

## Appendix B: Determining land-use suitability

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This appendix contains an overview of land-use suitability in the study area for arable farming, pasture, and meadow, based on the relationship between geomorphological setting, palaeo-surface elevation, lithological characteristics, and distance relations. Geomorphological setting, palaeo-surface elevation, and lithological characteristics were compiled by H.J. Pierik, MSc (Utrecht University). Land-use suitability per lithological unit was based on expert judgement by M.T.I.J. Gouw-Bouman, MSc (Utrecht University). Distance relations were determined by R.J. Van Lanen, M.A. (Utrecht University; Cultural Heritage Agency of the Netherlands) and H.J. Pierik, MSc.

### *Determining surface and shallow subsurface lithology*

Ascertaining soil and shallow-subsurface lithology is a very important factor for determining (past) land-use suitability, since it indicates nutrient availability, permeability, and tillage potential. The depth to which roots penetrate the soil can vary substantially, i.e. from ca. 1 cm to several dms, or in the case of trees even meters. In the land-use suitability reconstructions, we have assumed that the relevant soil and shallow-subsurface depth never exceeded 120 cm in accordance with generally accepted soil-survey methods (De Bakker & Schelling, 1989).

The geomorphological reconstructions were based on lithological borehole descriptions, which means that lithological units directly could be derived from these data. In the fluvial part of the study area, each mapped geomorphological unit in the reconstruction was assigned a specific surface and subsurface lithology (Table B.1). The lithology of levees of inactive channels belts was further refined since older levees (mainly active before 3000 BP) were sometimes covered by clayey-overbank sediments from younger river branches. To evaluate the clay-cover thickness for the AD 100 landscape ( $D_{AD100}$ ), we subtracted a grid showing the top of the levee material (directly interpolated from borehole data ( $Z_{Lev}$ )) from the AD100 palaeoDEM ( $Z_{AD100}$ ):

$$D_{AD100} = Z_{AD100} - Z_{Lev} \quad (1)$$

The resulting map shows an approximation of clay cover. For areas that yielded > 40 cm clay on top of inherited levees in the Roman period, we assigned the units: 'Clay on sandy clay on sand' or 'Clay on sandy clay'. For the Pleistocene sand area that flanks the study region, we defined the surface lithology using the national soil map of the Netherlands (1:50,000; De Vries et al., 2003). We distinguished three classes: (1) fine sands (mean grain size 50-210 $\mu$ m); (2) coarse sands (median grain size 210-2000  $\mu$ m); and (3) loamy sands (10-50% silt (>50  $\mu$ m; De Bakker & Schelling, 1989).

Table B.1 | Overview of geomorphological units in the study area based on Pierik et al. (*in review*) with corresponding lithology based on palaeo-surface elevation and soil data.

Geomorphological unit	Clay cover (in cm)	Mean grain size, silt percentage	Lithological profile	Lithological profile code
Pleistocene area	-	Cyfer = 21 (50-210 $\mu$ m)	Sand or fine sand	1
Pleistocene area	-	Cyfer = 23 (10-50% silt (>50 $\mu$ m))	Loamy sand	2
Pleistocene area	-	Cyfer = 30 (210-2000 $\mu$ m)	Coarse sand	3
Pleistocene area / Aeolian dunes	-	-	Sand, not specified	1
Active channel belt (with levee)	-	-	Sand / sandy clay on sand	141
Levee on inactive channel belt	-	-	Sandy clay on sand	41
Levee on inactive channel belt (levee with > 40 clay)	>40	-	Clay on sandy clay on sand	541
Crevasse splay	-	-	Sandy clay	4
Levee (outcropping)	-	-		
Levee (levee with > 40 clay)	>40	-	Clay on sandy clay	54
Res channel inactive	-	-	Clay	5
Floodbasin clay	-	-		
Floodbasin peat	-	-	Peat	6
Res channel active	-	-	Water	7

*Palaeo-surface elevation and land-use suitability*

Palaeo-surface elevation was used to further refine the lithology for specific geomorphological units, i.e. levees and crevasse splays respectively. Using the PalaeoDEM developed by Pierik et al. (in review) we further divided these specific geomorphological units based on their elevation using the classes ‘low’, ‘medium’, and ‘high’ (Table B.2).

