Boeotian landscapes. A GIS-based study for the reconstruction and interpretation of the archaeological datasets of ancient Boeotia.
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I.2.1

The physical landscape datasets

The physical landscape analysis of Boeotia is meant to individuate landscape information, and on this basis perform further analysis concerning the past use of the land and the resources available to past communities, as well as the past communities' cognitive approach to their landscape. The methodology established, as discussed in detail in chapter I.2.2, dealing jointly with material culture, and environment, opts for the 'region' as the analytical unit. It aims mainly to assess the interface between human and social actions and landscape[1]. The transformation of the landscape through time is also under study, in order to infer elements of human eco-dynamics.
The use of GIS can help in performing the analysis, being able to easily manage a large quantity of data and process them in a short time. In addition, it helps us to monitor the quality of the data, and to keep track of the processes employed and the calculations applied to the original records.

In this chapter, I will discuss the choices made and analyses performed on environmental datasets within the GIS system implemented. Physical landscape datasets inserted into the system will be described and examined.

Different physical datasets have been employed within the GIS system, and these come from different sources. They can be divided into:

- BASE data
- DERIVED data
- INTERPOLATED/managed data
- INTERPRETED and MODELLED data (results of analysis)

BASE data:
- Elevation data (manually digitised from georeferenced 1:50,000 topographical GYS[2] map): contour lines at 20m interval and spot heights[3]. The sheets used were: Athina-Eleusis, Bagia, Chalkis, Elateia, Erythrai, Kaparelion, Larymna, Libadia, Libanatai, Perachora, Thiva.
- Rivers and streams network (from 1:50,000 GYS map).
- Geological data (from 1:50,000 IGME[4] geological maps and surveys). Paper maps are based on the 1:50,000 GYS topographical maps.
- Aerial photographs for detail windows (Kephisos valley, Copais, Tanagra).

DERIVED and INTERPOLATED data:
- TIN interpolation from contours and spot heights (see BASE data) and the derived grid DEM (Digital Elevation Model) with a spatial resolution on the ground of 30x30m.
- Slope (derived from TIN model) – 30x30m grid.
- Aspect (derived from TIN model) – 30x30m grid.
- Hillshade (derived from TIN model) – 30x30m grid.
- Classified physiographical position from slope and elevation data (see dedicated section below) – 30x30m grid.

INTERPRETED data:
- Classified land capability (see dedicated section below) – 30x30m grid.
- Classified erodibility (tendency to erosion) (see dedicated section below) – 30x30m grid.

MODELLED data:
- Dynamic model of Copais lake fluctuations (realised according to topographic, environmental and historical data). For a detailed account of the model see chapter II.3.1 – THE PERILACUSTRINE LANDSCAPE- and appendix III.

ACCURACY OF BASE DATA

Environmental layers are usually comprised of continuous variables or discrete variables that cover the

[1] Barker – Mattingly 1999: ix

[2] GYS stands for *Geographiki Ypiresia Stratou*: the Hellenic Military Geographical Service. The 1:50,000 topographical maps are based on photogrammetric compilations from vertical serial stereographs, scale 1:42,000 approximately (1945; field checked 1971 to 1973 -Chalkis sheet in 1955-; photogrammetrical ckecking from aerial stereophotographs 1986 to 1988).

[3] When I started this PhD research, there was no digital topographical data available for Greece, and even today there is not easy access to them, and the costs are, in any case, enormously high. Therefore, during the first stage of my research, I digitised manually 11 topographical paper maps at a scale of 1:50,000 provided by the GYS. The digitised layers are: contour lines (20m interval) and high spots, rivers and streams, modern villages and towns, the main road network.

[4] IGME stands for *Institouto Geologikon kai Metalleftikon Erevnon*: the Greek Institute of Geology and Mineral Exploration. Fieldwork was carried out during the 1960s and 1970s. Maps were published between 1965 and 1986.

whole surface of the area under study. Spatial resolution of data can differ, as well as data quality, but environmental layers are usually characterised by a stronger linearity and consistency (at least in the way data have been collected and mapped, and in the way they have been inserted into the system)[5]. On the other hand, as will be discussed in the next chapter (I.2.2), archaeologically meaningful entities as well as social variables marked by a high degree of non linearity are often represented as discrete rather than continuous, and it is much more difficult to give them a coherent spatial form or a consistent structure (Van Leusen 2002: 2.18-19).

Accuracy of environmental data sets used for subsequent analysis of the archaeological landscape depends on the accuracy of base/row data used.
Quality of results is linked with the scale at which data have been collected (or: with the scale and resolution of the base data used). As always when talking about accuracy of data, we refer to the quality of the data in relation to the problem investigated as well as the goal of the research. In our case, aims and scale of the work make adequate and acceptable the accuracy level given by the thematic cartography available for the region under study (1:50,000 GYS topographical maps, 1:50,000 IGME geological maps and hydrogeological map, Davidson's land suitability for arable agriculture map[6]).
Available maps and literature data on geology and land classification were verified and corrected as much as possible with fieldwork on the ground, both by means of an extensive and non-systematic field survey, and punctual sampling in sample areas[7], while lacking a detailed study for soils over the whole region (not even at the same scale –1:50,000- of the geological maps available). At the local scale, in the area of ancient Thespiae (see chapter II.3.9) a study has been conducted by Shiel and Stewart (Bintliff-Howard-Snodgrass 2007: chapter 7) as for the reconstruction of land-use potential in the past, with attention to land degradation and soil dynamics. I used the work as general guidelines valid for the past land potential and land use in Boeotia, especially for areas with comparable soils and geomorphological characteristics (see below – GEOMORPHOLOGY AND LAND CLASSIFICATION).

