Abstract: In our studies the human impact on landscape evolution in modern history could be documented in detail for a loess area south of Pinczów. Mainly pedological and geomorphological investigations were carried out in the research area. Focusing on gully development, the dynamic changes of erosion and accumulation within the catchments were reconstructed, concluding that human activity, such as deforestation and agricultural use, resulted in the irreversible degradation of the land surface. The increase of population during the last two centuries in combination with extensive land use changes and the subsequent loss of forest cover induced a rise in erodibility. The suitability of the soil for arable cropping can be regarded as one of the main reasons for the deforestation. Due to agricultural use and the multiplicity of farm tracks the natural stability of soils has been under constant degradation.

Key words: land use change, human impact, soil erosion, soil degradation, gully erosion, Małopolska, Poland

Introduction

Since the Neolithic Age the loess landscape south of Pinczów is affected by human impact. Thereby, phases of deforestation and a subsequent intensive agricultural use can be correlated with the appearance of stronger sheet and linear erosion processes. The aim of this work is to assess human induced landscape changes and their effects on relief forming processes as well as on soil development.

Research area

The research area is located in the Makroregion Niecka Nidziańska, around 50 kilometres northeast of Kraków (fig. 1). Investigated catchments and study sides belong to the eastern part of Garb Wodzisławski, a loess area with an average thickness of loess about 10 to 15 meters. Lessivé (Luvisol), brown soil (Cambisol) and Chernozem are the dominating soil types whereas strong degraded or almost completely eroded soils are common in the research area. Today, the landscape is characterized by a traditional land use system (fig. 1).

Methods

Field methods in accordance with those of the four-dimensional landscape analysis framework are used to assess the landscape changes. To identify and quantify surface forming processes (fig. 2), a detailed pedological and geomorphological survey was carried out in the research area. Additionally the occurrence and distribution
of soils and the rate of land degradation was investigated. A GIS based analysis of historical maps to investigate the loss of forest cover, documents and photographs about historical settlements and land use changes as well as the analyses of aerial images and remote sensing data complement the findings of field survey. Furthermore, interviews with land owners and farmers gave additional information about the land use changes.

![Fig. 1. Location of study area in Poland and traditional land use pattern in the catchment near Słaboszów](Photo: Schmidt 2006)

![Fig. 2. Active gully erosion in the catchment near Słaboszów](Photo: Adler 2005)

**Results**

**Cultural history**

The loess areas in the south of Poland are the oldest, agriculturally used ones in Poland (Dobrowolska 1961). The first permanent settlements in the research area are dated back into 5380-4580 BC (Kruk et al. 1996). For several cultures of Neolithic Age the intensity of human impact can be determined only by the localisation and size of settlements, their mode of life as well as the structure of households (Kruk et al. 1996). The settlements and land use changes of the Funnelbeaker culture (3790-3060 BC) brought the first massive environmental changes on the loess plateaus and slopes. This is documented, for instance, by the malakozoological investigations from Alexandrowicz (Kruk et al. 1996). The following cultures of Bronze and Iron Age are documented less exact because of a lack of archaeological findings (Tunia 1997). The decrease of settlements and population during this time can be regarded as the main reason. The same facts may be accepted for the Roman times (Dobrzańska 1997). The lack of knowledge about the population and the chronology, structure and function of settlements makes it more difficult to assess the human impact. Another period of intensive agricultural use in combination with deforestation is proved for the Middle Ages and afterwards. Enquiries about the settlements suggest that most of the recent villages were founded in the 14th century. Additionally, historical papers with landscape descriptions and the name of the village Działoszyce (Działoszyce → Zalesice → ‘les’ → ‘las’ = forest), located in the study area, document the huge forest areas in historical times (Sznajderski 2004). The largest increase in population and land use is confirmed approximately for the period between the 1830s and 1920s (Schmidt 2007, Schneider et al. 2011).
Pedological survey

31 excavations and 98 drillings were carried out to analyse the distribution of sediments and soils within the study area. An assortment of profiles presented below sums up important results in different catchments.

