CGIAR Challenge Program on
WATER & FOOD

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Strengthening Livelihood Resilience in Upper Catchments of Dry Areas by INRM (CPWF PN 24)

5

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International Center for Agricultural Research in the Dry Areas

AEERO
Agricultural Extension, Education and Research Organization

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Research Report no. 5

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Contents

Preface

The Challenge Program on Water and Food (CPWF) contributes to international efforts to ensure global diversions of water to agriculture are maintained at the same level as in the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture — that is, to change the way water is managed and used to meet international food security and poverty eradication goals — in order to leave more water for other users and the environment. The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

The CPWF project PN24 'Strengthening Livelihood Resilience in Upper Catchments of Dry Areas by Integrated Natural Resources Management' combined a large-scale analysis of Iran's Karkheh River Basin by geographic information system (GIS) and rapid assessments, with detailed natural resources assessments, gender and livelihood analyses, and participatory development of agricultural technologies in two upstream watersheds. Due to the complex combination of biophysical and economic constraints, it is not easy to strengthen farmers' livelihoods. Besides development of the usual technical skills, this task required participatory skills and strong interdisciplinary and interinstitutional cooperation.

The two contrasting benchmark research watersheds were Merek watershed (242 square km) in Kermanshah Province and Honam watershed (142 square km) in Lorestan Province. The project operated through the active involvement of researchers and staff of five research institutes, under the umbrella of the Agricultural Research, Education and Extension Organization (AREEO); and the Forest, Range and Watershed Management Organization (FRWO), based in Tehran. At the provincial level, the main contributors were the Agricultural and Natural Resources Research Centers in the Provinces, which house researchers of these same institutes, the Jihad-e-Agriculture Organization, and the Agricultural Extension Offices. The project was managed by ICARDA and benefited from additional scientific support from the Catholic University of Leuven, Belgium.

Summary

The study of soils is important for land-use planning, agriculture, and natural resource development programs. Determination of soil characteristics and limitations is one of the most important duties of soil researchers. This report presents a semi-detailed soil survey of Merek watershed in Kermanshah Province, and Honam watershed in Lorestan Province, Iran. It is hoped that the analyses and recommendations will be of value to those interested in the optimum use of Iran's land and water resources.

The Merek watershed is located southeast of Kermanshah, the provincial capital, and has an area of 24,200 ha. Its climate is cold semi-arid, and soil temperature and moisture regimes are thermic and xeric, respectively. Lithological composition is mainly limestone, dolomite, marl, claystone and sandstone.

The Honam watershed is located south of Alashtar city and has an area of 14,200 ha. The area's high mountains contribute to a wet climate, and soil temperature and moisture regimes are mesic and xeric, respectively. Lithological composition comprises limestone, dolomite, marl, quartzite, shale, sandstone, and conglomerate.

Interpretive map units were produced for both watersheds using a geo-pedologic approach. The soil morphology, physical, and chemical characteristics determined in each map unit were: color, soil structure, rock fragments, voids, roots, clay cutans, soil reaction, soil salinity, soil alkalinity, calcium carbonate ($CaCO_3$), organic carbon, cation exchange capacity, soil texture, field capacity, and permanent wilting point.

In Merek, three landscapes, seven reliefs or moldings, and 21 land units were distinguished. Three soil orders were identified: Entisols, Inceptisols and Vertisols, with Entisols found in the mountains and hilly areas. Soil textures in the profiles are clay or silt clay. A subangular blocky structure is the dominant soil structure. The amount of subsurface gravel (fine and coarse) in the profiles dug on mountains and hilly areas varies between 25% and 60%. The pH varies between 7.3 and 7.9, electrical conductivity varies between 0.4 and 0.8 ds m^{-1}, organic carbon varies between 1% and 3%, and the amount of $CaCO_3$ in surface horizons varies between 17% and 32%.

In Honam, four landscapes, 10 reliefs or moldings, and 37 land units were distinguished. Two soil orders were identified: Entisols and Inceptisols, with Entisols found in the mountains and hilly areas and Inceptisols in the piedmonts and valleys. Textures in the soil profiles are clay or silty clay and the dominant soil structure is subangular blocky. The amount of subsurface gravel (fine and coarse) in the profiles dug on mountains and hilly areas varies between 0% and more than 75%. The pH varies between 7.3 and 8.0, electrical conductivity varies between 0.2 and 7.6 ds m^{-1}, organic carbon varies between 1% and 3.7%, and the amount of $CaCO_3$ in surface horizons varies between 1.7% and 43.42%. Topography, soil depth, stoniness, water erosion, and heavy soil texture (especially in the surface horizons) are the main limiting factors in the study area.

1. Introduction

The capacity of land to produce is limited by climate, soil, and landform condition, as well as land management. Accordingly, an understanding of land resources and their potential is a requirement for optimum land use and subsequent long-term agricultural and economic development. Soil is one of the most important components of the land. Identification of soils, determination of soil characteristics, and knowledge of the geographic distribution of soils provide the basic information necessary for land-use planning.

A large portion of west-central Iran is occupied by mountains, which continue towards the east into a high plateau. Storm fronts move in from the Mediterranean Sea and condense in a southeasterly direction through the mountains. The annual rainfall is low and restricted to winter months. In the mountains, the annual rainfall is 350 to 600 mm, while the plateau receives an average of 150 to 200 mm. Snowfall is common in the mountains. The plateau gradually becomes a desert towards the east, with average yearly precipitation of less than 100 mm. In the south and southeast of the country, the plateau stretches into low-lying plains at the head of the Persian Gulf, where the average yearly rainfall is as low as 50 mm. In general, the climate changes gradually from arid in the low-lying areas to semi-arid in the highlands.

Two semi-detailed soil surveys were undertaken in the upper Karkheh River Basin in the mountainous area of this region. The first survey covered a 24,200-hectare watershed in the Merek plain, referred to as Merek watershed (see Fig. 1). This area consists of several wide, relatively level plains and gently sloping surfaces that are intensively cultivated under irrigated and dry-land farming. The soil conditions are relatively favorable with salinization and alkalinization limited due to the elevated topographical position and a generally deep groundwater table.

The second semi-detailed soil survey covered 14,200 ha in the region of Honam, southeast of Khoramabad city in Lorestan Province, and referred to as Honam watershed. It consists of a number of wide, relatively level to gently sloping plains that are intensively cultivated under irrigated and dry-land farming. Soil conditions are similar to those in Merek.

The semi-detailed soil surveys were conducted to (1) assess the agricultural potential of the soils, (2) investigate soil properties that restrict crop production, (3) determine and interpret management-dependent soil properties as a basis for assessing the sustainability of the soil resources, and (4) gain knowledge about the magnitude and extent of the problems to be solved.

The methods of laboratory research, field survey, and soil classification are described in the next chapter. The third chapter describes the soil-formation processes in these two watersheds.

After that, Part A gives a general description of the Merek region in general and of the surveyed area in particular, dealing with the geoforms and geographic features. All geoforms are discussed and indicated on the maps to the extent allowed by the scale. Also described are the area's geology and the influence of tectonic movements on geomorphology and the development of rivers. The climate and vegetation are described in order to understand the prevailing environment and the conditions under which soils are formed. This information

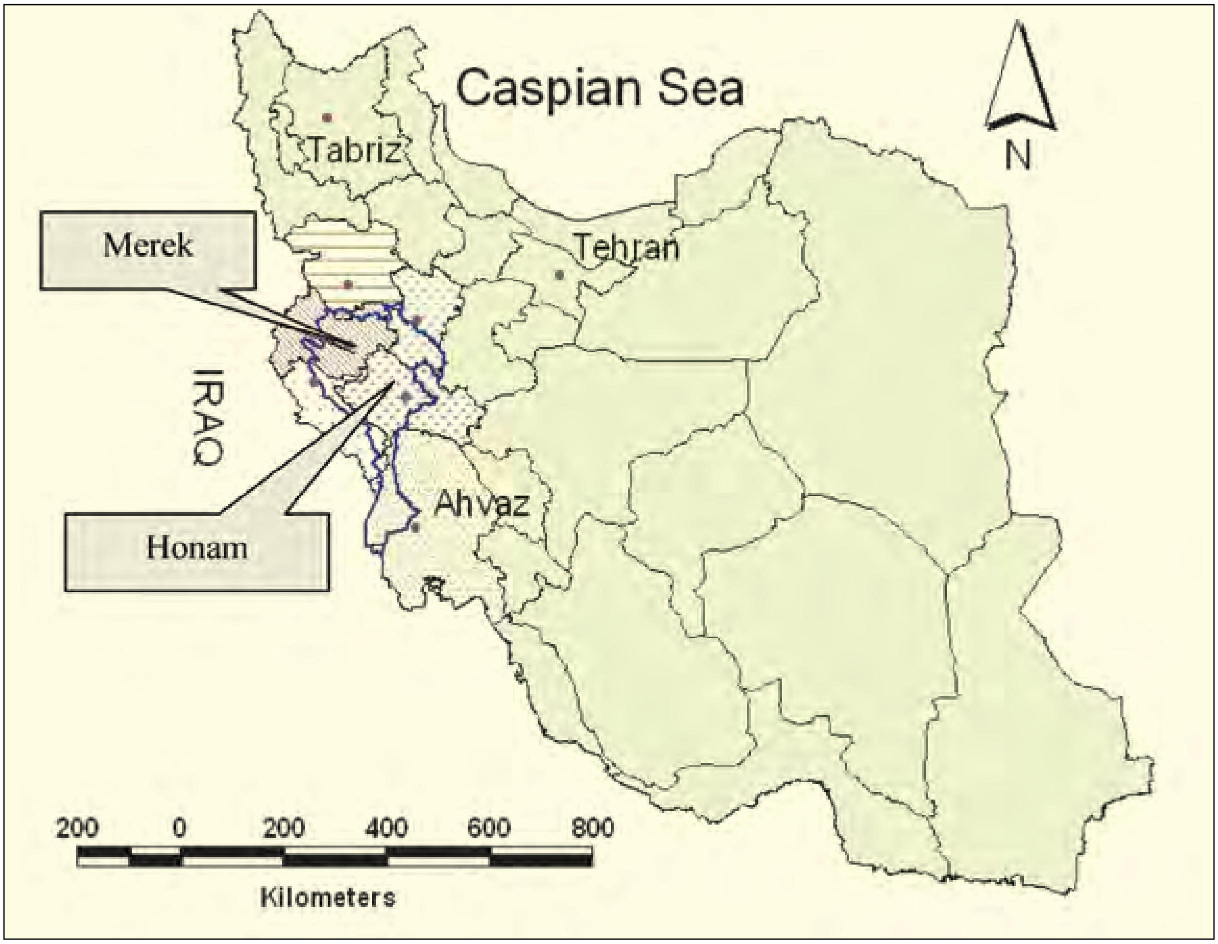

Fig. 1. Location of Merek and Honam watersheds in the Karkheh River Basin, Iran.

is important for the recognition of soils of different character and age, but may also be valuable to other scientists interested in the area.

The regional distribution of the various soils, their suitability for irrigation, and their present land use are represented on 1:50,000 soil maps and in land classification maps. Data about salt content of different soil layers are indicated on the salinity map. Other laboratory data are included in the descriptions of soil profiles.

The development of the soils and their profile characteristics are briefly discussed in the fourth chapter, which deals with pedogenetic, geogenetic, and anthropogenic factors of soil formation. The basis on which the various soils are distinguished and arranged in groups for mapping purposes (legend) is discussed. A set of recommendations on how soil and land can be used, particularly to cultivate crops, is presented at the end of Part A. Part B deals with the same information for Honam.

In the Appendices, the specifics of 7 (Merek) and 25 (Honam), representive soil profiles are listed. Maps of the distribution of all Honam soil units are also presented.

2. Methods and techniques

Field investigations

Survey operations

Field investigations were carried out during two periods: a reconnaissance survey in early spring 2007 followed by detailed fieldwork in mid-summer. The purpose was to time the field observations to coincide with image acquisition. The soil units were identified based on geomorphologically interpreted aerial photographs and field observations. One of the benefits of geomorphologically defined survey units is that they are relatively easy to identify from aerial photographs. They repeat themselves across the landscape and thus provide a basis for recognizing areas with similar resource characteristics. Further, they are permanent and closely related to a wide range of environmental phenomena, including soil conditions (Briggs and Shishira 1985). This approach assumes that a landscape has a hierarchical structure, such that sma present study) are nested in larger, spatially contiguous, but composite areas. In this study, an attempt was made to distinguish the range of this variability as far as soils are concerned, and to delineate the boundaries of the differentiated soil units within each landform.

Reconnaissance survey

The main activities performed during the reconnaissance survey were:

- Field observations to determine the relationship between the configuration of the landscape and its appearance in aerial photographs (this allowed the preparation of a preliminary photo-interpretation map for soil mapping).
- Selection of sample areas for soil characterization based on the photo-interpretation map.
- Collection of data on agricultural practices (including cropping systems, land-management activities, and irrigation).

Detailed survey

Detailed fieldwork concentrated on soil survey activities, including morphological and physical characteristics of the soils. The soils were identified, characterized, classified, and mapped. The delineations on the photo-interpretation map were checked and corrections were made where needed.

Survey procedure

Sampling schemes

Three types of recent soil data were used in this study: (1) data gathered through the reconnaissance soil survey over the whole area; (2) data collection in fieldwork; and (3) general data obtained by locating observation points in the main photo-interpretation units on a free-choice basis. For the data collected in the field and the large data set, a systematic sampling scheme was used. The area was divided into regularly spaced squares of 500 x 500 m and the sampling points were located at grid nodes. The sampling grid was aligned with the scale 1:50,000 topographic maps. This was helpful for adjusting the direction and tracking the sampling points. A level was used to give the direction on the field and the sampling points were located by pacing.

Compilation of maps

Black-and-white aerial photographs, from a mission flown in 1956 at a scale of 1:50,000, were interpreted and a photo-interpretation map was produced prior to our fieldwork. On each landform, several pedons were excavated to a depth of about 150 cm and soil morphological properties were studied. Auguring was done to determine the range in soil characteristics and laboratory data. Many soil profiles were determined of which 7 typical profiles for Merek and 25 for

Honam are presented in the Appendices. Most of the profiles were also sampled for laboratory analysis, results of which are attached to the pedon descriptions in the appendices. A semi-detailed geopedological map was produced by delineation of geomorphological units on the photos and observation in the field. Soil mapping was carried out following a geopedological approach (Zink 1989), which is based on the integration of geomorphology and pedology for mapping soil distribution and interpreting soil genesis. With this approach, reliable soil surveys can be carried out at reasonable cost, because the location of the soils on the landforms can be predicted by using knowledge of landscape patterns as inferred from the aerial photographs. Brief definitions of the geomorphic units are as follows.

- Landscape: A landscape is large portion of land characterized by either a repetition of similar relief type or an association of dissimilar relief type (e.g., mountain, valley, piedmont).

- Relief/molding: relief is a geoform type determined by a given combination of topography and geological structure (e.g., cuesta); molding is a geoform type determined by specific morphoclimatic conditions or morphogenic process (e.g., glacis, fan, terrace, delta).

- Lithology: lithology refers to the petrographic nature of the hard rocks and the facies of the soft cover formation. Lithology is placed at a lower categorical level than the concepts of landscape and relief/molding, respectively, because its elucidation often needs field and laboratory data.

- Landform: landform is the elementary geomorphic unit and lowest level of the hierarchical system. It can be subdivided only by means of phases.

Each landscape unit is divided into relief forms based on a combination of topography, geological structure, origin, and lithology. Each relief form is further subdivided into different landforms, and soils are further differentiated within landforms. The boundaries of the resulting geopodologic map are smoothed. Close to the boundaries, outliers or inliers of adjoining units may be found, and areas of other units, too small to be shown on the map, may occur within some units.

Soil descriptions were based on the guidelines of the Food and Agriculture Organization (FAO) of the United Nations (FAO 1977). The soils were classified at subgroup level according to the United States Department of Agriculture (USDA) soil classification system (Soil Survey Staff 2006). This system distinguishes 11 soil classes at the highest level (order) and an increasing number of classes at suborder, great group, subgroup, family, and series levels.

Guidelines given in Van Wambeke and Forbes (1986) were applied for naming the map units. The criteria used include the number of taxonomic components, the regularity of pattern, the physiographic contrast, the percent composition, and the similarity of the soils to be joined in one map unit. The map units are designated at subgroup level as consociation or association with their inclusions. When there were no observations or the number of observations was not sufficient to characterize a map unit, detailed soil maps (1:50,000) of the Soil and Water Research Institute (SWRI) of Iran were consulted.

Laboratory measurements

The laboratory determinations were carried out at SWRI in Kermanshah and in Lorestan, following standard laboratory methods. After air drying, the soil samples were sieved at 2 mm and analyzed for different properties. Soil samples collected in the field (426 samples total) were analyzed for pH and electrical conductivity (EC). Samples from representative soil profiles (85 samples) were analyzed for $CaCO_3$ equivalent, organic carbon, total nitrogen (N), sand, silt, clay, saturation percentage (SP: the amount of water needed to saturate a given volume of a soil), field capacity, permanent wilting point, and soil fraction larger than 2 mm.

3. Soil formation

Pedogenetic processes driven by climate, topographic position, and vegetation give soils their specific characteristics. The pedogenetic processes and soil formation in the watersheds are described here.

Pedogenetic processes of soil formation

The pedogenetic characteristics of soil formations in the region are weak. They are limited to movement and precipitation of lime. The development of visible lime is the result of the alternate moistening and drying of the soils. During moistening, lime dissolves and becomes mobile. When the soils dries up, the lime precipitates in distinct spots, forming white powdery pockets and hard nodules. Generally, the powdery pockets decrease and the concretionary nodules increase with depth. In soils in climates with up to 400 mm of annual rainfall, the dissolution takes place under the influence of carbonic acid. The carbon dioxide (CO_2) for this reaction originates from organic compounds in the soil or from penetration into the soil from organic surface material and from the atmosphere with rainwater. Upon drying, the dissolved $CaCO_3$ precipitates. This takes place preferably where CO_2 escapes the quickest: along animal and root holes, and larger soil pores. Visible lime is more likely to develop in areas where more water penetrates the soil. In areas with better external drainage (sloping and undulating terrain), the development of a zone of maximal accumulation is less pronounced. In soils with stronger external drainage, the zone of visible lime remains further from the soil surface, while in relatively level, somewhat depressed soils, visible lime may be found closer to the surface. This is accounted for by the smaller water reserve of the soil and less aeration in the top section of drained soils compared with more sloping land. This feature of profile development is of paramount importance in distinguishing the various soils and the superposition of different layers of soil materials. It reflects firstly the different water regimes of the soil, determined by water holding capacity (texture and structure), permeability, and external drainage (relief), and secondly the differences of age and development history of the various soils.

Structure formation and consistency

The formation of structure in the soils of this region is generally weak. The extent of structure formation depends on the moisture conditions of the soils. When moist, recognition of structure is not possible, but elements of some structures appear upon drying. Such soils are described as structure-less and break into non-massive angular blocky formations. As well as being influenced by inherent soil properties, the development of structure and consistency depends on the moisture regime of the soil profile.

Pores

Another characteristic of the soils is the presence of pores. With few exceptions, most sediments (whether young, old, natural, or caused by irrigation) are characterized by the occurrence of many soil pores, which are often small. Pores increase soil permeability.

Biological activity

In general, biological influence is not great in the process of soil formation. Homogenization of profile parts has not been observed to any extent.

3.1. Part A. Merek Watershed

3.1.1. General description of Merek watershed

Location

The Merek watershed is located southeast of Kermanshah City, the capital of Kermanshah Province. The study area is located between 47º04´25" to 47º22´18" E and 34º00´38" to 34º39´31" N (Fig. 1). Totaling 24,200 ha, the area is limited in the north by the Koh-e Sefid mountains and in the South by the Koh-e Nesar mountains. The main river is the Merek.

Climate

Merek watershed has cold winters and relatively mild summers. Precipitation data show that rainfall occurs in a regular wet-dry cycle. All significant precipitation falls from October to June, while the remainder of the year is very dry (Fig. 2). The average annual precipitation in Kermanshah is 458 mm. A substantial portion of the plain lies in the high mountains and receives more precipitation. At lower elevation, nearly all precipitation falls in the form of rain, whereas at higher elevation a significant amount occurs in the form of snow. According to the Gussian system (Jamab Consulting Engineers 1991) the area has a wet climate due to the high elevations. The mean monthly temperature ranges from 1.4°C in January to 27.2°C in July. The mean annual air temperature is 14.2°C, the mean maximum temperature is 22.2°C, and the mean minimum is 6°C (Table 1). The total annual potential evapotranspiration, measured with a class

Plate 1. A view of the Merek plain (S. Fatehi).

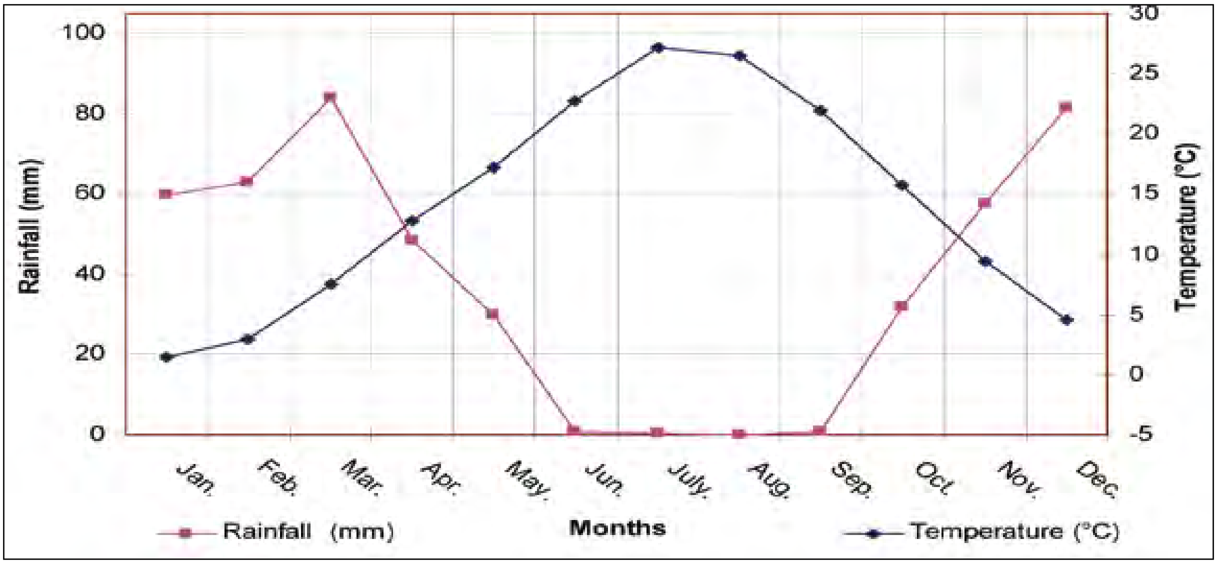

Fig. 2. Monthly precipitation and temperature at the Kermanshah synoptic station.

"A" pan in the Kermanshah station is 1785 mm (Table 1). The average monthly potential evapotranspiration is 61 mm in winter (January to March) and 254 mm in summer (July to September).

Soil moisture and temperature regime

The soil moisture regime is a major factor for the differentiation of soils at the Order level. The soil temperature regime is a distinctive criterion for the differentiation of soil families. The soil moisture and temperature regimes were calculated using the Newhall software (Newhall and Berdanier 1996). Data from the Kermanshah synoptic station showed that soil moisture and temperature regimes of that study area are xeric and thermic, respectively.