The grid used for raster data and analysis has been set to 30x30m cell size. Resolution of base maps (topographical and environmental data, at the scale of 1:50,000), as well as a DEM based on elevation contour lines at 20m intervals, do not allow for a better resolution.
It could be noted that the environmental layers are supposed to be interrelated and cross-analyzed with archaeological entities, which are mainly represented as points within the system, and therefore, when interrelated with raster datasets, they would be represented as cells of 30x30m size (a reasonable minimum size for archaeological entities like our sites –see chapter I.2.2). If one considers the scale of the work with problems and goals at a regional level, and the fact that the environmental layers are supposed to be interrelated and cross-analysed with the archaeological entities, the resolution chosen could be considered as reasonable, being in accord with the base datasets (mainly environmental) as well as with the archaeological-cultural layers involved in the analysis.

As often happens in regional landscape studies carried out at a relatively small and therefore general scale, datasets involved are results of research on the present landscape and environment. Modern landscape datasets have thus been used, processed and created through interpolation and integration processes, in an attempt to define characteristics of the modern landscape to infer information and have a base of reasoning for a possible landscape of the past.

GEOMORPHOLOGY AND LAND CLASSIFICATION

Three main aspects of the geomorphology of the landscape have been taken into consideration, and raster GIS layers were consequently created:

I. physiographical position
II. soil erosion
III. land capability

Those aspects combined together for the definition of physio-geomorphological features allow us to define a series of landscapes and their stability.

I. Physiographical position

A class of physiographical position can be defined as follows:

> ***Physiographical Class****: a unit of geomorphological forms (landforms) with common characteristics that identify elements of a specific landscape. Physiographical classes are not defined absolutely, but according to the specific landscape under study.*

[5] Physiographical/morphological and land capability layers are linear, based on the same base data (geological-topographical map georeferenced) and derived in the same way from the same base data sets (using the same classification, etc). On the other hand, we must take into account that topographical and geological maps are themselves results of sampling and interpolation processes, which the user cannot always easily detect and judge, especially if not a true expert in the discipline.
[6] A digitally drawn map result of D.A. Davidson's personal work carried out in Boeotia as for evaluation of land suitability for agriculture, with the use of core sampling (he focused especially on the plains and some hilly landscape areas). The map was made available to me through Prof. J.L. Bintliff. See also Davidson - Theocaropoulos 1992 and Davidson et al. 1994.
[7] See below for a discussion of the methodology applied.

Classifying the landscape in physiographical units can help in the location of human settlements and activities more precisely by comparing them with the physical characteristics of a landscape, and can help to understand the type and degree of relationship between human settlement and physical environment.
For instance, in the case of the Copais basin, the central lake plain is differentiated from the foothills, even if they lie at low elevations comparable to that of the plain, since in relation to that particular landscape they are elements with different characters: the former permanently or semi-permanently flooded; the latter not. Likewise, foothill landscapes are different from the uplands or the gentle slopes of the narrower, inner valleys, even though they are characterised by similar slope ranges.

At a further stage, features can be differentiated according to their different soil characteristics also: in the example of the Copais basin, the plain presents clay and slightly permeable silt (more fertile where the lake was not permanently present but always susceptible to flooding), while in the foothills limestone appears and constitutes the active karstic zone (less fertile, marked by the presence of *katavothrai*[8], but with a significant presence of seasonal or perennial water sources)[9].
The examination of physiographical position and of qualitative and quantitative presence of the different physiographical classes has been carried out in general terms for the whole of Boeotia[10], and in detail in the analysis of the physical landscape of each *chora*.

Physiographical position can be obtained from the combination of slope and elevation data, using a suitable grid size. In our case, we should be aware that the low resolution of the base DEM (30x30m) does not allow one to appreciate in detail slope differentiations, which remain therefore only indicative, as they lack the intervening morphological complexity.

The following is the list of physiographical classes used for the characterisation of the Boeotian landscape:

- *uneven*: hillside steep or very steep (between 20% and 35% or more than 35%)

- *hilly*: hillside moderately steep (10-20%), sometimes steeper, but low in altitude

- *undulating plateau*: moderate inclination (3-10%), sometimes almost flat

- *plain*: <5%

Those four classes can be applied to the three main elevation ranges: mountain (upper), hills, plain (lower) areas.

[8] The *katavothrai* are natural swallow-holes, usually draining water from karstic basins.
[9] For details see chapter III.1.
[10] See chapter II.1.

Valley below 200 m asl [<200]

code	**slope %**	**description**
P1 P2	<5	lacustrine basin, valley
P3	≥5 <10	gentle slope
P4	≥10	foothill

Hill below 600 m asl [≥200 <600]

code	**slope %**	**description**
H1	<5	plateau
H2	≥5 <10	gentle slope
H3	≥10 <20	moderate slope
H4	≥20 <35	severe slope
H5	≥35	very severe slope

Mountain above 600 m asl [≥600]

code	**slope %**	**description**
[M0]	<5	plateau
M1	<10	plateau, gentle slope
M2	≥10 <25	moderate slope
M3	≥25 <45	severe slope
M4	≥45	very severe slope

A map of physiographical classes for Boeotia can be found in chapter II.1 (fig.2).

