Archaeological land evaluation
van Joolen, Ester

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Chapter 2
Methodology
*Land evaluation, ALES, Pollen analysis*

2.1 Archaeological land evaluation

2.1.1 Land evaluation following the rules of the FAO

Although land evaluation was already developed in the early 1970s (Beek & Bennema 1972; Brinkman and Smith 1973; Young 1973; Beek 1975; Vink 1975), the concepts and methods of qualitative land evaluation were fully described by the Food and Agriculture Organisation of the United Nations (FAO) in 1976. In FAO terms, land evaluation is defined as “the assessment of land performance when used for specific purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use.”

Although in principle constructed for present-day or future land uses, it can also be applied to archaeology (Boerma 1989, Hunt et al. 1990, Kamermans 1993 & 2000, Finke et al. 1994, Farshad 1997, Verhagen et al. 1999). Land evaluation in archaeology tries to establish the potential suitability of ancient landscapes for ancient land uses. This implies a rather different approach, which is explained in 2.1.2. However, the first steps of potential land evaluation in archaeology can be considered as those in the FAO framework (figure 2.1).

*In all cases, land evaluation commences with initial consultations, concerned with the objectives of the evaluation, assumptions and constraints, and the methods to be followed (FAO 1976).*

<table>
<thead>
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<th>1. Initial consultations</th>
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<td>• objectives</td>
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<td>• data &amp; assumptions</td>
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<th>4. Visualization of the results</th>
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*Figure 2.1 Various steps for carrying out a potential land evaluation for Archaeology*

The main aim of this thesis is to draw suitability maps for pre-Roman and Roman agriculture (chapter 1). More specific purposes are, for example, broad inventories of the research areas to generate land...
ARCHAEOLOGICAL LAND EVALUATION

system\(^1\) maps and a detailed investigation concerning past land uses, including the soil requirements of ancient crops. The objectives serve to define the relevant kinds of land use and to minimise the required information.

Also in archaeological land evaluation, assumptions have to be made, which in turn can affect the final interpretation. Assumptions, such as farming on basis of sustainability and the least effort principle (Zipf 1949) are discussed at the end of this chapter.

One of the constraints of this research is the extent of the areas: it turned out to be impossible to generate very detailed land system maps (for example at a scale of 1: 10,000). But in the general aims of the RPC-project, mapping at a scale of 1:50,000 is considered to be adequate. At the end of this chapter, more constraints are described.

After the general objectives, assumptions and constraints have been determined, the level of intensity of the surveys (reconnaissance, semi-detailed or detailed surveys) has to be assessed. The choice is reflected in the scales of the resulting maps.

Reconnaissance surveys are concerned with a broad inventory of resources and the development possibilities at regional and national scales. Economic analysis is only in very general terms and land evaluation is qualitative (defined below).

Semi-detailed and detailed surveys are concerned with more specific aims (…), and land evaluation usually is quantitative (defined below).

Subsequently, a choice has to be made between the two approaches to land evaluation:

- A two-stage approach in which the first stage is mainly concerned with qualitative land evaluation, later (although not necessarily) followed by a second stage consisting of an economic and social analysis.
- A parallel approach in which analysis of the relationships between land and land use proceeds concurrently with the economic and social analysis (FAO 1976).

The main aim of land evaluation is to obtain a suitability classification for different kinds of land use. The classification can be qualitative or quantitative.

- A qualitative classification is one in which relative suitability is expressed in qualitative terms only, without precise calculation of costs and returns. They are based mainly on the physical productive potential of the land, with the economics only present as a background. They are commonly employed in reconnaissance studies, aimed at the general appraisal of large areas.
- A quantitative classification is one in which the distinctions between classes are defined in common numerical terms, which permits objective comparison between classes relating to different kinds of land use (FAO 1976).

Since we deal with relatively large research areas in the RPC-project, the archaeological land evaluation in the project was carried out at reconnaissance level. Furthermore, a two-stage approach was employed, excluding the economic and social analysis and qualitative classifications, because calculation of costs and returns is impossible in Archaeology. But, within the physical evaluation model, there are options to incorporate these analyses (which is explained later).

2.1.2 Carrying out a land evaluation in archaeology

Investigating the land use (uses): land utilisation types and land use requirements

After the above mentioned items have been determined (objectives, assumptions, type of survey, the approach to follow and the kind of classification), the major kinds of land use and/or the land utilisa-

\(^1\) A definition of a land system is presented in 2.2.2.
tion types have to be reconstructed.

*A major kind of land use is a major subdivision of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forestry, or recreation* (FAO 1976)

*A land utilisation type (LUT) is a kind of land use described or defined in the degree of detail greater than that of a major kind of land use (...). It is described with as much detail and precision as the purpose requires* (FAO 1976). For example, ancient rainfed agriculture can be divided into several LUTs, such as subsistence farming (mainly based on manual labour), or mixed farming (based on an increase of yields for market purposes and accompanied by sophisticated ploughing instruments).

Within every LUT, several farming-related aspects are described, such as the kinds of crops people cultivated, the technology and instruments they were acquainted with, the size and configuration of their land holdings, and which kind of agriculture they practised (subsistence farming or market-orientated farming).

In archaeology, information on land utilisation types usually has to be extracted from the literature (for example for Roman times agronomists as Columella or Pliny), excavations (these can provide clarity about, for example, agricultural tools, or ploughing furrows), pollen analysis (information about crop cultivation, or deforestation) or from the analysis of macro-remains (such as animal bones, and seeds).

A detailed investigation into the development of agricultural equipment is also necessary Forni (1990) published an extended volume relating to this subject). To summarise, a multidisciplinary approach is important to reconstruct the LUTs as well as, in accordance with past reality, possible.

The research must also provide data concerning the land use requirements and limitations of the LUTs. The FAO (1976) defines these subjects as *requirements of the land use (LURs)* which refer to a set of land qualities that determine the production and management conditions of a kind of land use. *Limitations are land qualities or their expressions by means of diagnostic criteria, which adversely affect a kind of land use.*

Unravelling land use requirements is not an easy task; for example, information about crop requirements of ancient (disappeared) cereals is hardly available. Fortunately, farmers in Northern Italy re-introduced emmer wheat (*Triticum dicoccum*), and the soil and management requirements were thoroughly investigated (Van Joolen and Woldring 2000). But the requirements of most crops must be extracted from the historic literature, with possible interpretation mistakes.

Investigating the research areas: land qualities and land characteristics

Also, the research area (areas), for which the land evaluation procedure must be executed, has (have) to be mapped and investigated. The scale and the mapping units depend on the aims of the research. The land characteristics of an area can be mapped on the basis of, for example, sedimentology, geomorphology, and/or geology.

Because the main objective of prehistoric land evaluation is to determine which fields were potentially suitable for a specific kind of ancient land use, landscape reconstruction had first to be performed. Of course, this was not always an easy procedure. Human activities, such as levelling with associated soil removal or addition, reclamation of land, changes in hydrology, and soil improvement can drastically change the original landscape. For instance, in the Pontine region fields have been levelled with soil from elsewhere. In the Salento Isthmus, we saw large machines breaking down a complete hill, whereas in the Sibaritide some fields were raised by about half a metre.