Geology

The Merek watershed is part of the Zagros mountain chain, stretching in a northwest-southeast direction. In general, the rocks of the Merek Plain are limestone, dolomite, marl, quartzite, shale, sandstone, siltstone, and conglomerate. Faulting and folding of soil layers is common. Due to their joints and fractures, together with karstic features, limestone formations act as natural reservoirs for water and give rise to many springs. Springs of various sizes are found in the study area.

The geological map of Merek watershed (Bavandpoor, 1999) is shown in Fig. 3. The absolute and relative surface areas of the lithological units in this figure are presented in Table 2. The main units are Servek, Ilam, Gorpi, Amiran, Khashkan, and Shahbazan.

Geomorphology

The Merek area is surrounded by mountains in the north and south. The dominant features of mountains are folding and faulting. Several peaks rise to over 3,000 m, notably in the north. Nearly half of the study area is very steep with slopes exceeding 12% (Fig. 4). Drainage follows a complicated pattern. Geomorphic studies were performed by aerial photo-interpretation (Zink 1989) as presented in the following chapter.

Table 1. Climatic data for the synoptic station in Kermanshah (1983-93).

	Month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Rainfall (mm)	59.8	62.8	83.8	48.4	29.8	0.8	0.5	0.1	0.7	32.0	57.9	81.4	458.0
Average temperature (ºC)	1.4	3.0	7.5	12.8	17.2	22.7	27.2	26.5	21.9	15.7	9.4	4.5	14.2
Average daily maximum temperature (ºC)	6.5	8.7	13.7	20.2	25.6	33.2	37.7	37.0	32.6	24.5	16.4	9.8	22.2
Average daily minimum temperature (ºC)	-3.8	-2.7	1.3	5.3	8.8	12.2	15.7	16.0	11.2	6.8	2.3	-0.9	6.0
Absolute minimum temperature (ºC)	-12.8	-10.8	-5.8	-1.0	3.1	7.4	11.8	11.6	6.1	1.4	-4.3	-7.5	-0.1
Day-time mean temperature (ºC)	4.3	6.0	10.4	15.8	20.3	26.4	31.0	30.6	26.6	20.1	13.3	7.6	17.7
Night-time mean temperature (ºC)	-0.8	0.6	4.7	9.2	13.0	17.2	21.8	21.4	17.0	11.8	6.4	3.2	10.5
Wind speed at 2 m elevation (m s-1)	3.2	3.4	3.6	3.7	3.5	3.4	3.4	3.2	3.1	3.2	3.3	3.0	3.3
Sunshine (h)	4.0	5.1	5.7	7.0	8.2	11.5	11.0	10.9	10.3	7.9	5.9	4.0	7.6
Relative humidity (%)	74.0	68.0	61.0	53.0	46.0	27.0	21.0	21.0	22.0	40.0	58.0	71.0	46.8
Potential evapo-transpi-ration (mm)	40.0	51.8	90.5	136.5	185.4	253.8	288.0	264.7	209.0	141.4	78.3	45.0	1784.4

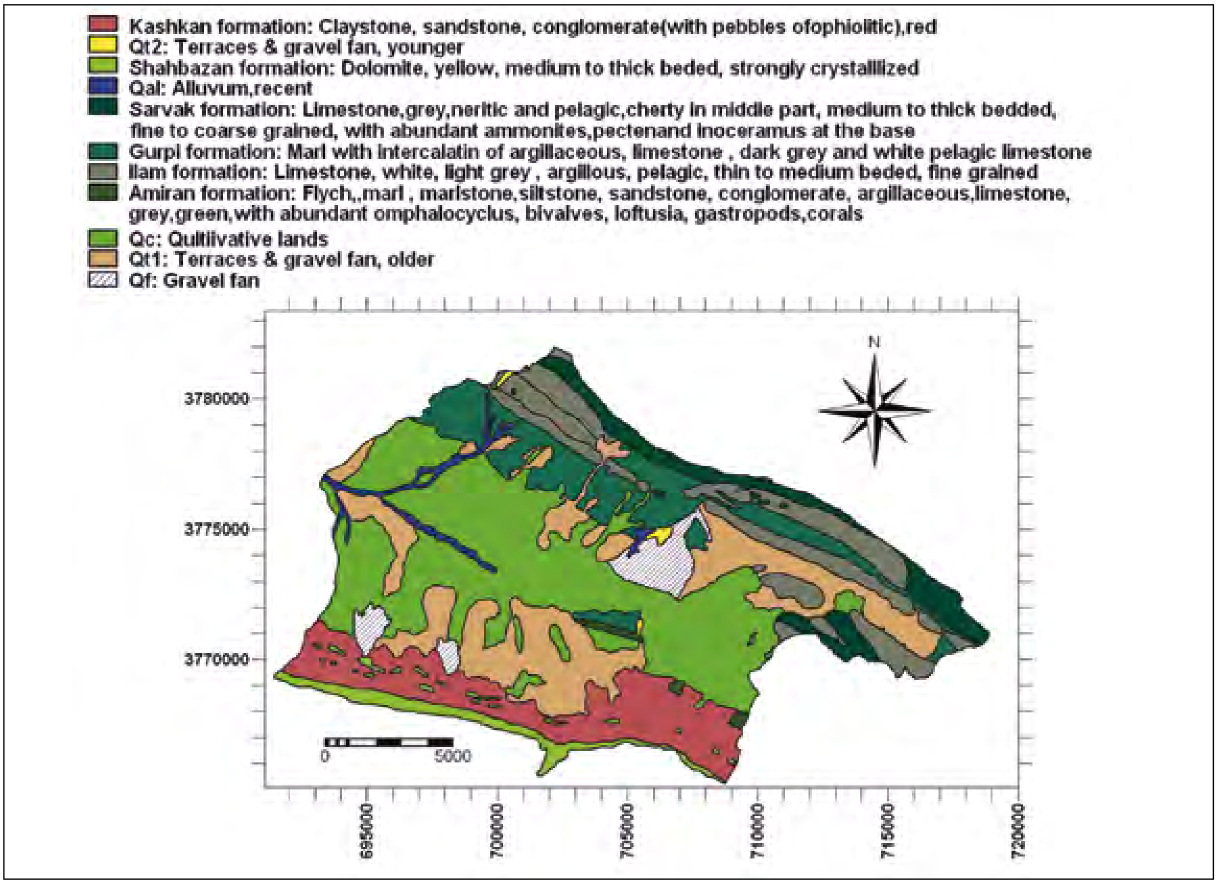

Fig. 3. The lithologic map of Merek watershed, extracted from the geologic map (Bavandpoor 1999).

Table 2. Geologic formations and their surface area in the Merek Plain.

Period	Formation	Description	Area ha	Area %
Quaternary		Recent alluvium	390.6	1.61
		Alluvium	7,757.1	32.1
		Alluvial fan	826.2	3.4
		Young plateau, terraces, and gravel fan	72.5	0.3
		Old plateau, terraces, and gravel fan	4,497.2	18.7
Eocene	Shahbazan	Yellow dolomite rocks	767.3	3.2
	Khashkan	Claystone, siltstone, red sandstone	2,970.3	12.3
Cretaceous	Ilam	Limestone, conglomerate, marl, shale	2,796.2	11.6
	Servek	Limestone, dolomite, breche	1,350.7	5.6
Lower Cretaceous	Amiran	Flysch, marl, marlstone, siltstone, sandstone, conglomerate	126.8	0.5
	Gorpi	Shale, marl, siltstone	2,647.9	10.9
		Total	24,202.8	100

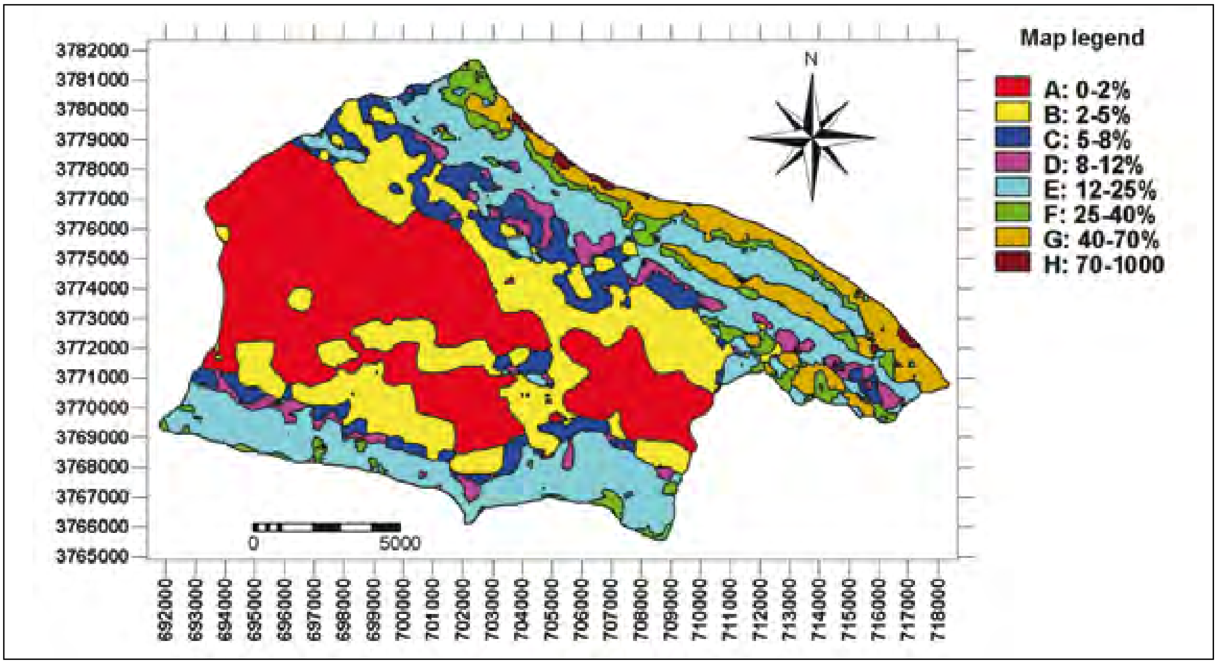

Fig. 4. Slope map of the Merek plain.

Soils

The soils, formed from medium-to-fine textured calcareous alluvium, derived from the limestone of the surrounding mountains and were deposited by the Merek River and its main tributaries. As a result, the soils are calcareous and exhibit an alkaline reaction. Lime content is very high. In some parts, lime is not visible in the soils. Locally, in areas of piedmonts, lime occurs in a soft powdery form or in rounded lime spots and concretions. The pH values are higher than 7.5. The organic carbon content is low to very low: values vary between 0.4% and 2.67% with an average of 1.2%. The structure of the top soil is usually massive, forming large clods when plowed. This unstable structure collapses easily on moistening. The soils have a fine–to-medium, moderate-to-strong angular blocky structure, gradually changing into a massive or weak subangular blocky structure with increasing depth. A detailed description of the soils and their classification is given in the next chapter.

Land use and native vegetation

Currently, the main dry farming crops in the study area are wheat, barley, and chickpeas. Dry farming is a common practice, especially on the hills. The main irrigated crops are wheat, barley, canola, chickpeas, clover, alfalfa, and sugar beet. A small area is covered by fruit orchards including walnut and cold-region fruit trees. Orchards are limited to the higher parts of study area on the banks of the Merek River and its tributaries, and production is mainly for local consumption.

Animal husbandry is strongly linked to the cropping systems. Traditionally, all meat and dairy products have been produced locally. Farmed animals include sheep, goats, and a limited number of cattle.

The native vegetation is diverse. Zonal distribution of the area's many species depends on topography, hydrology, and soil condition, among other factors.

Natural grass and weeds are commonly found on the lower slopes. Seasonal grass provides good pasture for goats and sheep in the spring months. Piedmonts support a variety of common weeds and grasses, including Glycyrrhiza glabra, Carthamus okiocanthus, *Papaver raas, Tragopogon* sp., *Alhaji camelorun, Cirsium* sp., *Astragallus* sp., *Achelia* sp., and *Mantha longifolia*.

Hydrology and water supply

Traditionally, irrigation water has derived from the Merek river system. The main contributor to irrigation water has always been the Merek River itself but contributions of springs and wells of varying depths have also been important. Analysis of water samples from the Merek River and other main sources of irrigation water shows good water quality (Table 3). According to the Wilcox classification system, the water quality is suitable for irrigation (United States Salinity Laboratory Staff 1954).

3.1.2. Soils of Merek watershed

Three main landscape types were recognized in Merek watershed: mountains (Mo), hills (Hi) and piedmont (Pi). These landscapes are taken as the first entry in the legend of the geopedologic map (Fig. 5). This gives an insight into the differences in physiography and elevation. Each landscape unit is subsequently divided into relief forms, land forms, and soils (Zink 1989).

In the moist conditions of the study area, where the parent materials are almost entirely derived from limestone, climate and parent material strongly control soil formation. Inceptisols, including Xerepts, cover the main part of area. Entisols, mostly Orthents and Fluvents, occur in the floodplains and at the foot of mountains. In total, two Great Groups were identified: Haploxerepts and Calcixerepts.

Table 3. Water quality characteristics from four local sources in Merek.

Source	pH	EC	Anions (meq l^{-1})					Cations (meq l^{-1})			Willcox. class.
		dS m^{-1}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Sum	Ca^{2+} + Mg^{2+}	Na^+	Sum	
Merek River	7.8	0.40	0.4	3.2	0.5	0.2	4.1	3.4	0.5	3.9	C2-S1
Well	8.1	0.35	0.2	1.9	1.8	0.0	3.9	3.6	0.3	3.9	C2-S1
Bear spring	8.3	0.48	0.3	3.6	1.5	0.0	5.4	4.2	0.4	4.6	C2-S1
Sarab-e Sar Firozabad	8.1	0.30	0.2	2.0	1.0	0.0	3.2	3.1	0.1	3.2	C2-S1

C2 (Medium-salinity water): can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

S1 (Low sodium water): can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

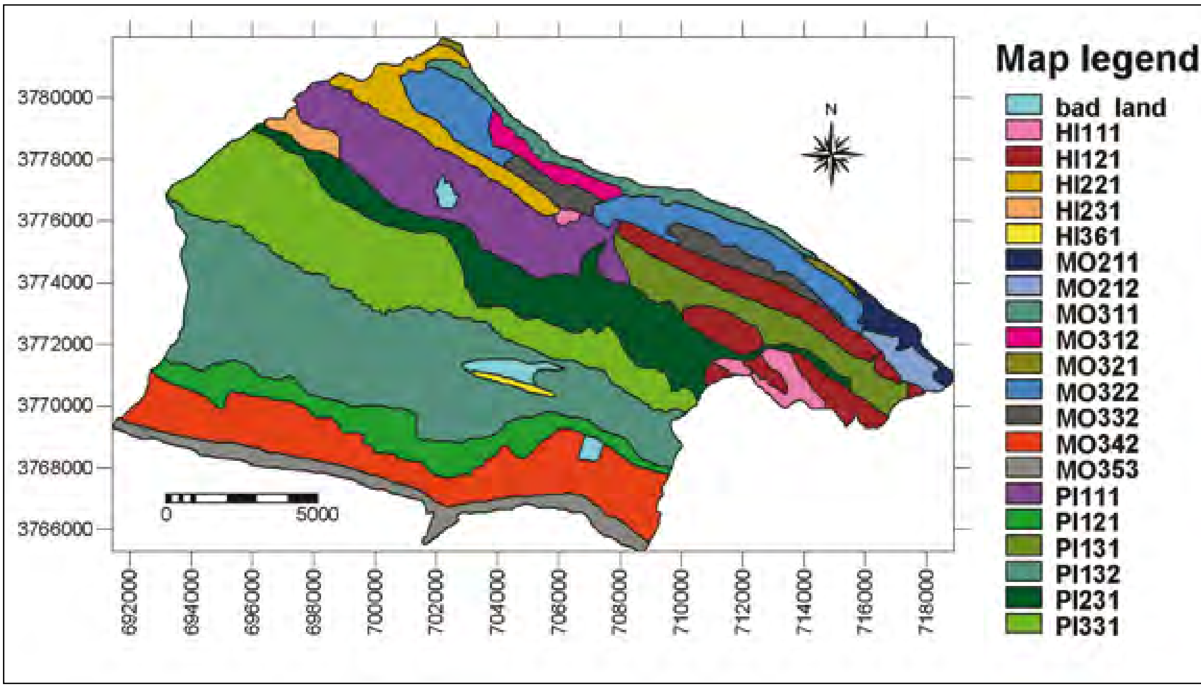

Fig. 5. Semi-detailed geopedologic map of Merek (see Table 4 for full description of legend).

The characteristics of the 21 resulting soil map units are summarized in Table 4 and in the following paragraphs. Seven representative soil profiles and related laboratory data are given in Appendix A.

Mountains

Mo211: In general, the elevation is about 900 m. Landforms are mainly scarp and rock outcrops (Plate 2). This map unit is soil-less. Average slope is more than 40%, and limestone is the most important mineral in rocks. Protection from use is recommended. This map unit occupies 226.3 ha, corresponding to 0.9% of the study area.

Mo212: These areas are located below the scarps and rock outcrops. They are mainly elongated ridge, a long, narrow elevation of the land surface, usually sharply crested with steep sides and forming an extended upland between valleys. Slopes are complex, varying from 12% to 25%, but the overall slope ranges between 40% and 70%. These areas are soil-less because of the steep slopes. This map unit occupies 217.3 ha corresponding to 0.9% of the study area (Plate 3).

Plate 2. Scarp and rock outcrops in the Merek study area (S. Fatehi).

Table 4. Legend of the geopedologic map of the Merek Plain.

Land-scape	Relief	Lithology	Map unit composition	Landform	Area ha	Area %	Symbol
mountain	middle hill	limestone, grey, neritic and pelagic	non soil	scarp	226.3	0.9	Mo211
	medium hill	limestone, grey, neritic and pelagic	non soil	elongate round type ridge	217.3	0.9	Mo212
		limestone, grey, neritic and pelagic	non soil	scarp	507.6	2.1	Mo311
		limestone, grey, neritic and pelagic	Lithic Xerorthents	elongate round	252.4	1.0	Mo312
		limestone, white, light grey, argillaceous, pelagic	non soil	type ridge scarp	68.9	0.3	Mo321
		limestone, white, light grey, argillaceous, pelagic	Lithic Xerorthents - Typic Haploxerept - Typic Calcixerepts association	elongate round type ridge	1324.5	5.5	Mo322
		marl with intercalatin of argillaceous, limestone , dark grey and white pelagic limestone	Typic Haploxerepts & Fluventic Haploxerepts	elongate round type ridge	490.9	2.0	Mo332
		claystone, sandstone, conglomerate with pebbles ofophiolitic), red	Typic Haploxerepts - Typic Xerorthents - Vertic Calcixerepts association	elongate round type ridge	2,508.8	10.4	Mo342
		dolomite	Typic Haploxerepts - Lithic Eorthents association	flank with slope complex facet	811.7	3.4	Mo353
hill land	high hill	limestone, white, light grey, argillaceous, pelagic	Typic Calcixerept - Lithic Xerorthents association	slope facet complex	290.1	1.2	Hi111
		limestone, grey, neritic and pelagic	Typic Calcixerepts- Lithic Xerorthents	slope facet complex	1,299.9	5.4	Hi121

Land-scape	Relief	Lithology	Map unit composition	Landform	Area		Symbol
					ha	%	
	medium hill	limestone, white, light grey, argillaceous	Typic Haploxerepts-Lithic Xerorthents association	slope facet complex	676.4	2.8	Hi221
		marl with intercalatin of argillaceous, limestone, dark grey and white pelagic limestone	Typic Calcixerepts-Lithic Xerorthents association	slope facet complex	167.4	0.7	Hi231
	high hill	flych, marl, marlstone, siltstone, sandstone, conglomerate, argillaceous, limestone, grey, green	Lithic Xerorthents	slope facet complex	55.5	0.2	Hi361
Piedmont	high glacis	marl with intercalatin of argillaceous limestone, pelagic limestone	Typic Calcixerepts & Vertic Calcixerepts	slope facet complex	2,133.6	8.8	Pi1111
		claystone, sandstone, conglomerate (with pebbles ofophiolitic), red	chromic calcixererts & Vertic Calcixerepts	upper upper glacis	1,401.1	5.8	Pi121
		alluvium and colluvium	Typic Calcixerepts & Vertic Calcixerepts & Fluventic Haploxerepts	middle upper glacis	5,035.1	20.8	Pi132
		alluvium and colluvium	Typic Calcixerepts	slope facet complex	991.1	4.1	Pi131
Piedmont	middle glacis	alluvium and colluvium	Typic Calcixerepts	slope facet complex	2,180.9	9.0	Pi231
	low glacis	alluvium and colluvium	Typic Calcixerepts & Vertic Calcixerepts	slope facet complex	3,332.7	13.8	Pi331
					234.2	1.0	Bad lands
Bad lands						100	
SUM					24,206.4		

Mo311: As for the above units, scarps and rock outcrops are the main landforms of this map unit. Elevation varies from 300 to 900 m. Gray limestone is the most important mineral in rocks. These areas have a slope of 40% and steeper, and are also soil-less. This unit occupies 507.6 ha, corresponding to 2.1% of the study area.

Mo321: Elevation varies between 300 and 900 m. Remarkable landforms are scarps and rock outcrops. The lithological composition is mainly white and light gray limestone. Overall slope is 40% and steeper, and the unit is mostly soil-less. This map unit occupies 507.6 ha, corresponding to 2.1% of the study area.

Mo312: Elongated round type ridges are the main landform of this map unit. Elevation varies between 300 to 900 m. Slopes vary between 25% and 70%. Rock outcrops occupy a maximum 30% of the area, and the remainder is Lithic Xerorthents, thus differing from other units. The map unit occupies 252.4 ha, corresponding to 1.0% of the study area.

Plate 3. A view of a complex slope on an elongated ridge (S. Fatehi).

Mo322: Elongated round type ridges are the main landform of this map unit. Elevation varies between 300 and 900 m. The lithological composition includes white and gray limestone and overall slope varies between 12% and 70%. Rock outcrops occupy a maximum 15% of the area, and the remainder belongs to a soil association including Typic Calcixerepts, Typic Haploxerepts, and Lithic Xerorthents as inclusion. This map unit occupies 1324.5 ha or 5.5% of the study area.

Mo332: Elongated round type ridges are the main landform of this map unit and elevation varies between 300 and 900 m. The lithological composition includes marl and limestone. The slope varies between 12% and 25%. The map unit is a consociation composed of rock outcrops that occupy 5% of the area; the remainder belongs to Typic Haploxerepts as main soil and Fluventic Haploxerepts as similar soil. This unit occupies 490.2 ha or 2.0% of the study area.

Mo342: Elongated round type ridges are the main landform of this map unit. Elevation varies between 300 and 900 m. The lithological composition includes claystone and stone and slope varies from 12% to 25%. The map unit is an association composed of Typic Haploxerepts, Typic Xerorthents, and Vertic Calcixerepts. This unit occupies 2634.4 ha, or 10.9% of the study area.

Mo353: Flank with slope complex facet is the main landform of this map. Elevation varies between 300 and 900 m. The lithological composition includes mainly dolomite and overall slope varies between 12% and 25%. The map unit is an association composed of rock outcrop (around 15%), Typic Haploxerepts, and Lithic Xerorthents. It occupies 811.7 ha, or 3.4% of the study area.