II. **Soil erosion**

Erosion is a natural process of surface soil sliding caused by various factors, and strongly influenced by human impact and in particular by land use (both agriculture and animal husbandry). Linked to the process of soil removal are the transportation and deposit of debris. Erosion is therefore a fairly complex phenomenon to analyse, because of the extreme variability of factors that can cause and influence it. Nevertheless, an attempt to classify it can be essential, considering the influence that erosion processes have on the actual soil potential (Gisotti 1983; Godard - Rapp 1987).
Generally speaking, for agriculture, erosion can be considered a negative phenomenon since its consequences are the alteration of the soil's superficial structure/aspect and thinning either of the 'arable soil' or, in the case of natural soil, of the superficial horizons/strata which are the most fertile. Thus, natural erosion can cause the removal either of the surface stratum (A horizon) or, in extreme cases, of the whole soil (Comel 1972; Gisotti 1983; Castiglioni 1991). On the other hand, eroded soil often ends up in lower elevations where it can then be used for cultivation.
The speed of erosion processes is influenced by human factors as well as natural phenomena. When soil removal is more rapid than soil formation (*accelerated erosion*), complete removal of soil and appearance of bedrock can be reached (Castiglioni 1991: 412ff.). Accelerated erosion is favoured by human activities, in particular

reduction of and changes in vegetation coverage (deforestation to gain land for agriculture, general reduction of wild/spontaneous vegetation), overexploitation of soil both for agricultural or pastoral activities, increasing of slope (Butzer 1974). Accelerated erosion can also be influenced by natural factors, in particular abrupt environmental variations which create a strong imbalance, such as a long drought, damages to the vegetation cover, etc. (Megaw 1977; Mehemet 2002).

Accelerated erosion is therefore caused by incidental factors (both natural and anthropic), which often induce rapid phenomena of erosion and deposition. On the other hand, the so-called 'geologic' erosion (a natural dynamic process linked to the natural tendency to balance of environmental features, and surface soil also) is usually slow enough to be compensated by pedogenesis processes and to allow for the soil to regenerate (see, among others, Rice 1977 and Gary at al. 1973[11]).

The risk of soil erosion has for a long time been one of the geological hazards to which human activities are exposed (Gisotti 1983: 37ff. discusses this issue, which, however, is also examined by many others). For Greece, the majority of the country is marked by a hilly and mountainous (rarely high mountain) landscape, often constituted by easily erodible rocks, with an uneven morphology. Boeotia also presents this character, even if its landscape is marked by some wide valleys and the presently drained basin of Copais, the largest karstic basin (*polje*) of Greece (Dercourt 1977; Higgins and Higgins 1996). The erosion of these kinds of soils and morphologies is often strong, favoured by the Mediterranean climate, which is characterised by long dry and hot periods alternating with periods of short and heavy rains[12]. On the other hand, Shiel (2000) notes, quoting Davidson and Theocharopoulos 1992, how in general the Boeotia area appears to be mostly remarkably immune to serious erosion[13] which plagues other parts of the Balkan Peninsula (Shiel – Chapman 1988).

The present work employs the research work carried out by D.A. Davidson in Boeotia (Davidson - Theocaropoulos 1992; Davidson et al. 1994). Davidson correctly states that soil erosion is related to slope, soil type and texture, as he notes: "*As is to be expected, a close relationship was found between soil erosion and slope. Land with slopes of 3% or less is distinguished by the lack of erosion whilst at the other slope range, land in excess of 18% is dominated by erosion class 4…*" (1994: 373). A relation between erosion, soil type and texture indeed exists, but it can be far too complex to be taken into consideration here. In addition, the relationship between well developed soils (vertisols, alphisols) and lack of erosion, and the larger variability in degree of erosion of younger soils, once verified on the ground, could not attain the same degree of occurrence and reliability demonstrated by the erosion-slope relationship[14].

Therefore, the classification made by Davidson (1994: 372) of four erosion classes is built substantially on the basis of the relation (considered as primary) between erosion and slope, and defines the percentage of subsurface horizon exposed, until the total erosion of soil A horizon:

1. None;
2. Subsurface horizon exposed in <30% area;
3. Subsurface horizon exposed in >30% area;
4. All of A horizon removed.

Davidson therefore determines the extreme classes:

≤ 3%	class 1
> 18%	class 4

from which the intermediate classes can be inferred:

>3 <10	class 2
>10 ≤ 18	class 3[15]

The combination of physiographical and erosion classes allows us to delineate 'morphological landscapes'. For instance, the colluvia that border the Theban plain towards Yliki lake can be classified as 'undulating plateaus' in valleys with high soil stability, while the Copais is a valley depression with a tendency to soil stability due to sedimentation, in various degrees from the central area to the border.

III. **Land capability** (in relation to agriculture)[16]

The employed methodology of land evaluation[17], in an attempt to evaluate, at a general level, land potential and limitations for agricultural use, takes into account physical components of landscape, such as geology,

[11] Geologic erosion is the "*Erosion of rocks and soils under natural environmental conditions, undisturbed by human activity.*" (Gary, McAfee Jr, Wolf 1973: 484). Accelerated erosion is an erosion process "*…occurring in a given region at a greater rate than normal erosion, usually brought about by the influence of man's activities in disturbing or destroying the natural cover*" (Gary, McAfee Jr, Wolf 1973: 4).

[12] On the complexity of erosion in the Mediterranean, see also Bintliff 2000d and 2002.

[13] See also Shiel-Stewart 2007 for Thespiae area in particular.

