Pedology Report
November 2017

WP5. Analysis of potential current and historical land uses

Università degli Studi di Palermo (UNIPA)

Universidad de Córdoba (UCO)

Università degli Studi di Padova (UNIPD)

MEDITERRANEAN MOUNTAINOUS LANDSCAPES
an historical approach to cultural
heritage based on traditional agrosystems
MEMOLA

1. Introduction

Soil is essential to human survival. We rely on it for the production of food, fibre, timber and energy crops. Together with climate, the soil determines which crops can be grown, where, and how much they will yield. In addition to supporting our agricultural needs, we rely on the soil to regulate the flow of rainwater and to act as a filter for drinking water. With such a tremendously important role, it is imperative that we manage our soils for their long-term productivity, sustainability and health. From an environmental point of view soil is the fundamental part of cultural landscapes as well as the main driving factor in conditioning local culture.

The first step in sustainable soil management is ensuring that the soil will support the land use activity. For example, only the better agricultural soils will support grain and vegetable production, while more marginal agricultural soils will support forage and pasture-based production. For this reason, agricultural development should only occur in areas where the soil resource will support the agricultural activity. The only way to do this is to understand the soil resource that is available. Soil survey information is the key to understanding the soil resource.

Soil survey is an inventory of the properties of the soil (such as texture, internal drainage, parent material, depth to groundwater, topography, degree of erosion, stoniness, pH, salinity, etc.) and their spatial distribution over a landscape. Soils are grouped into similar types and their boundaries are delineated on a map. Each soil type has a unique set of physical, chemical and mineralogical characteristics and has similar reactions to use and management. The information assembled in a soil survey can be used to predict or estimate the potentials and limitations of the soils' behaviour under different uses. As such, soil surveys can be used to plan the development of new lands or to evaluate the conversion of land to new uses. Soil surveys also provide insight into the kind and intensity of land management that will be needed.

1.1. Content of this report

In MEMOLA project soil has been considered as important factor for the landscape evaluation together with water resources and vegetation, representing the main driving factors conditioning the social and cultural aspects developed in the past. Such resources, not only represent the evidences of the societal evolution from the past, but also they can be used, in a sustainable way for the future development of the land. In this context soil information can represent the most reliable mean to develop land evaluations for future human activities, especially agriculture and environmental management.

The knowledge about soils in the four MEMOLA study areas ha been investigated since the beginning of the project. The first step in study soils, in fact, has regarded the collection of soil knowledge, in terms of already published studies in form of documents and maps. In Colli Euganei and Sierra Nevada we've found enough material (reports and maps) describing soils and their spatial pattern in different scales. Most important, the information in these two study areas was already available in detailed scale, which provided the base for further land evaluation application. In these two areas then the only information we needed was collected by means of detailed and specific surveys suitable for the application of the evaluation models in term of productivity and water use efficiency of the traditional agroecosystems.

In the Vjosa Valley and Monti di Trapani, the available soil knowledge was not enough to provide any information useful to provide evidences of the historical evolution of the landscape and to develop proper evaluation systems. In spatial term, while in Monti di Trapani the only soil information was from semi-detailed maps, in Vjosa Valley we did not find any maps, even in large scale. However, in both study areas the soil knowledge was not detailed to provide robust information to develop any type of evaluation in the in-deep study areas identified for the project.

Pedological surveys in MEMOLA had two different porpoises: i) to provide data (soil properties) for the development, calibration and validation of the productivity and water efficiency model in agriculture (in Colli Euganei and Sierra Nevada) and ii) to provide detailed information (maps and data – soil properties) for the application of land evaluation systems (Vjosa Valley and Monti di Trapani).

2. Soil water characteristics and soil nutrient properties (Sierra Nevada and Colli Euganei)

2.1. Objectives of the surveys

The analysis and the quantification of the productivity and water use efficiency of the traditional agroecosystems are essential steps towards the successful identification and implementation of suitable water and soil management recommendations aimed at maintaining the multifunctionality of these systems. In this regard, one of the objectives of the WP5 "Analysis of potential current and historical land uses" is the **analysis of the productivity and water use efficiency of these systems through an agronomic and hydrological resource-management model** (Deliverable 5.2). To achieve this target a **detailed characterization of the soil water characteristics and the soil nutrient properties** is needed in order to implement the model in the two study areas selected, Sierra Nevada (Spain) and Coli Euganei (Italy). Within these regions, a pilot area was selected for the high value of its agroecosystems and representativeness, 'Cáñar' and 'Abbazia di Praglia' in Sierra Nevada and Colli Euganei, respectively.

2.2. Soil sampling activities

The soil information needed for the implementation of the water use efficiency model includes the precise knowledge of the soil water characteristics and the soil fertility level. Table 1 reports the soil input parameters of the model and the methodology for their estimation. The needed information has been obtained by samples taken from specific points following a design or specific criteria and by direct observation of the soil conditions. The soil sampling procedureswere in line with the guidelines collected in the 'Protocol for soil sampling'(WP8).