Hill land

Hi111: Elevation varies between 90 and 300 m. The main lithology is gray limestone. Overall slope varies between 40% and 70%. The map unit is an association composed of Typic Calcixerepts and Lithic Xerorthents. It occupies 290.1 ha, or 1.2% of the study area.

Hi121: Elevation varies between 90 and 300 m. Lithological composition is mainly light gray and white limestone. Overall slope varies between 40% and 70%. The map unit is an association composed of rock outcrop (25%), Typic Calcixerepts, and Lithic Xerorthents. It occupies 1,299.9 ha, 5.4% of the study area.

Hi221: Elevation varies between 30 and 90 m. Lithological composition is mainly light gray and white limestone. Overall slope varies between 25% and 40%. The map unit is an association composed of Typic Haploxerepts and Lithic Xerorthents. This unit occupies 676.4 ha, or 2.8% of the study area.

Hi231: Elevation varies between 30 and 90 m. Lithological composition is mainly light gray and white limestone. Overall slope varies between 25% and 40%. The map unit is an association composed of Typic Calcixerepts and Lithic Xerorthents. It occupies 167.4 ha, or 1.7% of the study area.

Hi361: Elevation varies between 9 and 30 m. The lithological composition is mainly marl, flysch, and conglomerates. Overall slope varies between 12% and 25%. The map unit is an association composed of rock outcrop (nearly 50%) and Lithic Xerorthents. It occupies 55.54 ha, or 0.2% of the study area.

Piedmont

Pi111: An undulating high glacis with complex slopes on marl and limestone formations. Overall slope varies between 5% and 12%. This map unit is a consociation composed of Typic Calcixerepts and Vertic Calcixerepts. It occupies 2,133.6 ha, or 8.8% of the study area.

Plate 4 A view of the piedmont in Merek watershed (S. Fatehi).

Pi121: An undulating high glacis with complex slopes formed on claystone and conglomerate formations. Overall slope varies between 2% and 12%. This map unit is a consociation composed of Typic Calcixerepts and Chromic Calcixerepts. It occupies 1,401.1 ha, or 5.8% of the study area.

Pi132: An undulating high glacis with complex slopes formed on an alluvium-colluvium formation. Overall slope varies between 2% and 8%. The map unit is a consociation composed of

Typic Calcixerepts, Vertic Calcixerepts, and Fluventic Haploxerepts. It occupies 5,035.1 ha, or 20.8% of the study area.

Pi131: An undulating high glacis with complex slopes that were formed on an alluvium-colluvium formation. Overall slope varies between 5% and 25%. The map unit is a consociation composed of Typic Calcixerepts. It occupies 991.1 ha, or 4.1% of the study area.

Pi231: An undulating middle glacis with complex slopes that are formed on an alluvium-colluvium formation. Overall slope varies between 2% and 8%. The map unit is a consociation. Its composition is a Typic Calcixerept as main soil and Fluventic Haploxerepts as similar soil. This map unit occupies 2,180.9 ha, or 9.0% of the study area.

Pi331: An undulating low glacis with complex slopes that were formed on an alluvium-colluvium formation. Overall slope varies between 0% and 5%. The map unit is a consociation, composed of Typic Calcixerepts as main soil, and Vertic Calcixerepts and Fluventic Haploxerepts as similar soils. It occupies 3,232.1 ha, or 13.8% of the study area.

Bad lands: This map unit is highly eroded. It occupies 234.2 ha, or 1.0% of the study area.

3.1.3. General recommendations for land use in Merek

Based on the information obtained by the soil survey, the following recommendations for use of the land in Merek are suggested:

- High slopes and water erosion hazards are the most important land-use limitations in the mountain and hill lands of the two watersheds . Controlled grazing and development of soil and water conservation structures (such as gabions) could promote good conditions for pastures.
- Due to undulating conditions over more than 50% of the study area, the use of sprinkler and trickle irrigation systems is recommended.
- Conservation of natural pastures and dry farming are the best options environmentally.
- Leveling is not recommended, especially in areas where subsurface horizons contain large quantities of gravel and lime.
- Research projects should be established that further evaluate the suitability of the lands for crops, pastures, and forests, and thus promote optimum use of soil and water resources.

3.2. Part B. Honam Watershed

3.2.1. General description of Honam watershed

Location

Honam watershed is located south of Alashtar, the capital of Selsele County. The study area is located between 48º12´ to 48º28´ E and 33º45´ to 33º51´ N (Fig. 1). It is limited in the north by mountains near the Alashtar plain, in the south by the Espash, Darikanan, and Neshaneh Mountains, in the east by the Green Mountain, and in the west by the Doab Alashtar region and Zirtag and Syahpoosh villages. The area covers 14,200 ha, with farmland accounting for 4,270 ha (30%). The farms are located in the center of the area on a small plain running from east (Presk Village) to west (Ziretag Village). The main river is the Honam. It originates near Sarab village, flows east-west through the Alashtar plain, and joins other rivers in the Doab plain. A view of the northern and southern parts of the watershed are presented in plate 5 and 6.

Climate

Honam has cold winters and relatively modest summers. The rainfall occurs in a regular wet and dry cycle. All significant precipitation falls between October and May, while the remainder of the year is very dry (Fig. 6).

The average annual precipitation in Alashtar is 472 mm. A substantial portion of the watershed lies in the high mountains and receives more precipitation. At lower elevation, nearly all precipitation occurs in the form of rain, whereas at higher elevation a significant amount occurs in the form of snow. According to the Domartan system (Jamab Consulting Engineers 1991), the area falls within the wet climate, resulting from high elevated mountains.

The mean monthly temperature ranges from -4°C in February to 20.3°C in July (Fig. 6). The mean annual air temperature is 8.8°C, the maximum mean monthly temperature is 20.3°C, and the minimum mean monthly temperature is -4°C. The average annual

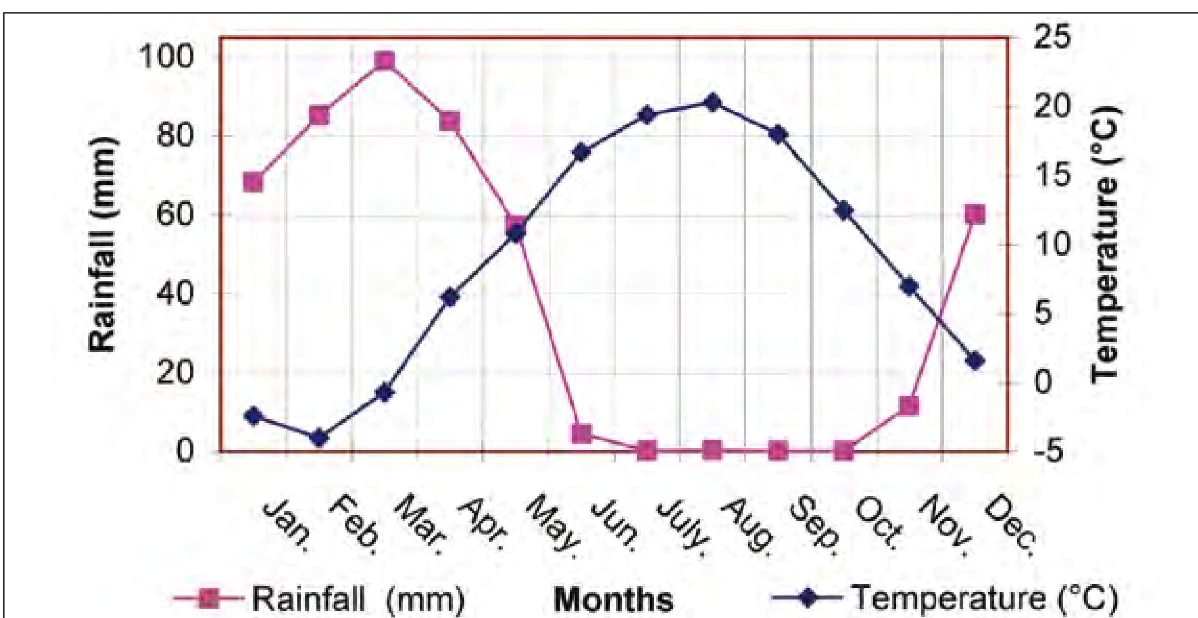

Fig. 6. Monthly precipitation and temperature at Alashtar station.

Plate 5. View of southern part of Honam watershed (M. Sephavand 2008).

Plate 6. View of northern part of Honam watershed (M. Sephavand 2008).

potential evapotranspiration, measured by a class A pan in Alashtar, is 1,137 mm (Table 5). The average monthly potential evapotranspiration is 35 mm in winter (January to March) and 176 mm in summer (July to September).

The soil moisture and temperature regimes were calculated using the Newhall software (Newhall and Berdanier 1996). Data from Alashtar station showed that the soil moisture and temperature regimes of Honam are xeric and mesic, respectively.

Geology

Honam is part of the Zagros mountain chain, stretching in a northwest-southeast direction. The rocks in Honam watershed are limestone, dolomite, marl, quartzite, shale, sandstone, and conglomerates. Faulting and folding are common characteristics. Due to their joints and fractures, together with karstic features, the limestone formations act as natural reservoirs for water and also give rise to many springs (Plate 7).

The geological map of Honam watershed (Geology Organization of Iran 1993) is presented in Fig. 7. Rocks in the mountains are of sedimentary origin. Limestone formations occupy 9,562 ha (45%) of the study area. Quaternary sediments (old alluvium, high terrace, and young alluvium) derived from the surrounding sedimentary rocks occupy 2,993 ha (35%) of the area, and other formations (radiolarian breccias, Bakhtiari conglomerate, marl, sandstone, and limestone) cover 1,462 ha (15%) of the area. Some characteristics of the lithological units in the study area are presented in Table 6.

Table 5. Mean monthly rainfall, temperature, and potential evapotranspiration in Alashtar station (1966-2001).

	Month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Rain (mm)	68.3	85.3	99.1	83.9	57.4	4.6	0.3	0.5	0.2	0.2	11.6	60.2	471.6
Temperature (ºC)	-24	-4.0	-0.7	6.2	10.8	16.7	19.4	20.3	18.0	12.5	7.0	1.6	8.8
Evapotranspi-ration (mm)	27.7	29.1	48.5	82.9	121.8	96.8	187.9	186.0	154.2	107.6	59.0	35.5	1,136.6

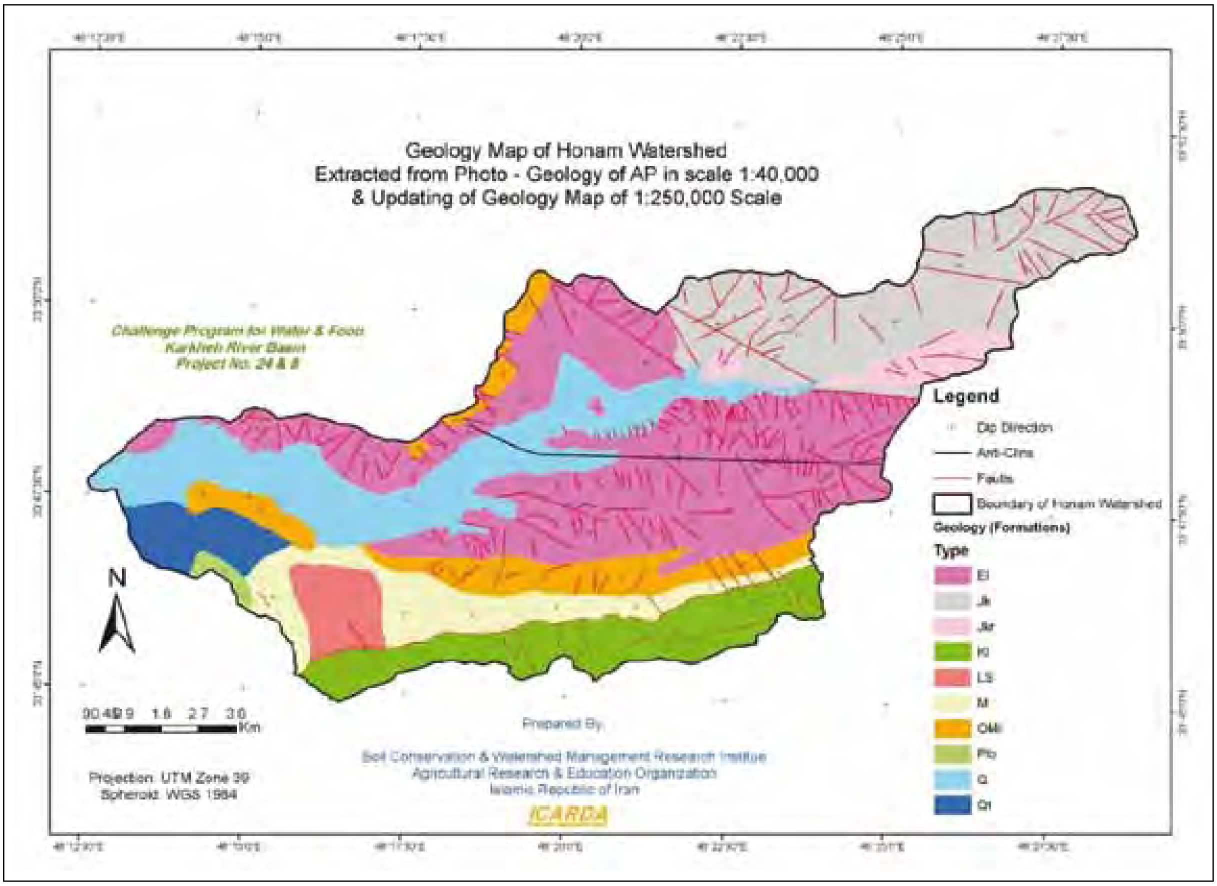

Fig. 7. The geologic map of Honam watershed (after Geology Organization of Iran 1993), see Table 7 for description of legend

Table 6. Lithological units, their epoch and surface area in the Honam watershed.

Epoch	Map-legend	Description	Area (ha)
Quaternary	Q	young alluvium	2,139.3
	Qt	old alluvium and high terrace	448.1
	Ls	landslides	405.7
Pliocene	Plb	bakhtiari conglomerate	73
Miocene	M	marl, sandstone, limestone	1,055.2
Oligo-Miocene	OMi	reefal limestone	1,106.1
Eocene	El	marl limestone	4,656.3
Early Cretaceous	Ki	rodist and orbitalina limestone	1,298.7
Early Cretaceous-late Jurassic	JKr	raddiolarian breccia	333.4
	JK	dolomitic limestone	2,500.6
Total			14,016.4

Plate 7. An example of a large spring at the Khaskhan River in Lorestan near Pol-e Dokhtar city.

Geomorphology

Honam watershed is surrounded by mountains in the north, west, and east. The dominant feature of the mountains are folding and faulting, and the drainage follows a complicated pattern. Several peaks rise to over 3,000 m, notably in the northeast. The geomorphology, obtained from aerial-photo interpretation, is described in the next chapter.

Soils

The study area is very steep, with slopes exceeding 12%. The soils, formed from medium-to-fine textured calcareous alluvium, derived from the limestone of the surrounding mountains and were deposited by the Honam River and its main tributaries. As a result, the soils are calcareous and exhibit an alkaline reaction. Lime content is very high. In some parts of the area, lime is not visible in the soils. Locally, in parts of piedmonts, lime occurs in a soft powdery form or in rounded lime spots and concretions. The pH values are above 7.5. The organic carbon content is low to very low. Values for organic carbon content vary between 0.1% and 3.7% with an average of 1.9%. The structure of the top soil is usually massive, forming large clods when plowed. This unstable structure collapses easily on moistening.
The soils have a fine-to-medium, moderate-to-strong angular blocky structure, gradually changing into a massive or weak subangular blocky structure with depth. The soils are described in detail in the next chapter.

Land use and native vegetation

Currently, the main dry farming crops in Honam are wheat, barley, and chickpeas. Dry farming is a common practice, especially on the hills. The main irrigated crops are wheat, barley, canola, chickpeas, clover, alfalfa, and sugar beet. A small part of the area is covered by fruit orchards including walnut and cold region fruit trees. Fruit orchards are limited to the higher parts of study area on the banks of the Honam River and its tributaries, and production is mainly for local consumption.

Animal husbandry is strongly linked to the cropping systems. Traditionally, all meat and dairy products have been produced locally. Farmed animals include sheep, goats, and a limited number of cattle.

The native vegetation is diverse. Zonal distribution of the area's many species depends on topography, hydrology, and soil condition, among other factors. Natural grass and weeds are commonly found on the lower slopes. Seasonal grass provides good pasture for goats and sheep in the spring months. The piedmonts and valley terraces support a variety of common weeds and grasses, including *Graminea* sp., *Legominosea* sp., *Agropyrum* sp., *Euphobia* sp., *Tragopogon* sp., *Althea sulphumca, Gundellia tournefortil, Convonvolous arvensis, Cartamus oxycanta, Astragalus* sp., and *Phlomis persica.*

Hydrology and water supply
Traditionally, irrigation water was derived from the Honam River. At present, irrigation water is mainly drawn from the irrigation canal of Shagnahr. The contribution of springs and wells of varying depths is also important. Analysis of samples collected from the Honam River shows good water quality (Table 7). According to the Wilcox classification system, the water quality is suitable for irrigation (C2-S1) (United States Salinity Laboratory Staff 1954).

3.2.2. Soils of Honam watershed

Four landscape types were recognized in Honam watershed: mountain (Mo), hill (Hi), piedmont (Pi), and valley (Va) (Table 8, Fig. 8). Each landscape was divided into relief forms based on a combination of topography, geological structure, origin, and lithology. Each relief form was further subdivided into different landforms. Soils were further differentiated within landforms, resulting in 37 map units (Fig 9). The soil units are described in Table 9 and the profile

Table 7. Quality of water in the Honam River.

pH	EC	Anions (meq l^{-1})					Cations (meq l^{-1})		
	ds m^{-1}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Sum	$Ca^{2+}+Mg^{2+}$	Na^+	Sum
8.2	0.40	-	0.5	3	1.5	5	3.8	1	4.8

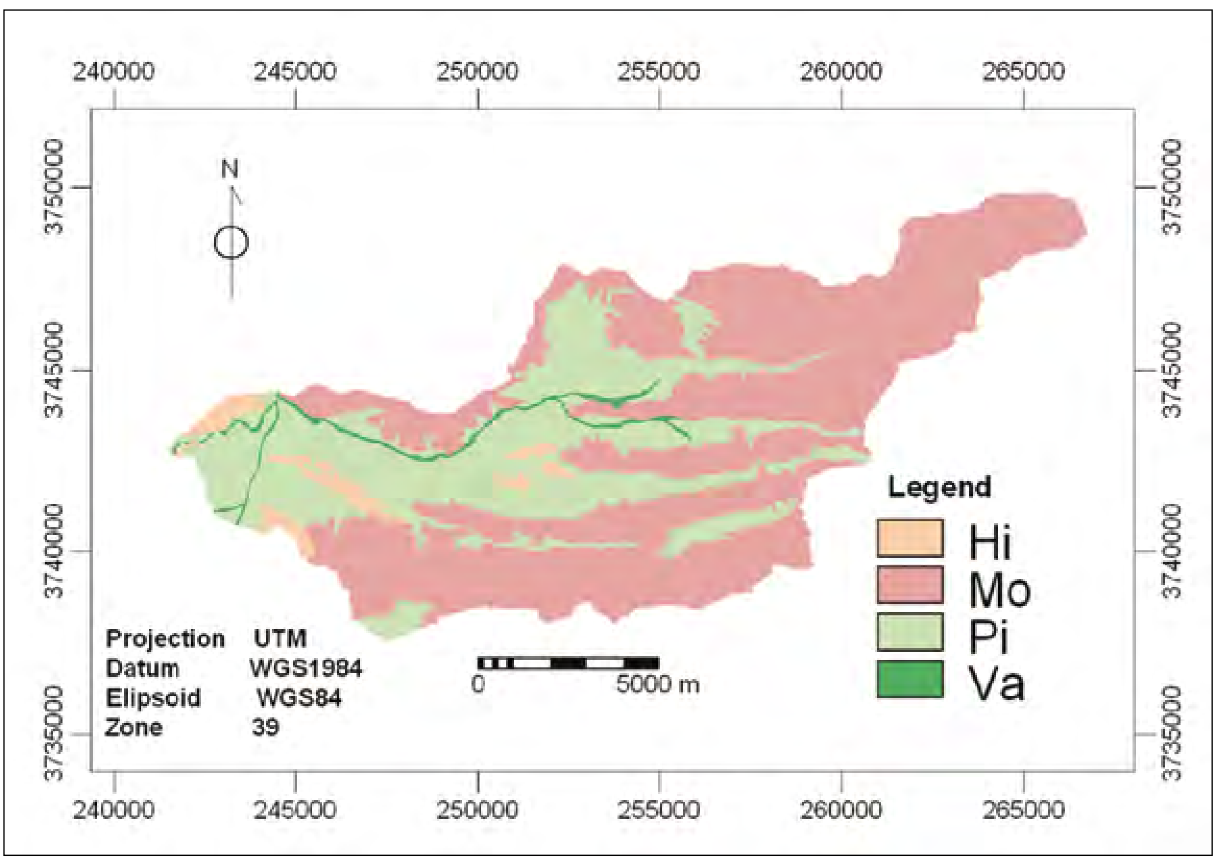

Fig. 8. Geomorphic units at landscape level in Honam.

descriptions and laboratory analyses of all units are given in Appendix B.

Soil orders

Three soil classes were found in Honam watershed. Their characteristics are described below.

Xerorthents

The Xerorthents are shallow and eroded, ranging from shallow, gravelly clay loam, derived from underlying calcareous materials, to very shallow, rocky sandy loam, derived from limestone and other calcareous rocks, on rugged topography at the highest elevation. Two subgroups, Lithic and Typic Xerorthents, occupy a large part of the study area.

Lithic Xerorthents are very shallow soils, developed on colluvial slopes at rocky mountain land. They have an ochric epipedon over a Lithic contact consisting of consolidated limestone.

Table 8. Honam watershed geomorphic landscape units and their corresponding area.

