Working Paper and Preprint No.88/6

SOIL MANAGEMENT OF SPODOSOLS WITH PLAGGEN EPIPEDON

D. Creutzberg and H. de Bakker

Presented at V International Soil Correlation Meeting (ISCOM)
Lake Placid, U.S.A., October 1988

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

ISRIC

SOIL MANAGEMENT OF SPODOSOLS WITH PLAGGEN EPIPEDON

D. CREUTZBERG, ISRIC, Wageningen, The Netherlands, and H. DE BAKKER, Stiboka, Wageningen [1]

INTRODUCTION

Soils with a thick man-made surface layer, traditionally called plaggen soils, occur throughout the sandy region of northwestern Europe. During the Holocene, Humods, Aquods and Aquepts developed in these materials which were very poor in nutrients and weatherable minerals. From Neolithic times onward, the region was inhabited by man who practiced shifting cultivation.The formation of plaggen soils dates back to medieval times or even earlier, when the increase of population required a higher productivity of the poor sandy soils. Intensive farming was only possible if sufficient manure was applied and gradually a land management system was developed which is now known as "plaggen management system": sods, with some adhering sand, cut from the adjacent heath lands and mixed with dung from sheep and cattle produced a sand-containing manure. Put on the fields this manure created a dark, humus-rich surface layer, often exceeding a thickness of 50 cm (the Plaggen epipedon).

The plaggen management system is primarily aimed at the compensation of the loss of nutrients as a result of prolonged arable cropping. It was therefore mostly practiced on the poor sandy Spodosols of the northwestern European lowlands. However, it should be mentioned that similar man-made surface horizons have been reported from other parts of the world, occurring on a wide variety of soils. Conry (1974) presents a comprehensive survey of the literature on this matter, showing that man-made surface covers also occur on parent materials other than sand (with Spodosols), such as loess (with Alfisols), peat (with Histosols), and fluviatile and marine sediments (with Fluvaquents). Eckelmann (1980) proposes a classification of plaggen soils for northwestern Germany, based on their occurrence on different parent materials, such as eolian and fluviatile sands, glacial outwash, glacial till, alluvial deposits, sandy loess and loess.

In this paper the discussion is restricted to Spodosols having a plaggen cover, occurring in the Pleistocene sandy district of Belgium, The Netherlands and northwestern Germany.

GEOLOGY AND PARENT MATERIALS

GEOLOGY

Spodosols on the mainland of northwestern Europe are restricted to those areas where coarse-textured Pleistocene materials occur at the surface. These are partly derived from the mountainous region in the south, transported in northwestern direction by the precursors of the rivers Scheldt, Meuse, Rhine, Ems, Weser and Elbe. During the Saalian Glaciation at the end of the Middle Pleistocene, a continental ice sheet which had its centre in the Scandinavian highlands, covered large parts of these sediments. Ice tongues intruded and scoured out pre-existing valleys and pushed up hills and ridges. Parts of the level areas in the northern part of The Netherlands and Germany were covered with ground moraine and fluvioglacial materials.

During the following interglacial stage (Eemian) with temperate climatic conditions, the relief was leveled through erosion and mass wasting, but remnants of the glacial valleys and ice-pushed ridges can still be recognized in the present-day landscape.

[1] Drs. D. Creutzberg, ISRIC, P.O. Box 353, 6700 AJ Wageningen, The Netherlands.
Dr. H. de Bakker, Churchillweg 79, 6707 JD Wageningen, The Netherlands.

The last glaciation (Weichselian) was marked by a renewed advance of the Scandinavian ice sheet which, however, only reached the north of the discussed region. In the area not covered by the ice, periglacial conditions prevailed, and in the arctic desert large parts of the landscape were covered with eolian sands. These "cover sands" have further contributed to the leveling of the topography, accumulating in great thickness in the valleys and depressions and being virtually absent on the highest ice-pushed ridges and in some isolated patches of the ground moraine. The eolian character of the deposits is evident from the well-sorted fine sandy texture and the slightly undulating relief with irregular depressions and somewhat higher elongated elevations which are considered to be remnants of longitudinal and parabolic dunes.