More problems arise when it is evident, that certain parts in the landscape changed during the research period (Bronze age till Roman age), for example due to erosion following deforestation. Investigation of such processes of change is necessary (sedimentation, erosion), preferably with the aid of datable archaeological remains and/or organic material.

Next, for each mapping unit, all relevant land characteristics and land qualities have to be determined.
A land characteristic (LC) is a land attribute, which can be measured or estimated... (FAO 1976), for example slope percentage, drainage and soil texture.

A land quality (LQ) is a complex attribute of land, which acts in the distinct manner in its influence on the suitability of land for a specific kind of use. Land qualities may be expressed in a positive or negative way (FAO 1976). Moisture availability, rooting conditions and workability are examples of land qualities.

Land qualities are a direct answer to land requirements. Assessments on the basis of land qualities are recommended therefore (Huizing et al. 1995).

Land qualities can be divided into several categories depending on the aim of the research. From the list the FAO published (1976: Table 1, p. 13), two groups of land qualities are included in this research: land qualities affecting growth of crops and other plants, and land qualities affecting animal husbandry. For archaeological purposes, a limited number of land qualities have to be and can be examined. For example, from the rather extensive list of 26 land qualities effecting rainfed agriculture, which Dent and Young (1981, 166–167) published, only a few are relevant for archaeological land evaluation, simply because of the lack of detailed information of certain ancient land characteristics, such as soil poisonousness or vegetation diseases or frost hazards.

To determine the limits of land suitability classes or subclasses, diagnostic criteria are used. A diagnostic criterion is a variable which has an understood influence upon the output from, for the required inputs to, a specific use, and which serves as a basis for assessing the suitability of a given area of land for that use. This variable may be a land quality, a land characteristic, or a function of several land characteristics. For every diagnostic criterion there will be a critical value or a set of critical values which are used to define suitability class limits (FAO 1976).

Comparison of land use with land
At this stage, the requirements of certain kinds of land uses (LURs) are compared with the qualities of the land (LQs), leading to a land suitability classification. Land suitability is the fitness of a given type of land for a defined use (FAO 1976).

<table>
<thead>
<tr>
<th>Land suitability orders:</th>
<th>Reflecting kinds of suitability for a specific crop or a specific kind of agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = suitable</td>
<td>(the crop can be cultivated without difficulty: no additional land improvement techniques are needed)</td>
</tr>
<tr>
<td>2 = slightly limited</td>
<td>(yields will be marginal when the soil is not improved. Therefore, additional techniques to improve the soil are needed, such as drainage and irrigation techniques or terrace building techniques)</td>
</tr>
<tr>
<td>3 = limited</td>
<td>(implementation causes problems; no notable yields)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land suitability suborders:</th>
<th>Reflecting kinds of limitation within orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>m = moisture deficiency</td>
<td></td>
</tr>
<tr>
<td>n = nutrients deficiency</td>
<td></td>
</tr>
<tr>
<td>w = poor workability</td>
<td></td>
</tr>
<tr>
<td>r = poor rooting conditions</td>
<td></td>
</tr>
<tr>
<td>e = erosion hazard</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1 Definitions and explanations of land suitability orders and suborders, as has been used in this thesis.

Although in the FAO framework at least four physical classes are employed to classify land suitability (S1 = highly suitable, S2 = suitable, S3/N1 = marginally suitable, and N2 = not suitable), in archaeo-
logical land evaluation three levels are used (suitable, marginally suitable and not suitable). Because of the many uncertainties in the research, we cannot define more specific classes. The suborders simply reflect the reason why a landform is classified limited or slightly limited. For instance, if the result from the suitability classification of an area of land for cereal cultivation turns out to be 3mw, this means that cereal cultivation for that landform is limited, because of poor drainage conditions (m = moisture availability/drainage). Furthermore, the soils in the area are too heavy to be worked (w = workability).

Suitability is determined by the limiting factor classification: the LQ, which influences the land use in a negative way, determines its suitability. For instance, all soils, which experience poor drainage conditions, are limited for cereal cultivation. The remaining soils, which are well or marginally well drained, negatively influence cereal cultivation by, for instance, its subsoil stoniness or low fertility. In this way, only those soils remain, which fulfil the LURs the best.

2.2 Collecting the data

This part of the chapter describes the way information is gathered, the difficulties that were encountered and the classification of the data.

2.2.1 Description of ancient land utilization types (LUTs)

Description of ancient land utilization types forms the important knowledge base in the land evaluation procedure. Information on ancient LUTs can partly be derived from the literature, and partly from recent research (see below: land use requirements). The description of each LUT shows specific attributes, such as:

- *Kind of agriculture*: subsistence farming or market orientated or mixed farming (partly arable farming and partly grazing)
- *Produce*: kinds of cultivated crops, kind of livestock
- *Power sources and technology*: cultivation by hand (human labour), use of animal draught, use of simple or sophisticated ploughs, use of fertilisers, possibilities and knowledge to build terraces and/or drainage canals, irrigation
- *Size and configuration of land holdings* (consolidated or fragmented)

Table 2.2 shows examples of ancient land utilisation types. However, as is indicated before, these examples must be elaborated further.

<table>
<thead>
<tr>
<th>Major kinds of land use</th>
<th>Examples of land utilisation types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed arable farming</td>
<td>Small holder; traditional technology</td>
</tr>
<tr>
<td></td>
<td>Intermediate farms; mixed farming; intermediate technology</td>
</tr>
<tr>
<td></td>
<td>Estates (latifundia); more sophisticated technology</td>
</tr>
<tr>
<td>Irrigated farming</td>
<td>Large estates with sophisticated technology, market-orientated, mono-cropping</td>
</tr>
<tr>
<td>Tree and shrub crops</td>
<td>Olives and grapes, intercropped with cereals</td>
</tr>
<tr>
<td>Grazing</td>
<td>Long-distance transhumance</td>
</tr>
</tbody>
</table>

Table 2.2 Examples of land utilization types
For each period under investigation (late Bronze Age, Iron Age, Archaic and Roman Age), all relevant LUTs have to be described, including their land use requirements.

It turned out to be rather difficult to gain information about LUTs in the late Bronze Age. Wolf, in his book *Peasants* (1966), provides us practical data. More recently, Forni (1989 and 1990) published more detailed information about this period. These valuable works especially deal with ancient Italian farming from the Neolithic until and even after Roman times.

Forni (1990) and Barker and Rasmussen (1998) describe the periods between the Bronze Age and Roman times rather extensively. In their book, Barker and Rasmussen describe the LUTs of Etruscan people; their lifestyles resembling those of the people in the Pontine region (personal communication Attema).

Most information on Roman agriculture can be derived from White (1967, 1970, 1984) and Spurr (1986). In his book, *Arable Cultivation in Roman Italy (c. 200 BC – c. A.D. 100)*, Spurr comprehensively depicts examples of various LUTs of cereal production and other agricultural activities.