Table 1 Soil input parameters of the water use efficiency model and the methodology for their estimation

Typology	Input parameter	Estimation method
Soil water characteristics	Soil depth	Field observation
	Soil water content at wilting point	Pedotransfer functions
	Soil water content at field capacity	Pedotransfer functions
	Soil water content at saturation	Pedotransfer functions
	Hydraulic conductivity at saturation	Pedotransfer functions
Soil nutrient properties	Soil fertility level	Physical and chemical parameters

Before beginning soil sampling, available relevant data (soil map and geology and hydrology information)on the target areaswere compiled and analysed.This material (Fig. 1)has been useful tool for the assessment of soil variability, and thus, for the design of the soil sampling. On the basis of these data and the land use and management practices, sixsoil monitoring unitsrepresenting the study area were selected for the soil sampling in both areas(Table2). Some soil monitoring unitswere divided into different sampling units (sub-units) due to differences in topography, parent material or management history. Thus, samples were collected from locations that are randomly distributed across the monitoring unit or sub-unit that are practically uniform and can be managed as one unit. The number of sampling sites in each monitoring unitwas conditioned by the monitoring unit area. All samples were combined in the field to form a single composite sample of each depth to be sent to the laboratory for analysis.

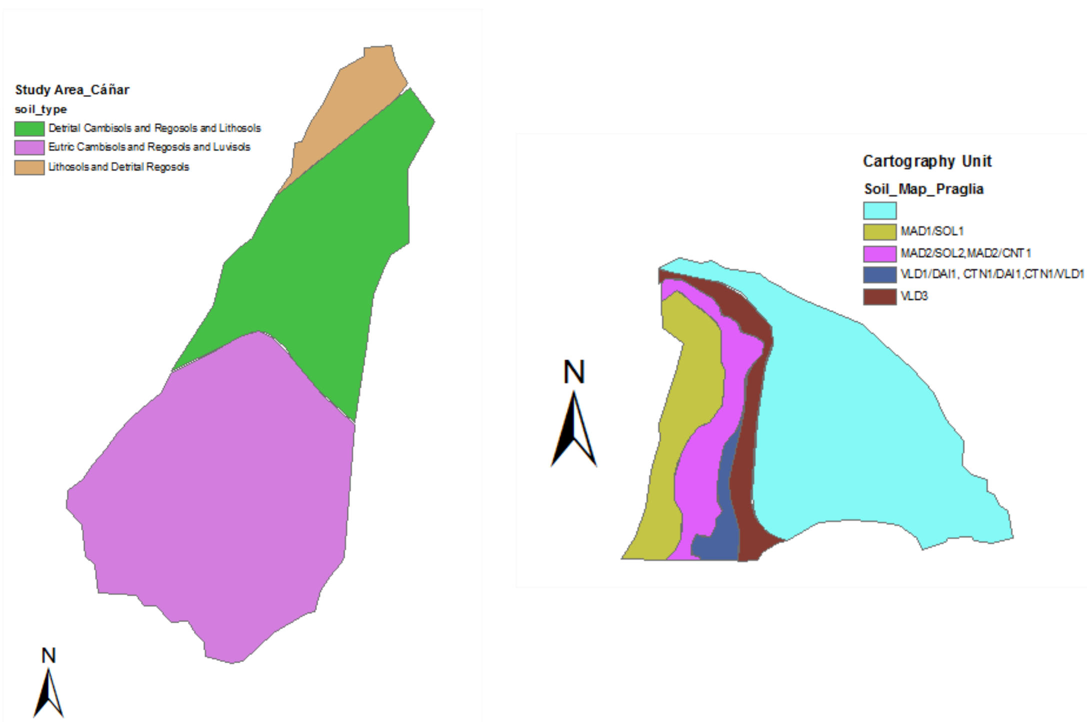


Figure 1. Soil maps of the study areas, Cáñar (Sierra Nevada) (1:400000; Source: REDIAM, Junta de Andalucía) and Abbazia di Praglia (Colli Euganei) (1:35000; Source: ARPAV, Provincia di Padova)

Table 2. Soil monitoring units and number of sub-units and sampling sites in Cáñar (Sierra Nevada) and Abbazia di Praglia (Colli Euganei)

Soil monitoring unit	Cadastral reference Polygon	Cadastral reference Plot	n° sub-units	n° sampling sites
Cáñar-1	1	36	1	10
Cáñar-2	4	31	1	4
Cáñar-3	7	74	1	4
Cáñar-4	7	27	1	5
Cáñar-5	4	66	3	8
Cáñar-6	7	16	3	9

Soil monitoring unit	n° sub-units	n° sampling sites
Praglia-1	1	4
Praglia-2	1	4
Praglia-3	1	4
Praglia-4	1	4
Praglia-5	1	4
Praglia-6	1	4

Figure 3. Soil sampling with Viehmeyer tube and auger inCáñar(Sierra Nevada) and Abbazia di Praglia (Colli Euganei).