Landscape	Area (ha)	Area (%)
Mountain	8,719.35	62.1
Hill	453.66	3.3
Piedmont	4,635.26	33.0
Valley	229.25	1.6
Total	14,037.52	100

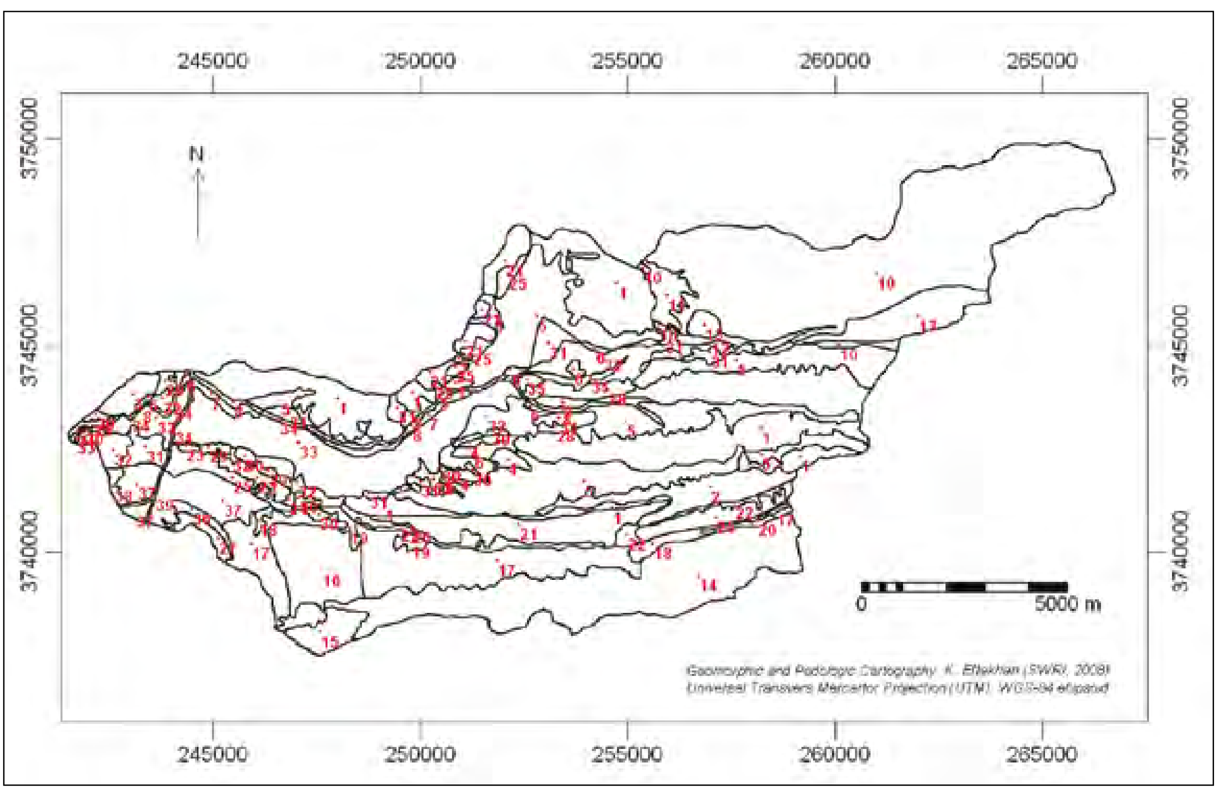

Fig. 9. Semi-detailed geopedologic map of Honam watershed.

Table 9. Legend of the geopedologic map of Honam watershed.

Landscape	Relief/Molding	Lithology	Landform	Map unit type	Polypedons Name	Polypedons % Obs.	Inclusion Name	Inclusion % Obs.	Soil map unit	Area ha	Area %
Mountain (Mo)	High hill (Mo1)	Marl, limestone (Mo11)	Low ridge and drainage way complex	Consociation	Typic Calcixerepts	50%	Rock outcrops	10%	1	2,133.49	15.2
					Lithic Calcixerepts	30%					
					Fluventic Haploxerepts	10%					
		Dolomitic limestone (Mo12)	High ridge and drainage way complex	Association	Typic Haploxerepts	40%	Rock outcrop	20%	9	2,423.43	17.4
					Lithic Calcixerepts	40%					
		Raddiolar in breccia (Mo13)	Medium ridge and drainage way complex	Consociation	Lithic Haploxerepts	50%	Rock outcrop	5%	12	314.19	2.2
					Typic Calcixerepts	45%					
		Rodist and Orbitalina limestone (Mo14)	Structural surface	Consociation	Rock outcrop	70%	Typic Haploxerepts	10%	13	1,279.38	9.1
					Lithic Xerorthents	20%					
		Reefal limestone (Mo15)	Medium ridge and drainage way complex	Consociation	Typic Haploxerepts	60%	Rock outcrop	10%	20	542.48	3.9
					Lithic Xerorthents	30%					
		Young alluvium (Mo16)	Outlying hills	Consociation	Lithic Xerorthents	50%	Rock outcrop	20%	27	103.44	0.7
					Fluventic Haploxerepts	30%					
	Medium hill (Mo2)	Marl, limestone (Mo21)	Old piedmont	Consociation	Typic Haploxerepts	60%	Lithic Haploxerepts	10%	2	281.62	2.0
					Rock outcrop	30%					

Table 9. Continued.

Land-scape	Relief/Mold-ing	Lithology	Landform	Map unit type	Polypedons		Inclusion		Soil map unit	Area	
					Name	% Obs.	Name	% Obs.		ha	%
Mountain (Mo)	hill (Mo2)	Landslide (Mo22)	Undulating backslope	Conso-ciation	Lithic Xe-rorthents	50%	Typic Hap-loxer-epts	10%	15	362.07	2.6
					Rock out-crop	40%					
		Marl, sandstone, limestone (Mo23)			Lithic Xe-rorthents	50%	Flu-ventic Hap-loxer-epts	20%	16	815.78	5.8
					Typic Cal-cixerepts	30%					
		Reefal limestone (Mo24)			Not sur-veyed				21	79.94	0.6
Hill (Hi)	High hill (Hi1)	Bakhtiari conglom-erate (Hi12)			Not Sur-veyed				26	47.73	0.3
		Old al-luvium and high terrace (Hi13)	Undulating backslope	Conso-ciation	Lithic Xe-rorthents	60%	Rock Out-crop	10%	35	34.7	0.3
					Typic Cal-cixerepts	30%					
	Medium hill (Hi2)	Marl, limestone (Hi21)	Foot slope and toea slope complex	Conso-ciation	Typic Cal-cixerepts	80%			3	82.29	0.6
					Lithic Xe-rorthents	20%					
		Reefal limestone (Hi22)			Not sur-veyed				22	67.79	0.5
		Young allu-vium (Hi23)			Not sur-veyed				28	65.88	0.5

Table 9. Continued.

Land-scape	Relief/ Mold-ing	Lithology	Landform	Map unit type	Polypedons		Inclusion		Soil map unit	Area	
					Name	% Obs.	Name	% Obs.		ha	%
Hill (Hi)	Low hill (Hi3)	Marl, limestone (Hi31)			Not surveyed				4	68.94	0.5
		Reefal limestone (Hi32)			Not surveyed				23	7.12	0.1
		Young alluvium (Hi33)			Not surveyed				29	81.37	0.6
Piedmont (Pi)	High glacis (Pi1)	Marl, limestone (Pi11)		Association	Typic Calcixerepts	46%	Calcic Haploxerepts	15%	5	1,824.68	13.0
					Fluventic Haploxerepts	38%					
		Dolomitic limestone (Pi12)			Calcic Haploxerepts	50%	Fluventic Haploxerepts	10%	10	104.38	0.7
					Typic Calcixerepts	40%					
		Rodist and Orbitalina limestone (Pi13)			Typic Calcixerepts	50%	Fluventic Haploxerepts	25%	14	122.11	0.9
					Calcic Haploxerepts	25%					
		Marl, sandstone, limestone (Pi14)			Not surveyed				17	81.17	0.6
		Reefal limestone (Pi15)		Consociation	Typic Calcixerepts	60%	Fluventic Haploxerepts	15%	24	302.12	2.2
					Calcic Haploxerepts	25%					

Table 9. Continued.

Land-scape	Relief/Mold-ing	Lithology	Landform	Map unit type	Polypedons Name	Polypedons % Obs.	Inclusion Name	Inclusion % Obs.	Soil map unit	Area ha	Area %
Pied-mont (Pi)	High glacis (Pi1)	Young allu-vium (Pi16)		Conso-ciation	Typic Cal-cixerepts	100%			30	306.02	2.2
Piedmont (Pi)	High glacis (Pi1)	Old allu-vium and high terrace (Pi16)		Conso-ciation	Typic Cal-cixerepts	66%			36	336.73	2.4
					Fluventic Haploxer-epts	34%					
	Middle glacis (Pi2)	Marl, lime-stone (Pi21)			Not sur-veyed				6	99.27	0.7
		Dolomitic limestone (Pi22)	Terrace floodplain complex	Conso-ciation	Fluventic Haploxer-epts	70%	Typic Xero-flu-vents	10%	11	56.64	0.4
					Typic Cal-cixerepts	20%					
		Marl, sandstone, limestone (Pi23)			Not sur-veyed				18	52.04	0.4
		Reefal lime-stone (Pi24)	Terrace floodplain complex	Conso-ciation	Fluventic Haploxer-epts	70%	Typic Xero-flu-vents	10%	25	97.65	0.7
					Typic Cal-cixerepts	20%					
		Young allu-vium (Pi25)	Terrace floodplain complex	Conso-ciation	Typic Cal-cixerepts	78%			31	564.78	4.0
					Fluventic Haploxer-epts	23%					

Table 9. Continued.

Landscape	Relief / Molding	Lithology	Landform	Map unit type	Polypedons		Inclusion		Soil map unit	Area	
					Name	% Obs.	Name	% Obs.		ha	%
Piedmont (Pi)	Middle glacis (Pi2)	Old alluvium and high terrace (Pi26)			Not surveyed				37	22.48	0.2
	Low glacis (Pi3)	Marl, limestone (Pi31)		Consociation	Calcic Haploxerepts	70%			7	87.08	0.6
					Typic Calcixerepts	30%					
		Young alluvium (Pi32)		Consociation	Typic Calcixerepts	88%			32	887.37	6.3
					Typic Haploxerepts	12%					
Valley (Va)	Floodplain (Va1)	Marl, sandstone, limestone (Va11)			Not surveyed				19	27.40	0.2
		Young alluvium (Va12)	Pointbar complex	Consociation	Fluventic Haploxerepts	75%			33	229.01	1.6
					Typic Calcixerepts	25%					
	Terrace (Va2)	Marl, limestone (Va21)	Trade riser complex	Consociation	Fluventic Haploxerepts	100%			8	26.82	0.2
		Young alluvium (Va22)	Trade riser complex	Consociation	Typic Calcixerepts	100%			34	17.19	0.1
Total										14,036.58	100

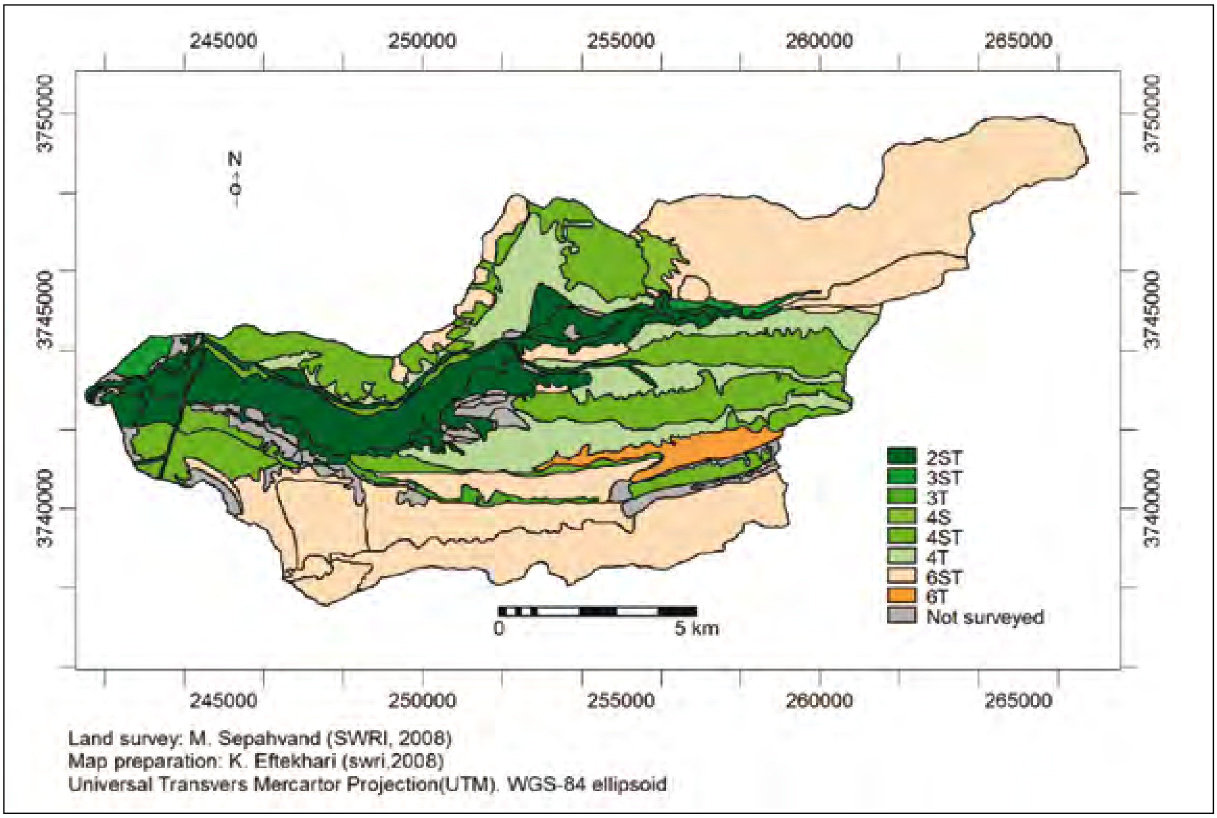

Fig. 10. Land classification map of Honam watershed (for legend, see text).

3.2.3. Honam land classification and improvement recommendations

A semi-detailed land-classification map was made to indicate the possibilities for development of irrigation (Fig. 10). The classification is based on a system developed in Iran and described in the "Irrigation, Soil Survey, and Land Classification Guide for Iran," prepared by the independent irrigation corporation Bongah Abiari in cooperation with the FAO. The second edition, published 15 years later, includes modifications of existing norms and new material to improve soil survey standards (Mahler 1979). In this report, technical and economical factors that co-determine the suitability of the land for irrigation are not considered.

Factors evaluated

The following factors were evaluated:

Soil characteristics

- Subsoil permeability
- Subsoil stoniness
- Topsoil texture
- Topsoil stoniness
- Soil depth
- Type of limiting layer
- Infiltration rate
- Salinity and alkalinity

Associated land features

- Overall slope
- Transversal slope
- Topography, including micro-relief
- Erosion, both water and wind
- Liability to flooding
- Present deposition statue

Drainage conditions (present and potential)
- Groundwater depth
- Other drainage limitations
- Pounding hazard
- Flooding hazard

Drainage conditions depend on soil characteristics and associated land features, thus both internal and external drainage are considered.

Land classification system

Classes of land

Factors mentioned above allow the division of land into six classes:

- Class 1: Very suitable for irrigation. The soil is deep, of medium to heavy texture, has good water-holding capacity and medium permeability, and is free of salt. The topography is usually favorable, with gentle slopes. There is no erosion, the water table is low, and there is no risk of flooding.

- Class 2: Suitable for irrigation. Soils are moderately suitable for irrigation but with lower productive capacity than class 1 land. Certain limiting factors are present—drainage may be too slow, water-holding capacity may be too low, there may be slight salinity or alkalinity problems, or an unfavorable relief.

- Class 3: Marginal irrigable land. This land is suitable for irrigation but less so than class 2 land because of greater deficiencies in the soil. Soil may be impeded and internal drainage may be too rapid; there may be appreciable surface run-off and erosion, risk of flooding, and moderate salinity or alkalinity problems.

- Class 4: Not suitable for irrigation of commonly cultivated crops except under special conditions. The land is usually too gravelly, too shallow, too severely eroded, too steep, or too frequently flooded for practical and economic development as crop land. Cultivation may be practical in special conditions or after special treatment.

- Class 5: Unsuitable for irrigation. The land is currently unsuitable but this situation may be reversed given positive economic conditions or future engineering options. The land suffers severe salinity or alkalinity problems or is poorly drained.

- Class 6: Nonirrigable land. Land that is permanently nonirrigable, and which includes steep, rough, broken land; riverwash; sand dunes; and highly saline land.

Subclasses of land

The six land classes indicate increasing degrees of limitations on the land; the sub classes show the type of limitations. Four subclasses are defined:

A: Salinity limitation.
S: Soil limitation (except salinity), related to texture, depth, and permeability.
T: Topographic limitation, related to steep or irregular slope. Erosion is considered a topographic limitation because of its relation to slope.
W: Wetness, drainage, or flooding problems.

Land classes in Honam watershed

Eight different land classes could be identified in Honam watershed (see Fig. 9 and Table 10). These are described below.

- Class 2ST: 14.28% of the area consists of class 2 lands with pedological and topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h). There is no

Table 10. The sizes of the different land classes in Honam watershed (see Fig. 10).

Map legend	Area (ha)	Area (%)
2ST	2,005.19	14.28
3ST	138.93	0.99
3T	97.65	0.70
4S	104.38	0.74
4ST	2,859.42	20.37
4T	1,851.50	13.19
6ST	5,997.58	42.73
6T	281.62	2.01
Not surveyed	701.14	4.99
Total	14,037.42	100.00

subsoil stoniness. Topsoil texture is mainly very heavy sandy clay, silty clay, and clay. Soils are very deep (deeper than 120 cm) without any limitation and have good salinity and alkalinity conditions. These are gently sloping lands with 2-5% overall slopes and 1-2% transversal slopes. Microrelief limitation (undulations observed within a 100-meter distance) is slight, with no apparent erosion by water or wind. No limitation was observed due to a ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 3ST: 0.99% of the area consists of class 3 lands with pedological and topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h). There is no subsoil stoniness. Topsoil texture is mainly very heavy sandy clay, silty clay, and clay. There is 15-35% topsoil stoniness. Soils are very deep (deeper than 120 cm) without limitations. Soils have good salinity and alkalinity conditions. These are gently sloping lands with 2-5% overall slopes and 2-5% transversal slopes. Microrelief limitation is slight. Slight erosion by water was observed. No limitation was observed due to ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 3T: 0.7% of the area consists of class 3 lands with topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h). There is no subsoil stoniness. Topsoil texture is mainly heavy clay loam, silty clay loam, and sandy clay loam. Soils are very deep, (deeper than 120 cm) without any limitation. Soils have good salinity and alkalinity conditions. These are gently sloping lands with 2-5% overall slopes and 2-5% transversal slopes. Microrelief limitation is moderate. Slight erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 4S: 0.74% of the area consists of class 4 lands with soil limitations. Permeability of the subsoil is low (0.1-2 cm/h); 35-75% coarse fragments in subsoil horizons. Topsoil texture is mainly very heavy sandy clay, silty clay, and clay; 15-35% coarse gravel was observed on the soil surface. Soils are moderately deep (between 50-80 cm) with a limitation due to gravel layers. Soils have good salinity and alkalinity conditions. These are gently sloping lands with 2-5% overall slopes and 2-5% transversal slopes. Microrelief limitation is slight. Slight erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 4ST: 20.37% of the area consists of class 4 lands with soil and topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h) and 35-75% coarse fragments were observed in subsoil horizons. Topsoil texture is mainly very heavy sandy clay, silty clay, and clay; 15% - 35% coarse gravel was observed on the surface. Soils are moderately deep (between 50-80 cm) with a limitation due to presence of gravel layers. Soils have good salinity and alkalinity conditions. They are sloping lands with 5-8% overall slopes and 5-8% transversal slopes. Microrelief limitation is slight. Slight erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 4T: 13.19% of the area consists of class 4 lands with topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h) and 15-35% coarse fragments were observed in subsoil horizons. Topsoil texture is mainly very heavy sandy clay, silty clay, and clay; 15-35% coarse gravel was observed on the surface. Soils are deep (more than 120 cm) without any limitation. Soils have good salinity and alkalinity conditions. These are sloping lands with 5% - 8% overall slopes and 5-8% transversal slopes. Microrelief limitation is moderate. Moderate erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 6ST: 42.73% of the area consists of class 6 lands with pedological and topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h), with 35-75% coarse fragments in subsoil horizons. Topsoil texture is mainly heavy clay loam, silty clay loam, and sandy clay loam; 75% coarse gravel was observed on the soil surface. Soils are moderately deep (50-80 cm) with a limitation due to presence of gravel layers. Soils have good salinity and alkalinity conditions. These are very steep lands with 40-70% overall slopes and 12-25% transversal slopes. Microrelief limitation is strong. Moderate erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

- Class 6T: 2.01% of the area consists of class 6 lands with severe topographical limitations. Permeability of the subsoil is low (0.1-2 cm/h) with 35-75% coarse fragments in subsoil horizons. Topsoil texture is mainly heavy clay loam, silty clay loam, and sandy clay loam; 35-75% coarse gravel was observed on the surface. Soils are moderately deep (between 50-80 cm) with a limitation due to presence of gravel layers. Soils have good salinity and alkalinity conditions. These are very steep lands with 40% - 70% overall slopes and 12-25% transversal slopes. Microrelief limitation is strong and slight erosion by water was observed. No limitation was observed due to presence of ground table, temporary waterlogging, an impermeable layer in the underlying materials (below 120 cm depth), or flooding or ponding hazards.

Land improvement practices and levels

Land improvement practices include leveling and grading, artificial drainage, salt leaching, and stone picking. For each type of land improvement practice, four levels are defined. These levels are set out by order of increasing amount of work required (low, moderate, high, and very high). In Honam, only leveling and grading and stone picking are needed, as described below.

Leveling and grading

Low grading requirement applies to lands with minor irregularities of microrelief. Moderate grading requirement applies to lands with slight irregularities in microrelief and in slope direction with a slope gradient of less than 5%. High grading requirement applies to lands with moderate irregularities in microrelief and slope direction and regular slopes of up to 8%. Very high grading requirement applies to lands with strong irregularities in microrelief and slope direction with a maximum gradient of 12%.

Stone picking

Requirements for stone picking apply for coarse fragments of more than 2.5 cm in size and for the top 20 cm of the soil only. Low stone picking requirements correspond to the removal of 10-30 cubic m of coarse fragments per hectare. Moderate stone picking requirements correspond to the removal of 30-60 cubic m of coarse fragments per hectare. High stone picking requirements correspond to the removal of 60-100 cubic m of coarse fragments per hectare. Very high stone picking requirements correspond to the removal of more than 100 cubic m of coarse fragments per hectare.

Technical recommendations for land improvement in Honam

The land improvement activities required are those necessary for removing or reducing land limitations that hamper the efficiency of moderately intensive cropping.

Class 2ST
These lands need high levels of grading and leveling. After this operation, the maximum land class will be improved but remain at class 2ST.

Class 3ST
These lands need high levels of stone picking, grading, and leveling. After these operations, the maximum land class will be improved to 2ST.

Class 3T
These lands need high levels of grading, and leveling. After this operation, the maximum land class will be improved to 2ST.

Class 4S
These lands need a very high level of stone picking. After this operation, the maximum land class will be improved to 3ST.

Class 4ST
These lands need a high level of stone picking. After this operation, the maximum land class will be improved to 4T.

Class 4T
These lands need high levels of stone picking, grading, and leveling. After these operations, the maximum land class will be improved to 3ST.

Class 6ST
These lands need a very high level of stone picking. After this operation, the maximum land class will be improved to 6T.

Class 6T
These lands need a very high level of stone picking. After this operation, the maximum land class will be improved to 6T.

General recommendations for land use in Honam

Based on the information obtained by the soil survey in Honam, the following land-use recommendations are suggested:

- Steep slopes and water erosion hazards are the most important limiting factors in mountain and hill lands in Honam. Conservation of the lands through reduced grazing and development of gabion structures can help improve the conditions for pastures.
- Because of undulating conditions in more than 50% of the study area, sprinkler and trickle irrigation systems must be used if irrigated areas are to be expanded.
- Leveling operations are not recommended, especially in areas with soil subsurface horizons with high gravel and lime contents.
- For soil and water resources conservation, sprinkler and trickle irrigation, improved pasture management, and dry farming are recommended.
- Further research is recommended to evaluate the suitability of the lands for crops, pastures, and forests, and thus promote optimum use of soil and water resources.

4. References

Abkav Consulting Engineering Company. 1972. *Sahne, Bistoon, Herseen, Mahidasht, Ravansar and Sanjabi Plains semi detailed soil survey and classification.* Abkav Company, Tehran, Iran.