To complete the description, we must include the fact, that farmers may have applied several land uses at the same time. *Multiple land use consists of more than one kind of use simultaneously undertaken on the same land* (FAO 1976). An example of a multiple land use is an olive yard with cereal undergrowth. The multiple land uses require different land qualities and are incorporated into the land evaluation as unique LUTs.

**Land use requirements of land utilisation types**

Almost all present-day crops have been genetically changed in such ways, that the soil and management requirements differ from their ancestors (personal communication professor D’Antuono2). That is why we cannot use the present-day requirements without careful study (as said before in 2.1.1). The soil and management requirements of emmer wheat have been investigated during a field research in Northern Italy (chapter 4 and Van Joolen & Woldring 2000). Information on other crops has been derived from the contributions of ancient agronomers, for example Columella and Pliny.

Researchers from the Archaeomedes project (1998, 203–208) studied human soil perception and classified soils and plants according to the Roman agronomers. This study and classification are important sources for the prehistoric land evaluation.

### 2.2.2 Land systems, land forms and land qualities

#### 2.2.2.1 Data collecting in the field

In this research, two areas (Pontine region and Sibaritide) have been mapped initially on basis of sediment and soil type, the third area (Salento Isthmus) on basis of geomorphology.

The first area to be mapped was the Pontine region. We based our mapping on *the soil map of the Agro Pontino and adjacent Campania* (Sevink et al. 1991). In general, the boundaries of the units have been followed and copied. However, some units were split and others were compiled to one unit, because of different scales and aims (see also the next chapter).

Geomorphological mapping turned out to fit best in the land evaluation research in the Salento Isthmus. Here, we only had geological maps at our disposal. These maps provided too little information about sediments and recent genesis of the landscape to create detailed soil maps (as was done by Sevink et al. (1991) in the Pontine region). The main aim of the field research was to create maps showing relevant land mapping units (scale 1:50,000). These units were defined on the basis of their geomorphological appearance in the field according to the standard guidelines of the FAO (1977: 8–9): for instance hills, plains, depressions, and undulating landscapes.

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2 Agronomy, Bologna University, Italy
The advantage of geomorphological mapping is that the units are rather stable in time and slope percentage can be considered as an important factor in the suitability classification (see below: workability). However, sedimentological mapping provides a lot of information about erosion and deposition, soils and sediments and genesis of the landscape.

The third and last area, the Sibaritide, was mapped in the same way as was done in the Pontine region.

2.2.2.2 Land systems

In order to compare the maps of the areas (the geomorphological map of Salento Isthmus with the soil and sediment maps of the Pontine region and Sibaritide), they were re-mapped into the same units: the so-called land systems. A land system is an area or group of areas with a recurring pattern of landforms, soils and vegetation (CSIRO 1963). Two Australian scientists, Christian and Stewart, first defined the concept in 1953. The advantage of mapping an area in land systems is that:

1. it is a relatively easy way of summarising a large amount of information,
2. the systems can be well expressed on a scale suited to reconnaissance surveys, and
3. the land systems are the reflection of interacting agents, such as lithology, climate and geomorphic evolution.

The land system approach attempts to express the integration of all elements of the land complex, recognising the causal links between them through an understanding of the genesis of the system itself (CSIRO, 1963).

Description of a land system

Primary, a land system is described in general terms, comprising location of the land system, total area of the system, drainage pattern, geomorphology and land use. It is visualised by a block diagram and/or a geomorphic map. Secondary, the characteristics of the constituting components (landforms) of the land systems are shown in a tabular summary. This table provides information about the landforms in terms of geomorphology (slope percentage), pedology, present-day vegetation and its approximate size. Finally, for archaeological land evaluation, some complementary information which was collected in the field, is described in the accompanying report (such as signs of human activities: presence of sherds, stone walls alongside the arable fields, and signs of levelling of soils).

2.2.2.3 Collecting field data

Most field data were collected using the guidelines for soil profile description (FAO 1977). The research areas were investigated at two levels: at the general level the land systems were described as a whole, at a more detailed level characteristic surface elements and sediments were studied.

The description of each land system included topography of the landforms, stoniness and rockiness at the surface, current land use and other human influences (such as ploughing, irrigation, signs of removal of stones out of the fields), natural vegetation, and signs of superficial erosion.

The characteristic soils in each land system were examined using a hand auger. We described the following characteristics: type of sediment boundaries, soil horizons, texture, consistency, drainage, stoniness, roundness of the stones, mottles (Fe & Mn), and possible human artefacts, shells, and roots. Soil colours were determined according to the Munsell colour chart. Slopes were calculated from contour lines or by using a slope-measuring instrument.

During the fieldwork we used the following equipment: an Edelman auger, a 1 m gouge, and a

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3 Description of the present-day ‘natural’ (not planted by humans) vegetation and land use is necessary because it is assumed that the suitability of an area for land use is an indication for its historical suitability.

4 In Salento Isthmus and Sibaritide, drainage was estimated on basis of texture, and oxidation/reduction features in the soil, whereas the soil map of Sevink et al. (1991) provided the information for the Pontine region.
Dachnovski core (Ø circa 5 cm) for sampling the peat. The peat samples were dated at the Centre for Isotope Research in Groningen (the Netherlands). Soils and stratigraphy were described using the FAO Guidelines for Soil Profile Description (FAO 1977).

2.2.2.4 Land qualities and land characteristics

As said before, this research deals with ancient potentially changed landscapes. Therefore, many former land characteristics cannot be measured or estimated anymore. Also, exact historical climatic data are not available, such as day length, temperature in growing season, minimum sunshine hours, and frequency of appearance of damaging frost (Dent and Young 1981). But, fortunately, some land characteristics can still be determined.

Table 2.3 shows an overview of prehistoric land evaluation performed by different authors in Italy and Iran. From the table it is clear that the authors not always use the same method to perform a land evaluation. This can be due to different aims of research, local conditions and, of course, available time and financial possibilities.

<table>
<thead>
<tr>
<th>Land qualities</th>
<th>Land characteristics</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of soil moisture</td>
<td>Drainage class</td>
<td>Sevink et al. 1991,</td>
</tr>
<tr>
<td></td>
<td>Soil texture, soil colour, position in the landscape</td>
<td>Kamermans 1993</td>
</tr>
<tr>
<td>Availability of oxygen in the soil</td>
<td>Drainage class, soil texture, organic material</td>
<td>Kamermans 1993, Finke et al 1994</td>
</tr>
<tr>
<td>Availability of nutrients in the soil</td>
<td>Soil type</td>
<td>Sevink et al. 1991,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kamermans 1993, Finke et al 1994</td>
</tr>
<tr>
<td></td>
<td>% CaCO3 Consistency of the upper 100 cm</td>
<td>Farshad 1997, Farshad 1997</td>
</tr>
<tr>
<td>Conditions affecting germination</td>
<td>Soil texture, Consistency of the upper 100 cm, stoniness</td>
<td>Kamermans 1993, Finke et al. 1994</td>
</tr>
<tr>
<td>Flooding hazard</td>
<td>Position in the landscape</td>
<td>Kamermans 1993, Finke et al. 1994</td>
</tr>
<tr>
<td>Physical degradation hazard</td>
<td>Soil texture, % CaCO3</td>
<td>Finke et. al. 1994</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Slope percentage, soil texture</td>
<td>Kamermans 1993</td>
</tr>
</tbody>
</table>

Table 2.3 Land characteristics and land qualities associated with references to the literature

Assessment of the land qualities:
For this research, the investigated land qualities are outlined and described below, associated with the most appropriate diagnostic criteria. In section 3.3, 2 (reference lists), the land characteristics are thoroughly described, in terms of acquisition, and classification.]