2.3. Soil analysis

The soil samples collected were cooled and protected from sunlight to minimize any potential reaction, and they were quickly analysed to avoid any deterioration. After air-drying and 2-mm sieving, the soil samples of Cáñar were sent to APROA C.B. Laboratory (Cordoba, Spain) to analyse the parameters depicted in Table 3. However, the soil samples of Abbazia di Praglia were analysed in the laboratory of pedology of UNIPA.As an example, Table 4 shows the results of the soil analysis of one soil monitoring unit in Cáñar (Sierra Nevada). Also, the soil water characteristics derived from these parameters using pedotransfer functions (Saxton and Rawls, 2006) are presented in Figures4and 5for all the soil monitoring units in both study areas.

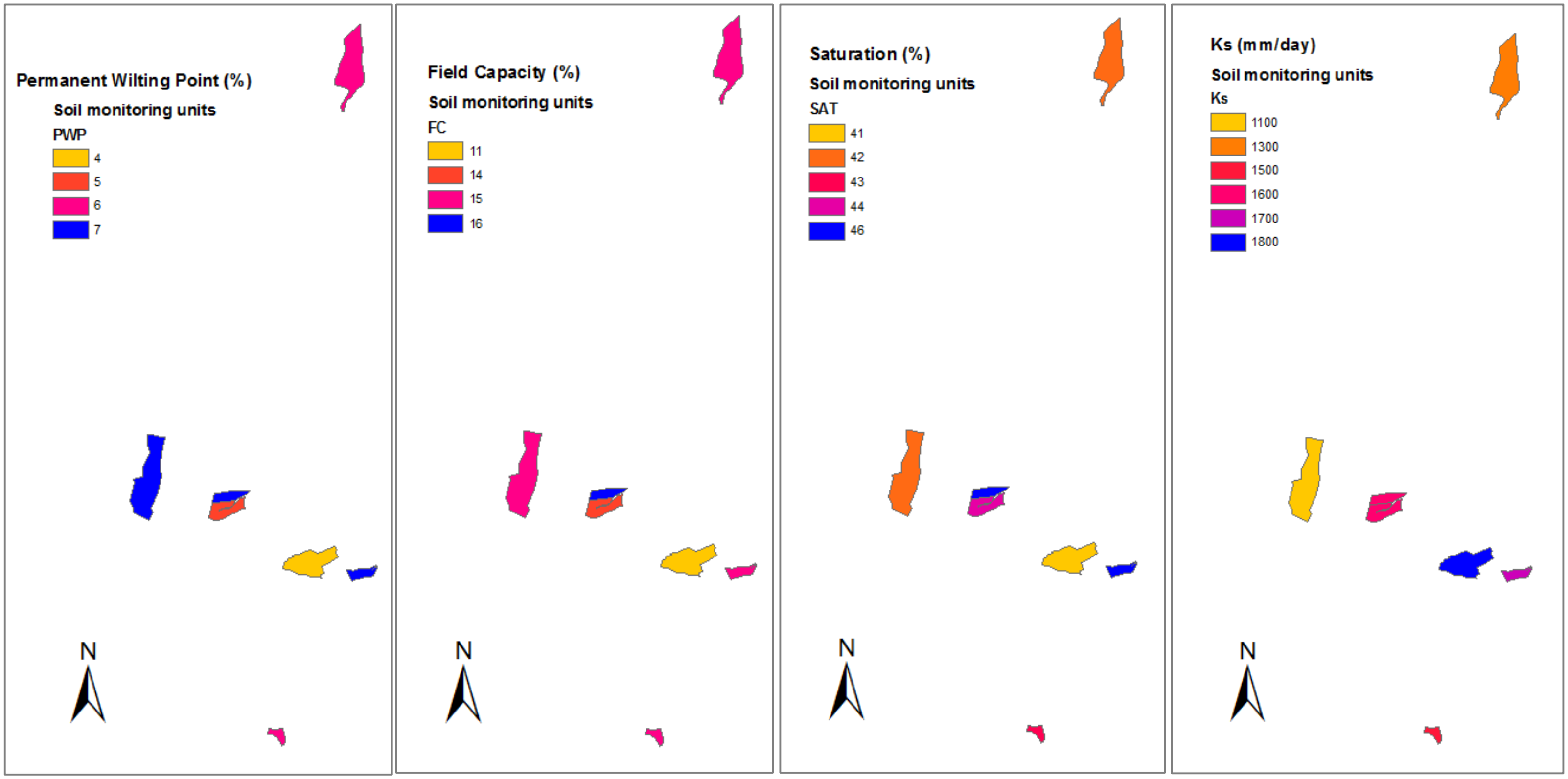
Table 3. Parameters analysed and methods

Parameter	Analysis method
Particle-size distribution	Densimetric
pH (1:2.5)	Potentiometric
Electric conductivity (1:5)	Potenziometric
Cation exchange capacity	Ammonium acetate
Exchangeable sodium	Flame photometry
Assimilable phosphorus	Olsen
Exchangeable potassium	Flame photometry
Assimilable calcium	Atomic absorption spectrophotometry
Exchangeable magnesium	Atomic absorption spectrophotometry
Carbonates	Calcimeter Bernard
Total organic matter	Volumetric
Total nitrogen	Kjdahl
Inorganic nitrogen	Kjdahl

Table 4. Values of the parameters analysed in the soil monitoring unit 'Cáñar-4'.