Bavandpoor, A.K. 1999. *Geology map of Iran, Kermanshah quadrant (1:100,000).* Geology Organization of Iran. Tehran, Iran.

Briggs, D. and Y.E.K. Shishira. 1985. Soil variability in geomorphologically defined survey units in the Albudite area of Murcia Province, Spain. *Soil and geomorphology, Catena supplement 6.* Catena Verlag, Germany, pp 69-84.

FAO. 1977. *Guidelines for soil profile description.* FAO, Rome, Italy.

Geology Organization of Iran. 1993. *Geology map of Khoramabad (1:250000). Geology Organization.* Tehran, Iran.

Jamab Consulting Engineers Company. 1991. Iran climatology survey. *Volume 4, Climatological classification.* Tehran, Iran.

Mahler, P.J. 1979. *Manual of land classification for irrigation. 3rd revised edition.* Soil and Water Research Institute of Iran (SWRI), Tehran, Iran.

Newhall, F. and C.R. Berdanier. 1996. Calculation of soil moisture regimes from the climatic record. *Soil Survey Investigations Report 46.* Soil Conservation Service, USDA, Washington, DC, USA.

Rossiter, D.E. 2000. *Methodology for soil resource inventories, 2nd Revised version.* Soil Science Division International Institute for Aerospace Survey & Earth Sciences (ITC), Enschede, The Netherlands.

Schoenberger, P.J., D.A. Wysocki, E.C., Behnam, and D. Broderson. 1998. *Field book for describing and sampling soils.* Natural Resource Conservation Service, USDA, National Soil Survey Center, Lincoln, NE, USA.

Soil Survey Staff. 1999. Soil taxonomy, a basic system of soil classification for making and interpreting soil survey (2nd ed.). *Agricultural handbook number 436.* USDA, U.S. government printing office, Washington, DC.

Soil Survey Staff. 2006. *Keys to soil taxonomy (10th ed.).* USDA, U.S. Government Printing Office, Washington, DC, USA.

United States Salinity Laboratory Staff. 1954. Diagnosis and Improvement of saline and alkali soils. *USDA Handbook No. 60.* U.S. Government Printing Office, Washington, DC, USA.

Van Wambeke, A. and T.R. Forbes. 1986. Guidelines for using soil taxonomy in the names of soil map units. *SMSS Technical monograph No. 10.* USDA, Washington, DC, USA.

Zink, J.A. 1989. Physiography and soils. Lecture notes for K6 course, Soil Division, ITC, Enschede, the Netherlands.

5. APPENDIX

5.1. APPENDIX A

Representative Soil Profiles and Laboratory Data of Merek Watershed

Pedon number:		**2**
Location:		37° 05´ 3.2″ N & 40° 14´ 6.7″ E
Map unit symbol:		Pi111
Physiographics position:		Piedmont
Taxonomic classification:		Fine, mixed, thermic Typic Calcixerepts
Top soil stoniness:		1-3%
Slope:		2-5%
Drainage:		Well drained
Land use:		Wheat (dry farming)
Horizon	Depth (cm)	Description
Ap	0-20	Brown (10YR 4/6), wet; silty clay; massive structure; hard, dry; very sticky and very plastic, wet; com mon, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw	20-35	Dark brown (7.5YR 5/4), wet; silty clay; weak, coarse angular blocky structure; hard, dry; very sticky and very plastic, wet; common, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bk1	35-90	Dark brown (7.5YR 5/4), wet; clay; strong, fine angular blocky structure; hard, dry; very sticky and very plastic, wet; common, very fine to fine vesicular pores; few, moderate vesicular pores; many, very fine to fine, roots; few moderate roots; common me dium, spherical, white, $CaCO_3$ concretion; gradual smooth boundary.
Bk2	90-120	Light brown (7.5YR 5/6), wet; clay; strong, fine an gular blocky structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; common medium, spherical, white, concretion, $CaCO_3$; few $CaCO_3$ pendants.

Analytical data for pedon 2

Depth cm	Clay %	Silt %	Sand %	Tex.	SP %	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-20	40.6	49.4	10	sic	48	7.7	0.34	32.5	1.05	3
20-35	46.6	42.4	11	sic	47	7.78	0.32	33.2	0.84	3
35-90	44.6	39.4	16	c	49	7.75	0.4	36.2	0.59	6
90-120	44.6	39.4	16	c	51	7.89	0.28	-	0.36	15

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-20	-	-	26.1	13.1	27	0.11
20-35	-	-	26.6	12.4	25.6	0.08
35-90	-	-	21	10.9	25.2	0.06
90-120	-	-	27.7	12.6	-	0.04

Tex. = texture
SP = saturation percentage
EC_e = electrical conductivity of saturated extract
OC= organic carbon
Sic = silty clay
C = clay
FC = field capacity (0.3 bar)
PWP = permanent wilting point (15 bar)
CEC = cation exchange capacity
Av. K = available potassium
Av. P = available phosphorus
Tot. N = total nitrogen

Pedon number:		**14**
Location:		34° 04´ 24.75˝ N & 47° 13´ 4.65˝ E
Map unit symbol:		Pi331
Physiographics position:		Piedmont
Taxonomic classification:		Fine, mixed, active, thermic Vertic Calcixerept
Top soil stoniness:		-
Slope:		2-5%
Drainage:		Well drained
Land use:		Wheat (dry farming)
Horizon	Depths (cm)	Description
Ap	0-30	Brown (7.5YR 4/4), wet; silty clay; massive structure; very hard, dry; very sticky and very plastic, wet; few, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw1	30-60	Brown (7.5YR 4/4), wet; silty clay; weak, medium subangular blocky structure; very hard, dry; very sticky and very plastic, wet; few, very fine to fine vesicular pores; few, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw2	60-90	Dark brown (7.5YR 5/4), wet; clay; strong, medium subangular blocky structure; firm, moist; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; gradual smooth boundary.
Bk	90-132	Light brown (7.5YR 5/6), wet; clay; strong, medium subangular blocky structure; firm, moist; very sticky and very plastic, wet; many, very fine to fine vesicular pores; common medium, Spherical, white, $CaCO_3$ concretion; few, very fine $CaCO_3$ threads.

Analytical data for pedon 14

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-30	47.8	44.6	6.6	sic	51	7.75	0.5	28	1.30	-
30-60	44.8	48.6	6.6	sic	59	7.07	0.37	29	0.91	-
60-90	54.8	21.6	23.6	c	54	8.06	0.37	36.2	0.70	-
90-132	48.8	41.6	9.6	c	51	7.91	0.4	30.2	1.38	-

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-30	-	-	28.7	15.5	27	0.13
30-60	-	-	28.6	14.5	25.6	0.09
60-90	-	-	28.8	15.6	25.2	0.07
90-132	-	-	28.6	15.9	-	0.14

For abbreviations: see pedon 2.

Pedon number:		12
Location:		34° 05´ 32.4˝ N & 47° 17´ 9.19˝ E
Map unit symbol:		Mo332
Physiographics position:		Mountain
Taxonomic classification:		Fine, mixed, superactive, thermic Typic Haploxerepts
Top soil stoniness:		35%
Slope:		12-25%
Drainage:		Well drained
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Brown (7.5YR 4/4), wet; silty clay; strong, very fine, subangular blocky structure; moderate, fine granular structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw1	20-40	Brown (7.5YR 4/4), wet; clay; strong, fine subangular blocky structure; very hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw2	40-70	Brown (7.5YR 4/4), wet; clay; strong, fine subangular blocky structure; very hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; many, very fine $CaCO_3$ threads; clear smooth boundary.
Bw3	70-103	Brown (7.5YR 4/4), wet; clay; strong, fine subangular blocky structure; very hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; many, very fine $CaCO_3$ threads; Clear smooth boundary.
Bw4	103-125	Brown (7.5YR 4/4), wet; clay; strong, fine subangular blocky structure; very hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores.

Analytical data for pedon 12

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-20	46.8	38	19.2	c	53	7.84	0.4	22	2.67	10
20-40	44.8	38	15.2	c	47	7.73	0.38	21	1.69	20
40-70	42.8	34	17.2	c	48	7.95	0.34	25	1.28	20
70-103	36.8	34	23.2	cl	45	7.96	0.33	31.8	0.82	30
103-125	42.8	38	29.2	c	41	8	0.28	44.5	0.65	50

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-20	-	-	32.4	14.5	27.4	0.27
20-40	-	-	25.6	12.9	28.8	0.17
40-70	-	-	24.7	12.9	29.8	0.13
70-103	-	-	22.9	11.5	25.2	0.08
103-125	-	-	-	-	-	0.08

For abbreviations: see pedon 2.

Pedon number:		**34**
Location:		34° 05´ 8.11˝ N & 47° 13´ 5.11˝ E
Map unit symbol:		Pi231
Physiographics position:		Piedmont
Taxonomic classification:		Clayey-skeletal, mixed, active, thermic Typic Calcixer-epts
Top soil stoniness:		35%
Slope:		2-5%
Drainage:		Well drained
Land use:		Wheat (dry farming)
Horizon	Depths (cm)	Description
Ap	0-30	Brown (7.5YR 4/4), wet; silty clay loam; massive structure; firm, moist; sticky and plastic, wet; many, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw	30-70	Brown (10YR 6/4), wet; clay loam; massive structure; friable, moist; sticky and plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bk1	70-120	Brown (10YR 6/4), wet; clay loam; massive structure; friable, moist; sticky and plastic, wet; many, very fine to fine vesicular pores; common, coarse, vesicular pores; few, very fine to fine, roots; many, coarse $CaCO_3$ as pendant; gradual smooth boundary.
Bk2	120-150	Brown (10YR 6/4), wet; silty clay loam; strong, fine subangular blocky structure; firm, moist; sticky and plastic, wet; many, very fine to fine vesicular pores; few to common, medium $CaCO_3$ as pendant.

Analytical data for pedon 34

Depth cm	**Clay %**	**Silt %**	**Sand %**	**Tex.**	**SP**	**pH paste**	**EC_e dS m^{-1}**	**$CaCO_3$ %**	**OC %**	**> 2 mm %**
0-30	36.8	40	23.2	sicl	47	7.60	0.64	38	0.48	35
30-70	36.8	38	25.22	cl	56	7.80	0.67	40.5	0.58	45
70-120	38.8	39	21.2	cl	59	7.60	0.74	39.8	0.43	45
120-150	38.8	46	15.2	sicl	46	7.60	0.69	45.8	0.40	15

Depth cm	**Av. K mg kg^{-1}**	**Av. P mg kg^{-1}**	**FC 0.3 bar**	**PWP 15 bar**	**CEC Cmol(+) kg^{-1}**	**Tot. N %**
0-30	-	-	23.7	12.5	21.6	0.04
30-70	-	-	24.6	13.1	19	0.06
70-120	-	-	24.9	12.1	22	0.04
120-150	-	-	25.8	12.9	-	0.04

For abbreviations: see pedon 2.

Pedon number:		**40**
Location:		34° 06´ 12.2˝ N & 47° 07´ 54.72˝ E
Map unit symbol:		Pi331
Physiographics position:		Piedmont
Taxonomic classification:		Clayey-skeletal, carbonatic, thermic Typic Calcixerepts
Top soil stoniness:		-
Slope:		2-5%
Drainage:		Well drained
Land use:		Wheat (dry farming)
Horizon	Depths (cm)	Description
Ap	0-20	Brown (7.5YR 4/4), wet; clay loam; massive structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bw	20-40	Dark brown (7.5YR 5/4), wet; silty clay; strong, fine subangular blocky structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; clear smooth boundary.
Bk1	40-95	Yellowish brown (10YR 5/6), wet; clay; strong, fine, subangular blocky structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, medium, vesicular pores; few, very fine to fine, roots; few, fine, spherical white $CaCO_3$ as concretion; clear smooth boundary.
Bk2	95-130	Yellowish brown (10YR 5/6), wet; silty clay; strong, fine subangular blocky structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, medium vesicular pores; few to common, fine, spherical, white $CaCO_3$ as concretion.

Analytical data for pedon 40

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-20	33.8	43.6	22.6	sicl	73	7.70	0.68	27	1.47	-
20-40	46.8	43.6	9.6	sicl	47	7.90	0.96	55.8	0.97	-
40-95	48.8	36	14.6	c	56	7.90	0.66	48	0.97	-
95-130	50.8	42.6	6.6	sic	59	7.90	0.7	40.5	0.57	-

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-20	-	-	26.4	16.3	-	1.5
20-40	-	-	26.1	12.8	-	0.1
40-95	-	-	25.9	12.8	-	0.1
95-130	-	-	27.3	12.9	-	0.06

For abbreviations: see pedon 2.

Pedon number:		**41**
Location:		34° 05´ 35.5˝ N & 47° 10´ 1.85˝ E
Map unit symbol:		Pi132
Physiographics position:		Piedmont
Taxonomic classification:		Fine, mixed, thermic Chromic Calcixerets
Top soil stoniness:		-
Slope:		2-5%
Drainage:		Well drained
Land use:		Fallow
Horizon	Depths (cm)	Description
Ap	0-25	Reddish brown (5YR 4/6), wet; silty clay; massive structure; hard, dry; very sticky and very plastic, wet; few, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; clear smooth boundary.
Bk	25-50	Reddish brown (5YR 4/6), wet; clay; weak, coarse, subangular blocky structure; hard, dry; very sticky and very plastic, wet; few, very fine to fine vesicular pores; few, very fine to fine, roots; few, fine, spherical white $CaCO_3$ as concretion and lime eye; gradual smooth boundary.
Bkss1	50-100	Reddish brown (5YR 4/6), wet; silty clay; strong, Medium, wedge structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; few, fine, spherical white $CaCO_3$ as concretion and nodule; many slickenside; gradual smooth boundary.
Bkss2	100-150	Reddish brown (5YR 4/6), wet; silty clay; strong, medium, wedge structure; hard, dry; very sticky and very plastic, wet; many, very fine to fine vesicular pores; few, medium vesicular pores; few to common, medium, spherical, white $CaCO_3$ as concretion and nodule; many slicken sides.

Analytical data for pedon 41

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-25	45.8	47.6	6.6	sicl	46	7.50	0.78	32	1.3	-
25-50	50.8	38.6	10.6	c	46	7.60	1.42	58.8	0.88	-
50-100	50.8	47	3.2	sic	55	7.60	1.01	36.2	1.04	-
100-150	48.8	42	9.2	sic	56	7.60	0.55	38.3	0.91	-

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-25	-	-	24.4	14	-	0.11
25-50	-	-	22.5	11.2	-	0.09
50-100	-	-	24	13.5	-	0.1
100-150	-	-	-	-	-	0.09

For abbreviations: see pedon 2.

Pedon number:		**65**
Location:		34° 01´ 28.53˝ N & 47° 13´ 49.68˝ E
Map unit symbol:		Mo353
Physiographics position:		Mountain
Taxonomic classification:		Fine, mixed (calcareous), thermic Lithic Xerorthents
Top soil stoniness:		15%
Slope:		5-8%
Drainage:		Well drained
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-30	Brown (7.5YR 4/4), wet; clay loam; strong, fine, subangular blocky structure; strong, fine, granular structure; hard, dry; very sticky and very plastic, wet; few, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; gradual smooth boundary.
R	>30	Parent material

Analytical data for pedon 65

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %
0-30	37.4	26	36.6	cl	45	7.41	1.24	29	3.2	-
+30	-	-	-	-	-	-	-	-	-	-

Depth cm	Av. K mg kg^{-1}	Av. P mg kg^{-1}	FC 0.3 bar	PWP 15 bar	CEC Cmol(+) kg^{-1}	Tot. N %
0-30	-	-	24.2	12	-	0.32
+30	-	-	-	-	-	-

For abbreviations: see pedon 2.

5.2. APPENDIX B

Representative Profiles and Laboratory Data of Honam Watershed

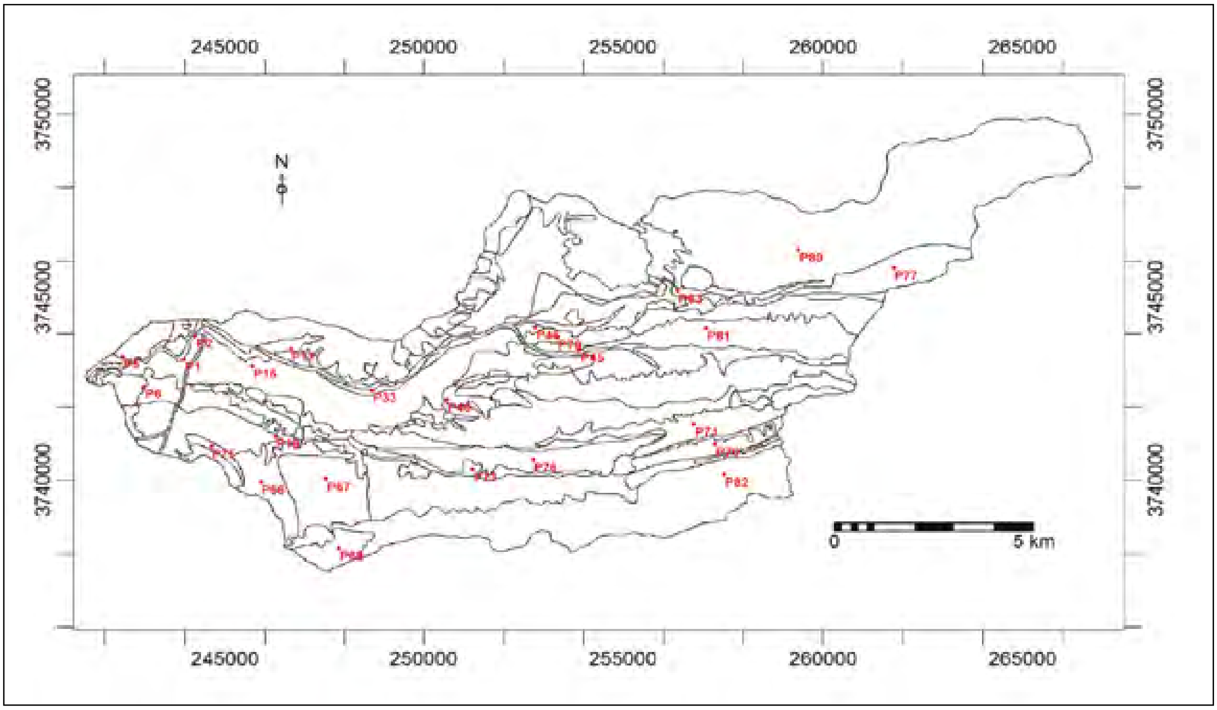

Fig. 11. Location map of representative soil profiles in Honam.

Map unit number		**1**
Pedon number:		81
Taxonomic classification:		Fine, mixed, mesic Fluventic Calcixerepts
Drainage:		Poor drained
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-20	Clay loam; yellowish brown (10YR5/4), dry; brown (10YR4/3), wet; weak, medium, granular structure, primary; weak, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine to fine vesicular pores; many, very fine to fine, roots; few moderate roots; few gravel; clear wavy boundary.
Bw	20-35	Clay loam; yellowish brown (10YR5/4), dry; yellowish brown (10YR5/6), moist; weak, medium, granular structure, primary; weak, medium to fine angular blocky, structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine, tubular pores; common, coarse and fine to very fine roots; few gravel; clear wavy boundary.
Bk	35-100	Clay loam; yellowish brown (10YR5/4), dry; yellowish brown (10YR5/6), moist; strong, medium, angular blocky structure, primary; strong, fine angular blocky , structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine, tubular pores; common, coarse, fine to very fine roots; common, small, spherical, white $CaCO_3$; few gravel; clear wavy boundary.
C	> 100	More than 75% gravel and stones.

Analytical data for pedon 81 (Map unit 1)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	46	44	10	sic	51	7.55	0.50	16.6	1.31	10	320
20-35	47	39	14	sic	49	7.72	0.47	26.9	1.02	15	-
35-100	60	37	3	c	49	7.84	0.46	35.5	0.67	20	-
>100	-	-	-	-	-	-	-	-	-	>75	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	3.8	-	-
20-35	-	-	-
35-100	-	-	-
>100	-	-	-

Tex. = texture
SP = saturation percentage
EC_e = electrical conductivity of saturated extract
OC= organic carbon
Sic = silty clay
C = clay
FC = field capacity (0.3 bar)
PWP = permanent wilting point (15 bar)
CEC = cation exchange capacity
Ava K = available potassium
Ava P = available phosphorus
Tot. N = total nitrogen

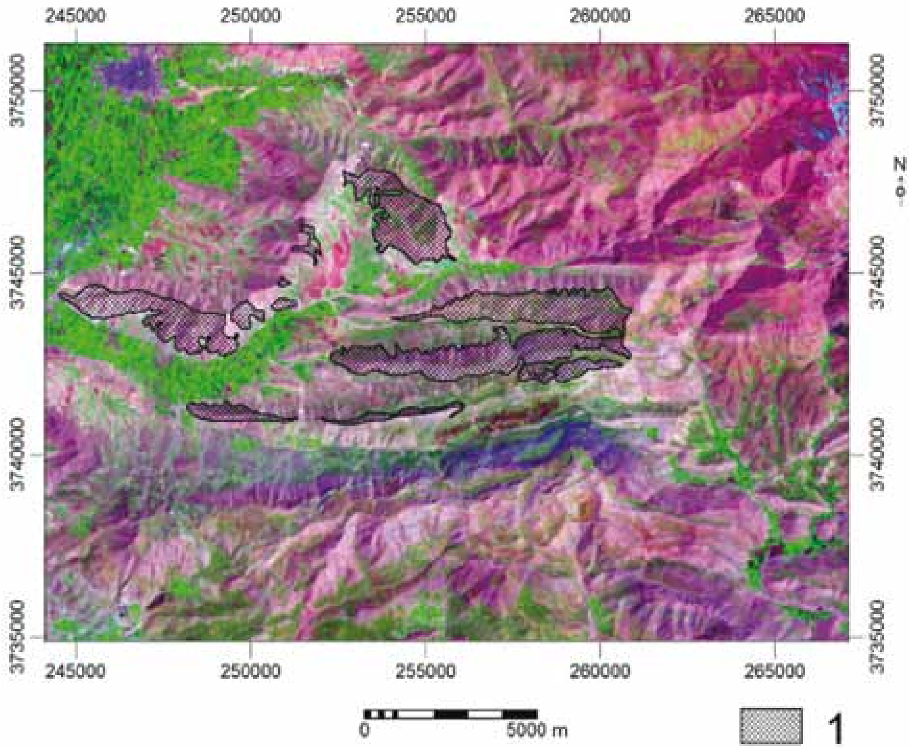

Fig. B1. Map of soil unit 1 in Honam watershed.

Plate B1. Fine, mixed, mesic Typic Calcixerepts (Map unit 1, Pedon 81) (M. Sepahvand, 2008).

Map unit number		**2**
Pedon number:		71
Taxonomic classification:		Clayey over fragmental, mixed, mesic Typic Haploxerepts
Drainage:		Poor drained
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-20	Clay; brown (7.5YR5/4), dry; brown (7.5YR4/4), wet; weak, medium, granular structure, primary; weak, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, coarse, fine to very fine tubular pores; common, fine to very fine, roots; few moderate roots; clear wavy boundary.
B	20-60	Clay; brown (7.5YR5/4), dry; strong brown (7.5YR5/6), wet; weak, medium, angular blocky, primary; weak, fine, angular blocky, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine, tubular pores; few, fine to very fine roots; gradual wavy boundary.
C	> 60	More than 75% gravel, stone and bulders.