Land qualities associated with ancient rainfed agriculture
(modified after FAO 1976, Huizing et al. 1995)
In our research areas, no evidence is available of Bronze Age or Iron Age people irrigating their fields in a sophisticated way by means of, for instance, pumps. The farmers depended on the amount of pre-
cipitation in order to get enough water for the crops. Therefore, for these periods, only those land qualities associated with rainfed agriculture are taken into account. Also, for these periods, use of drainage systems, or fertilisers, are left out of the evaluation.

However, in later epochs (Archaic and Roman times), people used irrigation in dry areas, drained their fields and improved soil fertility. In this way, the suitability of a lot of fields increased and these techniques are incorporated into the evaluation.

According to Kutschera (1960) in his *Wurzelatlas*, crops need warmth, light, water, air and nutrients (minerals) for growth and development of both the root system and the sprout.

Warmth is the most important growth factor, next to light, and both influence also seed germination. Every plant has its own optimum temperature. In this research, it is assumed that farmers cultivated their crops in the most favourable season.

Air in the soil has two functions: it provides oxygen and removes carbon dioxide. Almost all plants need well-aerated soils.

Water serves for metabolism, and the development and maintenance of cell pressure in the plant (Kutschera). In most cases, the root system can be adjusted in such a way, that a maximum of water can be withdrawn from the soil. For example, some plants develop long roots to reach deep ground water tables.

A. Availability of soil moisture

The availability of moisture in the soil depends on the amount of rainfall, irrigation, potential evapotranspiration and capabilities of the soil to hold water (Kamermans 1993). Exact data on the amount of rainfall and evapotranspiration in prehistory are not available. The measurable diagnostic criteria are (from the highest to the lowest importance):

* Drainage classes

Our fieldwork did not allow classifying the soils in the six drainage classes according to the FAO (1977) guidelines, because this classification was only achieved after intensive laboratory research of soil samples. Therefore, the following classes were used (see also below: 2.3 Reference lists; land characteristics):

- Poorly drained soils: too wet for the cultivated crops in ancient Italy; suitable only for grassland
- Drained soils: intermediate soils; well suited for most crops
- Excessively drained soils: too dry for rainfed agriculture; irrigation necessary

* Effective soil depth (depth to which roots penetrate)

Crop roots generally can penetrate the soil to a depth of approximately 100 cm. But it is not necessarily valid for all vegetation, for instance the roots of olive trees spread horizontally. Generally, shallow soils, with a maximum depth of 30 cm, are not suitable for agriculture. The suitability of deeper soils depends on other criteria, such as texture.

* Field capacity and wilting point of each soil horizon (in this research, influenced by texture and organic matter)

Water can only penetrate pure clay soils along cracks, fissures and other structural elements, and clay will not be saturated. Therefore, these soils are classified as poorly drained and limiting for ancient farming practices. But, when mixed with organic matter and/or silt and sand, their suitability increases. However, pure sandy soils cannot store water, so these soils are classified as excessively drained, and therefore are also limiting for prehistoric agriculture.
B. Availability of nutrients in the soil

Soil type is an indirect indication for soil fertility. Kamermans (1993) classifies the availability of nutrients as shown below (I inserted the definitions of the FAO-Unesco 1988):

* **Soil type classes**

Luvisols (relatively well developed soils showing various horizons), Vertisols (soils having more than 30 percent clay to a depth of at least 50 cm) and Fluvisol (soils, which receive fresh fluviatile, marine and/or lacustrine materials at regular intervals) are the most fertile soils. These are grouped as well-suited for ancient farming.

On the contrary, Arenosols (soils, with a coarser texture than sandy loam), Regosols (soils from unconsolidated materials, having few diagnostic horizons) and Planosols (soils showing stagnic properties and shallow depth) are the least fertile soils. Cultivation of crops is limited in terms of fertility.

* **Top soil thickness**

As has been discussed before, shallow soils (thickness less than 30 cm) are not (or less) suitable for agriculture.

C. Workability of the land

This land quality requires a different approach. Biological or physical rules cannot be applied here, because workability is expressed in terms of human perception of the land. It is clear from the study of Roman agronomers (chapter 4: Land utilisation types and land use requirements) that, where workability is concerned, special attention was paid to relief (slopes), drainage, soil texture, stoniness and soil thickness. But this attention probably changed through time (mainly because of improved agricultural tools, chapter 4) and the diagnostic criteria differed in importance.

* **Slope class**

Workability is closely related to technology. When dealing with manual labour, slope class cannot be considered the most important diagnostic criterion, because people are capable of walking on rather steep slopes. This kind of agriculture used to be rather common in Bronze Age Italy (chapter 4 and 5). But in later times, fields were also worked with the use of animal-traction tools (ploughs). Here, slope class indeed mattered.

According to the definitions of slope classes, described in the Soil Survey Manual (1951), plains and gently sloping areas offer no difficulty in the use of agricultural machinery (...). Sloping and moderately steep areas can be cultivated with agricultural machinery too, but with more difficulty, especially when large and heavy types are in use. Steeply sloping areas can be used only with the lightest types of agricultural machinery, whereas very steep slopes offer no possibilities for agriculture.

Discussion is necessary on the validity of these definitions for ancient agriculture. Of course, during the first millennium BC, the present-day heavy machinery did not exist. Moreover, in peninsular Italy, the so-called heavy ploughs were unknown during this period too (see chapter 4). So, steeper slopes could be cultivated using manual tools and/or light ploughs than today. The following system is used:

- **Cultivation of slopes using manual tools only**
  - 0 – 25% (flat to moderately steep slopes) = no problem
  - 25 – 55% (steep) = marginally suitable
  - more than 55% (very steep) = limited

- **Cultivation of slopes using light ploughs**
  - 0 – 13% (flat to sloping) = no problem
  - 13 – 55% (moderately steep to steep) = marginally suitable
  - more than 55% (very steep) = limited
* Presence of stones or rocks

The hindrance of stones and rocks in the field depends on the use of the various agricultural instruments. Some ploughs could be lifted up easily to pass a stone or rock. Other ploughshares could break when hitting a stone, yet other ploughs were hindered seriously (chapter 4). On the other hand, (partly) buried stones favour drainage and aeration, and they loosen up the soil (personal communication dr. Reynolds). So this is a very complex criterion and depends on the agricultural know-how in a particular period and the size of the stones (gravel, stones and boulders).

* Poor drainage conditions

Poorly drained soils were limited for ancient agriculture (Bronze Age, Iron Age) in Italy, because of the risk of drowning and rotted of the crops. But in later periods, the suitability of these soils could be increased because of improved knowledge on drainage practices.

