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# SOILS AND RELIEF AS A BASIS FOR A MODEL TO RECONSTRUCT THE IRON AGE LAND USE PATTERN IN THE VICINITY OF A CELTIC SQUARE ENCLOSURE IN SOUTHERN GERMANY

**Abstract -** The spatial distribution of fields, woodland, grassland or settlement areas in prehistoric time is nearly unknown. We developed a working scheme resulting in a model which reconstructs the land use pattern using the relief and soil parameters as the controlling factors of an agricultural land use. Here we present the results of a relief analysis and a soil mapping of a study site in Southern Germany which was used to reconstruct a «physiotopen model». The physiotopen model is a time independent model for a most likely spatial distribution of a land use pattern. The calculated areas (woodland, fields, grassland etc.) can be added with secondary information from the pollen analysis, the archaeology or the sediment chronology which leads to a land use model for a certain time.

**Key words -** Land use, Iron Age, geomorphology, soil analyses, GIS, Germany.

**Riassunto -** *Suoli e rilievo come base di un modello ricostruttivo dell'uso del territorio durante l'Età del Ferro presso un recinto quadrato (*Viereckschanze*) celtico in Germania meridionale*. La distribuzione spaziale di campi, boschi, pascoli ed insediamenti in tempi preistorici è quasi sconosciuta. È stato sviluppato uno schema di lavoro che ha dato origine ad un modello che ricostruisce l'uso del territorio utilizzando rilievo e parametri pedologici come fattori di controllo dell'uso agricolo del territorio. In questo lavoro si espongono i risultati dell'analisi del rilievo e della cartografia dei suoli in un sito della Germania meridionale che è stato utilizzato per ricostruire un «modello dei fisiotopi», un modello tempo-indipendente per l'individuazione della più probabile distribuzione dei tipi di uso del terreno. Le aree individuate con il calcolo (bosco, pascolo, campi, ecc.) possono essere incrociate con informazioni secondarie derivanti da analisi polliniche, archeologia o cronologia dei sedimenti, ottenendo un modello di uso del terreno in un determinato periodo.

**Parole chiave -** Uso del territorio, Età del Ferro, geomorfologia, analisi dei suoli, GIS, Germania.

## INTRODUCTION

The knowledge of the land use pattern of prehistoric men is still very poor especially when it comes to the reconstruction of the spatial pattern of fields, wood, grassland, settlements etc. Some percentage distributions have been reconstructed from archaeology (Jäger, 1994), the archaeobotany (Aaby, 1994) or the archaeozoology (Pöllath, 2001) but there is no information on exact locations. To understand the development and the changes of today's cultural landscape, also in the sense of global change, it becomes more and more important to discuss mankind-environment interactions on a comparative scale from nowadays towards the past. For example: is accelerated soil erosion a consequence of land use or changing climate or both? A detailed knowledge of the actual and the past land use is necessary to discuss such phenomena (Slaymaker, 2001). Leopold (2003) developed a model to reconstruct a prehistoric land use pattern. Working scheme and the different working levels (see Fig. 1) have been discussed by Leopold & Völkel (2004).

In this paper we present the results of two working levels, relief analysis and sedimentological and pedological mapping. They function as the main steps within this reconstruction as the needs of ancient rural societies are mainly orientated on soil quality (soil type and according physical and chemical parameter) and the possibility of cultivation (soil parameter and relief). Both steps result in the exclusion of areas which are suitable or not for farming and lead to a development of a physiotopen model (working level IV in Fig. 1). The physiotopen are the smallest ecologically relevant landscape areas with homogeneous physical geographical structures which determine in their composition a natural spatial structure (Troll, 1950; Neef, 1964). They function as a basic pattern having a strong correlation with land use (*e.g.* Müller-Wille, 1955).

## The study area

The above working scheme was practically applied to a study area located in Southern Germany, 10 km south of the city of Regensburg and about 3 km east of the Danube River.

The geological setting of the region involves a southeastward dipping of the Jurassic sediments beneath the Cretaceous and Tertiary deposits. The latter are part of the filling of the South German Molasse basin. The Miocene feldspar-sands which was deposited by the Tertiary river system of the Naab is the base upon which Quaternary sediments were deposited (Unger, 1996). They are overlaid by up to 5 m of loess which is often mixed up with the underlying feldspar-sands by solifluction processes.

The pedological situation is characterised by remarkably well-developed calcic Luvisol in the forested areas whereas in the nearby agricultural areas the calcic Luvisols are partly or fully eroded. Thick layers of colluvium of different ages can be found along the hills and in nearby valleys (Leopold, 2003).

The investigation area is situated in the so called Altsiedelland which is an area where long term settlement