After the disappearance of the permafrost a groundwater level established itself, showing great variations in depth over relatively short distances due to the irregular eolian relief. Shallow groundwater promoted peat growth and caused hydromorphic soils in the level areas. Well-drained soils formed on the elevated terrain and on dunes.

Summarizing, fine eolian sands ("cover sands") constitute the dominant parent material of the Spodosol region of the mainland of northwestern Europe. They have an undulating relief, resulting in a variation of groundwater level over short distances. Only in some of the highest parts, reaching 30-100 m above sea level, the early and mid-Pleistocene sandy and gravelly deposits appear at the surface; the soils in these places are somewhat excessively drained. Most of the adjacent fluvioglacial sandar have more or less the same characteristics.

COMPOSITION OF THE PARENT MATERIALS

The cover sands consist of fine sand or, less commonly, loamy fine sand. The particle size distribution of two samples from The Netherlands is given in Table 1.

Table 1. Particle-size distribution (weight %) of two cover sands from The Netherlands (Stiboka, 1965)

2000 1000	1000 500	500 100	250 100	100 50	50 20	20 2	<2 (um)
0	2	18	34	22	9	9	6
0	1	16	55	21	2	3	2

Outcrops of ice-pushed early and mid-Pleistocene deposits and adjacent fluvioglacial deposits normally have coarser sands and are slightly gravelly.

The dominant mineral in the cover sands is quartz, which constitutes 65-90% of the minerals. Feldspars range from 5-15%. The percentage of heavy minerals such as augite, hornblende, epidote etc. normally does not exceed 10% but commonly occurs in quantities of less than 5 %. The Netherlands Soil Survey Institute (Stiboka) makes a distinction between "poor sands" and "very poor sands" on account of the mineral composition which is evident in the field from the colour of the sand.

The composition of some samples, representative for cover sands in The Netherlands is given in Table 2.

Table 2. Mineral composition (weight %) of some representative samples of cover sands from The Netherlands (Stiboka, 1965)

	quartz	feldspar	heavy minerals	unidentified
"poor sand"	68	16	8	8
"poor sand"	66	13	4	17
"very poor sand"	92	6	1	1
"very poor sand"	90	8	2	-

CLIMATE AND VEGETATION

At the end of last glaciation climatic conditions became milder and moister. From then on, throughout the Holocene, the climate has been, with some variations, more or less similar to the present climate. The mean annual temperature is just below 9°C and the precipitation is 700-800 mm/y. Climatic data for De Bilt (central Netherlands) are presented in Table 3.

Table 3. Climatic data of The Netherlands; monthly averages from 1930-1961 at De Bilt (near Utrecht)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Temp. (°C)	1.7	2.0	5.0	8.5	12.4	15.5	17.0	16.8	14.3	10.0	5.9	3.0	9.3
Precip. (mm)	68.0	52.2	44.6	48.8	51.5	58.0	76.8	88.0	71.2	72.2	70.0	63.4	764.7
Evap. (Eo) (mm) (Penman)	4	17	42	78	109	126	118	96	61	28	9	3	691

As a consequence of the amelioration of the climate, the vegetation changed from a tundra into a forest, with the full forest sequence of the Holocene epoch. Early Holocene vegetation, mainly consisting of Pinus and Betula, was succeeded by Corylus, Ulmus and Quercus, and later Tilia, Fraxinus and Alnus, and still later Fagus and Carpinus. Late Holocene vegetation was characterized by forests with Quercus and Fagus on the "poor sands" and Quercus and Betula on the "very poor sands", whereas Alnus dominated in the wet places.

SOIL FORMATION

Soil formation started at the beginning of the Holocene (10000 y BP) with decalcification and weathering of minerals. This is inferred from a deep excavation in the western part of The Netherlands. In this excavation it was demonstrated that the Late Weichselian cover sands were drowned by the rising sea and were covered with peat and lagoonal deposits, preserving the pre-existing soils. The excavation was large enough to expose the undulating topography of the cover sands, showing the same toposequence of soils as in the actual landscape in the eastern part of the country: Aquepts (Gleysols) in the brook valleys and Spodosols (Podzols) on the low ridges and in the depressions.

