

Characteristics and distribution of soil piping erosion in loess-derived soils of Belgium.

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ABSTRACT

Subsurface erosion (piping, tunnel erosion) in non-karstic landscapes has been considered of little importance compared to sheet and gully erosion for a long time. Although the basic factors responsible for piping in certain environments are well understood, there is still uncertainty about the topographic and soil properties inducing subsurface pipe development in loess-derived soils under temperate climate. Therefore, this research aims at understanding the factors controlling the occurrence of piping erosion in the loess-derived soils of the Flemish Ardennes (Belgium). Analysis of orthophotos as well as field surveys were conducted to detect the sites with piping in the study area. Enquiries among farmers and technical services were carried out. In total, 114 sites (parcels) with 301 collapsed soil pipes were found in a 179 km² study area. For each site with piping, data was collected on possible controlling factors: topographic parameters, land use, lithology and soil type. Land use plays an important role as 94% of the sites with piping are found under pasture. Furthermore, the probability of piping increases rapidly on slopes with gradients exceeding 8%. The areas with the Aalbeke Member, a relatively thin layer of homogenous blue massive clays, under the shallow loess cover are most prone to piping. Over 28% of the sites with piping are located on this lithologic layer, while this layer covers only 8% of the study area. The rest of the sites with piping are located on two lithologic layers containing clay as well as silt and sand.

Keywords: soil piping erosion - subsurface flow - loess

INTRODUCTION

In the case of soil piping erosion (further named piping), linear voids are formed by concentrated flowing water in soils or unconsolidated deposits, which can cause collapse of the soil surface and formation of discontinuous gullies (Jones, 2004). A more extensive discussion about the terminology of the different processes causing subsurface erosion features can be found in Dunne (1990) or Bryan and Jones (1997). Piping has been observed in both natural and anthropogenic landscapes, in a wide range of climatological, geomorphological and pedological circumstances (Jones, 1981; Bryan and Jones 1997). In Europe, Faulkner (2006) distinguished 3 piping-prone contexts: (i) organic peats (Histosols) and Gleysols (ii) dispersive sodic marls (Xerosols) and (iii) collapsible loess-derived soils (Luvisols). Most research on piping was performed on peat in the United Kingdom (e.g. Jones 1997) and dispersive material in the Mediterranean area (e.g. Farefteh and Soeters, 1999), while limited information exists about piping in loess-derived soils in temperate climate. However, observations made in Belgium (Poesen, 1989), Germany (Hardenbicker, 1998; Botschek et al., 2002) and Hungary (Kerényi, 1994) reveal the importance of piping in this context. As there is still uncertainty about the topographic and soil properties triggering subsurface pipe development in collapsible soils in temperate climate, this research aims at better understanding the main factors controlling piping in the loess-derived soils in Belgium.

MATERIAL AND METHODS

Study area

The 179 km² study area for this research is situated in the Flemish Ardennes (Belgium; Figure 1). It corresponds to a maritime temperate humid climate with mild winters and an average annual rainfall of about 800 mm, well distributed over the year. It is a hilly region with altitudes ranging from 10 m a.s.l. in the valley of the river Scheldt to 150 m a.s.l. on the hills. Less than 0.5% of the area has a slope gradient steeper than 20%. Most valleys are asymmetric with the steepest slope sections located on slopes facing south to northwest (Vanmaercke-Gottigny, 1995). The Tertiary lithology consists of an alternation of sands and less permeable clays, covered by Quaternary loess (Jacobs et al., 1999; Table 1). Weathering of the loess resulted in loamy soils (i.e. Luvisols and Albeluvisols). Many springs and a high drainage density characterize the hydrology of the region. Cropland is located on the loess-covered plateaus of the lower hills, and pastures dominate on gentle and moderately sloping hillslopes. The Tertiary hills and the steepest hillslopes are forested.

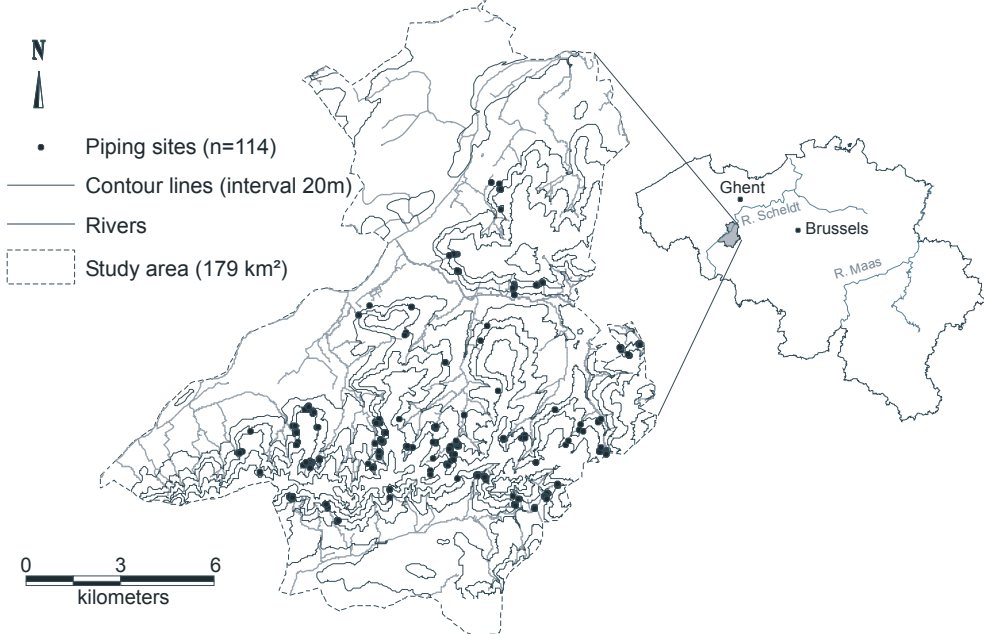


Figure 1. Map of the study area with indication of the 114 sites with 301 collapsed pipes (left) en the location in Belgium (right).