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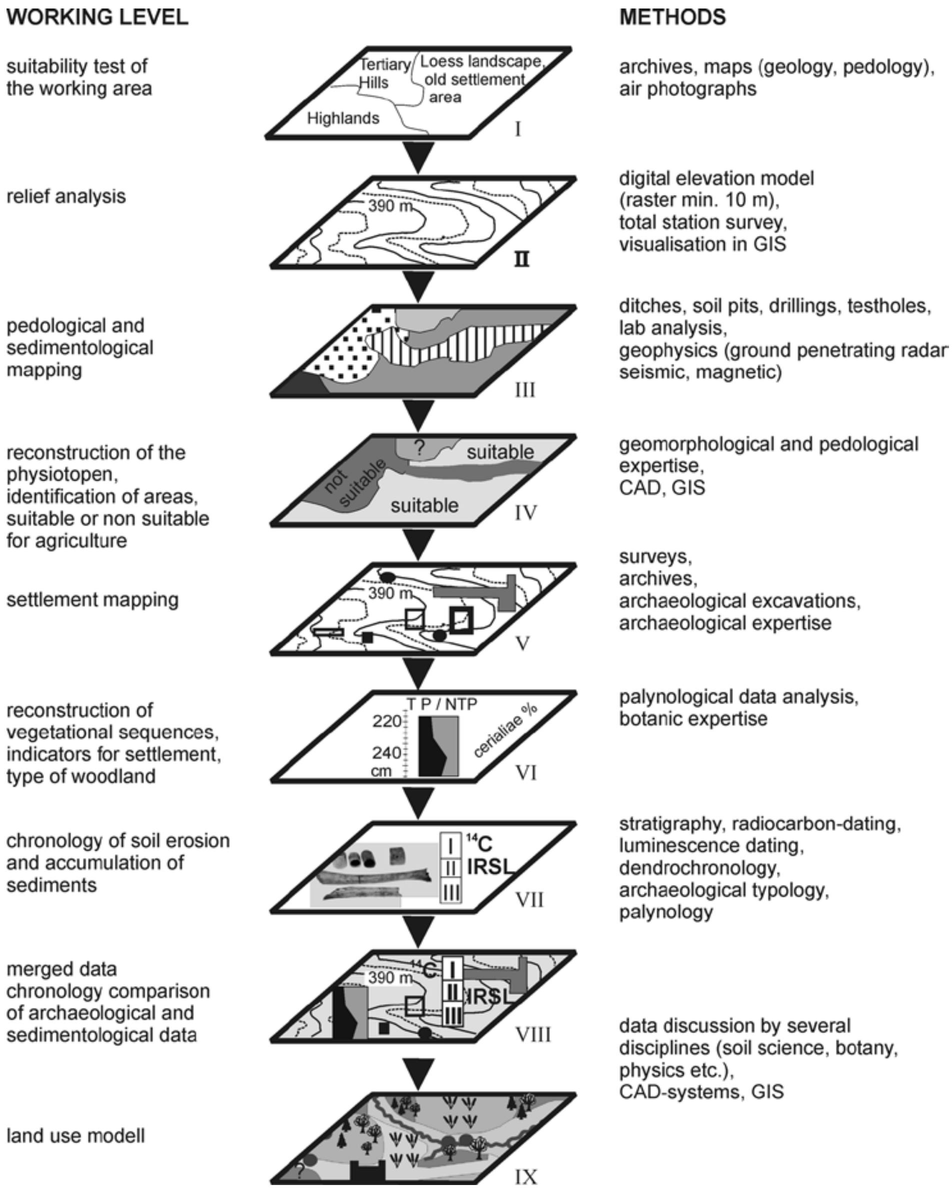


Fig. 1 - The developed working scheme presenting the different working levels and methods. Running through the different levels results in a land use model (after Leopold, 2003).

can be traced back to the Palaeolithic era (Torbrügge, 1984). Prehistoric settlement is widely represented by archaeological findings. Especially the Iron Age period is well represented by a Celtic square enclosure – the *Viereckschanze of Poign*. Previous work documented contemporaneous high rates of soil erosion of min. 20 t/ha/a around this earthwork (Leopold & Völkel, 2000; Völkel *et al.*, 2002). The question that arose was whether these high rates of erosion are a unique phenomenon or whether they are a part and the result of the usage of the landscape in those days due to normal farming. In order to answer this question a La Tène period land use model had to be developed.

## METHODS

The following methods were used to achieve the results of working level II and III. For detailed references of the different methods see Leopold (2003).

### Total station survey of the relief

An electronic total Station from LEICA (TC 600) with an accuracy of 1.5 mgon concerning angles and 3 mm concerning distances was used. For an area of 900 m x 700 m a total of 2,648 relief-points have been measured. The data was processed using a standard laptop and the LISCADplus 3.12 software.

**Sedimentological/pedological field work**

The mapping was achieved using soil pits and motor hammer drillings (5-10 cm in diameter). More than 160 profiles were described using the German soil classification (AG Boden, 1994) and samples were collected at least every 10 cm for further lab analysis (in sum more than 600).

Colluvium as a correlated sediment of human-induced soil erosion plays a crucial role in a land use reconstruction and therefore great emphasis was laid upon its characterisation. Note: in the English literature the term colluvium is used for any slope deposits whereas in the German literature the word colluvium is used for human-induced eroded and accumulated sediments (Leopold & Völkel, 2005). The following catalogue of criteria was applied to determine a colluvium:

– Stratigraphic position above a fossil in-situ horizon.
– Artefacts (ceramics, flints etc.).
– Macrofossils (bones, charcoal etc.).
– Bulk density, compaction.
– Hydromorphic features (a.o. bleached stripes, accumulation of Oxides).
– Texture correlating rather closely with the eroded sediment (often a reduction of clay can be observed).
– Maintenance of structures (*e.g.* original fabrics with clay cutans etc.) of the eroded soil.
– Distinct change of colour towards the fossilised soil.
– Traces of transport *e.g.* rounding of Fe-Mn concretions visible in thin sections.
– Micromorphologically visible enrichment of clay cutans in contrast to the actual vertical pedo-dynamic.

**Sedimentological and pedological lab analysis**

The soil colour was determined under constant lab conditions using the Munsell Soil Colour Chart. Texture was classified using a combination of sedimentation (clay and silt) and sieving (sand), the content of $CaCO_3$ was calculated using the gas-volumetric method by Scheibler-Finkener. pH was determined in $CaCl_2$ with a glass electrode from WTW (pH 521) and the content of C, N and S using a multi analyser from Elementar (Vario EL III). The CEC ratio, heavy metals and pedogenic oxides were measured with an atomic absorption spectrometer from UNICAM (Solaar 939). Multi-element analyse were carried out using a mobile x-ray fluorescent analyser from Niton (XL722s). Clay minerals were characterised using the diffractograms of different slides (magnesium, potassium, heated etc.) analysed by X-ray diffraction (XRD; Siemens D5000).