Pollen analysis proved that the Spodosols were formed under forest, mainly Pinus sylvestris and Betula, whereas Alnus dominated in the brook valleys. The age of the peat overlying the buried soil (determined by pollen analysis and C14 methods) dated back to about 7000 y BP. From these observations it is inferred that the buried soils were already decalcified and podzolized before being covered with 15 to 20 m of Holocene deposits (Pons, 1959). Apparently, soil formation in the sandy material under consideration started after sedimentation and had already proceeded to a stage more or less comparable to the actual soils at about 7000 y BP.

The present-day toposequence of soils in the cover sand region, if modifications by man are disregarded, comprises of Humods (Humic Podzols) on the well-drained sites, Aquods (Gleyic Podzols) in the depressions and Aquepts (Gleysols) in the brook valleys. Man, however, has modified the soils in many places. It is believed that the strongly developed, slightly to strongly cemented black spodic Bh-horizon, often showing an incipient thin iron pan (not satisfying the definition of the placic horizon, see De Bakker, 1979: 162-165) is caused by man-induced transformation of forest into heathland.

A more recent modification of the Spodosols was caused by deliberate action of man, and was a consequence of the plaggen management system. In this system heather-sods were used as bedding material in the cowsheds and sheepfolds. These sods consisted of the O-horizon with some adhering sand from the Spodosols of the heathlands. The dung-impregnated bedding was used to manure the arable land. Consequently, by using this earth-containing so-called plaggen manure, the arable fields were raised very gradually (Edelman, 1950; Slicher van Bath, 1963; De Bakker, 1979), changing the Spodosols into Plaggeptic Spodosols and Plaggepts (Table 4). More details of this management system are given in the next Section.

Table 4. Areas of Pleistocene sandy soils on the Soil Map of The Netherlands, 1:250 000 (Steur et al., 1985)

soil unit	area: hectares	area: %
Spodosols	517 300	43.8
Plaggepts	146 400	12.4
Plaggeptic Spodosols	80 100	6.8
Association of Plaggepts and Plaggeptic Spodosols	124 800	10.6
other Pleistocene sandy soils	312 300	26.4
total area	1 180 900	100.0%

HISTORY OF LAND USE

EARLY HUMAN INFLUENCE

Human influence first became evident in the Middle Holocene (the late-Mesolithic era, about 5000-6000 y B.P.). Ever since, man has been increasingly active and the forests were gradually cut down for agricultural purposes.

From early medieval times onward, crops were produced in small clearings in the forests, topographically situated on low ridges amidst the wet depressions and the valley bottoms of small streams. During the following centuries extensive sheep grazing accelerated the disappearance of the forests: sheep prevented the regrowth of trees. The forests gave way to heaths with a low shrub vegetation: on the wet places dominantly cross-leaved heath (Erica tetralix) and on the dry sites ling (Calluna vulgaris). This process reached its peak in the middle of last century. At that time about 50% of the sandy soils of The Netherlands were covered with heath.

PLAGGEN MANAGEMENT SYSTEM

The above-mentioned shifting cultivation system changed most probably gradually into the plaggen management system. For many centuries (from about 1000 AD until the introduction of fertilizers around the turn of last century) land use was: arable crops on the low ridges with Humods and grassland for the cattle in the small brook valleys with sandy Humaquepts.

Arable crops were rye, buckwheat and oats, later mangolds and potatoes; after rye Swedish turnips were often grown as a second crop.

The heathlands were communal lands, in contrast with the private arable fields and the grassland. The soils, mainly Aquods, were used as rough grazing land for a special breed of sheep. The flock had to spend the night in the sheepfold so that all the droppings could be collected. In these pens, and also in the cowsheds heathersods were used as bedding material.

The introduction of fertilizers changed this system completely. The heathland was neither needed anymore as rough grazing land nor as a source of manure for the arable land.

A large area was reclaimed and converted into arable land and grassland (limed and fertilized). Part of the heathland was reafforested, mainly with Scots Pine (Pinus sylvestris). In 1866 there were more than 600 000 ha of heathlands; today less than 60 000 ha remain!

The increased arable area enabled the farmers to use straw as bedding material in the barns, tables, consequently the introduction of fertilizers brought the plaggen management system to an end.