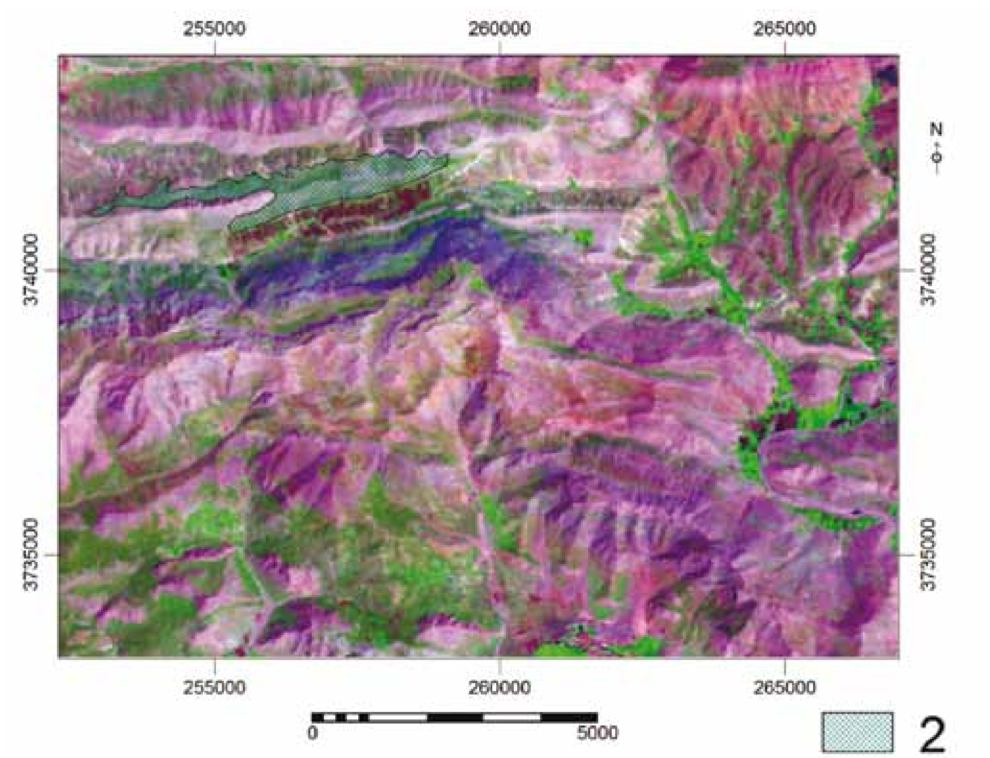

Fig. B2. Map of soil unit 2 in Honam watershed.

Analytical data for pedon 71 (Map unit 2)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	60	35	5	c	59	7.53	0.22	1.7	1.58	-	-
20-60	65	30	5	c	51	7.60	0.18	4.1	1.03	-	-
> 60	-	-	-	-	-	-	-	-	-	>75	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	-	-	-
20-60	-	-	-
> 60	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Plate B2. Clay over fragmental, mixed, mesic Typic Haploxerepts (Map unit 2; Pedon 71) (M. Sepahvand, 2008).

Map unit number		**3**
Pedon number:		5
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Poor drained
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Silty clay; brown (10YR5/3), dry; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine to fine tubular pores; many, very fine to fine, roots; few moderate roots; clear wavy boundary
Bw	20-35	Silty clay; brown (10YR5/3), dry; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine to fine tubular pores; many, very fine to fine, roots; few moderate roots; slightly gravelly; clear wavy boundary
Bk	35-75	Silty clay; yellowish brown (10YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; many, very fine to fine, tubular pores; many, small, soft, spherical, white $CaCO_3$; few, very fine to fine, roots; gradual wavy boundary.
Cr	75-130	Silty clay; dark yellowish brown (10YR4/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine to fine, tubular pores.

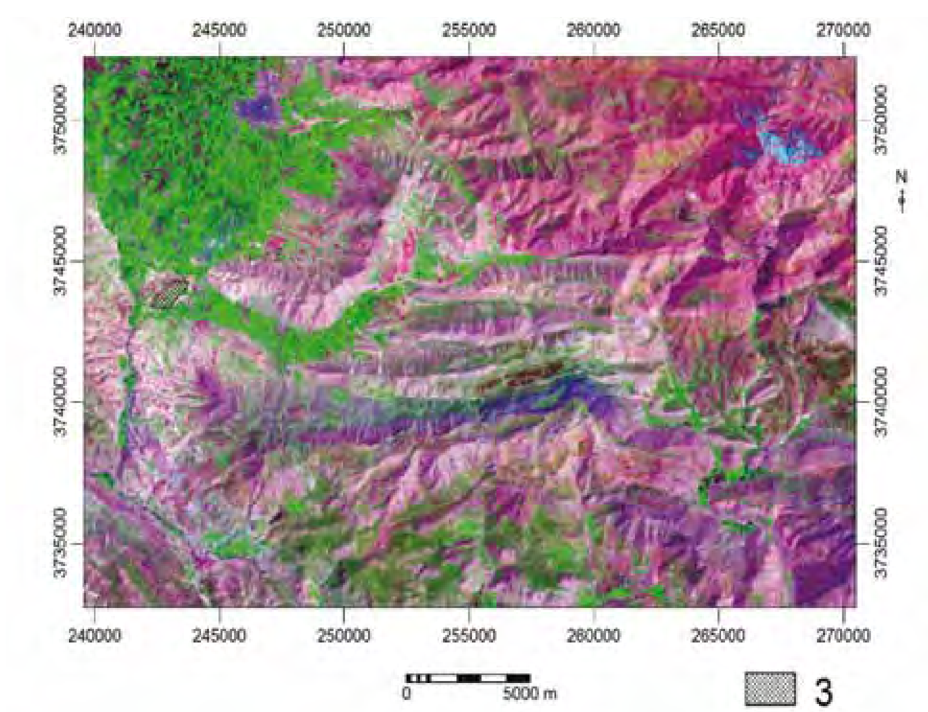

Fig. B3. Map of soil unit 3 in Honam watershed.

Analytical data for pedon 5 (Map unit 3)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	43	49	8	sic	47	7.68	0.42	27	0.8	-	315
20-35	50	43	7	sic	47	7.59	0.43	34.5	0.57	5-10	235
35-75	51	44	5	sic	46	7.55	0.46	33	0.27	-	190
75-130	46	50	4	sic	47	7.69	0.29	31.8	0.12	-	180

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	7	26.8	14.7
20-35	2.2	23.4	14.4
35-75	2	29.1	14.2
75-130	2.5	28.7	15

For abbreviations, see pedon No.81 (Map Unit 1).

Map unit number		**5**
Pedon number:		17
Taxonomic classifica-tion:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Wheat
Horizon	Depths (cm)	Description
Ap	0-20	Silty clay loam; pale brown (10YR6/3), dry; brown, (10YR5/3), wet; moderate, medium to fine, granular structure; hard, dry; firm, moist; sticky and plastic, wet; many, very fine to fine tubular pores; few, very fine to fine, roots; clear wavy boundary.
Bw	20-35	Silty clay; brown (10YR4/3), wet; weak, medium angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine, tubular pores; few, very fine roots; few gravel; gradual wavy boundary.
Bk	35-55	Silty clay; brown (10YR5/3), wet; moderate, medium to fine, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; many, very fine to fine, tubular pores; many, small, soft, spherical, white $CaCO_3$; very few gravel; few, very fine, roots; clear wavy boundary.
C	55-70	Silty clay; light yellowish brown (10YR6/4), wet; massive structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; many, very fine to fine, tubular pores; many, small, soft, spherical, white $CaCO_3$; very gravely; few, very fine, roots; clear wavy boundary.
BK_b	70-135	Silty clay; brown (10YR5/3), wet; moderate, medium to fine, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine to fine, tubular pores; many, small, soft, spherical, white $CaCO_3$; slightly gravelly; few, very fine, roots.

Analytical data for pedon 17 (Map unit 5)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-20	40	53	7	sic	43	7.70	0.37	28.3	0.71	-	295
20-35	47	48	5	sic	42	7.62	0.4	34.8	0.59	10-15	200
35-55	45	47	8	sic	45	7.68	0.34	39.5	0.47	5	170
55-70	44	46	10	sic	43	7.73	0.34	41.8	0.45	40-50	170
70-135	41	52	7	sic	47	7.85	0.27	38.8	0.1	5	140

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP15 bar
0-20	15.4	22.80	13.40
20-35	7.4	32.10	15.00
35-55	3.2	22.80	14.00
55-70	3.1	24.70	13.00
70-135	3.2	28.80	15.60

For abbreviations, see pedon No.81 (Map Unit 1).

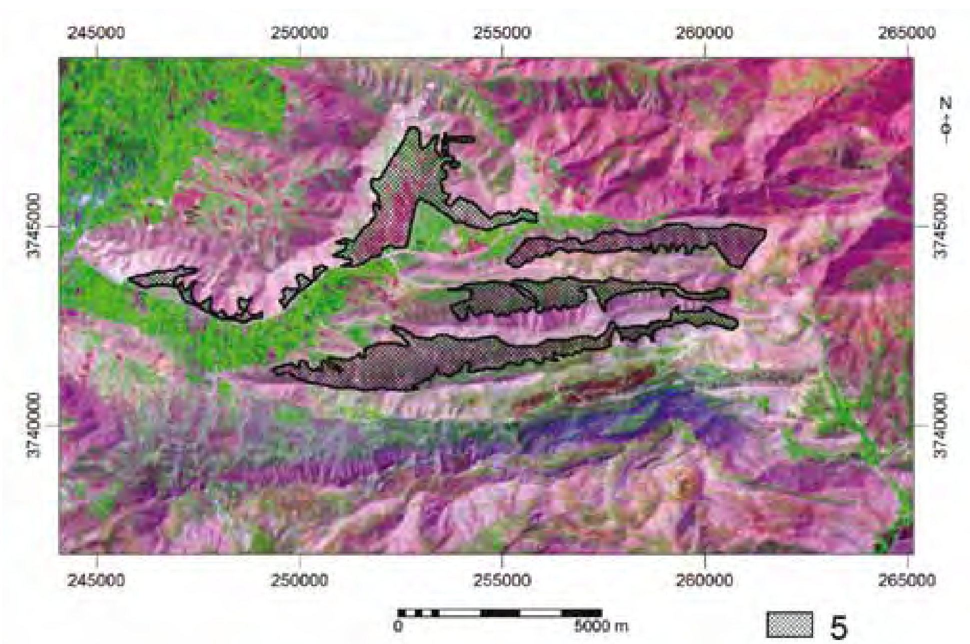

Fig. B4. Map of soil unit 5 in Honam watershed.

Map unit number		**7**
Pedon number:		33
Taxonomic classification:		Clayey over fragmental, mixed, mesic Calcic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, coarse, fine to very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bw	20-45	Clay loam; brown (10YR5/3), dry; dark yellowish brown (10YR4/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, fine to very fine tubular pores; very few, very fine, roots; clear wavy boundary.
C	45-100	Loamy sand; very pale brown (10YR7/3), dry; dark yellowish brown (10YR4/4), wet; massive structure, primary; single grain structure, secondary; loose, dry; loose, moist; nonsticky and nonplastic, wet; interracial pores; very many gravel (>75%) .

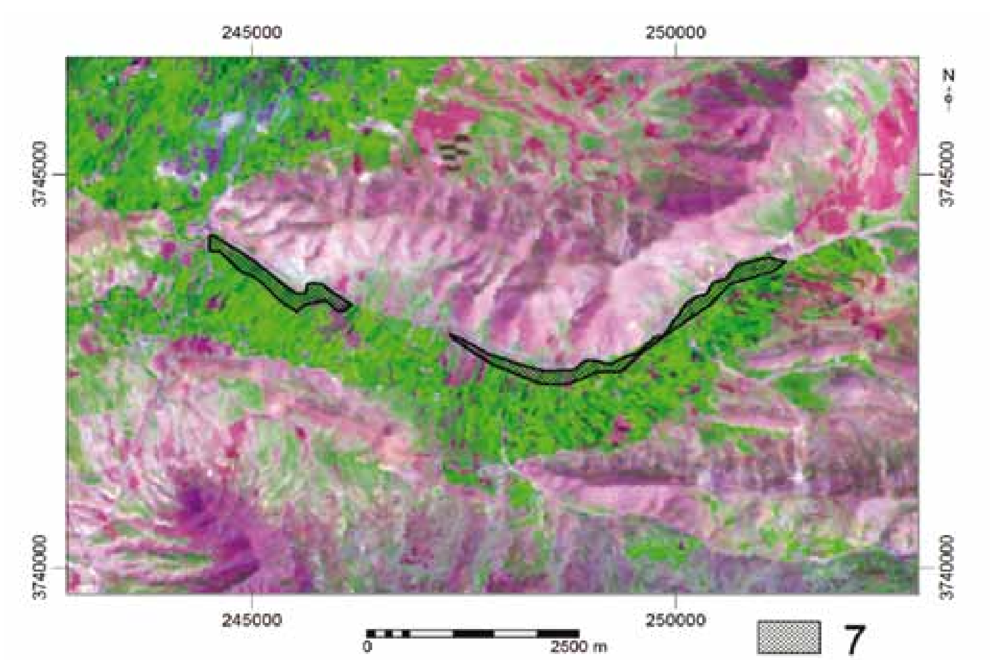

Fig. B5. Map of soil unit 7 in Honam watershed.

Map unit number		**8**
Pedon number:		45
Taxonomic classification:		Fine, mixed, mesic Fluventic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-15	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, medium, fine to very fine tubular pores; few, fine to very fine, roots; gravelly; clear wavy boundary.
AB	15-40	Clay loam; brown (10YR4/3), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, medium, fine to very fine tubular pores; few, fine to very fine, roots; gravelly; gradual wavy boundary.
Bw	40-70	Clay loam; yellowish brown (10YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, medium, fine and very fine tubular pores; few, fine to very fine, roots; gravelly; gradual wavy boundary.
B1	70-130	Clay loam; light yellowish brown (10YR6/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, medium, fine and very fine tubular pores; few, fine to very fine, roots; very gravelly.

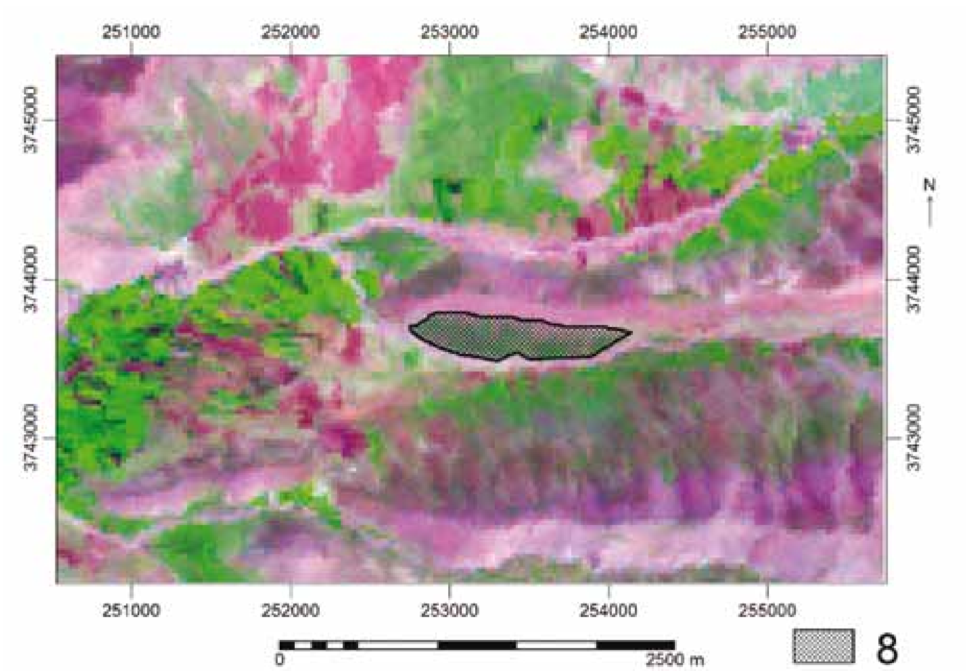

Fig. B6. Map of soil unit 8 in Honam watershed.

Map unit number		**9**
Pedon number:		15
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-30	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, medium, fine to very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
Bw	30-60	Silty clay; brown (10YR4/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots; gradual wavy boundary.
Bz1	60-90	Silty clay; brown (10YR4/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; very few, very fine tubular pores; very few, very fine, roots; gradual wavy boundary.
Bz2	90-130	Silty clay; brown (10YR4/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; very few, very fine tubular pores.

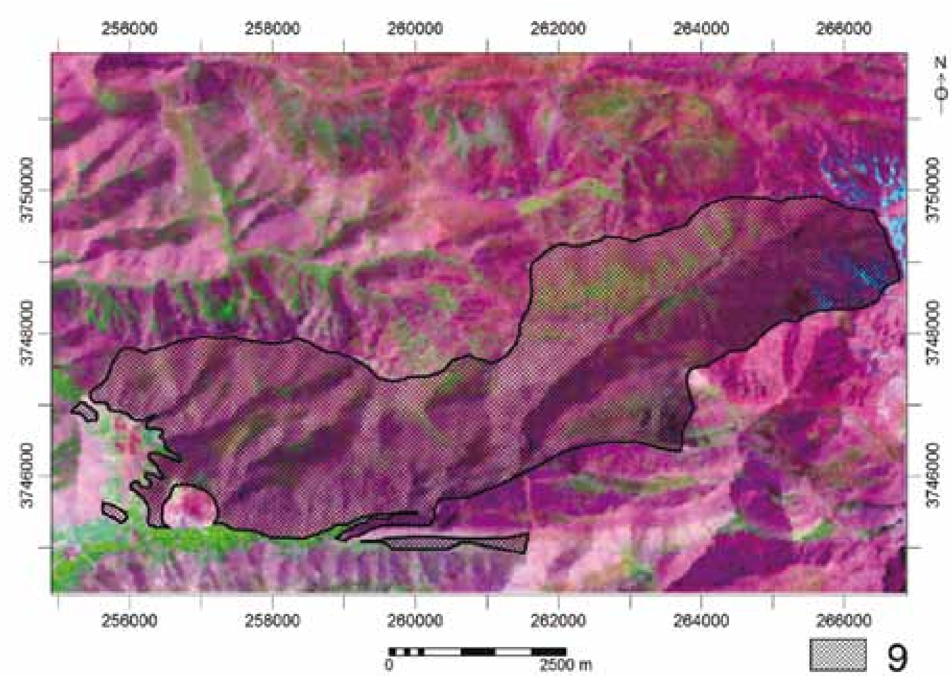

Fig. B7. Map of soil unit 9 in Honam watershed.

Map unit number		**10**
Pedon number:		80
Taxonomic classification:		Very-fine, mixed, mesic Typic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-25	Clay loam; light brown (7.5YR6/3), dry; brown (7.5YR5/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
B1	25-45	Silty clay; brown (7.5YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots; gradual wavy boundary.
B2	45-100	Silty clay; strong brown (7.5YR5/6), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots.

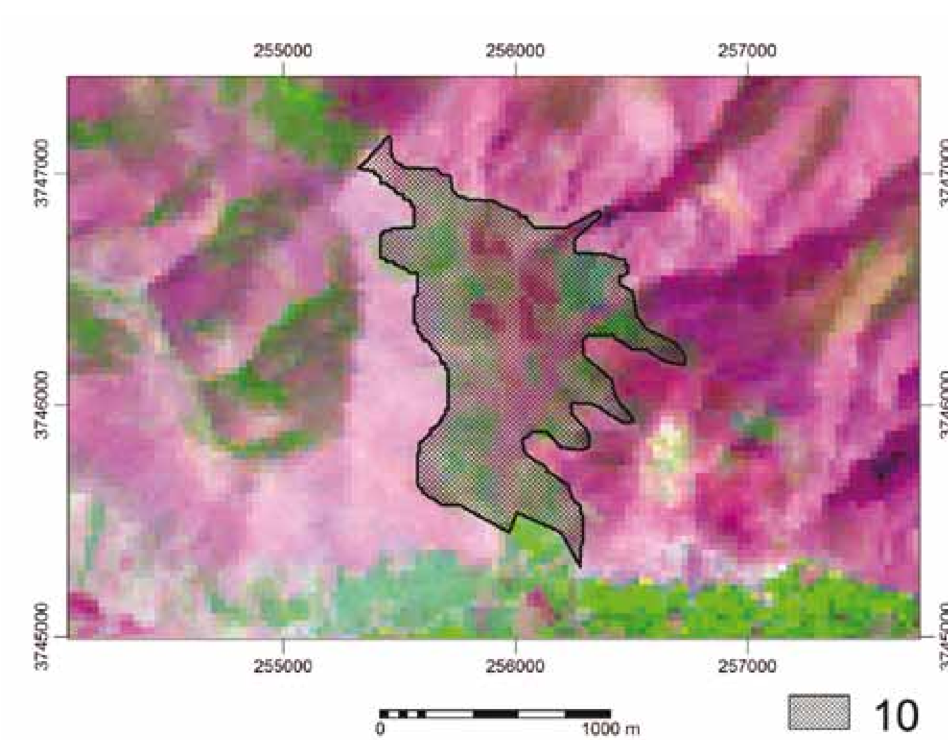

Fig. B8. Map of soil unit 10 in Honam watershed.

Analytical data for pedon 80 (Map unit 10)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-25	61	37	2	c	54	7.30	0.26	2.3	1.81	-	-
25-45	67	31	2	c	55	7.35	0.24	3.3	1.25	-	-
45-100	68	30	2	c	60	7.57	0.17	3.0	0.93	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-25	-	-	-
25-45	-	-	-
45-100	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Map unit number		**11**
Pedon number:		63
Taxonomic classification:		Fine , mixed, mesic Fluventic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-30	Silt clay loam; brown to yellow (10YR 6/3), dry; brown, (10YR 5/3), wet; moderate, medium to fine, granular structure; hard, dry; sticky, wet; many, very fine to fine vesicular pores; few, very fine to fine, roots; gravely; clear wavy boundary.
B1	30-60	Silt clay; brown (10YR 5/3), moist; moderate, medium to fine angular blocky structure; firm, moist; sticky, wet; common, very fine and fine, tubular pores; few, very fine roots; clear wavy boundary.
B2	60-120	Clay loam; brown (10YR 5/3), moist; moderate, medium to fine, angular blocky; firm, moist; sticky, wet; common, very fine and fine, tubular pores; few, very fine roots.

Analytical data for pedon 63 (Map unit 11)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-30	38	43	19	sicl	60	6.79	1.50	20.8	2.89	20-30	735
30-60	47	45	8	sic	51	7.64	0.54	20.5	1.41	5-10	360
60-120	48	42	10	sic	50	7.57	7.57	19.8	1.29	5-10	270

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP15 bar
0-30	41.0	29.50	18.80
30-60	5.80	27.10	17.30
60-120	4.40	28.70	17.90

For abbreviations, see pedon No.81 (Map Unit 1).