**Geographic Information System (GIS)**

For mathematical calculations of slope inclinations or area distributions and a better visualisation GIS (IDRISI, ArcInfo) were applied. They were used only as one out of many methods and do not play as an important role as the field methods.

**Dating**

Establishing a sedimentologically based chronology required the use of several dating techniques:

– radiocarbon dating of charcoal or organic macrofossils (Hanover, Erlangen);
– attempts were made to date sediments by IRSL (Denmark);
– archaeological typology helped to date artefacts within the colluvium;
– sediment stratigraphy allowed the development of a relative chronology.

## RESULTS

**Working level II relief analysis**

As parts of the study area have been under a young and dense spruce tree cover, total station survey was ideal to achieve the necessary detailed information. The measurement was carried out in a circle with an identical start and endpoint. The calculated variance after more than 4 km was 8 cm in height and 12 cm in distance. The accuracy of the contour line model towards the reality was estimated to be between 10 and 20 cm in height. The area measured with total station was virtually combined with the officially available map 1:5,000 from the Bayerische Vermessungsamt (Fig. 2). Here the great strength of the high resolution relief mapping clearly shows up, as details like ditches or flat areas within a uniform slope could be detected. These atypical relief forms often indicate anthropogenetically influenced areas so they are an important guide to for further soil and sediment analysis.

Taking the above data a digital terrain model was calculated using the ARCtin module. Figure 3 visualises the study area in a 3-d perspective. Local area names, archaeological features, watershed and the location of minerotrophic mires were added manually.

The analysis of the slope angles points out a distinct asymmetry of the relief which is characteristic for the tertiary hills (Karrasch, 1970). Well developed North-South as well as West-East asymmetries can be documented. Table 1 shows some examples where locations are visible in the map of the calculated slope angles (Pl. 3). To characterise the grade of asymmetry the difference after Poser & Müller (1951) and the quotient after Karrasch (1970) were applied. This rather high grade of asymmetry, as documented in section A-A', gives a first hint on a possible land use. If a steep and a flat slope stood opposite to each other during a period of moderate pressure on Middle European land, agricultural use would always prefer the flatter slope whereas the steep side would be used as woodland. Based on this principle Plate 3 was classified using the numbers of Table 2. This classification is rather common in landscape ecological studies where 7 is seen as the maximum slope angle for agricultural usage without machines (Kugler, 1974; Marks *et al.*, 1992). So in this study 7 was used to divide areas possible for farming (blue colours in Pl. 3) from areas possible for woodland (red/green colours in Pl. 3) as the first step in the reconstruction of the physiotopen model. As a result about 1/5 of the whole area is steeper than 7, and therefore not suitable for farming in the module of the relief analysis.