Land use changed considerably in the last decades. From mixed arable/dairy farms, farming on the Pleistocene sandy soils changed into nearly completely dairy systems. The rye practically disappeared and was replaced by maize for silage, and a large area of the arable land changed into grassland. The original grasslands as well as these new grasslands are regularly resown (a kind of long-term leys) in order to improve their production capability.

CHARACTERISTICS AND PROPERTIES

FIELD CHARACTERISTICS

The plaggen management system has resulted in the formation of small fields, not larger than 5 hectares but often much smaller, with rectilinear and rectangular soil boundaries. Characteristically the fields are located in the vicinity of villages and small settlements, situated between the brook valleys and the higher parts of the landscape. Locally they occur as narrow elongated strips, elevated 2-5 m above the surrounding hydromorphic soils of brook valleys, being built up on the remains of longitudinal dunes which date back to late-glacial times.

Plaggen soils have a dark-coloured surface horizon (the "plaggen cover") with a thickness of at least 30 cm, overlying a buried Spodosol. Normally the thickness of the plaggen cover ranges from 40-80 cm, but some plaggen soils are reported to have a thickness exceeding 120 cm.

The colours of the plaggen cover are black, very dark gray, very dark brown, or very dark grayish brown, with a hue of 10YR, or less commonly 7.5YR, with moist values of 1.5-3.5 and moist chromas of 0.5-2.

Both in The Netherlands and in the Federal Republic of Germany a distinction is made between "black" and "brown" plaggen soils (De Bakker and Schelling, 1966; Arbeitsgruppe Bodenkunde, 1982). It is generally assumed that the colour differences are due to different kinds of sods that were used. Sods derived from heathlands caused black colours, whereas sods cut from grassland, or the application of forest litter, produced brownish colours.

Spade marks, artifacts like charcoal, pottery fragments and burnt loam etc. indicate the anthropogenic nature of the plaggen cover.

CHEMICAL CHARACTERISTICS

The humus content of plaggen covers varies considerably but is always high as compared with the surface horizon of the buried soil. The organic carbon content ranges from 1.5-4% with an average value of 3% (Pape, 1970; Eckelmann, 1980). Micromorphological studies show that the organic matter consists of coarse to extremely fine fragments of decayed plant remains, located in the interstitial pores between the uncoated sand grains.

The pH (KCl) ranges from 3.5-4.5 and the CEC (pH 7) has values of 4-15 cmol(+)/kg, depending on the content of organic matter (Pape, 1970; Eckelmann, 1980). The exchange capacity is almost entirely attributable to the organic matter.

Plaggen covers are relatively high in phosphorus as compared with the subsoil and with the surface horizon of the surrounding soils. Analytical data of plaggen covers representative for The Netherlands, are given by Pape, indicating that the total P content (extracted with concentrated H_2SO_4/HNO_3, 1:1) ranges from 800-2200 mg/kg with an average of about 1400 mg/kg (elemental P). Eckelmann (1980) found lower values for the plaggen covers in the cover sand region of northwestern Germany, viz. a range of 300-500 with an average of 380 mg/kg (extracted with $HClO_4/HNO_3$, 1:1).

CLASSIFICATION

USDA SOIL TAXONOMY

The concept of the plaggen cover of Western Europe has been adopted by Soil Taxonomy (Soil Survey Staff, 1975; 1987) and is called a plaggen epipedon. It is identified by the occurrence of artifacts and spade marks throughout its depth; it has been produced by long-continued manuring. The epipedon has a thickness of 50 cm (20") or more.

The larger part of the area with plaggen soils in northwestern Europe meets these requirements, they key out in Soil Taxonomy as Plaggepts. Great groups and subgroups have not been developed in this suborder. At family level these Plaggepts are classified as sandy, siliceous or mixed and mesic.

A part of the plaggen soils have a surface layer that meets all requirements for the plaggen epipedon except thickness. As a consequence these soils are classified according to the underlying soils. These may be Haplohumods, Haplaquods, Haplorthods or Udipsamments. Analogous to the Plaggeptic Haplohumods and Plaggeptic Fragiorthods (the latter are unknown to the authors) we propose the suborders Plaggeptic Haplaquod and Plaggeptic Udipsamment for the Haplaquod and Udipsamment with a thin plaggen cover.