* Texture of the soil material

The appraisal of soil texture, once more, depends on technology. Clayey soils could be worked, but required a lot of labour and time.

D. Water erosion hazard (runoff)

The most diagnostic criterion is slope class (Soil Survey Manual 1951). Flat or almost flat areas experience no significant water erosion. Also, no serious problems are encountered in gently sloping (undulating) areas, provided that simple precautions are taken. Erodibility increases in sloping (rolling) regions, but depends on soil characteristics and management practices. The soils are generally suitable for standard rotations. The soils in moderately steep (hilly) terrains are likely to erode under cultivation....Those soils (are) suited only to pasture or to rotations dominated by sod-forming crops... Finally, steep or very steep areas are not suitable for ancient farming.

E. Rooting conditions

For root development, the soil has to supply enough water, air and nutrients, and the effective soil depth must be at least 30 cm. These land qualities have been previously discussed. Below, two diagnostic criteria are described, which influence soil penetration of roots.

* Phases

There are only a few soils which roots cannot penetrate (Soil Survey Manual 1951). These include soil horizons such as cemented pans (unless fractured), or the strongly developed fragipans (a loamy hard or very hard subsurface horizon, which is seemingly cemented when dry; FAO-Unesco 1988).

* Soil structure and texture

The roots of plants have an important relation to soil structure (Soil Survey Manual 1951). New vegetation maintains the granular or (mixed) blocky structure by filling the gaps left by decaying roots. In this way, deeply rooted plants can penetrate even heavy B-horizons. But this rather positive picture of soil penetration is a diminished picture by the fact that, when the deeply rooted plants are removed, the soil can become massive and poorly drained. Nowadays, it is difficult to reconstruct structure of ancient soils. Therefore, heavy clays are classified as limited for rooting possibilities.

In the end, with the results from the pollen analysis, it may be possible to pinpoint some clayey areas, which have been deforested in the research period. The suitability of these soils probably decreased in terms of soil structure, during the years after the deforestation.

2.3 Automatic Land Evaluation System (ALES): data entry

ALES is a computer program (designed by Rossiter and Van Wambkeke 1997) that allows land evaluators to build their own, location specific, models to evaluate land according to the methods of the FAO. The land evaluator himself/herself has to determine and import the lists of land use require-
ments, land utilisation types and land mapping units with their land characteristics. As such it acts as a sole framework.

When all data from the various variables discussed have been entered in the programme, ALES will compare and compute the suitability of a particular land mapping unit for a specific kind of land use. The results can then be visualised on maps using a Geographic Information System.

ALES entails the following components (figure 2.2 after Farshad 1994):

- A framework for a **knowledge base** describing potential land uses, in this research in physical terms only; the knowledge base deals with potential land utilisation types with the associated land use requirements;
- A framework for a **database** describing the land areas to be evaluated; the database comprises the descriptions of the land mapping units (geomorphological units) in terms of land characteristics and land qualities; the database will be preceded by reference lists comprising the land characteristics classes. These lists can then be applied to the description of all land mapping units.
- An **interference mechanism** to relate these two, thereby computing the physical (and economic) suitability of the set of map units for a set of proposed land uses;
- An **explanation facility** that allows model builders to understand and fine-tune their models;
- A **consultation mode** that allows a casual user to query the system about one land use at a time;
- A **report generator** (on screen, to a printer, or to disk files);
- **Import/export modules** that allow data to be exchanged with external databases, geographic information systems, and spreadsheets.

![Figure 2.2 Components of ALES (after Farshad 1994)](image)

### 2.3.1 ALES data entry scheme

**General**

Define the research areas; in this research three areas are under investigation:

- land suitability classification of the Pontine region area
- land suitability classification of the Salento Isthmus region
- land suitability classification of the Sibari tide region

#### 2.3.1.1 Knowledge base: land use

According to Rossiter and Van Wambeke (1997), we can summarize the information above as follows:

Land utilisation types (LUTs) have land use requirements (LURs),
Land systems have land qualities (LQs).

The ALES model builder specifies the LURs,
ALES compiles the values of the corresponding LQs.

In this section, we must describe and enter all LUTs and LURs, which may have/have been practiced in each region. First of all, clear abbreviations are specified for each land utilisation type.
a. Define land utilisation type (LUT) code
For example:

- LUT1 = Cegr = Cereals in rotation with grass
- LUT2 = Olce = Cultivation of olive trees together with cereals
- LUT3 = SSF = Small-holder, self-subsistence farming

b. Define all land use requirements (LURs) for each land utilisation type (LUT)
For example:

LUT1 Cegr, LURs:

- LUR Ma = Moisture availability
- LUR Oa = Oxygen availability
- LUR Work = Workability

---

**Figure 2.3 ALES program flow (overview) (modified after Rossiter and Van Wambeke 1997)**

---

c. Define for each land use requirement the so-called severity level names
For every LUT, the accompanying LURS have been defined, for example cereals need well-drained soils to grow. Wet soils favor rotting processes, dry soils will cause desiccation. So moisture availabil-
ity and drainage are closely related (as we have seen before). The severity levels express classes of the requirements of the LUT for optimal development or implementation. We distinguish three severity levels: no problem, slightly limited and limited.

Name for severity level 1: no problem. This means that implementation of a certain LUT will not cause any problems and no additional management is required.

Name for severity level 2: slightly limited. Implementation of a certain LUT is only possible with additional management.

Name for severity level 3: limited. Implementation of a certain LUT is not recommended.

2.3.1.2 Reference lists

The reference lists form the basis for the description of the land systems and land mapping units. They include and clarify the classifications of all land characteristics.

Below, the definitions of the land characteristics are shown, as described by Soil Survey Staff (1951) and the guidelines for soil profile description by the FAO (1977). The list is divided into two parts: one part describes the land characteristics that will be incorporated in ALES. The second part deals with additional information (such as soil consistency or sediment boundaries), which is also important in the research.

Reference lists which will be incorporated into ALES

a. Topography of the land systems

Topography refers to the overall shape of the land system. The land systems were classified according to the table below. Additional classified landforms were, for example, depressions.

<table>
<thead>
<tr>
<th>Topography</th>
<th>Slope Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain (Pl)</td>
<td>slopes not steeper than 2%</td>
</tr>
<tr>
<td>Gently sloping (Gs)</td>
<td>slopes between 2% and 8%</td>
</tr>
<tr>
<td>Rolling (Rol)</td>
<td>slopes between 8% and 16%</td>
</tr>
<tr>
<td>Hilly (Hil)</td>
<td>slopes between 16% and 30%</td>
</tr>
</tbody>
</table>

The term *undulating* is somewhat confusing. During the fieldwork, we switched to the ‘waving’ meaning of the word, indicating landscapes with minor hills and valleys, to separate them from the plains that had no relief at all. So undulating land sometimes experiences no gradient (Undulating Land = UL), or slopes along a gradient of, for instance, 8–13 % (Undulating Sloping Land = USL).

b. Slope classes

At representative locations, in all landforms, one or more cores were taken to examine the soil for various characteristics. Simultaneously, slopes of the surrounding surface were determined by using the map or a slope-angle-measuring device. These representative inclinations are the diagnostic criteria of several land qualities such as workability. The table shows the six slope classes, as we used them in the field.