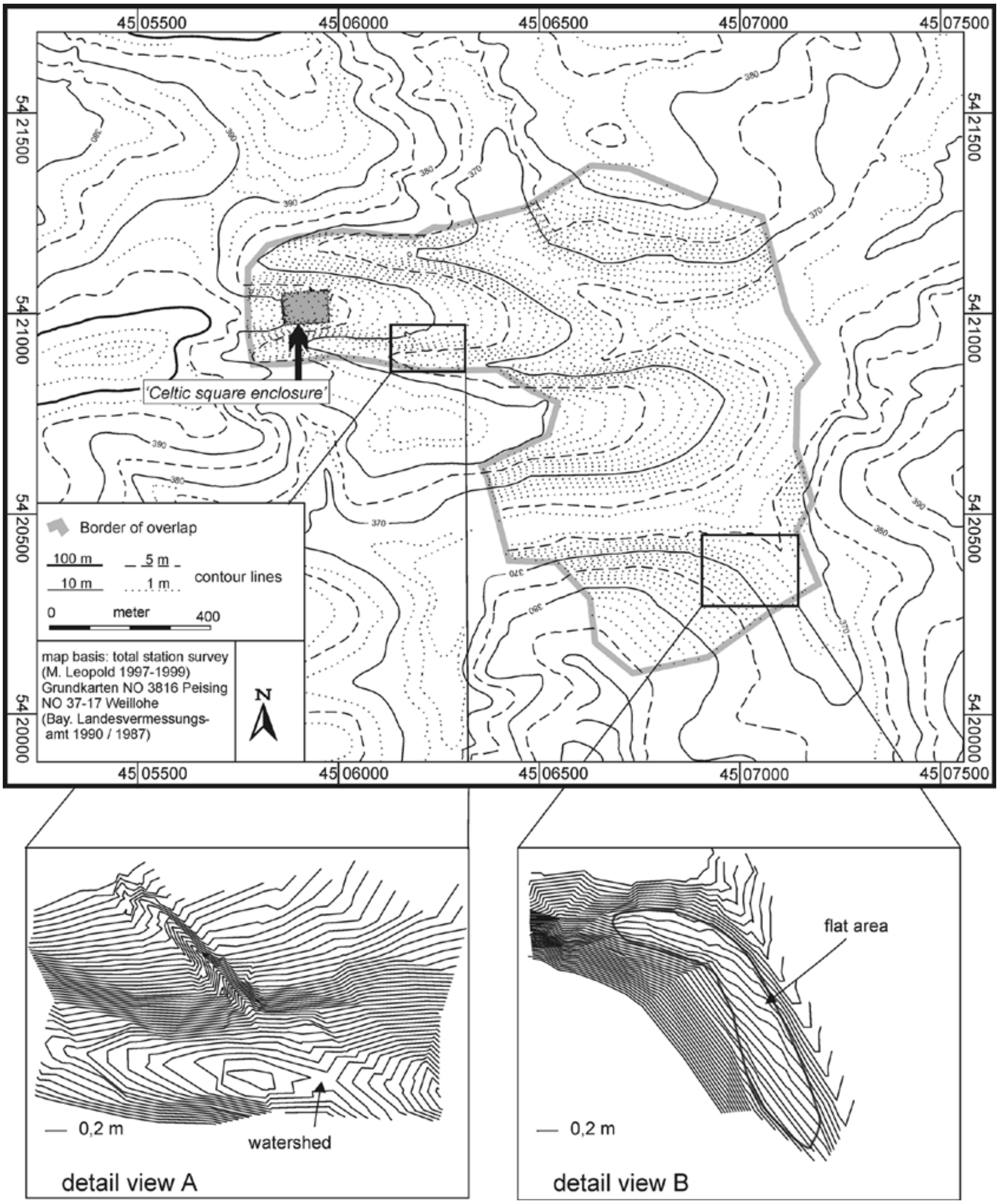


Fig. 2 - Contour map of the study area as basis for the relief analysis. The grey line marks the area measured by high accuracy total station survey which was combined with the official available map at 1:5,000. Some relief details indicating human influence are presented at the bottom.

**The sedimentological and pedological mapping**

Additionally to the relief analysis a well and carefully carried out sedimentological and pedological mapping is the second and most important step in the scheme of land use reconstruction.

The basic idea of this working level is that within a farming system people have always tried to cultivate most efficiently on the best soils to have greatest success. Following this simple condition the knowledge of soil quality in the sense of nutrient supply, compaction, erodibility, water supply etc. is the key to localizing ancient field areas.

The result of the sedimentological and pedological mapping is presented in Figure 4. The spatial distribution of the several soil types is calculated in the GIS and presented in Table 3. This data is compared with a

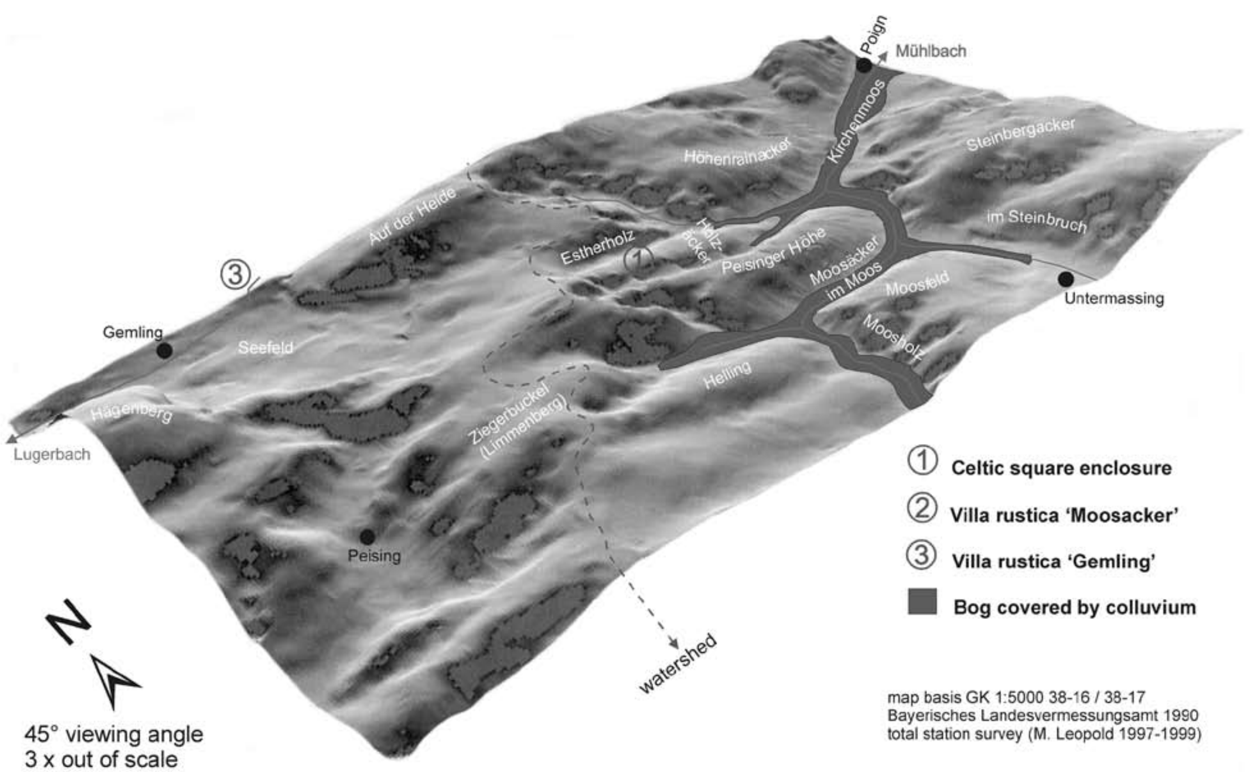


Fig. 3 - Digital terrain model of the study area with local names. Rivers, watershed, location of mires and settlement areas were added manually.