The catchment in Izykowice is characterised by strong soil degradation. Denudation processes eroded the fertile humus topsoil of Chernozems and Cambisols. Profiles near the watershed are highly degraded. Profiles next to the gully are overlain by colluvial sediments up to 60 centimetres in thickness. The profiles at the base of the gully show many different colluvial layers. The excavation Pi06-050 (fig. 3) is situated at the alluvial fan of this gully. The horizon IV-M of this profile is characterised by a high ratio of marl debris. The transport capacity for such debris has to be high. According to this it may be regarded as the sediment layer accumulated by the first massive gullying processes at this place in the middle of the 19th century.

Within the catchment in Szyszczycyce up to 3 metres of colluvial sediment could be identified in the depth contour of the dry valley. Investigations show that relocations of sediment are still in progress. At the slopes degraded Luvisols and Cambisols were investigated. There, in most cases the farmers plough in the illuvial horizon of Luvisol and sometimes already in the calcareous loess – the parent material of soil development.

Excavations and drillings in the catchment north of Słaboszów show similar results (Heinrich and Krüger 2005, Schmidt 2007, Schüttoff 2008). Degraded and eroded soil profiles are widespread on the slopes. The excavation Pi06-054 (fig. 4) is situated next to a road gully. The remains of partly banded illuvial horizon of Luvisol are overlain by colluvial sediments. The former eluvial topsoil of Luvisol was eroded (fig. 4). Rendzinas (Rendzic Leptosols) on Mesozoic marlstone are intersected at the steep slopes, exposed to the west.

Distribution of land degradation

Geomorphological field investigations and the interpretation of topographical and soil maps as well as of remote sensing data show that the appearance of gullies and road gullies in the study area is highly connected with the relief and the distribution of sediments (Heinrich and Krüger 2005). In the sandy northern parts of Niecka Nidziarska less spectacular forms exist, whereas the number and size of erosion forms is larger in the southern loess areas. Additionally, the hillier land surface of Garb Wodzisławski in the south is predestined for stronger
soil erosion processes (Schneider 2009). Occurrence and distribution of gullies and road gullies during the last 220 years were analysed with the aid of historical maps (approximately 1790 - 2010). Gullies are situated at the steep slopes of the loess plateaus next to the valley floors (fig 5). Most of them are located next to the favoured settlement places in historical times. Linear and dendritic gully systems are incised into the loess sediments. The slope angles within the gully systems measure about 25-35 degree. In most cases the gully edges are even vertical and the incision of the gullies reaches the base of loess sediments - Mesozoic limestone and marlstone. In spite of these slope angles the vegetation cover prevents the deposition of sediment. Currently almost all gullies are stabilised by a dense vegetation/forest cover. During the last decades relocations of sediment can be observed above all next to the gully heads (Ostaszewska et al. 2011). Otherwise, in almost all road gullies the translocation of huge amounts of sediment, already during low rainfall events, is caused by current agriculture.

Historical maps show that there is no gully north of Słaboszów until 1890 (fig 5). Investigations confirm that the entire gully developed in the 20th century. The initial structure for erosion processes was a farm track and later on an artificial canal (cf. Schmidt 2007) along the depth contour of the dry valley. The catchment occupies an area of about 10 square kilometres. 80% is used by agriculture (fig 1). Field survey shows that already during low rainfall events erosion processes on the land surface can be observed (cf. Schmidt 2007). Today, the linear gully north of Słaboszów is around 700 metres long and currently active (fig 2). The last 100 metres up to the gully head were formed between 1995 and 2004. Several years with heavy rainfall events caused the extension of the gully. The reconstruction of several erosion events for the last century was the basis for the calculation of the volume of the translocated sediment (Schmidt 2007, Schmidt and Heinrich 2010, Schmidt and Heinrich 2011).