Parameter	Unit	Horizon	Value	Description
Clay	%	H1	6.2	
		H2	5.7	
		H3	5.8	
		H4	6.2	
Silt	%	H1	18.6	
		H2	17.6	
		H3	17.4	
		H4	18.7	
Sand	%	H1	75.2	
		H2	76.7	
		H3	76.8	
		H4	75.1	
pH (1:2.5)		H1	7.62	Neutral
		H2	7.12	Neutral
		H3	7.10	Neutral
		H4	7.48	Neutral
Conductivity (1:5)	µS/cm	H1	53	Normal
		H2	39	Normal
		H3	36	Normal
		H4	36	Normal
Cation exchange capacity	meq/100g soil	H1	5.8	Very low
		H2	5.4	Very low
		H3	5.2	Very low
		H4	2.3	Very low
Exchangeable sodium	ppm	H1	60	Very low
		H2	45	Very low
		H3	42	Very low
		H4	115	Low
Assimilable phosphorus	ppm	H1	14.8	Low
		H2	18.6	Normal
		H3	17.4	Normal
		H4	15.7	Normal
Exchangeable potassium	ppm	H1	141	Low
		H2	93	Low
		H3	38	Low
		H4	98	Low
Assimilable calcium	ppm	H1	840	Low
		H2	470	Low
		H3	360	Low
		H4	180	Low
Exchangeable magnesium	ppm	H1	63	Low
		H2	49	Low
		H3	38	Low
		H4	15	Low
Carbonates	% CO_3Ca	H1	0	Low
		H2	0	Low
		H3	0	Low
		H4	0	Low
Total organic matter	%	H1	1.22	Low
		H2	0.97	Low
		H3	0.45	Low
		H4	0.32	Low
Total nitrogen	%	H1	0.08	Normal
		H2	0.06	Low
		H3	0.07	Low
		H4	0.04	Low
Inorganic nitrogen	ppm	H1	5.3	Low
		H2	3.8	Low
		H3	4.7	Low
		H4	4.3	Low

Figure 4 and 5. Soil water characteristics of the soil monitoring units estimated from the soil analysis results. Maps: Cáñar(Sierra Nevada). Table: Abbazia di Praglia (Colli Euganei)



Soil monitoring unit	Soil water content (%)			Hydraulic conductivity at saturation (mm/day)
	Permanent Wilting Point	Field Capacity	Saturation	
Praglia-1	9.0	19.0	41.0	694
Praglia-2	6.6	16.7	45.4	1715
Praglia-3	15.2	28.4	42.6	243
Praglia-4	19.9	34.2	46.1	125
Praglia-5	8.7	19.7	39.1	484
Praglia-6	8.7	19.7	39.1	484

2.4. Soil analysis report for farmers

In addition to the information derived from the sample analysis for modelling purposes, these data provide valuable information for the advisory support to farmers related to the soil and water management. To this end, a 'Soil Analysis Report' (Fig.6) was made for each farmer in order to offer general guidelines for a sustainable management of both resources.

Proyecto Europeo MEMOLA

'Una aproximación histórica al patrimonio cultural basada en los agroecosistemas tradicionales'

Informe análisis de suelos

Zona de estudio 'Sierra Nevada'

Cáñar (Granada)

Agricultor/a: Ramón Álvarez Guerrero
Polígono catastral: 7
Parcela catastral: 74

4. Interpretación de los resultados

- **Capacidad de retención hídrica:** Suelo de textura ligera con baja capacidad de retención hídrica (83 l/m^2 por metro de profundidad) y alta conductividad hidráulica (Conductividad hidráulica en saturación= 65 l/m^2 por hora). Los riegos deben ser ligeros y frecuentes.
- **Capacidad de retención de nutrientes:** Suelo con baja capacidad de retención de nutrientes (baja capacidad de intercambio catiónico) debido a la tipología y bajo contenido de arcillas.
- **pH:** El pH ligeramente alcalino puede reducir la disponibilidad de los diferentes nutrientes para la planta. La aplicación de algunos tipos de materia orgánica (e.j. acículas de pino) puede ayudar a una disminución del pH. También puede dismuirse aplicando azufte de forma que las tiobacterias del suelo lo transformen en ácido sulfúrico lentamente, evitando desequilibrios en el suelo.
- **Salinidad:** No existen problemas de salinización (conductividad eléctrica del suelo normal).
- **Materia orgánica:** El alto contenido de materia orgánica en los primeros 30 cm del suelo mejoran las características físico-químicas del suelo (capacidad de retención de nutrientes y estructura del suelo). Es importante continuar con el aporte de materia orgánica para mantener un 3% de materia orgánica en los primeros 30 cm del suelo.
- **Nitrógeno:** Contenido de nitrógeno normal.
- **Fósforo:** Contenido de fósforo asimilable por las plantas alto.
- **Potasio:** Suelo pobre en potasio de forma natural, debido al contenido y tipo de arcillas presentes. Un abonado frecuente con estiércol puede incrementar notablemente el contenido de potasio en el suelo. También las cenizas de madera previamente compostadas pueden aportar cantidades considerables de potasio al suelo. El potasio es crítico para la síntesis de proteínas y para una adecuada regulación hídrica de las plantas. Las plantas con deficiencia pueden ser más susceptibles a los daños por helada y enfermedades. La deficiencia afecta con mayor frecuencia a los frutos (manzanas, tomate, etc.) y a las legumbres.
- **Calcio:** Contenido alto de calcio en los primeros 30 cm. Sin embargo, la relación Calcio/Magnesio es adecuada, por lo que el contenido de calcio no induce deficiencias en magnesio.