Tab. 1 - Selected valley asymmetries in the study area. For the location of the profiles see Pl. 3.

| **Section** | **Direction** | **Steep slope** | **Flat slope** | **Difference (Poser & Müller, 1951)** | **Asymmetric quotient (Karrasch, 1970)** |
|---|---|---|---|---|---|
| A-A' | W-E | 12° | 2° | 10° | 0.8 |
| B-B' | N-S | 7-8° | 3.5° | 3.5-4° | 0.6 |
| C-C' | WNW-ESE | 9° | 2° | 7° | 0.8 |

Tab. 2 - Landscape ecological classification of the slope angles after Bastian & Schreiber (1999) used for the calculation in Pl. 3.

| **Classification of slope angle (Bastian & Schreiber, 1999)** | **0-2°** | **2-7°** | **7-12°** | **12-15°** | **15-25°** |
|---|---|---|---|---|---|
| German name of the class | Eben und flach geneigt | Flachhängig | Lehnhängig (1) | Lehnhängig (2) | Steilhängig |

virtual reconstruction of the conditions before people interfered in nature. It clearly indicates that the soil pattern in those days was much more homogeneous. This means that the heterogeneity of the soil type distribution in middle European farmland correlates with the intensity of human influence on the landscape in the sense of farming and clearing.
The heterogeneity of the soil type distribution partly correlates with the relief. The steep and west facing hills are covered mainly with Miocene feldspar sands and developed eutric Cambisols. These are very acid soils with pH 3.1 to 3.8 ($CaCl_2$). The CEC ratio varies from 3.8 to a maximum of 6.5 mmol/100 g in the upper horizon. The cations are dominated up to 90% by aluminium and the saturation is not higher than 38% except for the humic horizon at the surface (Tab. 4a).
In contrast the eastward facing slopes are covered with loess sediments and well developed calcic Luvisols. Their acidity is between pH 4.5 and 7.3 ($CaCl_2$). The CEC ratio varies vertically between 10 and 25

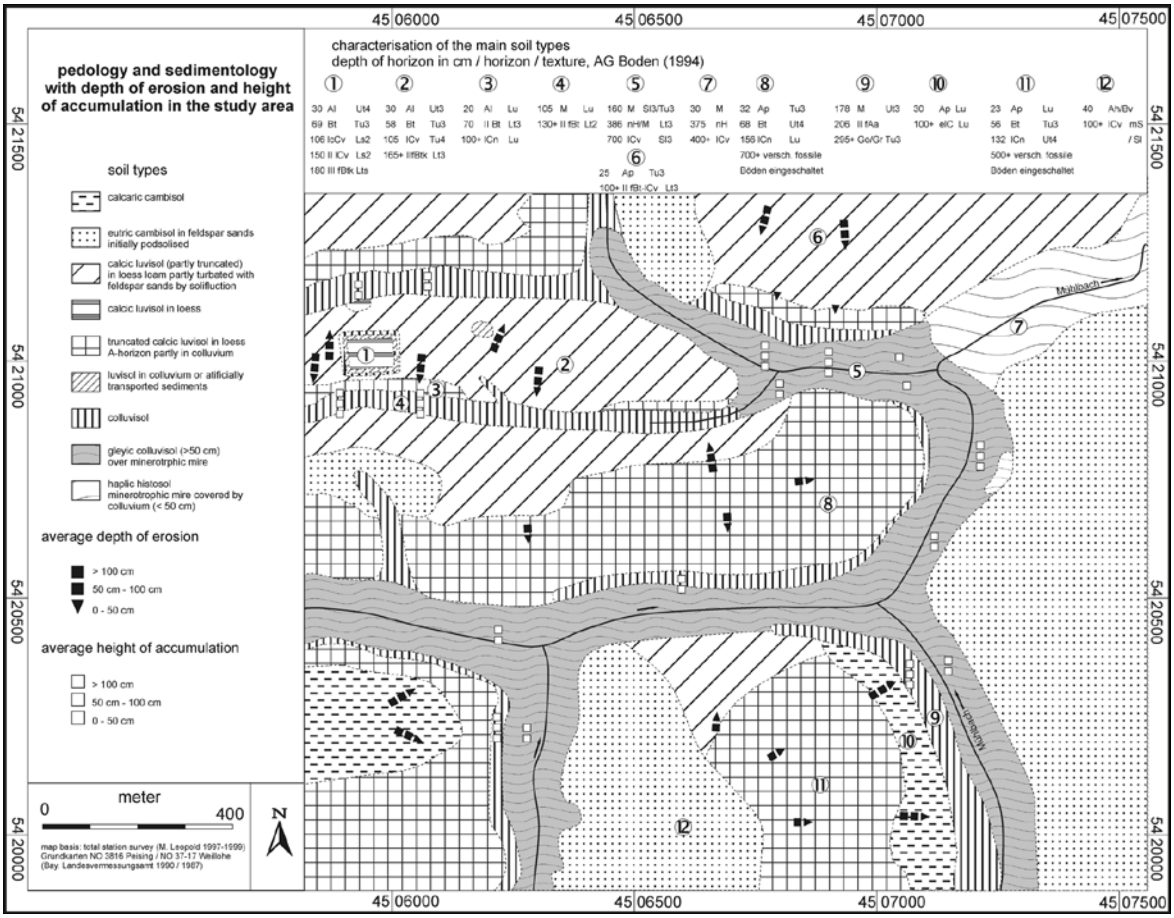


Fig. 4 - Overview of the soil distribution pattern based on the sedimentological and pedological mapping. Depth of erosion and height of accumulation are additionally marked. Upper Box gives a short characterisation of the main soil types based on depth of the horizons and the texture after Boden (1994).

