Research Institute, 1998. Arcview, GIS Version 3.1, Copyright 1992–1998. Environmental Systems Research Institute Inc.

FAO, 1990. Guidelines for Soil Profile Description. Soil Resources Management and Conservation Service, Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome.

FAO, 1994. Ecocrop Version 1.1. FAO, Rome.

FAO, ISRIC, ISSS, 1998. World reference base for soil resources. World Soil Resources Reports, Vol. 84. FAO, Rome, Italy.

Gobin, A., Campling, P., Deckers, J., Feyen, J., 1998. Integrated toposequence analysis at the confluence zone of the River Ebonyi headwater catchment (southeastern Nigeria). Catena 32, 173–192.

Guillet, D.W., Furbee, L., Sandor, J.H.B.R., 1996. The Lari soils project in Peru—a methodology for combining cognitive and behavioural research. In: Warren, D., Slikkerveer, J.L., Brokensha, D. (Eds.), The Cultural Dimension of Development: Indigenous Knowledge Systems. Intermediate Technology Publications, London, pp. 71–81.

Habarurema, E., Steiner, K.G., 1997. Soil suitability classification by farmers in southern Rwanda. Geoderma 75, 75–87.

Katsoyannos, P., 1992. Olive Pests and Their Control in the Near East. FAO, Rome.

Kundiri, A.M., Jarvis, M.G., Bullock, P., 1997. Traditional soil and land appraisal on fadama lands in northeast Nigeria. Soil Use Manage. 13, 205–208.

Landon, J.R., 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical/Wiley, USA/New York.

Mikkelsen, B., 1995. Methods for Development Work and Research: A Guide for Practitioners. Saga Publications, New Delhi.

Ministry of Land Registration, 1992. Topographical map of Rajo, Syrian Arab Republic. Sheet No. NJ37-V-E-a, Region No. 4 extended in Region 5, Scale 1:50,000. Ministry of Land Registration, Service of Military Geography, Syrian Arab Republic (in Arabic).

Munsell, 1954. Munsell Soil Color Charts. Munsell Color Company Inc., Baltimore 2, Maryfield, USA.

Nordblom, T., Shomo, F., Goebel, W., Harris, H., 1993. Agro-ecological characterisation for resource management: validation and use of farmer interview methods to define crop yield distributions for yield-gap estimation with crop-growth simulation. Farm Resource Management Programme, Annual Report for 1992. Report No. ICARDA-058. ICARDA, Aleppo.

Norton, J.B., Roman, R., Sandor, J.A., 1998. Observation and experience linking science and indigenous knowledge at Zuni, New Mexico. J. Arid Environ. 39, 331–340.

Protasevich, L.N., Maksimov, A.A., 1966. The geological map of Syria. Scale 1:200,000, Sheet J-37-I,II (Halab, Antakya), Explanatory Notes. Department of Geological and Mineral Research, Ministry of Industry, Syrian Arab Republic.

Ryan, J., Garabet, S., Harmsen, K., Rachid, A., 1996. A soil and plant analysis manual adapted for the west Asia–north Africa region. Technical Bulletin. ICARDA, Aleppo, Syrian Arab Republic.

Sandor, J.A., Furbee, J., 1996. Indigenous knowledge and classification of soils in the Andes of southern Peru. Soil Sci. Soc. Am. J. 60, 1502–1512.

Steiner, K.G., 1998. Using farmer's knowledge of soils in making research results more relevant to field practice: experiences from Rwanda. Agric. Ecosyst. Eviron. 69, 191–200.

Sys, C., Van Ranst, E., Debaveye, J., 1991. Land Evaluation. Part I. Principles in Land Evaluation and Crop Production Calculations. Agricultural Publications 7.1, General Administration of Development Cooperation of Belgium, Brussels, Belgium.

Sys, C., Van Ranst, E., Debaveye, J., Beernaerts, F., 1993. Land Evaluation. Part III. Crop Requirements. Agricultural Publications 7.3, General Administration of Development Cooperation of Belgium, Brussels, Belgium.

V.O. Technoexport (Moscow), 1963. Geological map of Aleppo, Syria. Scale 1:200,000. Department of Geological and Mineral Research, Ministry of Geology, USSR and Syrian Ministry of Industry, Damascus, Syrian Arab Republic.

Zurayk, R., El-Awar, F., Hamadeh, S., Talhouk, S., Sayegh, C., Chelab, A., Al Shab, K., 2001. Using indigenous knowledge in land use investigations: a participatory study in a semi-arid mountainous region of Lebanon. Agric. Ecosyst. Environ. 86, 247–262.