<table>
<thead>
<tr>
<th>Slope Class</th>
<th>Slope Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat or almost flat (Fl)</td>
<td>slopes between 0% and 2%</td>
</tr>
<tr>
<td>Gently sloping (Gs)</td>
<td>slopes between 2% and 8%</td>
</tr>
<tr>
<td>Sloping (S)</td>
<td>slopes between 8% and 13%</td>
</tr>
<tr>
<td>Moderately steep (Ms)</td>
<td>slopes between 13% and 25%</td>
</tr>
<tr>
<td>Steep (St)</td>
<td>slopes between 25 % and 55%</td>
</tr>
<tr>
<td>Very steep (Vs)</td>
<td>slopes more than 55%</td>
</tr>
</tbody>
</table>
In the original text (FAO 1977) the upper boundary of the class ‘gently sloping’ is at 6%, but this is to my opinion rather confusing as the upper boundary of the landform classes is set at 8%. I have set both at 8%.

c. Top soil thickness
Most agricultural crops (except for olive trees) need a minimum soil depth of at least 30 cm. So, a distinction was made between shallow soils (less than 30 cm) and deeper soils (more than 30 cm).

d. Stoniness classes
In the field, we defined stones as massive consolidated rocks, having a diameter between 5 cm and 25 cm. Stones having diameters between 2 mm and 5 cm are labelled gravel, stones larger than 25 cm are called rocks or boulders (FAO 1977). Furthermore, the boundary of 25 cm was practical in the field, because it turned out that it is not easy to lift larger rocks out of the ground manually (‘one man lift’ stones). The cairns and walls bordering the arable fields were constructed with stones averaging less than 25 cm. Stoniness was determined by estimating the percentages at the surface and in the core (stoniness classes are shown below).

Stones in the agricultural fields can be both profitable and disadvantageous. The only research I could find so far concerning this subject has been executed in Sweden. Szabó (1989) provides a detailed investigation concerning clearing of stony grounds for cultivation purposes, as has been encouraged by the government during the last few centuries. According to Szabó, many positive effects can be addressed to a stony field: stones on top of a surface retain the moisture in the soil and hide the seeds during drought, whilst during heavy and prolonged rain it filters the water and helps it to sink quickly into the ground (Persson 1781). Other advantages of a stony surface are the topsoil minerals release and better weed control.

However, the disadvantages are also manifold: stones take away space for growing plants; rotational cultivation is almost impossible, because to work these soils requires a lot of time and special skills; and special equipment is needed, which can be lifted up easily, otherwise it will be damaged. Stones in and on the ground determine to a large extent the ease at which fields could be ploughed and cultivated in the past. Stones also capture a lot of seed, preventing it to germinate and develop.

So it is clear from the research of Szabó, that we must be careful in judging a stony field. However, the FAO stoniness classification is especially focused on tillage possibilities, and this classification is used during the research.

| Class 0 (Ns): | No stones or very few stones; too few stones to interfere with tillage. Stones cover less than 0.01% of the area. |
| Class 1 (Fs): | Fairly stony; sufficient stones to interfere with tillage but not to make intertilled crops impractical. Stones cover 0.01% to 0.1% of the area. |
| Class 2 (S):  | Stony; sufficient stones to make tillage of inter-tilled crops impractical, but the soil can be worked for hay crops or improved pasture if other soil characteristics are favorable. Stones cover 0.1% to 3% of the area. |
| Class 3 (Vs): | Very stony; sufficient stones to make all use of machinery impractical, except for very light machinery or hand tools. Other soil characteristics make the fields especially favorable for improved pastures. Stones cover 3% to 15% of the area. |
| Class 4 (Es): | Exceedingly stony; sufficient stones to make all use of machinery impractical. Stones cover 15% to 90% of the area. |
| Class 5 (Rl): | Rubble land; land essentially paved with stones which occupy more than 90% of the surface area. |
e. Rockiness classes
Rocks or boulders having a diameter of at least 25 cm. They are situated on the surface or are exposed as bedrock, being a small part of a larger underground rock body.

| Class 0 (Nr): No rocks or very few rocks; no bedrock exposure or too few to interfere with tillage. Less than 2% bedrock exposed. |
| Class 1 (Fr): Fairly rocky; sufficient bedrock exposures to interfere with tillage but not to make inter-tilled crops impractical. Rocks or bedrock covers 2% to 10% of the surface. |
| Class 2 (R): Rocky; sufficient bedrock exposures to make tillage or inter-tilled crops impractical, but soil can be worked for hay or improved pasture if soil characteristics are favorable. Rocks or bedrock cover 10% to 25% of the area. |
| Class 3 (Vr): Very rocky; sufficient rock outcrop to make all use of machinery impractical, except for light machinery where the other soil characteristics are especially favorable for improved pasture. Rocks or bedrock cover 25% to 50% of the surface. |
| Class 4 (Er): Extremely rocky; sufficient rock outcrop to make all use of machinery impractical. Rocks or bedrock cover 50% to 90% of the area. |
| Class 5 (Ro): Rock outcrop; over 90% of the land is exposed bedrock. |

f. Soil texture
The first letter refers to the main constituent of the sediment, whereas the next small letter indicates the additional lithology. It does not represent the whole list of 16 lithologies. These can be found in the appendix.

- Sand (s)
- Silt (si)
- Clay (c)
- Loam (l)
- Loamy sand (ls)
- Clayey silt (csi)
- Loamy clay (lc)
- Marl (m)
- Clayey sand (cs)
- Sandy silt (ssi)
- Sandy clay (sc)

- Consistency of the soil horizons
Consistency influences many land qualities and characteristics, such as workability, rate of germination, and moisture and oxygen availability. But, of course, consistency depends on the amount of precipitation in a particular season. Most fieldwork was done during the summers of 1998, 1999 and 2000, so consistency was determined in all three regions in the same season.
Firm: it is hardly possible to squeeze the soil material
Sticky: the soil material is wet and sticks to the hands
Loose: the soil material falls apart quickly

### i. Presence of lime in the soil horizons
Presence of lime was tested using a drop of HCl (10%). Very calcareous horizons sparkle visibly, calcareous horizons only sparkle audibly and non-calcereous horizons do not sparkle at all.