FAO-UNESCO SOIL MAP OF THE WORLD LEGEND

This system has been devised for the FAO-Unesco Soil Map of the World 1:5,000,000 (FAO-Unesco, 1974). Although a plaggen A horizon is mentioned in the text no provision has been made to accommodate plaggen soils: "Because of the scale of the map it has not been possible to separate soils which are characterized by such man-made surface layers" (page 24).

In the draft Revised Legend (FAO, Unesco and ISRIC, 1988) a new diagnostic horizon -the fimic A horizon- has been defined to accommodate soils with a plaggen cover. It is defined as follows: " The fimic A horizon is a man-made surface layer 50 cm or more thick which has been produced by long continued manuring with earthy admixtures. The fimic A horizon commonly contains artifacts such as bits of brick and pottery throughout its depth. The fimic A horizon as defined here includes the plaggen epipedon and the anthropic epipedon of Soil Taxonomy (U.S. Soil Conservation Service, 1975). If the fimic A horizon meets the requirements of the mollic A horizon it is distinguished from it by an acid P_2O_5 content which is higher than 250 ppm by 1 percent citric acid" (pages 21 and 22).

This definition is mostly in agreement with the definition of the plaggen epipedon of the USDA system, but it should be noted that the inclusion of the anthropic epipedon has been proposed.

In the Revised Legend soils with a plaggen cover of 50 cm or more thick meet the requirements of the Major Soil Grouping Anthrosols and of the Soil Unit Fimic Anthrosols. Following the guidelines for distinguishing soil subunits (p. 56) soils with a plaggen cover thinner than 50 cm could be classified as Anthri-Gleyic Podzols or Anthri-Haplic Podzols if the cover is thicker than 30 cm. If the cover is thinner than 30 cm the soils key out as Gleyic and Haplic Podzols.

THE NETHERLANDS

In "The System of Soil Classification for The Netherlands" (De Bakker & Schelling, 1966) plaggen soils with a cover thicker than 50 cm are classified as "Enkeerdgronden" ("Enk" earth soils).

As stated in the section "Field characteristics", and like in Germany, a distinction is made in "brown" and "black" "Enk" earth soils.

Soils with a plaggen cover thinner than 50 cm are classified on account of their buried subsoil. If they have a plaggen cover between 30 and 50 thick they are separated on subgroup level from the slightly or non-raised soils.

THE FEDERAL REPUBLIC OF GERMANY

The "Bodenkundliche Kartieranleitung" (Arbeitsgruppe Bodenkunde, 1982) presents the system of soil classification for the Federal Republic of Germany.

Plaggen soils are included in the section "Anthropogene Böden (Kultisole)" (=anthropogenic soils). The Type "Plaggenesch" must have a plaggen cover exceeding 40 cm in thickness. The normal type is named "Typischer Plaggenesch", synonymous with "Grauer Plaggenesch". Like in the Dutch system a "brown" one is separated, but also a grey-brown one as an intergrade.

If the plaggen cover is thinner than 40 cm, the soil carries the name of the buried soil with the addition "mit Plaggenauflage" (with a plaggen cover).

SOIL MAP OF THE EUROPEAN COMMUNITIES 1:1.000.000

No separate Map Unit is defined for the Soil Map of the European Communities (Dudal & Tavernier, 1985) to accommodate soils with a plaggen cover, but the Plaggensol has been defined and is an inclusion in some associations. The Plaggensol is defined as follows: "Soils that have a manmade surface layer of 50 cm or more that has been produced by long continued manuring ("plaggen epipedon")."

SUITABILITY

The suitability of the sandy soils depends largely on two factors: depth and seasonal fluctuations of the groundwater, and the available water. The latter depends on the thickness of the rootable layers.

As mentioned in the previous Sections, the groundwater level in the area under discussion varies considerably over short distances. As Spodosols have shallow rooting possibilities, available water is low. Consequently, the soil pattern shows great variation in suitability due to these differences in groundwater depth.

Because of the thick plaggen cover, the plaggen soils are deeply rootable and have a high amount of available water; therefore, they are less dependent on the capillary rise of the groundwater.