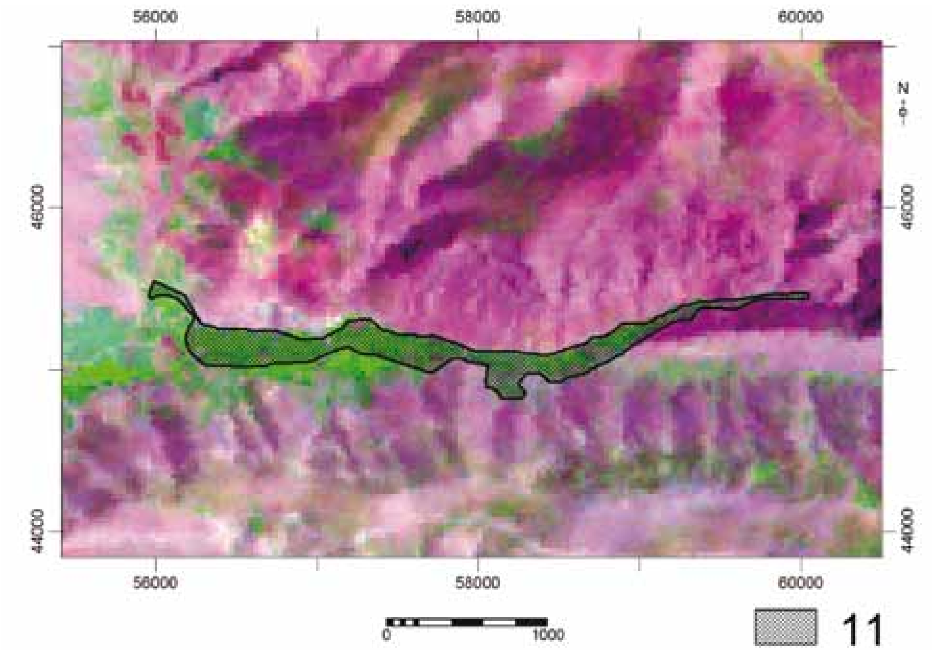

Fig. B9. Map of soil unit 11 in Honam watershed.

Map unit number		**13**
Pedon number:		82
Taxonomic classification:		Very-fine, mixed, mesic Typic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-30	Clay loam; brown (7.5YR5/4), dry; brown (7.5YR4/4), wet; weak, medium, granular structure, primary; weak, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
B	30-60	Silty clay; strong brown (7.5YR5/6), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
C	> 60	More than 75% gravel.

Analytical data for pedon 82 (Map unit 13)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-30	56	40	4	sic	56	7.17	0.35	1.7	1.74	-	-
30-60	61	35	4	c	56	7.19	0.30	2.2	1.29	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-30	-	-	-
30-60	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

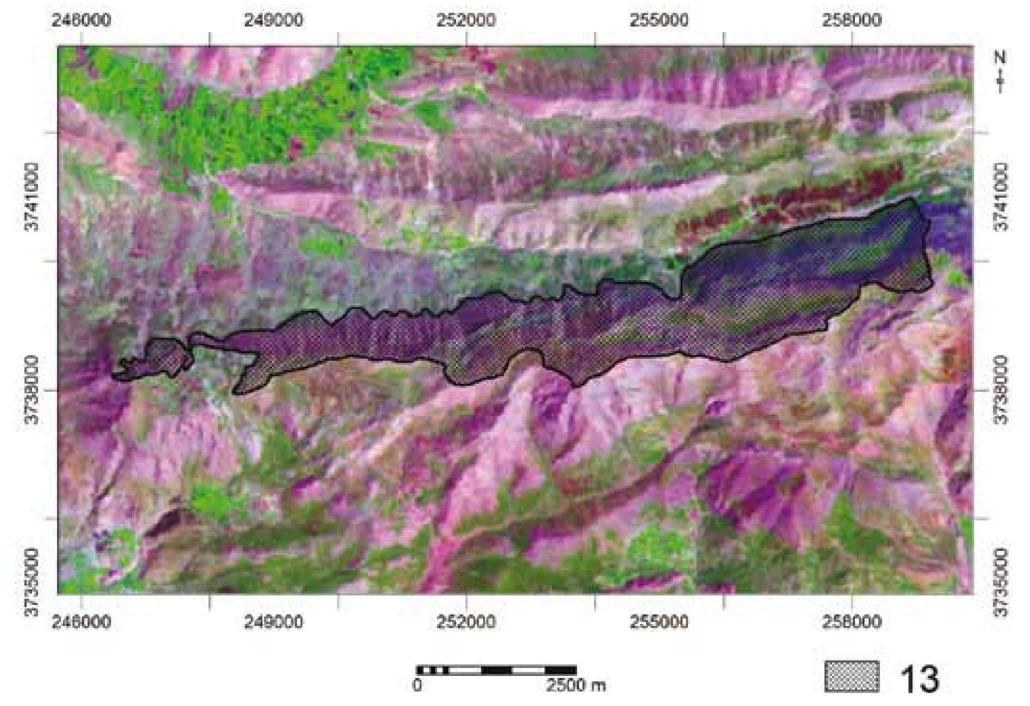

Fig. B10. Map of soil unit 13 in Honam watershed.

Plate B3. Very fine, mixed, mesic Typic Haploxerepts (Map unit 13, Pedon 82) (M. Sepahvand, 2008).

Map unit number		14
Pedon number:		68
Taxonomic classification:		Fine, mixed, mesic Lithic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bw	20-45	Clay loam; yellowish brown (10YR5/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
R	> 45	Bed rock.

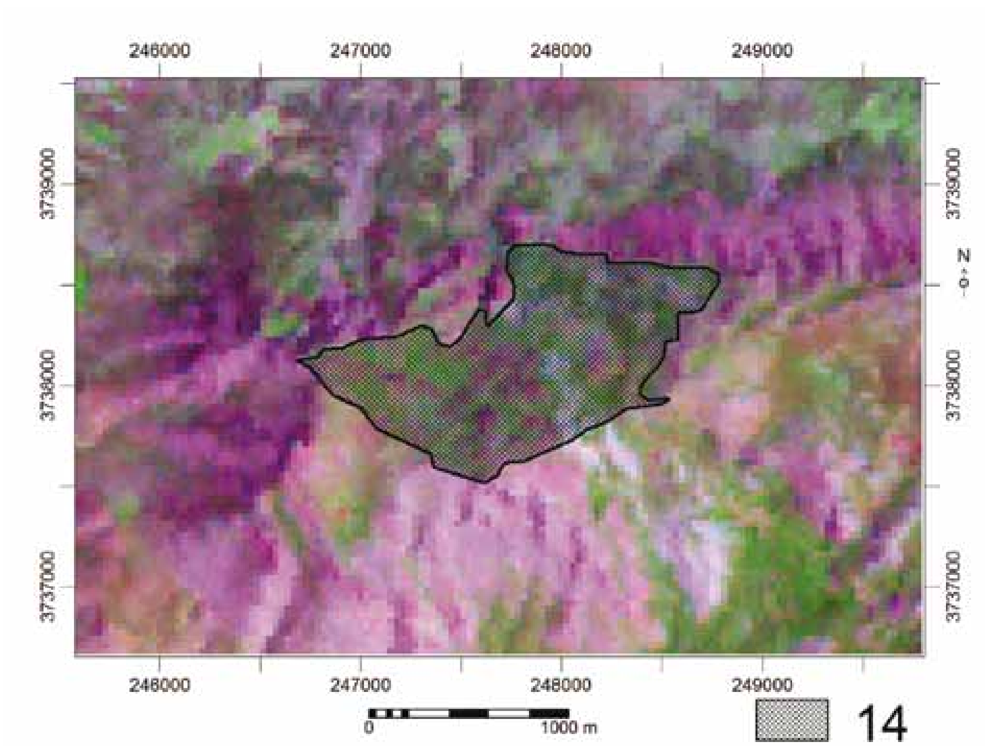

Fig. B11. Map of soil unit 14 in Honam watershed.

Analytical data for pedon 68 (Map unit 14)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	40	43	17	sic	58	7.58	0.29	24.6	3.74	-	-
20-40	43	42	15	sic	58	7.67	0.25	18.3	3.18	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	-	-	-
20-40	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Plate B4. Fine, mixed, mesic Typic Haploxerepts (Map unit 14, Pedon 68) (M. Sepahvand, 2008).

Map unit number		**15**
Pedon number:		67
Taxonomic classification:		Fine, mixed, mesic Lithic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Clay loam; yellowish brown (10YR5/4), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
Bw	20-60	Silty clay; yellowish brown (10YR5/6), wet; weak, coarse, angular blocky structure, primary; weak, medium, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
C	60-100	More than 75% gravel, stone.

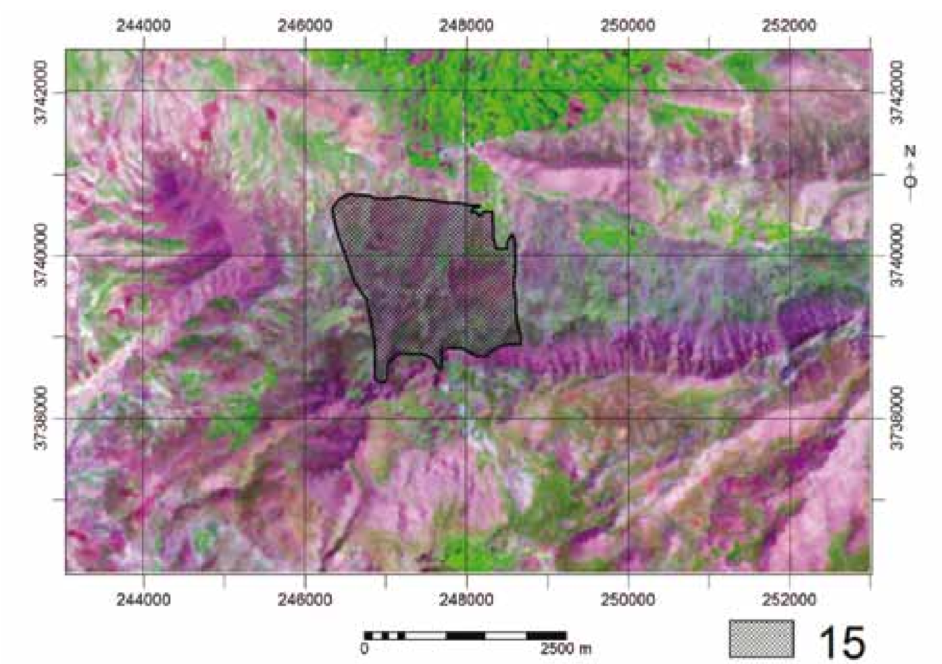

Fig. B12. Map of soil unit 15 in Honam watershed.

Analytical data for pedon 67 (Map unit 15)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-20	59	36	5	c	59	7.54	0.51	3.2	1.22	-	-
20-60	62	36	2	c	58	7.66	0.43	1.9	0.84	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP15 bar
0-20	-	-	-
20-60	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Map unit number		16
Pedon number:		66
Taxonomic classification:		Fine, carbonatic, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-30	Clay loam; pale brown (10YR6/3), dry; brown (10YR5/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
Bk1	30-60	Silty clay; pale brown (10YR6/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; few, small, soft, spherical, $CaCO_3$; Gradual wavy boundary.
Bk2	60-120	Silty clay; very pale brown (10YR7/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine to very fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; very few, fine to very fine, roots; many, small, soft, spherical, $CaCO_3$.

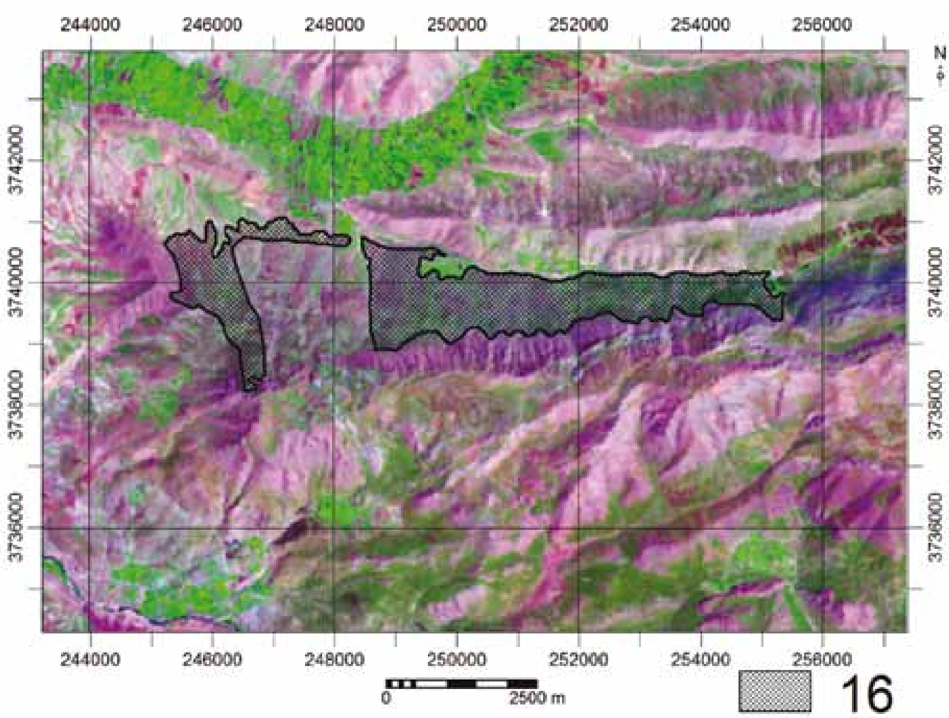

Fig. B13. Map of soil unit 16 in Honam watershed.

Analytical data for pedon 66 (Map unit 16)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-30	49	43	8	sic	52	7.87	0.59	43.4	1.55	-	-
30-60	47	42	11	sic	51	7.81	0.36	54.1	0.74	-	-
60-120	43	45	12	sic	50	7.88	0.41	62.2	0.45	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-30	-	-	-
30-60	-	-	-
60-120	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Map unit number		**20**
Pedon number:		76
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-20	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
B	20-40	Silty clay; brown (7.5YR5/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; gradual wavy boundary.
C	> 40	More than 75% gravel, sand and stone.

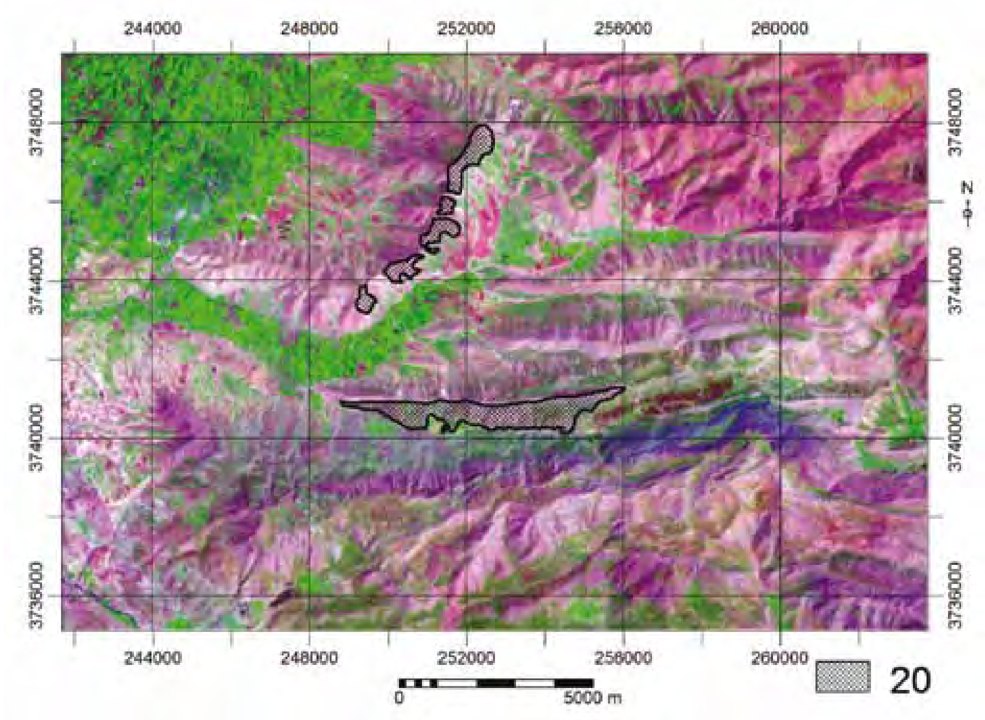

Fig. B14. Map of soil unit 20 in Honam watershed.

Analytical data for pedon 76 (Map unit 20)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	52	43	5	sic	58	7.36	0.53	2.9	1.80	-	-
20-40	63	34	3	c	61	7.40	0.38	17.3	1.80	-	-
> 40	-	-	-	-	-	-	-	-	-	>75	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	-	-	-
20-40	-	-	-
> 40	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

Map unit number		**24**
Pedon number:		70
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Silty clay loam; brown (7.5YR5/4), dry; brown (7.5YR4/4), wet; weak, medium, granular structure, primary; weak, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bk1	20-60	Silty clay loam; light yellowish brown (10YR6/4), wet; weak, medium, angular blocky structure, primary; weak, very fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots; very few, small, soft, spherical, white $CaCO_3$; clear wavy boundary.
Bk2	60-100	Silty clay loam; light yellowish brown (10YR6/4), wet; moderate, medium, angular blocky structure, primary; moderate, very fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine tubular pores; few, fine to very fine, roots; few, small, soft, spherical, white $CaCO_3$.

Analytical data for pedon 70 (Map unit 24)

Depth cm	**Clay %**	**Silt %**	**Sand %**	**Tex.**	**SP**	**pH paste**	**EC_e dS m^{-1}**	**$CaCO_3$ %**	**OC %**	**> 2 mm %**	**Av. K mg kg^{-1}**
0-20	58	37	5	c	63	7.87	0.39	9.9	1.25	-	-
20-60	58	36	6	c	56	7.41	0.22	11.3	0.94	-	-
60-100	58	35	7	c	60	7.63	0.19	12.1	0.80	-	-

Depth cm	**Av. P mg kg^{-1}**	**FC 0.33 bar**	**PWP 15 bar**
0-20	-	-	-
20-60	-	-	-
60-100	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

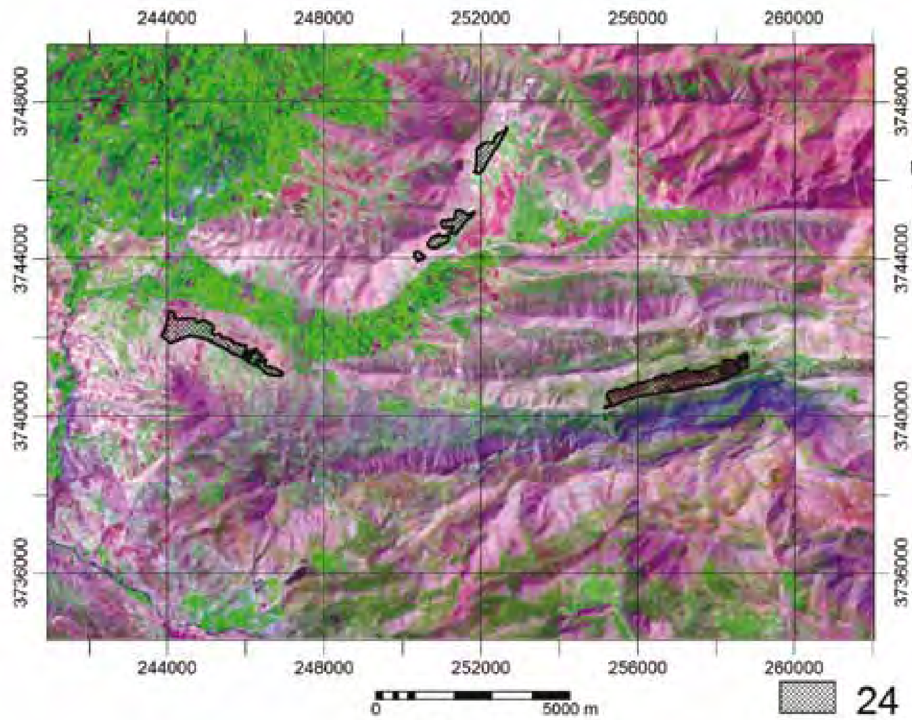

Fig. B15. Map of soil unit 24 in Honam watershed.

Plate B5. Fine, mixed, mesic Typic Calcixerepts (Map unit 24, Pedon 70) (M. Sepahvand,2008).

Map unit number		**25**
Pedon number:		73
Taxonomic classification:		Fine, mixed, mesic Fluventic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-30	Clay loam; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
Bw	30-45	Silty clay loam; brown (7.5YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; gradual wavy boundary.
Bk	45-120	Silty clay loam; strong brown (7.5YR5/6), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; few, fine to very fine, roots; many, small, soft, spherical, white $CaCO_3$.

Analytical data for pedon 73 (Map unit 25)

Depth cm	**Clay %**	**Silt %**	**Sand %**	**Tex.**	**SP**	**pH paste**	**EC_e dS m^{-1}**	**$CaCO_3$ %**	**OC %**	**> 2 mm %**	**Av. K mg kg^{-1}**
0-30	56	41	3	c	62	7.69	0.40	10.0	1.96	-	-
30-45	61	36	3	c	62	7.90	0.45	8.3	1.00	-	-
45-120	62	34	4	c	56	8.03	0.34	18.4	0.88	-	-

Depth cm	**Av. P mg kg^{-1}**	**FC 0.33 bar**	**PWP 15 bar**
0-30	-	-	-
30-45	-	-	-
45-120	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

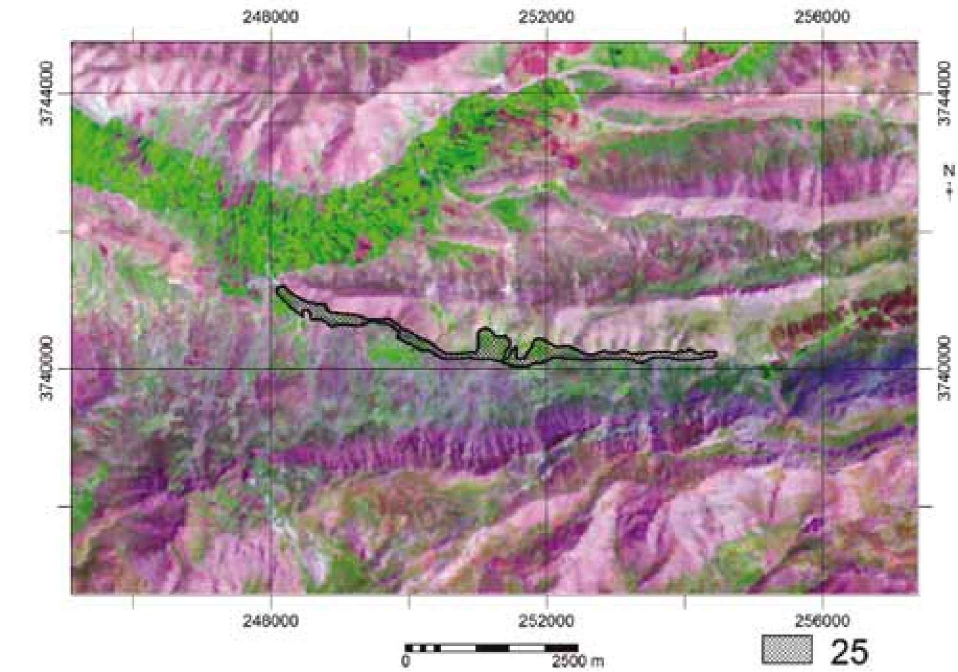

Fig. B16. Map of soil unit 25 in Honam watershed.