Informe Análisis de Suelos – Zona de estudio 'Sierra Nevada' 4

Figure 6. Example of 'Soil Analysis Report' for farmers with general guidelines for a sustainable management of soil and water (Soil monitoring unit: Cáñar-3)

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3. Soil surveys (Monti di Trapani and Vjosa Valley)

3.1 Objectives of the surveys

The mission of the soil surveyswas to help us understand soils, what type they are, where they are,how and when they formed, and how they function. An integral part of that learning has been an awareness of soils have been used in the past, also of the fragility of soilecosystems and how the proper functioning of these ecosystems influences man's survival,therefore, we have also become advocates for the wise use of these resources.The soil survey is a program which describes, identifies, classifies, characterizes, andmaps soils, and interprets their behavior.Soil maps(i.e. the geographical representations showing diversity of soil types and soil properties (soil pH, textures, organic matter, depths of horizons etc.) were the typically the end result of a soil survey program we developed for these two MEMOLA study areas. Soil maps represents the operative toolwe used for land evaluation, spatial planning, agricultural and agro-ecosystem sustainability.

In mapping soils we used the traditional (conventional) approach: "hand-drawning" soil polygon,representing distribution of soil types. We used however digital drawing as we developed a Soil Information System (digital maps linked to a database containing soil information – soil properties).

Soil mapping has been carried out in the in-deep areas selected in MEMOLA study areas: In Monti di Trapani 4 in-deep areas (named Angimbè, Baida, Baronia,Macari) while in Vjosa 3 in-deep areas representing the soil variability and diversity (named Grabove, Kutal, Dracove).

3.2 Organization of the surveys

Phase 1 - Area selection and preliminary and general recognitions: In this step (started in the first year of the project) we selected e delineated the in-deep study areas. For each area we made several recognitions in field to understand the complexity of the landscape, type of soils and their spatial pattern, and the complexity of soil-landscape relationships. This phase has been conducted for the entire survey period until the production of the final soil maps. Soil observations have been made by using hand-augering.

In this phase also we collected all the available spatial information (mainly in form of digital maps) describing the principal soil forming factors responsible of the soil spatial variability (i.e. DEM for analyzing geomorphology, land use maps, geological maps, historical maps).

Phase 2 – Sampling: any soil survey requires a particular sampling to understand soils and measure their properties. The soil profile is the most important conceptual sampling in soil science. It is a key to understanding the processes that have taken in soil development and is the means of determining the types of soil that occur and is the basis for their classification. The soil profile is defined as a vertical section of the soil from the ground surface downwards to where the soil meets the underlying rock (it can be as little as 10 cm thick in immature soils and as deep as several metres in certain areas).

Phase 3 – Mapping: the final drawing of the map has been carried out by conventional approach using the conceptual model of the surveyor in correlating soil and landscaped through relationships. The working map scale has been fixed around 1:5.000 (very detailed).

Phase 4 – Soil information: The soil is divided into various different layers top to bottom and this arrangement is termed as the soil horizons. The categorization into various soil layers is known as the soil profile. Each layer is of different make up, texture, age and characteristic. Surveying a vertical section through a soil showing its succession of horizons and the underlying parent material (this means studying the Soil Profile) allows to extract complete information on how soil is made (presence of different types of horizons having different physical, chemical, mineralogical, biological properties). The soil information extracted for the soil profile study is about the soil morphology, described in field, and analytical data determined in laboratory**for each horizon**. This is the most complete information that characterizes any soils and that we use to understand the soil genesis, the past use by humans, and to evaluate soils for future sustainable uses.

In MEMOLA in-deep study areas we studied at least **one representative soil profiles for every map units**we delineated in the mapping phase. These represent the source of information to understand soils and their spatial variability. Data (soil properties) extracted from representative soil profile is extended to map units for further spatial elaborations and modeling, including the application of land evaluation systems.

Phase 5 – Archiving and managing the soil information: The soil information, both in terms of geodata (polygons of map units and points indicating soil observations and profiles) and data (soil descriptions and properties), has been implemented in a **Soil Information System**. Data have been archived in form of relational database.

3.3 Specifics of the survey

Once fixed the extent of the in-deep study areas and concluded the preliminary recognition in field by remote sensing using aerial photogrammetry, general recognitions on soil and soil-landscape relationships has been conducted along the survey period up to the conclusion of the mapping phase. Soil observations have been noted by mean of notes, videos, audio, and pictures. In total **more then 300 hundred observations** were carried out. The phase 1 allowed to draft a first version of the soil map units and to plan the soil sampling.