Spodosols with a plaggen cover of less than 50 cm thickness are more liable to have water deficits during the growing season. Spodosols without plaggen cover are considered unsuitable for arable crops if the mean highest groundwater level is deeper than 50 cm.

Likewise, the presence of a plaggen cover appreciably increases the suitability of the sandy soils for grassland. High groundwater levels which tend to make the soils less suitable for arable cropping, however, may still produce good quality grasslands, whereas very deep groundwater may seriously affect the growth of grass, more so than arable crops.

As a matter of fact, the nutrient availability of sandy soils is greatly improved if they have a plaggen cover because of the relatively high content of organic matter. Since the introduction of fertilizers, however, this aspect has become of less importance for the productivity of the soils.

It is regarded beyond the scope of this paper to discuss their various potential alternative uses.

LITERATURE CITED

1. Arbeitsgruppe Bodenkunde. 1982. Bodenkundliche Kartieranleitung. (Eds.: Benzler, J.-H, H. Finnern, W. Müller, G. Roeschmann, K.H. Will and O. Wittmann). Bundesanstalt f. Geowissensch. u. Rohstoffe u. den Geol. Landesämter in der BRD.
2. Conry, M. 1974. Plaggen soils, a review of man-made raised soils. Soils Fertil. 37: 319-326.
3. De Bakker, H. 1979. Major soils and soil regions in the Netherlands. Junk, The Hague, Boston, London / Pudoc, Wageningen.
4. De Bakker, H. and J. Schelling. 1966. Systeem van bodemclassificatie voor Nederland, de hogere niveaus (with 30 pages summary: A system of soil classification for The Netherlands, the higher levels). Pudoc, Wageningen.
5. Dudal, R. and R. Tavernier. 1985. Classification and definitions of the soil and map units. In: Commission of the European Communities, Soil Map of the European Communities, 1:1,000,000, Luxembourg.
6. Eckelmann, W. 1980. Plaggenesche aus Sanden, Schluffen und Lehmen sowie Oberflächenveranderungen als Folge der Plaggenwirtschaft in den Landschaften des Landeskreises Osnabrück (Germ. with Eng. summ.). Geol. Jb. Reihe F, Heft 10. Hannover. 95 pp.
7. Edelman, C.H. 1950. Soils of The Netherlands. North Holland, Amsterdam.
8. FAO-Unesco. 1974. FAO-Unesco Soil Map of the World 1:5 000 000, Volume I, Legend, prepared by the FAO of the U.N. Unesco, Paris.
9. FAO, Unesco and ISRIC. 1988. FAO-Unesco Soil Map of the World, Revised Legend, prepared by the FAO of the U.N. World Soil Resources Report 60. FAO of the U.N., Rome.
10. Pape, J.C. 1970. Plaggen soils in the Netherlands, Geoderma 4: 229-255.
11. Pons, L.J. 1959. Fossil soil profiles in the cover sand of the Velsen excavation (Dutch, with Eng. summary). In: Boor & Spade X: 170-209. Veenman, Wageningen.
12. Slicher van Bath, B. 1963. The agrarian history of western Europe, A.D. 500-1850. (translated by Olive Ordishe). London.
13. Soil Survey Staff. 1975. Soil Taxonomy, A basic System of Soil Classification for Making and Interpreting Soil Surveys. Soil Conserv. Ser., U.S. Dept. Agric. Handb. 436. U.S. Govt. Printing Office, Washington, D.C.
14. Soil Survey Staff. 1987. Keys to Soil Taxonomy. Soil Management Support Services. Techn. Mon. No. 6. 3d pr., Cornell Un.
15. Steur, G.G.L., F. de Vries en C. van Wallenburg. 1985. Bodemkaart van Nederland, 1:250 000. Beknopte beschrijving van de kaarteenheden. (Dutch, no Eng. summ. Soil Map of The Netherlands, 1:250 000, condensed description of the mapping units). Stichting voor Bodemkartering, Wageningen.
16. Stiboka. 1965. De bodem van Nederland, toelichting bij de Bodemkaart van Nederland, schaal 1:200 000. (Dutch, no Eng. summ. Soils of The Netherlands, explanation to the Soil Map of The Netherlands, 1:200 000). Stichting voor Bodemkartering, Wageningen.