[14] As a more general reference, Davidson's work employes the Universal Soil Loss Equation - USLE (Wischmeier-Smith 1965) commonly adopted in Europe (FAO-Unesco 1981).

[15] For the present work on Boeotia I have corrected Davidson's erosion classes (with multiple values) according to slope and physiographical classes.

[16] A definition is given by a Dictionary of Soil Science (Canarache et al. 2006): "*Land capability classification: the classification of lands according to their performances for various farming uses* (Soil Survey Staff 1993). *It is a qualitative land evaluation procedure* […]". In this classification, lands are classified for the production of the more common field crops (in our case: arable crops more common in the past, olives and grapes), but not for crops requiring little cultivation or for flooded crops.

[17] "*Land Evaluation: a general term for any procedure used to estimate land quality.* […] *The term often has a more or less synonymous sense to the term soil evaluation, most procedures making use, to a great extent, among other land characteristics, of soil properties. Qualitative, semiquantitative and quantitative land (soil) evaluation procedures are often differentiated* […]" (Canarache et al. 2006).

geomorphology, pedology. The undertaken task was to combine the more relevant components of the environment in order to individuate the land capability of each area of landscape within the region, employing qualitative evaluation procedures. This examination has been interrelated with cultural factors; mainly the agricultural techniques and husbandry practice in use in different periods (plough agriculture, pre-ploughing agriculture, etc.). In order to define land capability, the geomorphological and pedological examination must be combined with an examination of climatic, vegetational and faunal factors, which, due to their complexity, especially when referred to the past, have been taken into consideration for the present work only in extremely general terms, being conscious of the limitations and risks of such a choice. On the other hand, the examination considers, at a simplified level, parameters influenced by different factors: rock erodibility, underground water circulation, morphology, slope (Gisotti 1983).

First step was the enucleation of geological formations and lithologies: more stable parameters, as landscape elements only slightly or not at all modifiable on a human scale. Once the formations were delineated through the examination of the available geological maps, different aspects have been analysed: technical characters, influence of surface morphology, phenomena to which they might be subjected, soils that they usually produce. Soils deriving from different rocks, delineated in this way, were classified. Afterwards, the results were verified and integrated with Davidson's and Shiel and Stewart's studies (see above), and with tests in the field. Finally, the resulting dataset was correlated with physiographical values, and the land capability classification scheme was set out.

The land capability values used in the present work result from the relationship between a basic soil classification, soil erosion and a general consideration of the degree of workability of soil related to low-technology agriculture.

A. *Soil classification*

Soil is the earth's surface layer, the contact environment between the inside and the outside of the earth (Duchaufour 1970; Comel 1972; Foth 1990; Arnoldus-Huyzendveld 2003), between rocks, sediments and subsurface water on the one hand, and air, pluvial water, vegetation, fauna, and human activities on the other. Soil is created by the alteration processes of the rocks once in contact with atmosphere and biosphere. In some respects, the soil has similar characteristics to the lithologies from which it derives, but differs from them since modifications occur related to the presence of vegetation, fauna, and micro-organisms, in addition to a whole series of transformations caused by human action. Soil is in fact sensitive to both natural and human influenced transformations of the environment (variation in climate and environment, settlement traces, land use, etc.), to which it reacts and of which it maintains traces, being at the same time both factor and consequence.

The formation and character of the soil are therefore influenced by several factors: the presence of biological activity (mainly produced by vegetation and animals), whose type and intensity strongly influence the character of the soil itself; man's action, that can strongly condition the nature and development of soil; the composition of the bedrock from whose alteration the soil is formed; climate, since rain, wind, sun and ice assist the physico-chemical rock alteration. Pedogenesis is the result of the integrated action of those diverse factors. The length of pedogenetic processes gives the age of a soil, whose formation starts at the moment when the alteration of the original bedrock begins. The development and age of a soil are the result of the combination of pedogenetic factors with morphogenetic processes (soil erosion and deposition) that model the surface and create landscape morphology (Gisotti 1983; Arnoldus-Huyzendveld 2003; Canarache et al. 2006).

Soil is considered a 'renewable natural resource', even if in fact it is quite fragile, considering that hundreds or even thousands of years might be necessary for its formation, while accelerated erosion or human action can destroy it in a few years or even a few hours. This is true not only today, but also in the past human action played a crucial role. Overexploitation of soil, due either to demographic pressure or to agricultural practices (in the ancient Mediterranean, for instance, with no use of crop rotation), could have led to the impoverishment of the soil in certain areas, with a consequent drop in soil fertility as well as renewal capacity[18].

The subject of soil nature, characteristics and dynamics, is much more complex, and a detailed pedological study would be a basic tool in order to define both the nature and potential of different soils. However, considering the limitations of my own knowledge and work on the matter, a very simplified soil classification has been attempted. For the region of Boeotia, a soil map is not publicly available, and creating a map with adequate detail would certainly fall beyond the purpose of the work and the ability of the writer.

In order to produce an overall large scale mapping of Boeotian soils I used as a basis the available 1:50,000 geological maps, which cover almost the whole region[19] at a reasonably good qualitative level (approximate resolution 35/40 metres[20]). The diverse lithologies have been classified considering the soil type that would most probably correspond to each bedrock type. In table 1 is a catalogue of formations mostly present in the region of Boeotia, identified on the base of the lithologies derived from geological maps and grouped according to similar characters.

Soil types (to be related with land capability) were defined and mapped according to lithology, geomorphology and physiographical classes. The two factors that have been systematically employed in classification and analysis are slope and elevation.