Soil sampling has been made using two different levels: the first level (providing quick but less complete information) was carried out by means of soil observations by hand-auger. For the whole program we made **124 first level sampling points**. These allowed to delineate the map units, to build the conceptual soil-landscape model of the surveyor and to validate the final delineation of the soil map units. The second level of sampling was carried out by means of representative soil profiles. This second level took from July 2016 until November 2016. In **Monti di Trapani we surveyed in total17 representative soil profiles** while in **Vjosa Valley only11 representative soil profiles**. (Tab.5 and Fig. 7 - 14,). In total we studied, for the MEMOLA soil survey program**, 28 Soil Profiles**.

Table 5. Number of representative soil profiles studied in the MEMOLA soil survey program.

In-deep area	Number of representative soil profiles surveyed
Monti di Trapani	

Angimbè	5
Baida	6
Baronia	3
Macari	3
Vjosa Valley	
Grabove	6
Kutal	2
Dracove	3

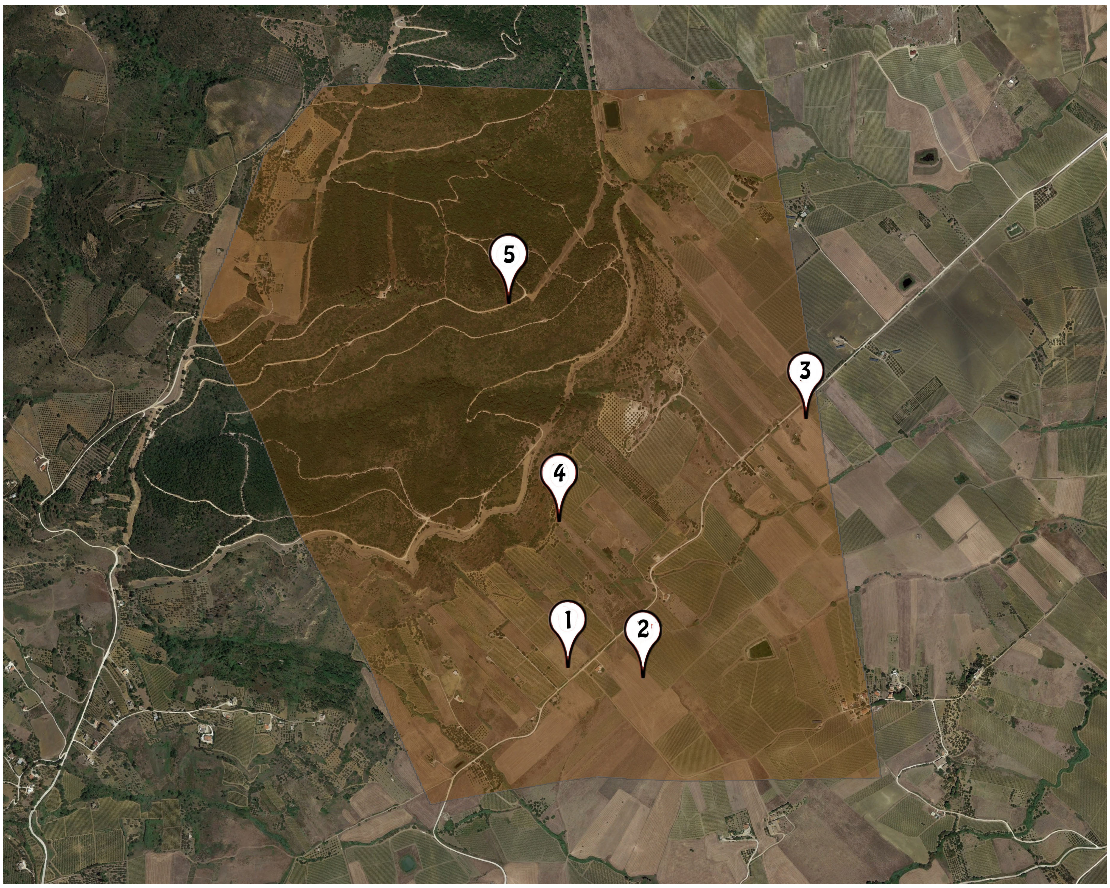

Figure 7. Soil Profiles in Angimbè study area.