Tab. 3 - Absolute and percentage calculation of the area of the different soil types classified by the mapping in the study area in contrast to a most likely area distribution of the soils before the time of human influence.

| Type of soil | Area ($m^2$) | Area (%) | Area (%) before land use |
|---|---|---|---|
| Eroded calcic luvisol | 639,707 | 24.47 | - |
| Eutric cambisol | 601,220 | 23.00 | 23.00 |
| (Eroded) luvisol on solifluction lobes | 539,761 | 20.65 | 11.19 |
| Gleyic-colluvisol | 433,260 | 16.57 | - |
| Colluvisol | 189,693 | 7.26 | - |
| Calcaric cambisol | 115,612 | 4.42 | - |
| Haplic histosol | 84,313 | 3.23 | 19.80 |
| *In situ*-calcic luvisol | 6,862 | 0.26 | 46.01 |
| Luvisol on colluvial material | 3,868 | 0.15 | - |
| Sum | 2,614,296 | 100 | 100 |

mmol/100 g with saturation between 90 and 100% in the lower part of the profile (Tab. 4b). The rather high acidity with a correlated with a high amount of aluminium in the upper part of the profile was much more moderate during prehistoric times. Compared to the soil properties of the sandy eutric Cambisol in the study area the calcic Luvisol is an agricultural soil of a much higher quality. Prehistoric farmers who had the

Tab. 4a - Cation Excange Capacity of a typical sandy eutric Cambisol.

| Probe | Horizon | Depth | K | | Na | | Mg | | Ca | | Al | | Fe | | Mn | | CEC | Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (cm) | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | |
| 1 | Ah | 0-2 | 0.27 | 4.08 | 0.21 | 3.13 | 0.49 | 7.34 | 2.02 | 30.34 | 3.27 | 49.17 | 0.27 | 4.10 | 0.12 | 1.85 | 6.65 | 44.88 |
| 2 | Ahl | 2-8/13 | 0.07 | 1.62 | 0.02 | 0.37 | 0.10 | 2.21 | 0.20 | 4.63 | 3.81 | 88.50 | 0.09 | 2.13 | 0.02 | 0.53 | 4.31 | 8.84 |
| 3 | Al | 8/13-16 | 0.07 | 1.88 | 0.02 | 0.61 | 0.05 | 1.27 | 0.09 | 2.31 | 3.48 | 91.44 | 0.04 | 1.11 | 0.05 | 1.36 | 3.80 | 6.06 |
| 4 | Al | 16-25 | 0.10 | 2.05 | 0.04 | 0.77 | 0.09 | 1.85 | 0.12 | 2.38 | 4.46 | 91.56 | 0.02 | 0.40 | 0.05 | 0.99 | 4.87 | 7.05 |
| 5 | Bt | 25-33 | 0.14 | 2.59 | 0.07 | 1.22 | 0.10 | 1.75 | 0.18 | 3.21 | 4.90 | 89.16 | 0.08 | 1.45 | 0.03 | 0.63 | 5.50 | 8.76 |
| 6 | Bt | 33-41 | 0.13 | 2.79 | 0.07 | 1.48 | 0.10 | 2.23 | 0.16 | 3.49 | 4.10 | 88.83 | 0.01 | 0.23 | 0.04 | 0.96 | 4.62 | 9.98 |
| 7 | Bt | 41-50 | 0.15 | 2.85 | 0.07 | 1.30 | 0.45 | 8.56 | 0.84 | 15.90 | 3.64 | 69.35 | 0.07 | 1.29 | 0.04 | 0.76 | 5.25 | 28.60 |
| 8 | ICv | 50-70 | 0.15 | 3.04 | 0.07 | 1.47 | 0.61 | 12.59 | 1.00 | 20.83 | 2.89 | 59.88 | 0.06 | 1.15 | 0.05 | 1.02 | 4.82 | 37.94 |

Tab. 4b - Cation Excange Capacity of a typical calcic Luvisol.

| Probe | Horizon | Depth | K | | Na | | Mg | | Ca | | Al | | Fe | | Mn | | CEC | Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (cm) | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | % | mmol | |
| 84/5 | Ahl | 1-4 | 0.09 | 0.70 | 0.00 | 0.00 | 0.34 | 2.63 | 0.86 | 6.64 | 11.32 | 87.36 | 0.18 | 1.38 | 0.17 | 1.29 | 12.96 | 9.96 |
| 84/6 | Al | 4-9 | 0.06 | 0.59 | 0.02 | 0.14 | 0.15 | 1.41 | 0.32 | 2.88 | 10.25 | 93.37 | 0.05 | 0.48 | 0.12 | 1.13 | 10.98 | 5.02 |
| 84/7 | Al | 9-15 | 0.07 | 0.71 | 0.01 | 0.13 | 0.11 | 1.21 | 0.18 | 1.95 | 8.79 | 94.70 | 0.01 | 0.10 | 0.11 | 1.20 | 9.29 | 4.00 |
| 84/8 | Al | 15-21 | 0.06 | 0.65 | 0.00 | 0.00 | 0.12 | 1.25 | 0.16 | 1.66 | 9.30 | 95.02 | 0.00 | 0.04 | 0.14 | 1.38 | 9.79 | 3.56 |
| 84/9 | AlBt | 21-30 | 0.10 | 0.85 | 0.00 | 0.04 | 0.27 | 2.25 | 0.52 | 4.33 | 10.88 | 90.89 | 0.00 | 0.00 | 0.20 | 1.64 | 11.97 | 7.47 |
| 84/10 | Bt | 30-40 | 0.23 | 1.26 | 0.00 | 0.00 | 1.47 | 8.21 | 3.51 | 19.59 | 12.47 | 69.66 | 0.00 | 0.00 | 0.23 | 1.28 | 17.90 | 29.06 |
| 84/11 | Bt | 40-50 | 0.21 | 1.19 | 0.04 | 0.20 | 2.95 | 16.29 | 7.69 | 42.55 | 7.12 | 39.40 | 0.00 | 0.02 | 0.06 | 0.36 | 18.08 | 60.23 |
| 84/12 | Bt | 50-60 | 0.20 | 1.16 | 0.02 | 0.11 | 3.77 | 21.71 | 11.88 | 68.38 | 1.49 | 8.57 | 0.00 | 0.00 | 0.01 | 0.08 | 17.38 | 91.35 |
| 84/13 | BtICv | 60-69 | 0.14 | 0.79 | 0.04 | 0.23 | 3.74 | 21.03 | 13.69 | 77.07 | 0.15 | 0.84 | 0.00 | 0.00 | 0.01 | 0.05 | 17.77 | 99.11 |
| 84/14 | ICv | 69-76 | 0.13 | 0.62 | 0.01 | 0.05 | 3.36 | 16.08 | 17.35 | 83.13 | 0.03 | 0.12 | 0.00 | 0.01 | 0.00 | 0.00 | 20.87 | 99.87 |
| 84/15 | cICcv | 76-86 | 0.11 | 0.44 | 0.04 | 0.15 | 2.94 | 11.55 | 22.35 | 87.85 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 25.44 | 99.99 |
| 84/16 | cICcv | 86-96 | 0.009 | 0.37 | 0.01 | 0.05 | 2.68 | 11.20 | 21.12 | 88.25 | 0.03 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 23.94 | 99.87 |
| 84/17 | cICcv | 96-106 | 0.11 | 0.49 | 0.02 | 0.09 | 2.24 | 10.27 | 19.44 | 89.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 21.81 | 100.00 |