[18] For mainland Greece see among others van Andel and Zangger 1990; Bintliff 2002.

[19] A sheet –*Chalkis*- is missing from the IGME archives.

[20] The resolution is indicated on the IGME paper maps.

Slope influences soil depth and development in particular. In plain areas, under the same pedogenetic conditions as for other factors, depth would be at its maximum value, while in areas with increasing slope, soil depth has a tendency to decrease due to erosion. Slope also influences external drainage, as well as surface water flow, and favours washing out processes on steep hillsides as well as stagnancy in flat areas or depressions.
Elevation influences the leaching[21] processes of bedrocks and clay, due to the increase in rainfall at higher elevations, and, especially, a progressive slowing down of the mineralisation process of organic elements due to lower temperatures.

I believe that this method, despite its evident limitations (it does not directly consider, for instance, climate and vegetation coverage), can be considered suitable for the purpose of the present work, since:

a. Bedrock is one of the most important pedogenetic factors (see above), as it influences soil type, on one hand with regards to chemical characteristics/behaviour, producing soils more or less rich in nutritive elements, and on the other hand with regards to physical properties, since more or less compact or strong/hard bedrocks can produce deeper or shallower soils accordingly, and more sandy or clayey soils, as well as soils of lesser or greater workability, especially with low-technology agricultural practices.
b. The greater part of Boeotia has fairly rough morphologies, with a discontinuous vegetation cover that easily allows for erosion processes and hydrogeological breakdown. Furthermore, those soils have been subjected to millennia of human actions (tilth, vegetation burning to gain land for cultivation, overexploitation by pasturage and agricultural activities soil is not capable enough). Thus, soils are affected by frequent/recurrent renewal and are not greatly developed. All this assumed, one can consider the influence of bedrock quite prevalent compared to other pedogenetic factors.
c. Soils of Boeotian valleys, and the Copais basin in particular, follow different dynamics, and can be included in a general classification in which deposition factors are stronger than those of erosion. In the case of the Copais, a specific analysis has been carried out to estimate and clarify the state (either a large swamp or a proper lake) of the basin before the drainage, and consequently the type and availability of soils in different periods of history (see chapter II.3.1 – THE PERILACUSTRINE LANDSCAPE - and appendix III).

[21] Alteration of rock surface due to chemical factors. Some elements dissolve in water, so the process is enhanced by rain, for instance.

A	**Alluvia**	Recent alluvial plains. Fluvial and Fluviolacustrine deposits. Clays, silt, fluvial sands and pebbles. Limno-palustrine as well as lacustrine sediments, recent and contemporary. Grey, brown, black/dark soils.
		Terraced ancient alluvia. River and lake deposits at elevations higher than the present river bed. Alluvial terraces. Talus, alluvial talus, alluvial pediments.
B	**Colluvia** Incoherent surface deposits that would cover mountain and hill slopes or are situated at their feet.	Deposits in foothill areas. Hillslope deposits. Elluvial and/or colluvial deposits. Glacis. Aquifer deposits, detrites, gravels. Red soils. Bauxites. Glacial deposits.
C	**Metamorphic Rocks**	Metamorphic rocks. 'Green rocks', 'ophiolites' (gabbros, serpentine, diabases).
D	**Clays**	Clays, tectonic heterogeneous complexes with clay as prevalent component. Schists; flysch; schistose clays and clayey schists.
E	**Marls** Marls are rocks whose composition is intermediate between limestone and clay.	Prevalently marl formations, marl-sand formations (when the marl component is prevalent).
F	**Carbonate Rocks** Carbonate rocks are constituted of calcium carbonate (CaCo3) and/or magnesium carbonate (MgCo3). Those constituted mainly by CaCo3 are limestones; those in which MgCo3 prevails are dolomites.	Compact and hard limestone. Mainly carbonate rocks, compact and hard, limestone, marls limestone, calcarenites (sandstone made of limestone grains rather than of quartz and pheldsphate grains), limestone breccia, crystalline and fossiliferous limestones, silex limestones, dolomite limestones, dolomites.
		Soft limestones, porous limestones, slightly coherent. Travertine deposits, calcarenites, limestone conglomerates, sandy limestones. To this category can be associated the slope breccia, comprised of deposits of cemented hard-break rock fragments, that often cover, with thin layers, limestone mountain and hillsides.
G	**Sandy Formations**	Siliceous sands more or less cemented, polygenic conglomerate, pudding stone, breccia. Ancient cemented talus. Sandy-marl flysch, sandy-clayey flysch. Sandstones with different components. Soft sandstones.
H	**Flysch** Flyschs are constituted by diverse rocks rhythmically alternated; they correspond to a series of various materials which regularly alternate in great thickness.	Flysch constituted by sandstone in alternation with marl, or limestone with clay, etc. The fertility of soils originating from flysch is strongly influenced by the component rocks.

Table 1. *List of formations mostly present in the region of Boeotia.*

B. *Soil erosion*

Determination of soil erosion has been carried out according to the procedure illustrated above (section II – SOIL EROSION). Soil erosion values are linked mainly to slope values but also to the degree of sustainability of agricultural exploitation and practice (mostly lacking, in ancient times, techniques of soil preservation[22]).