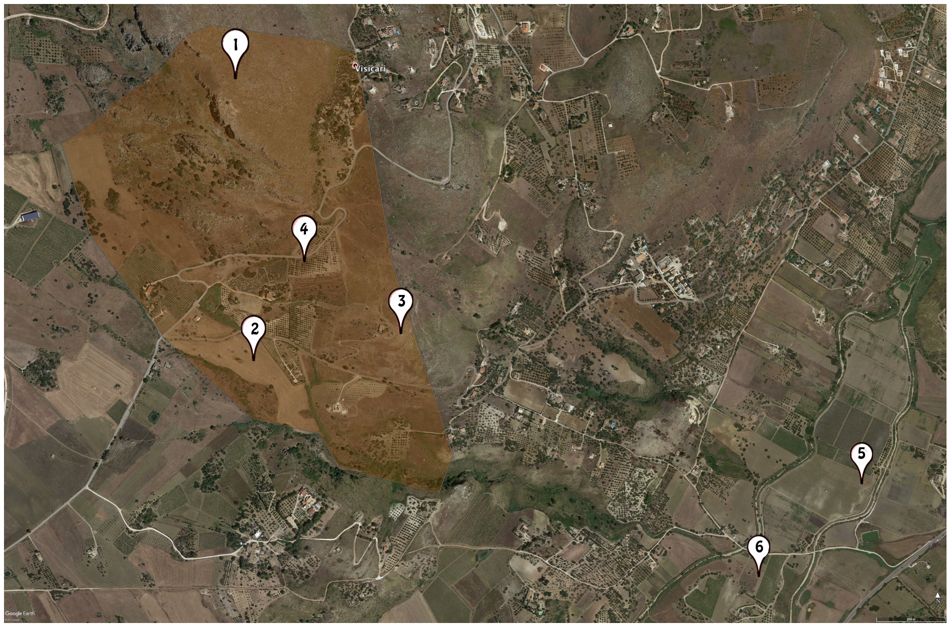

Figure 8. Soil Profiles Baida study area.

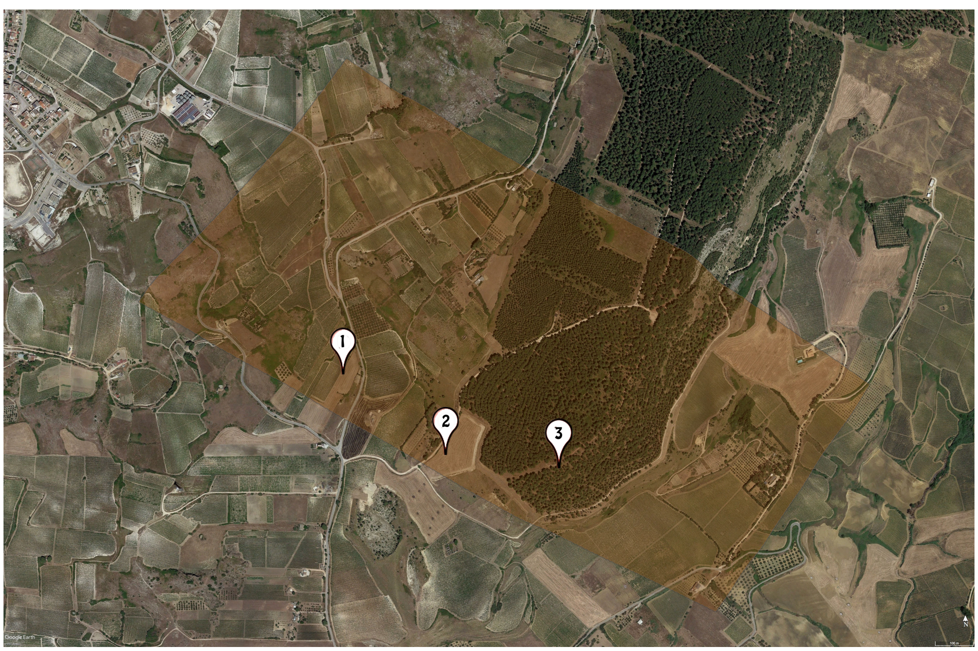

Figure 9. Soil Profiles in Baronia study area.

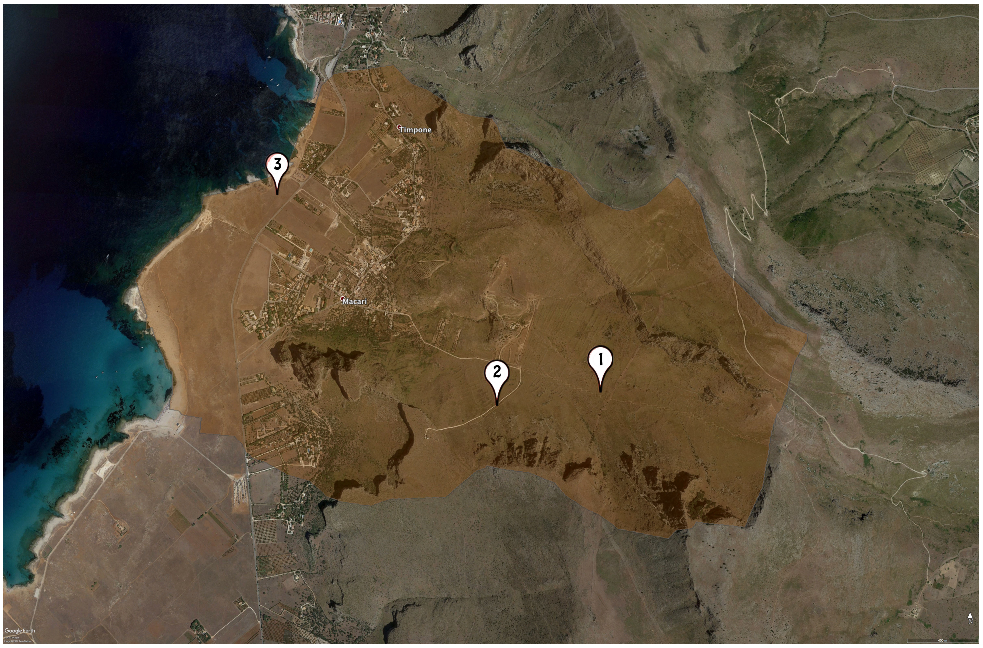

Figure 10. Soil Profiles in Macari study area.