choice of selecting the best field sites would always prefer the loess sites.
Over thousands of years agriculture led to massive soil erosion which results in partly or fully truncated soil horizons. The total erosion of a calcic Luvisol leads to the development of a calcaric Cambisol. The correlated sediments of the soil erosion can be found as colluvial material mainly in the valleys but also partly on the hill tops and mid-hill areas in sediment traps. The valley bottoms are covered with large bogs which are nowadays overlaid by up to 1.5 meters of colluvium. Colluvium can be found mainly in the valley bottom but partly also on the slopes and in depressions on the top of the hill. The depth of erosion and accumulation varies between different locations from less than 50 cm up to 2 m. Areas with high erosion correlate with loess areas, which give a first hint of preferred use areas in the past.
All the data was used to create a model which differentiates between areas which are suitable for farming (loess sediments, loess loam, high amounts of nutrients, moderate soil density, good drainage) and areas which are not suitable or are less suitable for farming (acid sandy sediments, low amount of nutrients, high erosion risk, poor water supply etc.).
In a following step, the two models (relief analysis and soil mapping) of areas suitable or not suitable for farming were combined and result in a Physiotopen model (Fig. 5). It is a time-independent model of the pattern of possible fields or woods.
Soil-catenas focussing on the processes of their genesis produce additional data for a focused time period. The idea was that whenever farming takes place on a hill the possibility of soil erosion during the time of use is high and correlated sediments will be partly deposited in the valley bottom. Localising and dating these sediments determines the place and time of agriculture usage on the hill above.
Bogs dating back to the Allerød/Younger Dryas which are widely located in the valley bottom of the study area (*e.g.* Fig. 3) have been of great use as geoarchives. As parts of the correlated sediments were transported down into the valley, they were deposited on the bog surfaces. When farming was given up on the hill site the peat started to recover and grew over the colluvium. In consequence a rich geoarchive of several phases of deposition and regrowth of the bog developed (Fig. 6). Dating (Radiocarbon) the peat above and below the colluvium gave a time span during which the deposition must have taken place. Iron Age land, the time focused in this study, is clearly represented by the data in Figure 6 (all data are calibrated 2 sigma). The deposition phase 3 in the drill core 7038-102 and the phase 2 in 7038-111 are shown to be Iron Age colluvium. Iron Age farming must have taken place on the nearby slope, since there was no indication of a transportation of the colluvium along the valley floor. Using this principle several sites of Iron Age land use were determined and were classified as fields in the final Iron Age land use model. Other areas which have been identified as potentially suitable