Map unit number		**27**
Pedon number:		78
Taxonomic classification:		Fine, mixed, mesic Lithic Xerorthents
Drainage:		Very poor
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-20	Sandy clay loam; brownish yellow (10YR6/6), dry; yellowish brown (10YR5/4), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
R	> 20	Bed rock

Analytical data for pedon 78 (Map unit 27)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2mm %	Av. K mg kg^{-1}
0-20	35	56	9	sicl	50	7.73	0.34	6.6	1.59	-	-
> 20	-	-	-	-	-	-	-	-	-	-	-

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP15 bar
0-20	-	-	-
> 20	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

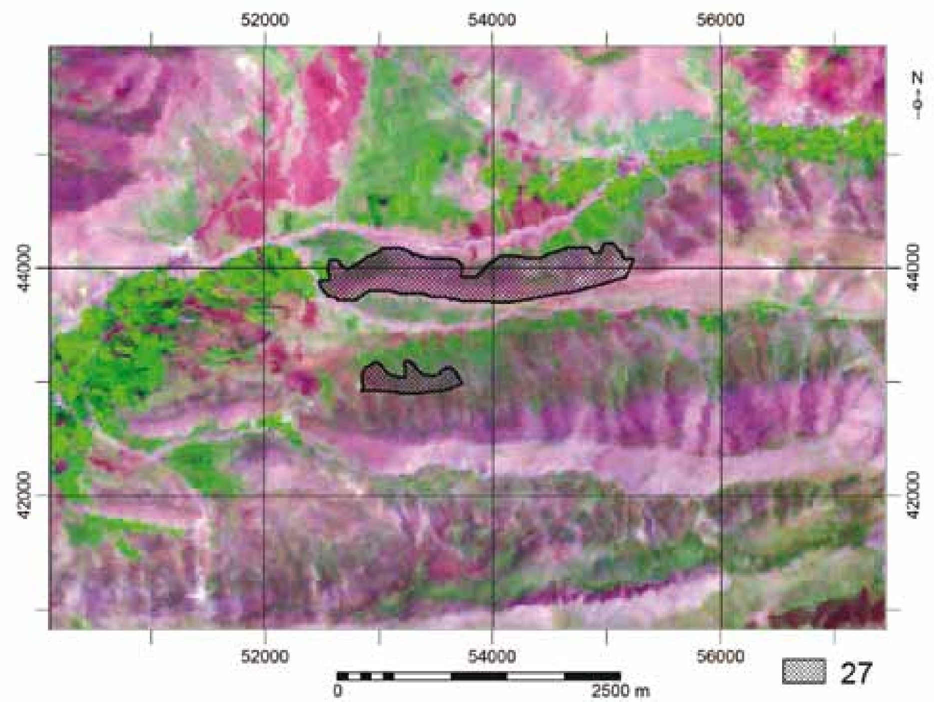

Fig. B17. Map of soil unit 27 in Honam watershed.

Plate B6. Fine, mixed, mesic Lithic Xerorthents (Map unit 27, Pedon 78) (M. Sepahvand, 2008).

Map unit number		30
Pedon number:		6
Taxonomic classification:		Fine, carbonatic, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Clay loam; light yellowish brown (10YR6/4), dry; yellowish brown (10YR5/4), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, very fine to fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
Bw	20-50	Silty clay loam; light yellowish brown (10YR6/4), dry; yellowish brown (10YR5/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine to fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bk1	50-80	Silty clay loam; light yellowish brown (10YR6/4), dry; dark yellowish brown (10YR4/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine to fine tubular pores; few, fine to very fine, roots; few, small, soft, spherical, white, $CaCO_3$; gradual wavy boundary.
Bk2	80-120	Silty clay loam; light yellowish brown (10YR6/4), dry; dark yellowish brown (10YR4/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine to fine tubular pores; few, fine to very fine, roots; many, small, soft, spherical, white, $CaCO_3$.

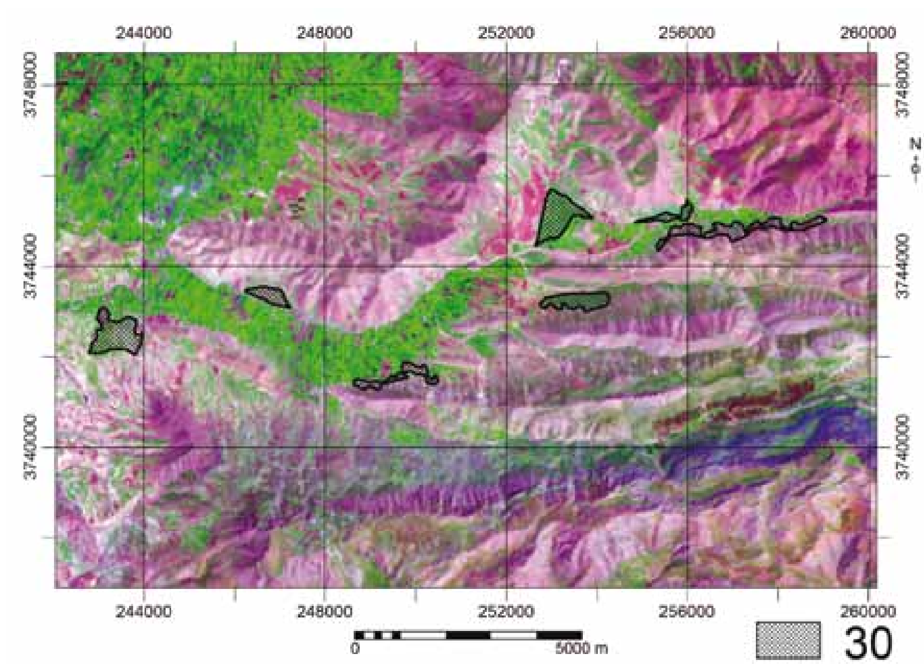

Fig. B18. Map of soil unit 30 in Honam watershed.

Map unit number		**32**
Pedon number:		1
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-30	Silty clay; pale brown (10YR6/3), dry; brown, (10YR5/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; sticky and plastic, wet; many, very fine to fine tubular pores; many, medium to fine, roots; clear wavy boundary.
Bw	30-55	Silty clay; pale brown (10YR6/3), dry; brown, (10YR5/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; very hard, dry; sticky and plastic, wet; few, very fine to fine tubular pores; few, medium to fine, roots; clear wavy boundary.
B	50-80	Silty clay; yellowish brown, (10YR5/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; sticky and plastic, wet; few, very fine to fine tubular pores; few, fine to very fine, roots; gradual wavy boundary.
Bk	80-130	Silty clay; yellowish brown, (10YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; sticky and plastic, wet; few, very fine to fine tubular pores; few, small, soft, spherical, white $CaCO_3$.

Analytical data for pedon 1 (Map unit 32)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-30	52	43	5	sic	53	7.55	0.54	26.3	1.31	-	435
30-55	55	41	4	sic	53	7.67	0.43	26.8	0.51	-	270
55-80	49	46	5	sic	53	7.63	0.41	28.0	0.29	-	230
80-130	47	47	6	sic	54	7.73	0.31	29.5	0.16	-	180

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-30	10.2	29.60	18.90
30-55	2.8	27.70	16.60
55-80	2.8	28.60	15.60
80-130	2.0	30.10	15.90

For abbreviations, see pedon No.81 (Map Unit 1).

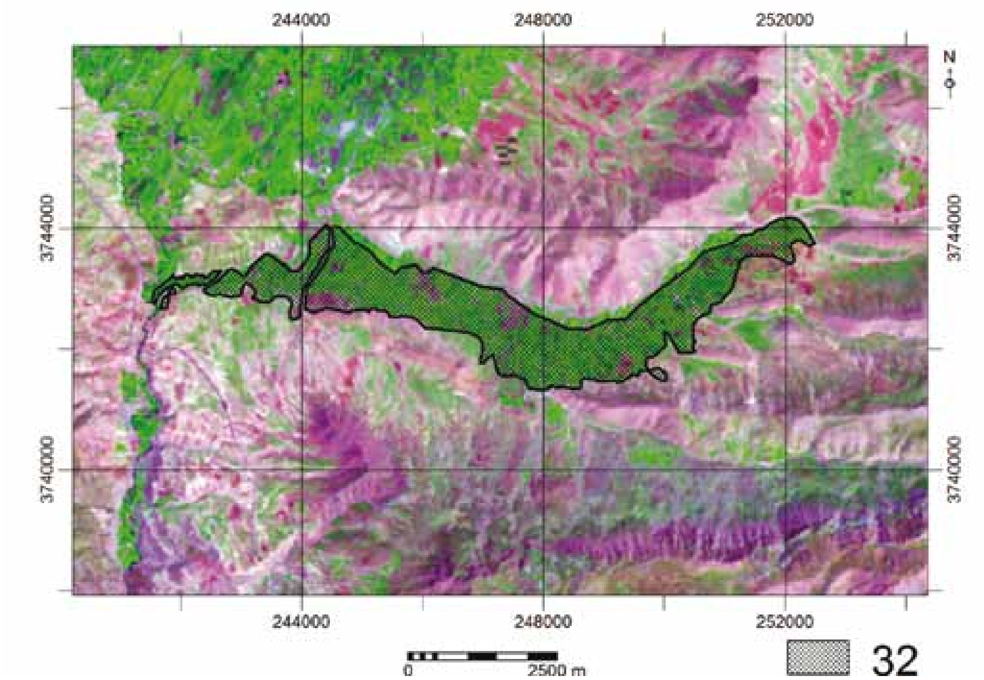

Fig. B20. Map of soil unit 32 in Honam watershed.

Map unit number		33
Pedon number:		2
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-25	Silty clay; brown (10YR5/3), dry; brown (10YR4/3), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bw	25-45	Silty clay; brown (10YR5/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores; very few, fine to very fine, roots; gradual wavy boundary.
Bt	45-70	Silty clay; brown (10YR4/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, fine to very fine tubular pores; gradual wavy boundary.
Bk	70-130	Silty clay; brown (10YR5/3), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, fine to very fine tubular pores; few, small, soft, spherical, white $CaCO_3$.

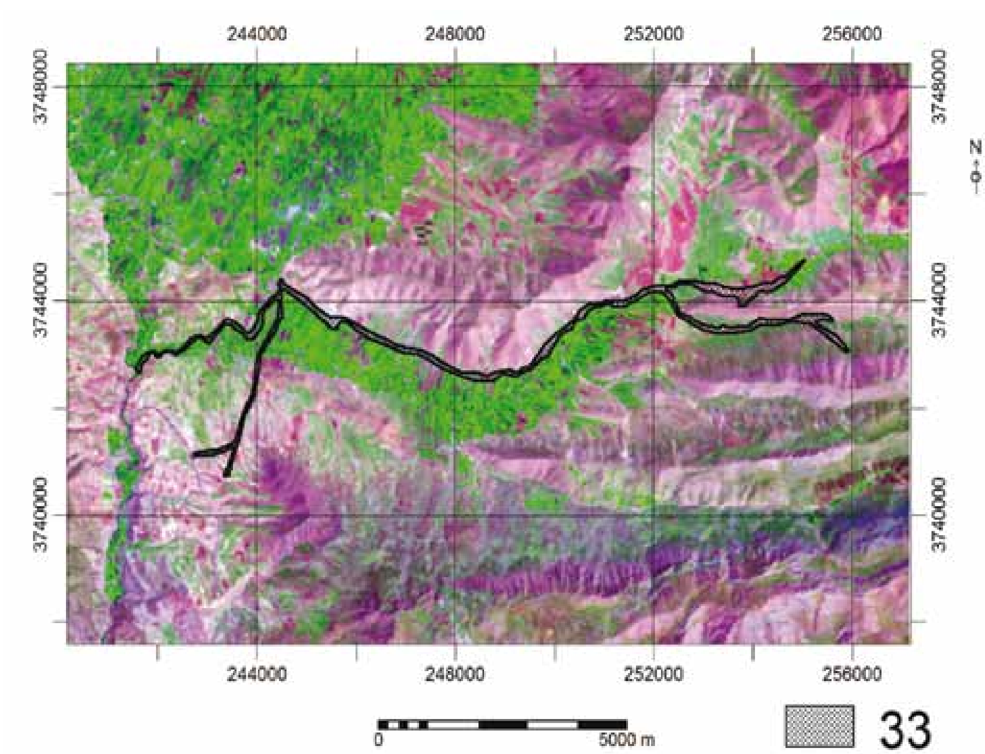

Fig. B21. Map of soil unit 33 in Honam watershed.

Map unit number		**34**
Pedon number:		46
Taxonomic classification:		Fine, mixed, mesic Typic Calcixerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Clay loam; light yellowish brown (10YR6/4), dry; yellowish brown (10YR5/4), wet; moderate, medium, granular structure, primary; moderate, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
Bw	20-45	Silty clay; yellowish brown (10YR5/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores; few, fine to very fine, roots; clear wavy boundary.
B	45-100	Silty clay; pale brown (10YR6/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores.

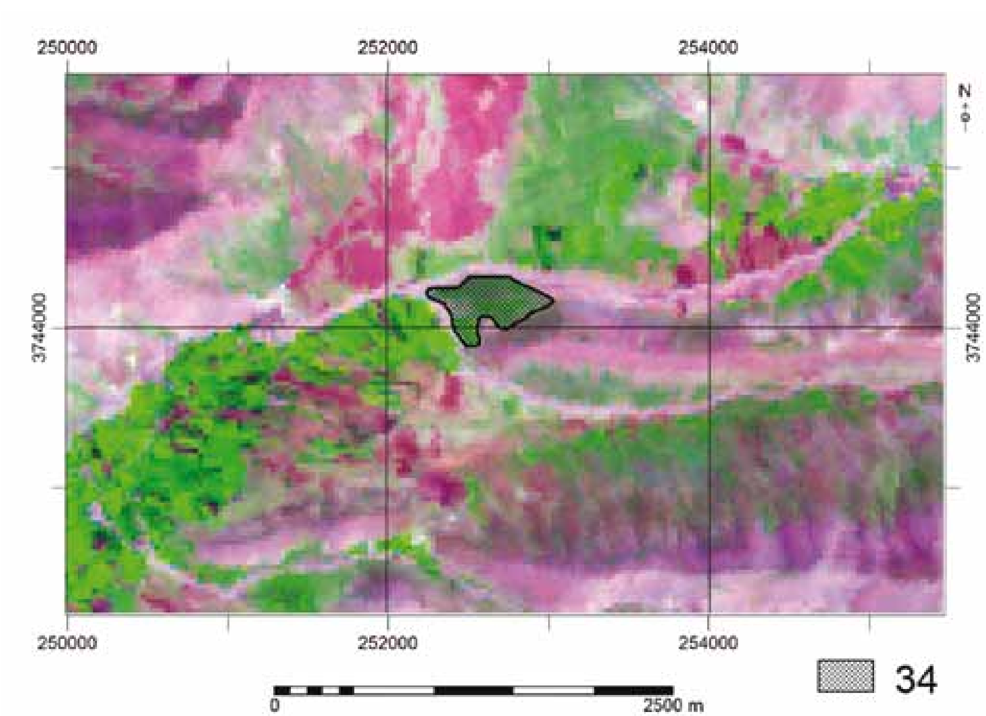

Fig. B22. Map of soil unit 34 in Honam watershed.

Map unit number		**35**
Taxonomic classification:		Fine-loamy, mixed, mesic Lithic Xerorthents
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
A	0-15	Clay loam; pale brown (10YR6/3), dry; brown (10YR5/3), wet; weak, medium, granular structure, primary; Weak, fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; common, fine to very fine tubular pores; common, fine to very fine, roots; clear wavy boundary.
R	> 15	Bed rock

Analytical data for pedon No. 75 (Map unit 35)

Depth cm	**Clay %**	**Silt %**	**Sand %**	**Tex.**	**SP**	**pH paste**	**EC_e dS m^{-1}**	**$CaCO_3$ %**	**OC %**	**> 2mm %**	**Av. K mg kg^{-1}**
0-15	23	32	45	sil	33	7.81	0.57	22.0	0.73	-	-
+ 15	-	-	-	-	-	-	-	-	-	-	-

Depth cm	**Av. P mg kg^{-1}**	**FC 0.33 bar**	**PWP15 bar**
0-15	-	-	-
+ 15	-	-	-

For abbreviations, see pedon No.81 (Map Unit 1).

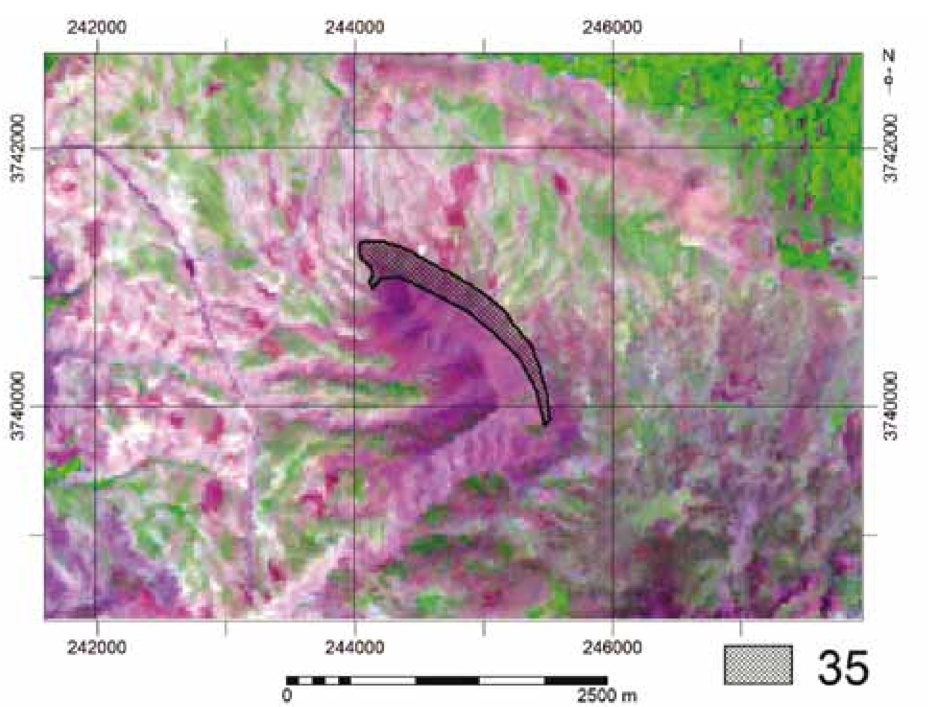

Fig. B23. Map of soil unit 35 in Honam watershed.

Plate B7. Fine-loamy, mixed, mesic Lithic Xerorthents (Map unit 35, Pedon 75) (M. Sepahvand, 2008).

Map unit number		**36**
Pedon number:		19
Taxonomic classification:		Fine, mixed, mesic Fluventic Haploxerepts
Drainage:		Well
Land use:		Pasture
Horizon	Depths (cm)	Description
Ap	0-20	Silty clay; light yellowish brown (10YR6/4), dry; brown, (10YR5/3), wet; moderate, medium, granular structure, primary; fine, granular structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; many, very fine to fine tubular pores; few, very fine to fine, roots; clear wavy boundary.
Bw	20-40	Silty clay; brown (10YR4/3), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine, tubular pores; few, very fine roots; gradual wavy boundary.
Bt1	40-60	Silty clay; dark yellowish brown (10YR4/4), wet; weak, medium, angular blocky structure, primary; weak, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine, tubular pores; few, very fine roots; gradual wavy boundary.
Bt2	60-130	Silty clay; yellowish brown (10YR5/4), wet; moderate, medium, angular blocky structure, primary; moderate, fine, angular blocky structure, secondary; hard, dry; firm, moist; sticky and plastic, wet; few, very fine, tubular pores; few, very fine roots.

Analytical data for pedon 19 (Map unit 36)

Depth cm	Clay %	Silt %	Sand %	Tex.	SP	pH paste	EC_e dS m^{-1}	$CaCO_3$ %	OC %	> 2 mm %	Av. K mg kg^{-1}
0-20	46	48	6	sic	44	7.69	0.35	20.5	0.65	-	410
20-40	51	45	4	sic	46	7.64	0.37	21.8	0.57	-	280
40-60	50	46	4	sic	47	7.86	0.34	23.5	0.46	-	250
60-130	51	47	2	sic	49	7.93	0.31	25.5	0.36	-	245

Depth cm	Av. P mg kg^{-1}	FC 0.33 bar	PWP 15 bar
0-20	9.6	28.50	14.90
20-40	1.6	28.00	14.20
40-60	1.2	26.70	13.80
60-130	1.7	27.70	12.80

For abbreviations, see pedon No.81 (Map Unit 1).

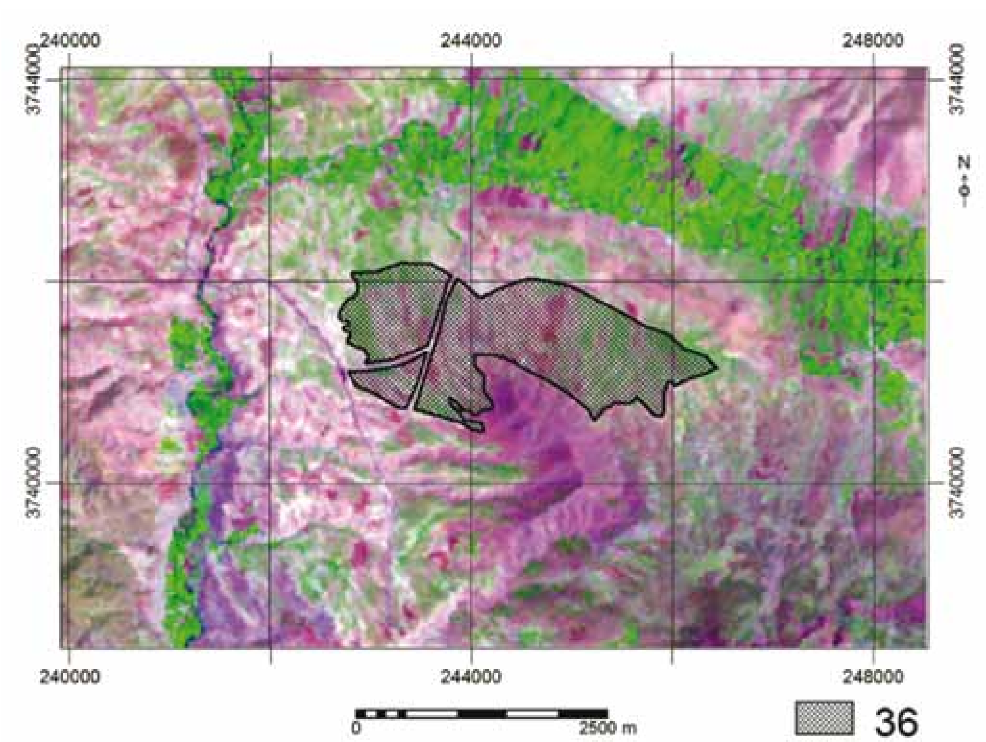

Fig. B24. Map of soil unit 36 in Honam watershed.

Benchmark river basins

The CP Water & Food is a research, extension and capacity building program aims at increasing the productivity of water used for agriculture. The CP Water & Food is managed by an 18-member consortium, composed of five CGIAR/Future Harvest Centres, six National Agricultural Research and Extension Systems (NARES) institutions, four Advanced Research Institutes (ARIs) and three international NGOs. The project is implemented at nine river basins (shown above) across the developing world. The Karkheh River Basin (KRB) in western Iran is one of the selected basins. The program's interlocking goals are to allow more food to be produced with the same amount of water that is used in agriculture today, as populations expand over the coming twenty years. And, do this in a way that decreases malnourishment and rural poverty, improves people's health and maintains environmental sustainability.

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