C. *Soil workability*

Soil workability can be directly influenced by slope, soil stoniness[23], and terrain drainage properties. While dealing with past agriculture, soil workability must be considered in relation to low-technology agricultural practices (i.e. dry – non irrigated - agriculture, soil worked with hoes and/or wooden ploughs, the latter probably the exclusive instrument in Prehistoric periods – from Final Neolithic onwards in the Aegean - but still in use in the Classical period, along with the iron plough, which was, however, mostly in use in more recent periods (Roman / Late Roman[24]), often as a high value item[25], which the majority of farmers could hardly afford.

Soil workability is a crucial factor, since we should always consider the agro-pastoral techniques presumably employed in the periods considered in order to determine land evaluation values.

The general assumption is that both for late Prehistory and Greco-Roman antiquity, we are dealing with low-technology agricultural practice, employing low-technology tools, as well as with land/soil preservation practice[26].

As attested by several scholars (recently Van Joolen 2003; Kamermans 1993), land workability is the element that influences farmers' choices, rather than soil fertility. This is because, in the case of non-mechanised agriculture, land capability depends, as stated above, both on the possibilities offered by applied technology and on the quantity of labour required. Different technologies and practices, as well as the different integration between agriculture and husbandry (recently Van Joolen 2003; Nixon-Price 2001), would better exploit different areas and soils within the same region. This is true particularly in the Mediterranean area, which is characterised by a high degree of variability of soils, microclimate, etc[27].

In the present work, the scale adopted to define land evaluation values, aiming at a starting point for a research framework for the definition and interpretation of the ancient landscape, allows us to consider two main general categories of agricultural practices:

- Hoe agriculture in the earliest periods (Neolithic)
- Plough agriculture, mainly with the wooden plough, with a progressive introduction of the iron plough in more recent periods (Final Neolithic to Late Roman)

Hoe agriculture was certainly accompanied by herding practices since Initial Neolithic (Perlès 2001: 73). Some scholars would suggest that along with farming and herding, gathering activities would maintain a role in the group's economy (Thomas 1990; Van Joolen 2003), but Perlès (2001: 16-17) for mainland Greece disagrees, noting how early farmers made little use of wild resources, as natural plant and animal resources do not seem to have influenced the location of Early Neolithic settlements. Regardless, landscapes less appropriate for cultivation (steep or moderately steep slopes with stony soil, or land with a marshy character – Perlès 2001: 10) were probably only partially protected and marked by rich vegetation, good for both gathering and grazing.

More suitable for hoe agriculture are light soils, not too deep (30cm), well drained on moderate slopes[28] and characterised by a low degree of stoniness. On the other hand, hoe agriculture is impracticable on heavy terrains (e.g. clayey textures) or soils either too well-drained or not drained at all, with too much or no water. It is also impracticable on completely rocky soils (extended surface rock, different from pebbles)[29] or on severe slopes, greater than 25-30%.

Many scholars seem to believe that hoe agriculture, probably along with the 'slash and burn' practice, was not accompanied by soil preservation measures (Neuenschwander and Peters 1988; Palmet al 2005; Bellwood 2005). If this was the case, very steep slopes, highly subject to erosion, would not be considered suitable for agriculture and were probably used for pasturage.

Among the classes of physiographical position defined and employed in this work, the most suitable for hoe agriculture would be P3, P4, H1, H2, H3, M0, M1 and partially M2.

Plough agriculture can be differentiated into i) a practice characterised by the use of the wooden plough, without fallow and with simple drainage technique, and ii) a practice characterised by the use of both wooden and iron ploughs and by short periods of field fallow, though

[22] We must consider, though, that terracing techniques for the retention of soil were in use since the Bronze Age. There is a long debate on this aspect for the Prehistoric period (Wagstaff 1992; Simpson 1992; Atherden 2000; Conolly 2002-4 among others) as well as dated examples from the Greco-Roman period (among others Lohmann 1992 –Atene Survey).

[23] A definition of stoniness can be found in FAO 1977 (55ff.) and is reported by Van Joolen 2003 (cap.2).

[24] See Forni -personal communication- in Van Joolen 2003:112.

[25] See White 1976 for the Medieval period, though many scholars do not agree.

[26] On the use of ploughing in earlier periods there is much literature available (Halstead 1995; Sherratt 1981; Pullen 1992). See also above, footnote 23, on terracing techniques.

[27] For the climate of Boeotia see chapter II.1.

[28] Slope classification for hoe agriculture: 0-25% (suitable); 25-55% (suitable with few limitations); >55% (severe limitations of use).

[29] For instance on upland slopes of central Helicon, above Evangelistria towards the Valley of the Muses (see chapter II.3.8).

without proper crop rotation (White Jr. 1976, Forni 1989a; Forni 1989b; Forni 1990; van Joolen 2003).

i) In practice, without fallow and with a simple drainage technique (probably employed in prehistoric periods), the wooden plough has a limited potential. For this practice, as well as for hoe agriculture, light soils are more suitable, but deeper (at least 50cm) and resistant to pulverisation. The wooden plough 'crumbles' rather than ploughs. Generally speaking, wooden plough agriculture prefers the same terrain as that preferred by hoe agriculture, but with significant differences. It is characterised by a higher productivity potential, i.e. it allows for the cultivation of less favourable land (such as dry soils with simple irrigation systems), increasing cultivable areas, and increases soil productivity, favouring a better filling of the earth for seeds. The use of a wooden plough also allows one to cultivate the heavier soils of low river terraces[30], while the use of the iron plough, certainly in use during the Archaic and Classical periods, would allow for a proper cultivation of alluvial valleys (see below). On the other hand, the best areas for the use of wooden ploughs without fallow practice are light soil land, marked by a low degree of slope[31] and stoniness. Unlike in the case of hoe agriculture, pebbles are in fact a strongly limiting factor for use of the wooden plough. Nevertheless, both practices tend to avoid extreme terrains, especially those too heavy or clayey, as well as steep slopes, difficult to cultivate with a plough drawn by man or animal, and also more subject to erosion processes.
Among the classes of physiographical position defined and employed in this work, the most suitable for wooden plough agriculture are P3, P4, H1, H2, H3, M0, M1 and M2.