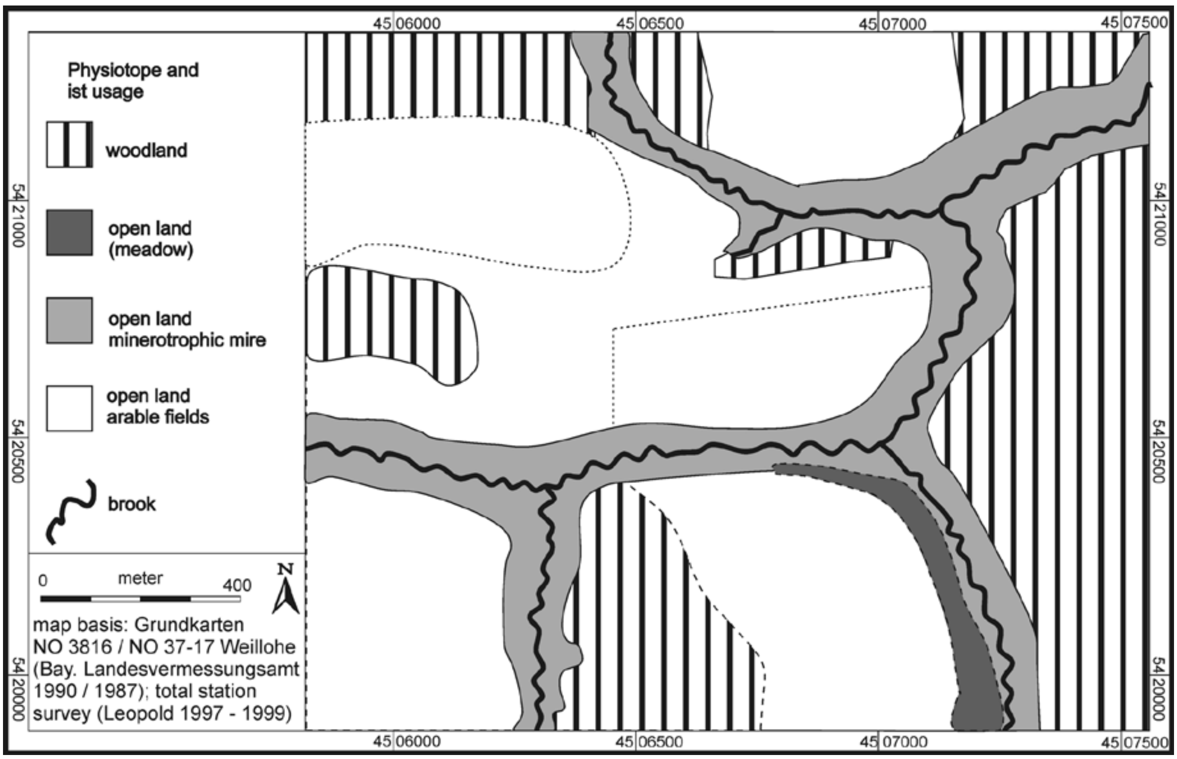


Fig. 5 - The Physiotopen model based on the results of the relief analysis and the sedimentological and pedologigal mapping. Presented is a time independent model with the most likely land use in the study area.

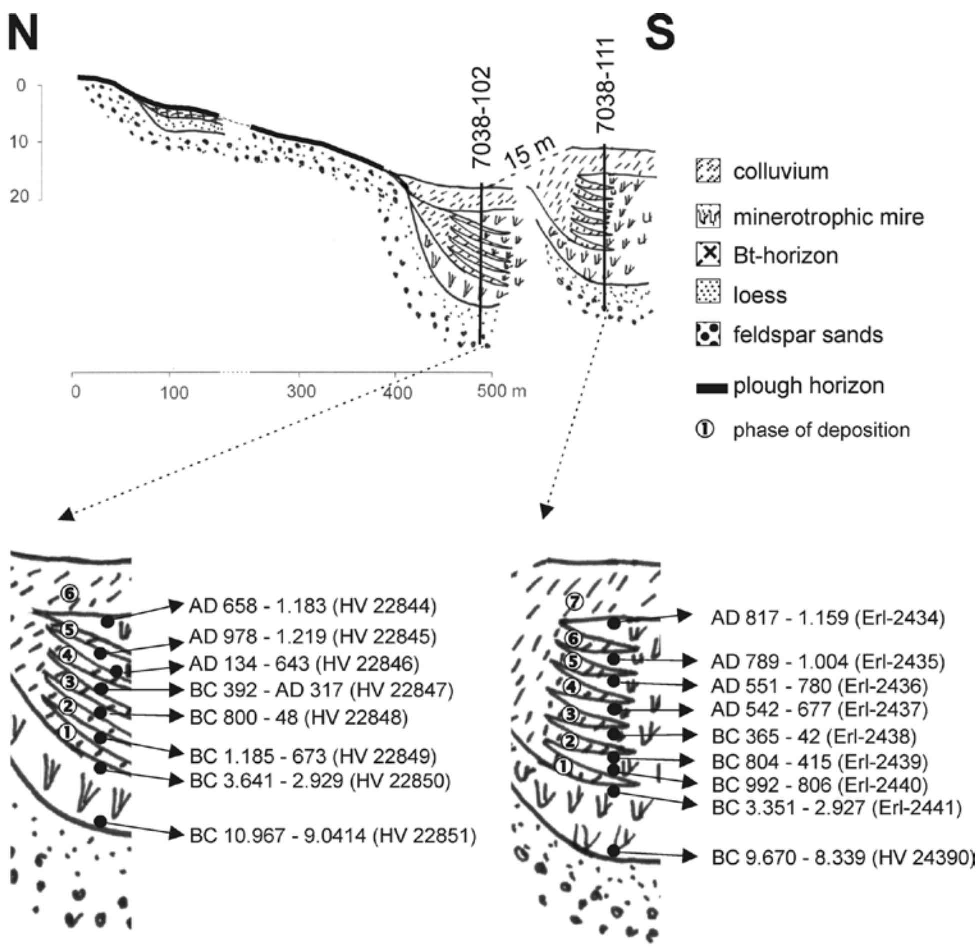


Fig. 6 - An example of two process-genetical catena with its endpoints. Results of the radiocarbon data of the peat (calibrated years, 2 σ interval with lab. code) which show several phases of colluvium accumulation. Iron Age land use in the sense of farming is clearly proved in both drill cores.

for farming (loess sediments, high amount of nutrients, low relief etc.) were classified as potential fields.
Areas where no colluvium was found correlated with areas classified as not suitable for farming in the Physiotopen model.

## CONCLUSIONS

Relief analysis and soil mapping are the basis to construct very effectively a physiotopen model. The linkage between the Physiotope and the land use pattern is widely known and proved.
The biggest advantage of this model is its spatial meaningfulness. An independent reconstruction of areas with a certain kind of use can be connected with additional data (pollen, archaeology, chronology etc.) (Leopold & Völkel, 2004, Raab *et al.*, 2004) and results in a land use reconstruction for a certain time period.

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