<table>
<thead>
<tr>
<th>Landform</th>
<th>Symbol</th>
<th>Description</th>
<th>Sub-units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill</td>
<td>H</td>
<td>Form of considerable positive relief (more than 10 m compared with surrounding area) with steep slopes</td>
<td>Top&lt;br&gt;Steep slope (25 – 55%)&lt;br&gt;Flat parts (0 – 2%) along hill</td>
</tr>
<tr>
<td>Rolling land and Ridges</td>
<td>RR</td>
<td>Alternating hills and valleys</td>
<td>Top of hill or ridge&lt;br&gt;Slope of hill&lt;br&gt;Base of valley</td>
</tr>
<tr>
<td>Undulating gently Sloping Land</td>
<td>UgSL</td>
<td>Relatively small valleys and all sloping at the same gradient (2 – 8%)</td>
<td>Top and slope of relatively small hill&lt;br&gt;Base of relatively small valley</td>
</tr>
<tr>
<td>Undulating Land</td>
<td>UL</td>
<td>Relatively small valleys and relatively small hills, but any gradient is lacking</td>
<td>Area with stoniness classes 0 to 2&lt;br&gt;Area with stoniness classes 3 to 5</td>
</tr>
<tr>
<td>Plain</td>
<td>PL</td>
<td>Area with relative minor or no relief or terraced, gradient 0 – 2%</td>
<td>Areas having shallow soils (less than 30 cm)&lt;br&gt;Areas having deeper soils (more than 30 cm)</td>
</tr>
<tr>
<td>Straight gently Sloping Land</td>
<td>SgSL</td>
<td>Area with relative minor or no relief or terraced, but sloping along a certain gradient (2 – 8%)</td>
<td>Areas having shallow soils (less than 30 cm)&lt;br&gt;Areas having deeper soils (more than 30 cm)</td>
</tr>
<tr>
<td>Dunes</td>
<td>DN</td>
<td>Forms of positive relief together with relatively flat parts, having an irregular pattern and beaches</td>
<td>No separate distinction</td>
</tr>
<tr>
<td>Singular Slope</td>
<td>SS</td>
<td>Area having a sloping to moderately steep gradient (8 – 25%) connecting two areas of different elevations.</td>
<td>No separate distinction</td>
</tr>
<tr>
<td>Singular Steep Slope</td>
<td>SSS</td>
<td>Steep to very steep slope (25 – 55% and &gt; 55%) connecting two areas of different elevations. Minimum height is 50 m, at the coast 20 m.</td>
<td>No separate distinction</td>
</tr>
<tr>
<td>Depression</td>
<td>DP</td>
<td>Flat or almost flat area of at least 500 m in width surrounded by higher areas</td>
<td>No separate distinction</td>
</tr>
<tr>
<td>Concavely Sloping Land</td>
<td>CSL</td>
<td>Relatively large concave slopes at the base of SSS. Distances between top and foot measure at least 1000 m</td>
<td>Upper part of the slope&lt;br&gt;Lower part of the slope</td>
</tr>
<tr>
<td>River Valley</td>
<td>RV</td>
<td>A (dry) river valley of which the maximum width between the incised walls measures at least 100 m, with slopes of more than 20 m in height, and possibly having terraces</td>
<td>River valley floor&lt;br&gt;River valley wall&lt;br&gt;Terrace floor</td>
</tr>
<tr>
<td>Canyon-like River Valley</td>
<td>CRV</td>
<td>An steeply or very steeply incised (drought up) river valley (25 – 55%, and &gt; 55%), at least 20 m deep, with a maximum width of 200 m</td>
<td>Relatively small river valley floor and terraces&lt;br&gt;River valley walls</td>
</tr>
<tr>
<td>Lagoon</td>
<td>LG</td>
<td>A bay inshore lying parallel to the coast (Skinner and Porter 1987). Bay may or may not be filled with water.</td>
<td>No separate distinction</td>
</tr>
</tbody>
</table>

**Table 2.4 Overview of the landforms used in this research**
Additional information necessary for the research

j. Soil boundaries and soil classification
Soils were described and classified according to the key to major soil groupings and soil units (FAO-Unesco 1988). Soil type indicates, for example, the degree of fertility, the presence of impermeable layers and/or shifting ground water levels.

2.3.1.3 Land mapping units: the database

At this point, the database has to be created. For each land system, all landforms have to be entered and described. First, landforms must receive a specific code (the table on the previous page is an example).

Next, we can enter the values of all land characteristics for each landform in the same systematic way.

For example:

<table>
<thead>
<tr>
<th>Landform:</th>
<th>Undulating gently sloping land (UgSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope class:</td>
<td>Gs (Gently sloping)</td>
</tr>
<tr>
<td>Drainage class:</td>
<td>ed (excessively drained)</td>
</tr>
<tr>
<td>Soil texture:</td>
<td>S (Sand)</td>
</tr>
<tr>
<td>Stoniness class:</td>
<td>vs (very stony)</td>
</tr>
<tr>
<td>Rockiness class:</td>
<td>nr (no rocks)</td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
</tr>
</tbody>
</table>

2.3.1.4 Create the severity level decision trees

A decision tree will allow ALES to infer the severity level of the land quality corresponding to a certain LUR from some set of land characteristics (Rossiter and Van Wambeke 1997). In other words, the decision tree shows, which land characteristics are the most important and which are the less important with respect to a profitable introduction of a certain LUT with its specific LURs. The severity classes include (1) no problem, (2) slightly limited, and (3) limited.

The next example will clarify the above stated information. One of the land use requirements (LURs) of cultivation of cereals (LUT) is moisture availability. The first diagnostic criterion is considered to be the drainage class. When a soil is poorly drained, cultivation of cereals is slightly limited, because the soil has to be drained to prevent rotting. An excessively drained soil is unsuitable for the cultivation of the crop, because of water deficiency in rainfed agriculture. Only well-drained areas pose no problems for cereal farming.

In ALES, this can be visualized as follows:

\[ LUT: \text{cereal farming}; \text{LUR: moisture availability} \]

<table>
<thead>
<tr>
<th>Drainage</th>
<th>severity class</th>
</tr>
</thead>
<tbody>
<tr>
<td>pd (poorly drained)</td>
<td>&gt; 2 (slightly limited)</td>
</tr>
<tr>
<td>wd (well-drained)</td>
<td>&gt; 1 (no problem)</td>
</tr>
<tr>
<td>ed (excessively drained)</td>
<td>3 (limited)</td>
</tr>
</tbody>
</table>
The ‘>-sign’ indicates the presence of other diagnostic criteria, which can influence the suitability. On the map, excessively drained soils are classified as Nm = limited, caused by moisture deficiency. This is only valid for cultivation of cereals in rainfed agriculture. For poorly and well-drained soils we can go further. The next diagnostic criterion for moisture availability is effective soil depth. Suppose that, beneath the poorly drained soils, an impermeable layer is located at a depth of 20 cm. For cereal cultivation, the effective soil depth is too shallow. No such layer is found in the well-drained soils.

In ALES, this can be visualized as follow:

\[ \text{LUT: cereal farming; LUR: moisture availability} \]

<table>
<thead>
<tr>
<th>Drainage</th>
<th>severity class</th>
<th>Effective soil depth</th>
<th>severity class</th>
</tr>
</thead>
<tbody>
<tr>
<td>pd</td>
<td>&gt;2</td>
<td>20 cm</td>
<td>3 (limited)</td>
</tr>
<tr>
<td>wd</td>
<td>&gt;1</td>
<td>&gt; 30 cm</td>
<td>1 (no problem)</td>
</tr>
</tbody>
</table>

So, poorly drained soils having an effective soil depth of less than 30 cm, are not suited for cereal farming in rainfed agriculture (Nef).

Now, suppose that in some fields the well-drained soils are covered with large rocks and stones. Stoniness and rockiness have a large influence on workability. This land quality can also be incorporated in the severity level decision tree. The tree can be as extensive as we wish.