ii) The use of iron ploughs (but together with wooden ploughs in the majority of cases) and practices of field fallow and rotation of crops, enlarges agricultural potential considerably, especially as far as the alluvial valleys and the lacustrine plains[32] are concerned, i.e. the most fertile areas and with the highest productivity potential (White 1976). Cereal cultivation, in particular emmer wheat (*triticum dicoccum*), can be extended. Heavy, wet soils can be worked by iron ploughs, which parallels a development of drainage and irrigation techniques, well described by Roman authors (i.e. Columella, *De Re Rustica* and Cato, *De Agricoltura*) and reported by Renaissance authors (i.e. Torello, *Ricordo di agricoltura*). At this stage, limitations to soil workability are linked to the socio-economic structures of the communities, rather than technology.
Among the classes of physiographical position defined and employed in this work, the most suitable for wooden/iron plough agriculture are P1-P2, P3, P4, H1, H2, H3, H4, M0, M1 and M2.

Within the present work, land classification processes have been applied using the first two criteria (soil classification for land capability and soil erosion) and taking into consideration the physiographical position. Proceeding to classification according to the third criterion (soil workability) would have required data collected on a different scale, and with a larger number of collected samples in different areas. Studying a large number of sample windows[33] in detail would probably be the best solution for this kind of research, but it is certainly time-consuming, and would probably need the support of a specialist soil scientist. Therefore, for the time being, information on soil workability remains at the level of an unclassified qualitative dataset which informed the general land classification (see below).

The resulting general soil land classification has been verified and corrected through fieldwork, through a more detailed study of some sample areas, of diverse lithologies, paying particular attention to the soils of the upland plateaus, hill slopes, foothills and talus areas, as well as of alluvial basins and major river valleys (Copais basin, plains of Thebes, Thisbi and Thespiae valleys, Tanagra basin).
The working hypothesis, checked, monitored and corrected this way, was compared with other dedicated studies, both on Boeotia (Davidson 1992; Davidson et al 1994; Shiel-Stewart 2007) and on other Mediterranean areas (Kamermans 1993; Van Joolen 2003; for similar work see also Wallace 2001 and Tomkins et al. in press).
For the present work, a first classification of land capability was created according to a simplified qualitative classification of soils, focused in particular on agricultural potential (FAO 1967; FAO 1968; FAO 1976; FAO 1977; FAO-UNESCO 1994; FAO 1998; Soil Surface Staff 1975; Soil Surface Staff 1975; see above for details). It is similar to that used by Shiel in its detailed study of Thespiae area (Shiel-Stewart 2007), developed by the Conservation Service of the US Department of Agriculture (Soil Surface Staff 1975; Soil Surface Staff 1975)[34]. Its structure of eight land capability classes was simplified to four classes.

The defined four classes of land capability are:

F - Lands with few limitations restricting their uses (due to a tendency to wetness or dryness or very moderate erosion).

MF - Lands that have some limitations for agriculture (which reduce the choice of crops or

[30] See the middle/low Asopos terrace (appendix I.14 – THE TANAGRA SURVEY PROJECT).
[31] Slope classification for plough agriculture: 0-13% (suitable); 13-55% (suitable with few limitations); >55% (severe limitations of use).
[32] For instance the plains of Central and Eastern Boeotia.
[33] See as an example the work carried out in the Tanagra area (resumed in I.14 – THE TANAGRA SURVEY PROJECT and in Bintliff et al. 2006, and illustrated in detail in Farinetti-Sbonias in preparation).
[34] This classification adjusts land capability classes based on limitations due to erosion, wetness, rooting zone, and climate (Foth 1990).

require moderate conservation practices), due to wetness caused by different factors[35].

LF - Lands that have more limitations for agriculture (which reduce the choice of crops or require moderate conservation practices), due to dryness and meagre soil depth which causes rooting problems or to high slope degree.

U - Lands that have severe limitations for agriculture (which reduce the choice of crops and require very careful management), due to very meagre soil depth and high slope degree, causing serious problems for access and rooting. In the majority of cases, they can be suitable for pasture, forestry, and grazing[36].

Note: class MF and class LF produce the same effect in terms of limitations for agriculture, but should be separated due to the different strategies that can be used to overcome the problem (different conservation strategies). In a more simplified classification the two classes could also be merged.

A peculiar case is represented by FLYSCH formations, whose derived soils can be less or more fertile according mainly to the percentage of pebbles and rock components. For instance, flysch formations with a high schist component are characterised by a low degree of fertility (LF) and can be locally unfertile (U). In some areas flysch formations have been checked in the field during extensive fieldwork. These visits revealed that the fertility of flysch in the Boeotian landscape can also vary according to elevation. Therefore, the land evaluation layer was queried within the GIS according to elevation values.

Flysch below 600m: MF.
Flysch above 600m: LF (considering climate restrictions, i.e. slower soil formation as well as probable cold winters that might slow down vegetation growth).

Ultimately, the general classification of flysch as MF and LF according to elevation seems to be the most acceptable.