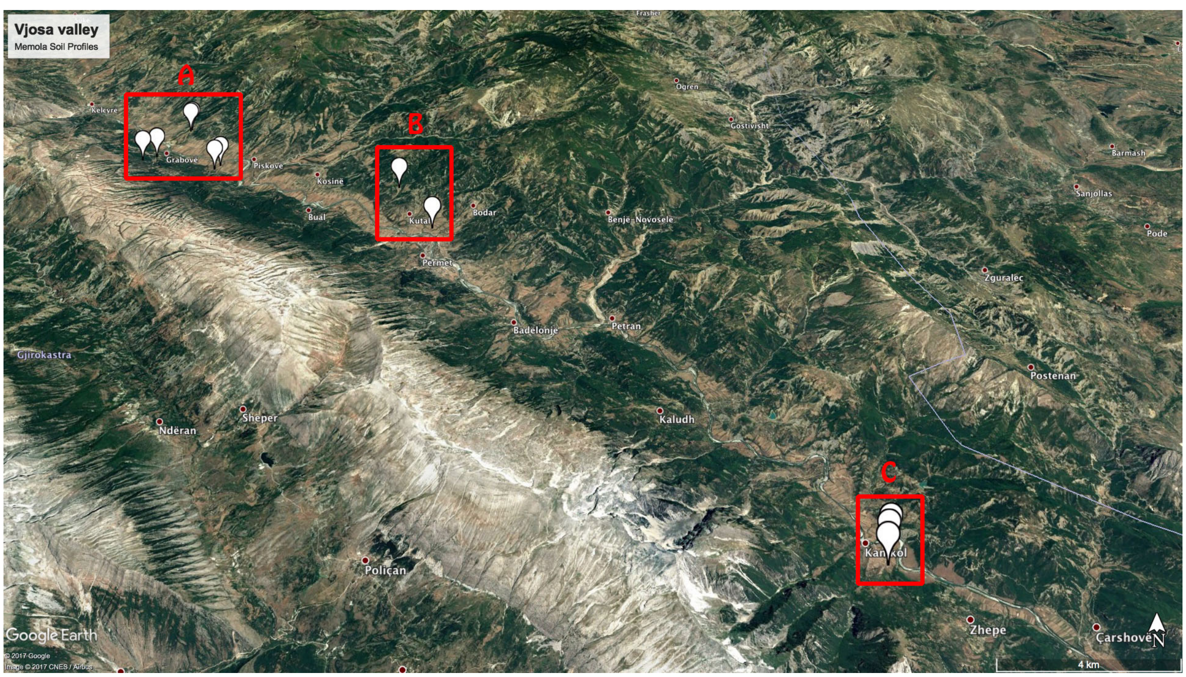

Figure 11. Soil Profiles location in Vjosa Valley.

Figure 12. Soil Profiles in Grabove study area.

Figure 13. Soil Profiles in Kutal study area.

Figure 14. Soil Profiles in Dracove study area.

Most of soil profiles in Monty Trapani were been dug by a proper rented escavator (fig. 15), while in Vjosa valley the most cost-effectiveness way soil profiles was hand-digging (fig. 16).

Figure 15. Soil Profiles digging in Monti di Trapani (July 2016).

Figure 16. Soil Profiles digging in Vjosa Valley (September 2016).

Soil Profiles were described in Field according to the Manual of Soil Survey (Schoeneberger et al., 2012). Site description, description of soil morphology made by horizon, soil profile pictures, and many pictures of the site were recorded and archived digitally in the database.

Each soil horizons have been sampled from the profile. Sampled were air-dried for a couple of weeks, sieved at 2 mm and registered for the laboratory of soil analysis in UNIPA. The number of **soil samples collected in Monti Trapani was 64**,**in Vjosa we collected 35 soil samples**. From December 2016 to April 2017 we performed lab analysis for the following determinations:

Particle-size distribution
pH (in water and KCl)
Electric conductivity
Gypsum
Cation Exchange Capacity
Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})
Base Saturation
Total Carbonates
Organic Carbon
Nitrogen

In total **99 soil samples were analyzed in Lab**. Analytical data per soil horizon have been archived in the relationaldatabase, together with morphological horizon description and site description.

Once analytical data have been complete representative soil profiles were classified according the main international classifications: WRB (IUSS Working Group, 2015) and USDA Soil Taxonomy (Soil Survey Staff, 2014).

After classifying representative soil profiles and verified for each map the coherence of the polygon delineation and the soil classification, all data have been implemented in the Soil Information System and linked with geodata in the relational database.

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