Mapping piping and controlling factors

Orthophotos (1:12 000; AGIV, 2006) were analyzed and the sites with signs of collapsed roofs of pipes were selected for an intensive field check. Furthermore, farmers and local technical services were interviewed. The field survey focused on pasture but the enquiries was also asked for piping under arable land. The forests within the study area were checked for piping during recent research on landslides (Van Den Eeckhaut et al., 2007). In total, 114 parcels having over 300 collapsed pipes were mapped with GPS (Trimble 2005 GeoXT). Topographical variables such as hillslope gradient and aspect were derived from the LiDAR data (Light Detection And Ranging; DEM of Flanders, 2005) using the standard routines available in IDRISI Andes. A more detailed discussion about the LiDAR data can be found in Van Den Eeckhaut et al. (2007). Information on lithology and soil was derived from the Tertiary geological map (1:50,000; AGIV, 2001) and the soil map (1:20,000; AGIV, 2001) respectively, both converted to raster data with a 10 m resolution.

RESULTS AND DISCUSSION

The number of sites with piping mapped during the field survey was twice those mapped by analyzing the orthophotos. The collapsed pipes were not visible on the orthophotos because of their small size, because they were filled up when photos were taken, because they were more recent than the photos or because they were obscured by the shadow of trees or other obstacles. The land use of 94% of the sites with piping is pasture, while only 4% and 2% occurs under arable land or forest respectively. Figure 1 shows that the collapsed pipes are preferentially located on the hillslopes and less in the valley-bottoms and plateaus. In the study area, piping occurs on slopes between 2% and 31%, with a sharp increase in the frequency of piping on slopes with gradients exceeding 8% (Figure 2(a)). As piping occurs on a wide range of slope gradients (Jones, 1981), it is more common to consider minimum and maximum thresholds. On very steep slopes infiltration generally decreases due to an increase of surface runoff. Moreover, there is a greater probability that mass movements occur, destroying subsurface pipes (Farefteh and Soeters, 1999). Strikingly more piping occurs on slopes facing to the west, similarly to the presence of the landslides in the area (Van Den Eeckhaut et al., 2007). These slopes are steeper, because of the abovementioned valley-asymmetry, and probably also wetter as rains in Belgium are dominantly coming from the west (Brisson et al., Submitted). The areas with the Aalbeke Member (> 50% smectite clay) under the shallow loess cover are most prone to piping. More than 28% of the sites with piping are located on this lithologic layer, while this covers only 8% of the study area (Figure 2(b)). The rest of the collapsed pipes are located on two lithologic layers that contain clay as well as silt and sand, covering a great part of the study area. Soil texture, drainage class and profile development seem to be of less importance. The texture of the soils with piping ranges from silty-clay loam to sandy loam. Moderate wet soils are favoured above very wet or dry soil. The high frequency of piping on soils with no profile development indicates that colluvium is more susceptible for piping, but this is partly due to the location of colluvium in the landscape (lower part of hillslopes, suitable for piping).

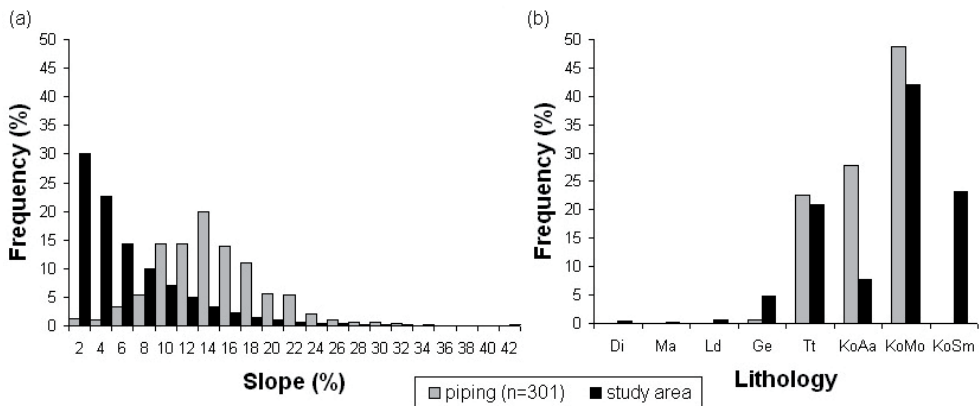


Figure 2. Distribution of slope (a) and lithology (b) for all mapped piping features and for the whole study area.

Lithologic layers: *Diest* (Di) glauconitic sand; *Maldegem* (Ma) clay and glauconitic sandy clay; *Lede* (Ld) sand; *Gent* (Ge) glauconitic sand and clay with sand lenses; *Tielt* (Tt) glauconitic clayey sand, with clay and lithified sand layers; *Aalbeke* (KoAa) homogeneous blue massive clay; *Moen* (KoMo) clayey silt to sand with clay layers; *Saint-Maur* (KoSm) silty clay.

CONCLUSIONS

The use of orthophotos taken at optimal field conditions (winter) allows the detection of piping in open landscapes. However, field surveys are still necessary. Land use plays an important role as 94% of the sites with piping are found under pasture. The probability of piping increases rapidly on slopes with gradients exceeding 8%. The areas with the Aalbeke Member, a relatively thin layer of homogenous blue massive clays, under the shallow loess cover are most prone to piping.

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