In some cases flysch land capability values were treated separately. In the peculiar micro-landscape of the Valley of the Muses, for instance, sampling in the field shows that flysch could be generally classified as fertile –F (1)-, without exception. Through the attribution to this soil capability class, together with the attribution to a specific physiographical class (see above – PHYSIOGRAPHICAL POSITION; SOIL WORKABILITY) and the assignation of specific soil characteristics (soil stability for instance) one could obtain further information about a surface: for instance, soils on hill slopes are affected by differentiated erosion according to slope degree, etc. In the case of the Valley of the Muses, historical information supported the decision. This criterion cannot be extended though to other Boeotian landscapes, in some cases because flysch was checked in the field and proved to have a different behaviour, in other cases because soils could not be investigated adequately within the framework of the present research.

A map of land capability classes of Boeotia is shown in chapter II.1 (fig.3).
The classes in the map are applicable to both wooden and iron plough agriculture, though one should consider that the lower fertile areas, such as a bonified Copais basin or areas of the Theban plain, as well as the Kephissos basin and Asopos lower terrace in its lower course in the Tanagra basin, were ploughed with more difficulty with a wooden plough (see above – SOIL WORKABILITY).

Models based on land evaluation are *generic* (they can be applied to any area with a similar environment without reference to its archaeology) and *falsifiable* (Van Leusen 2002: 5.14), with archaeological fieldwork and/or core sampling. Certainly, I am aware that a proper land evaluation study would require a larger investment in palaeo-geographic reconstruction, also by means of systematic core-sampling programmes as well as palaeo-botanical analysis for palynological reconstructions. On the other hand, as already mentioned, for the purpose of assessing a landscape situation, the datasets that were available, and our limited fieldwork and core sampling, might perhaps constitute a methodology suitable for archaeologists involved in similar studies, which do not have available, as in this case, detailed pedological studies applied to so-called 'traditional' agriculture.
In any case, we should keep in mind that the landscape derived from modern maps and terrain visits is the landscape of today; a result of all the past transformations and interactions, and all the methods for reconstruction of past landscapes deserve more attention. Within the framework of the present research, an attempt has been made in this direction only in the case of peculiar landscapes, such as the Copais basin. For this, an attempt at reconstruction of the past landscape in different periods could be made (see appendix III and chapter II.3.1). Also in the case of intensively studied windows, such as the Tanagra region, a much more detailed study could be made, which could lead to an analytical reconstruction of the recognisable element of past landscapes.

A definition and a map of land capability classes built in this way could therefore constitute a first degree of improvement of the interpretation of environment and soils simply related to the natural elements of quality of soil in relation to agriculture (pedogenetic and morphogenetic factors), which are often carried out in archaeological landscape work. This interpretation, even if basic and correct, carries the risk of simplifying the relationship soil type - most suitable cultivated crops. The

[35] Such as a superficial aquifer or a high clay percentage.
[36] Only few areas would correspond to the Conservation Service of the US Department of Agriculture's 8th class of land capability (rough land, even for woodland or grazing, and limited use to wild life food or cover and watershed) and therefore in the simplified classification used for this research categories have been merged. The U class is comprehensive of the 5th to 8th categories.

example reported in the chart below (table 2) may constitute an attempt in this direction, and could be used as a basis to examine the agricultural structure and potential of a past landscape, being conscious though, as its author notes, that it should be enhanced with a careful examination of cultural, technical and socio-economic factors involved.

In particular, for Boeotian soils, Shiel and Steward (2007) evaluated the agricultural potential of soils in the area of ancient Thespiae. The chart below (table 3), summarising Shiel's results in matching soils to crops, can complete the table above taking into account specific local soils. The categories used in table 3 can be applied to soils and topographical units of many areas of Boeotia, and generally correspond to our LF, MF and F land evaluation classes (see above in this chapter)[40].

EVALUATION	high	medium	low
CEREALS[37]	Soils with fine texture, deep or with limited depth, presenting low risk of hydric stress	Soils with medium or rough texture, deep or with limited depth, presenting a moderate risk of hydric stress	Soils with a meagre depth, or with limited depth and rough texture, presenting a high risk of hydric stress
OLIVE TREES[38]	Soils deep or with limited depth, not influenced by aquifer	Soils with a meagre depth, not influenced by aquifer	Soils influenced by aquifer (either permanent or temporary)
For grapes[39] the same criteria as for olive trees can be considered.			

Table 2. *Soil evaluation criteria for production of cereals (mainly wheat) and olive trees (after Arnoldus-Huyzendveld 2008).*

SOIL	arable crops	olives/grapes	vegetables	fruit trees
dry clay/calcareous shallow stony soils	moderate	high	poor	high
clay soil with silt and sand and good water capacity	high	high	poor	high
clay soil in foothill zones and streams with good water capacity	moderate	moderate	fairly high	low
clay/loam soil with good water capacity (flood plain)	low	low	high	low

Table 3. *The chart resumes the results of Shiel and Steward's work (2007) in the area of ancient Thespiae in Boeotia for soil evaluation criteria for production of different crops.*

[37] Mainly wheat, without differentiation.
[38] Tassinari (1976: 798): for olive trees, very compact, wet or very loose soils are not suitable.
[39] Tassinari (1976: 750): for grapes, soils of different natures can be suitable, and only excessively wet soils are not at all suitable.
[40] The F class is comprehensive of the two last soils in table 2, including foothills, lower plains and stream valleys.