2.3.1.5 Compute and view the evaluation results

During this step the landforms with their individual land characteristics are compared with the land utilisation types and their land use requirements. For each land quality (e.g. nutrients availability or workability) the suitability classification is determined. Using the limiting factor classification, ALES quickly shows in tabular form which land quality limits the cultivation of a certain LUT for the specific landform.

2.3.1.6 Visualisation of the results

The tables with the evaluation results can be entered into a graphical program (for example ArcView). Finally, on digitised maps the derived suitabilities are presented.5

2.4 Remarks concerning data and assumptions underlying archaeological evaluation of the three research areas

2.4.1 Data on land characteristics

Limits concerning the collection of field information

Sevink and others studied the soils in the Pontine region and the available data are far more detailed than the available data from the Salento Isthmus and the Sibaritide. Because of the size of the latter two research areas, detailed mapping was impossible and only a reconnaissance survey could be carried out (see chapter 3). The terrain units identified could only be examined for land characteristics at representative locations. Therefore, I will not exclude the possibility that deviating land characteristics

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5 A full description of the actions with have to be taken for a land suitability classification is given in the ALES User’s Manual (Rossiter and Van Van Van Wambeke 1997).
occur at (some) locations within the landforms. But within the limited time available for fieldwork, large-scale mapping seemed the best solution to carry out a land evaluation. Obviously, this method has some restrictions, which will be dealt with in the following chapters.

The reliability of data available from the studied area
The reliability of the field data depends, in the first place, on the knowledge about land development activities such as deep ploughing and digging. Fortunately, these anthropogenic landscape changes were visually evident: for example raised fields, fields without stones in a very stony environment, and large and deep drainage ditches in wet areas. However, these changes cannot be considered as very significant compared to the large scale of the research area and its landforms, since they did not alter the overall geomorphology of the area nor did they lead to large-scale modification of the earlier, ancient land surface.

Changing soil types
During the RPC conference (held in Groningen in April 2000), it became clear, that soil type is an important issue in archaeology. My opinion is that, in archaeological land evaluation, we cannot include present-day soil types straight away, since soil types may have changed over the centuries. But I agree that it is very difficult to decipher the possible changes of the soils through time without a detailed study of soil succession under the specific conditions. The dynamics of the landscape through time play an important role. In a highly dynamic area, for example, soils will usually not have time to develop fully and the present-day soil probably resembles the ancient soil. Therefore, when treating of soil development, it is clear that landscape reconstruction is very important.

2.4.2 Assumptions

Farming on the basis of sustainability
In the present land evaluation research, farming on the basis of sustainability implies that farmers did not exhaust the soils or wandered around the area searching for suitable arable fields, leading to the instability of the land use. Growing crops withdraw nutrients from the soils, and without careful management the fields will be less suitable (or even unsuitable) for farming after a couple of years. Fortunately, we know (Wolf 1966) that already in early agriculture (Bronze Age), people were aware of this problem. After a few years of cultivation, they let the soils rest for about seven to ten years. Soil fertility could then regain and adjacent fields were used, thus creating a sustainable land use at the system level.

But we also know from Greece (Bintliff 2000), that some soils were exhausted as a consequence of imperfect management practices. However, archaeological land evaluation basically is focused on natural soil fertility, but it can deal with soil exhaustion too.

Least effort principle (after Kamermans 1993: 11–12)
According to the least effort principle (Zipf 1949), people exploit the natural environment for optimal production results with a minimum of effort, which involved that agricultural activities took place in the vicinity of the settlement. Travel, transport and other kinds of movement and spatial interaction would always be minimized (Zipf 1949).

Despite criticism, such as that many people are in fact willing to expend a considerable amount of time and energy on pursuits which they culturally or individually favour (Carlstein 1982), I agree with Kamermans that the least effort principle is an useful tool to determine the most suitable kind of land use in a specific social context.

Economic systems, including agrarian technology remained (rather) constant during the individual distinguished periods and during these periods the suitability of the area and land forms contained in it did not change.

For each research period, various representative land uses are distinguished. Each land use is described
according to the agricultural tools used, the cultivated crops and the technology, which the farmers were familiar with. Some examples of land uses are Iron Age self-subsistence farming or Roman Age large-scale olive cultivation.

In this research, it is assumed that, for instance, that all Iron Age autarkic farmers used the same tools and technology to cultivate their land and that all Roman Age farmers managed their land equally.

2.5 Pollen analysis

2.5.1 Location of the cores

In this research, three suitable cores have been taken in the Pontine region using a Dachnovsky corer. This instrument has a length of 25 cm and measures about 4 cm in diameter. The first core, Lago di Fogliano, is situated in the south of the area near the Thyrrenean Sea. From the sediment, 15 levels have been analysed at the University of Groningen. Next, from a badly smelling, (probably because of the presence of sulphide) almost dried up lake, in the Laghi di Vescovo area south east of Sezze, we took a core and eight levels were analysed. The final core was taken in the western part of the Pontine region, in the peat area near Colle San Lorenzo and the Alban hills, and also eight levels have been analysed for pollen.

For the interested researcher, we also obtained sediment from Lago di San Antonio (near Le Ferriere in the centre of the research area, Lago di Caprolace (south east of Latina), Sezze (south of Sezze) and Lago di Fondi (west of Terracina). In chapter (Results from pollen analysis), related details are described, such as radiocarbon dates and some reasons, why we decided to disregard these cores.

2.5.2 Preparation of the pollen

In the laboratory, we took samples from the cores, at variable depths. These samples, with a thickness of approximately one-cm, were mixed with one tablet of lycopodium spores (± 12,000 spores).

The continuation of the procedure depended on the composition of the sediment: presence of carbonates, clay, sand and/or organic remains. Removal of each component requires different methods.

Removal of calcareous material (CaCO₃) was achieved by the addition of hydrochloric acid (HCl 10%). KOH (10%) splits the cohesive forces between clay particles, so no clay pebbles were left. Subsequently, a separation was established between relatively heavy components and the relatively light components (including the pollen) by the bromoform-alcohol (specific weight 2.0) floatation method. The light components in the fluid were sieved out by pouring them through a copper small-mesh wire netting. In principle, the remaining fluid only contained pollen, but sometimes sand particles had to be removed with HF 40–45 % (hydrofluoric acid) and organic material by addition of 9 parts acetic anhydride and 1 part sulphuric acid (H₂SO₄) (acetolysis). Finally, the pollen was coloured red by addition of safranine, and conserved in silicon-oil.

2.5.3 Pollen analysis

Using a microscope at magnifications of 400x and 1000x, the author and Dr. Stuyts performed the counting. We pursued a target of a minimum of 200 Arboreal pollen (AP), but in the diagrams we decided to exclude *Alnus* (alder) from the pollen sum, because of its local character. Besides, it turned out to be not always possible to achieve this pollen sum, simply because of the scarce presence of arboreal pollen in some samples.
Pollen identification was performed using reference material and Moore and Webb's *guide to pollen analysis* (1978).

With the computer program GRAPPA, the results were visualised graphically.