Tabel B.2 | *Boundaries conditions for low, medium and high elevated levees and crevasse splays inferred from the PalaeoDEM. Land-use suitability (i.e. 0-5, referring respectively to unsuitable to very well suited), which is determined based on geomorphology and lithology, is further refined based on palaeo-surface elevation, since lower parts were more prone to general wet conditions and floods.*

PalaeoDEM elevation	Classification	Land-use suitability
< -0.5 m	Low	-2
-0.5 - 0 m	Medium	-1
> 0 m	High	0

*Determining land-use suitability*

We assigned vegetation assemblages to these combined geomorphological and lithological units using the following land-use types distinguished in the model: arable farming, pasture, meadow, and woodland (Table B.3). For each geomorphological-lithological unit, land-use suitability was determined using a value ranging from 0 to 5, with a value of 0 reflecting no potential and 5 reflecting a high potential for a specific kind of land use. Nutrient availability, groundwater level (moisture content), permeability, and flooding frequency depending on geomorphology and lithology were important factors for determining the suitability for the different vegetation units. We used the ecological preference of vegetation as described in Westhoff et al. (1970a, 1970b; 1970c); Weeda et al. (1985; 1987; 1988; 1991; 1994; 2000; 2003; 2005). The different vegetation assemblages distinguished in this study have different ecological preferences, which are listed below.

- *Arable land* often consists of nutrient-rich soils with a low flooding potential and a good permeability. Therefore, the low and wet flood basins in the study area have a low potential for arable functions and sandy Pleistocene soils poor in loam are also less suitable since they lack abundant nutrients for the crops. Low levees and crevasse splays have a moderate potential, and the higher alluvial ridges have a high potential for arable land use.
- *Pasture and meadow land* tolerate most conditions except permanently saturated situations and water (i.e. active channels and open residual channels). They were mostly situated in areas that were too wet for arable land use, such as lower alluvial ridges. Land-use suitability of areas for pasture and meadow was assumed to be equal, since difference between these types of land use mainly are determined by socio-cultural variables such as the distance to a settlement (Appendix C).

Due to lacking data availability, ‘woodland’ as a land-use type (i.e. yielding fuel and timber) was not included in the calculations. The presented PLUS assumes woodland was a constant and therefore had no effect on other land-use types (see main text, Section 6.1).

Table B.3 | *Geomorphological units and associated lithology in the study area. For each unique combination between geomorphological and lithological setting, the suitability for specific land-use types is given.*

Landscape			Suitability			
Geomorphology	Lithology	Lithology_ Code	Elevation	Arable farming	pasture	meadow
Active channel belt	Sand or sandy clay on sand	141	n/a	3	4	4
Crevasse splay	Sandy clay	4	high	4	5	5
Crevasse splay	Sandy clay	4	medium	3	5	5
Crevasse splay	Sandy clay	4	low	2	5	5
Flood-basin clay	Clay	5	n/a	0	5	5
Flood-basin peat	Peat	6	n/a	0	5	5

Levee	Sandy clay	4	high	5	5	5
Levee	Sandy clay	4	medium	4	5	5
Levee	Sandy clay	4	low	3	5	5
Levee	Clay on sandy clay	54	high	5	5	5
Levee	Clay on sandy clay	54	medium	3	5	5
Levee	Clay on sandy clay	54	low	3	5	5
Levee on inactive channel belt	Sandy clay on sand	41	high	5	5	5
Levee on inactive channel belt	Sandy clay on sand	41	medium	5	5	5
Levee on inactive channel belt	Sandy clay on sand	41	low	3	5	5
Levee on inactive channel belt	Clay on sandy clay on sand	541	high	5	5	5
Levee on inactive channel belt	Clay on sandy clay on sand	541	medium	5	5	5
Levee on inactive channel belt	Clay on sandy clay on sand	541	low	3	5	5
Residual channel (abandoned)	Clay	5	n/a	0	5	5
Residual channel (open)	Water	7	n/a	0	0	0
River	Water	7	n/a	0	0	0
Top pleistocene	Sand or fine sand	1	n/a	2	4	4
Top pleistocene	Coarse sand	3	n/a	2	4	4
Top pleistocene	Loamy sand	2	n/a	5	5	5

### Distance relations

Distance relations used to determine land-use competition (i.e. the amount of time it takes to walk from a settlement to arable fields, meadows, and pastures), were derived from De Kleijn et al. (submitted). Following definitions and spatial rules defined in this study, we determined the time it takes to cross each lithological unit using a resolution of 100m (Table B.4).

Table B.4 | Overview of distance relations (time to travel 100 metres) per reconstructed lithological unit.

Geomorphological unit	Lithology	Elevation class	Time (s) to travel 100 metres (in seconds)
Active channel belt	Sand or sandy clay on sand	high	75
		medium	75
		low	75
Crevasse splay	Sandy clay	high	75
		medium	75
		low	75
Floodbasin clay	Clay	high	88
		medium	88
		low	88
Floodbasin peat	Peat	high	96
		medium	96
		low	96
Levee	Sandy clay	high	75
		medium	75
		low	88
	Clay on sandy clay	high	100
		medium	100
		low	100
Levee on inactive channel belt	Coarse sand	medium	75
	Sandy clay on sand	high	75
		medium	75
		low	88
	Clay on sandy clay on sand	high	100
		medium	100
low		88	
residual channel (abandoned)	Clay	high	88
		medium	88
		low	88
Residual channel (open)	Water	high	320