The total gully system in Słaboszów was measured in length, width and height. These cross-sections are necessary to calculate the volume for several gully segments. Including all information about land use history, the translocated sediment volume for each of the identified erosion events affecting this gully was calculated (table 1). A heavy rainfall event in 1937, for instance, eroded approximately 22 000 cubic metres of sediment. The results for 1995, 2004 and 2010 are estimated and based on interviews and field survey.

Table 1. Calculated sediment volume of the gully north of Słaboszów

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>length of the entire gully [m]</td>
<td>270</td>
<td>420</td>
<td>520</td>
<td>(570)</td>
<td>610</td>
<td>700</td>
<td>(700)</td>
<td>(710)</td>
</tr>
<tr>
<td>length per erosion event [m]</td>
<td>-</td>
<td>150</td>
<td>100</td>
<td>50</td>
<td>40</td>
<td>90</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>sediment volume per erosion event [m³]</td>
<td>10 855</td>
<td>22 668</td>
<td>3510</td>
<td>(1000)</td>
<td>5396</td>
<td>4800</td>
<td>(500)</td>
<td>(150)</td>
</tr>
</tbody>
</table>

**Forest cover and land use change**

The following examples sum up the results of the GIS based analysis of historical and topographic maps (approximately 1790 - 2010) to investigate the loss of forest cover and land use change. In Izykowice the investigated catchment is used for agriculture since more than 200 years. After massive erosion processes in the first half of the 19th century the entire gully is covered by forest (cf. fig. 5). Soil excavation in and around the gully (cf. fig. 3) prove that until today there was no more gully erosion process within this catchment.

The oldest available map (around 1790) of the surrounding of Szyszczycyke shows huge forest areas. But the historical map also clearly shows the signature of an older gully under this forest. The first modern forest clearance in the catchment in Szyszczycyke can be observed on the map of 1890. Land use change during 19th and 20th century reactivated gully erosion processes within this catchment as a result of the spreading agriculture. Already in 1936 the forest area reached its current size. Only few trees at the edges of the erosion form appear later.
Up to the end of the 19th century the catchment in Słaboszów is 50% covered with forest (cf. fig. 5). During a period of only 46 years it decreased to less than 10%. This is one of the reasons for the gully erosion processes in this catchment (see above). New small forest areas at steep slopes led to an increase up to 13% during the last decade. For the entire study area maps show that the intensive agricultural exploitation in the second half of the 19th and the first decades of the 20th century caused a massive deforestation.

With the aid of a GIS-based survey the quantitative detection of land use change is possible through a multi-temporal comparison of different maps. Table 2 shows the results for two areas. The tendencies of the qualitative land use analysis can be confirmed by the statistical assessment of vegetation cover. The highest values (37.01% and 47.43%) are detected for 1830. During the following one hundred years this ratio decreased to nearly half of it (1936: 18.97% and 23.61%). Depending on the considered scale in 1982 around 20% up to 25% of land is covered with forest (cf. table 2). In spite of decreasing forest ratios, the total number of forest areas always rises. According to this the size of the average forest area has to diminish consequently (table 2).

These fragmented forests within the study area are mostly situated near the gully systems, road gullies or in the wet floodplain areas. There are different ways of origination. On the one hand, these fragments resulted from successive forest clearance during the period of intensive agricultural use, starting around 1830. On the other hand, forest fragments arise in the surrounding of erosion forms, near settlements as private forest and orchard as well as in recent time on infertile land (cf. Schmidt 2007). In the sandy northern parts of the study area larger forest areas still exist, although these areas represent only a relict of the former widespread forest areas. Analyses of the historical maps show that parts of them have been forest during the last 220 years.

**Conclusion**

Investigations prove the causal correlation between human impact and landscape changes. In the second half of the 19th and the first decades of the 20th century intensive agricultural exploitation caused massive deforestation. Investigations showed that the occurrence of alluvial and colluvial sediments can be correlated with periods of intensive land use or settlement activities. Future studies will have a stronger focus on the development of typical soils and their distribution as well as on special pedological phenomena.
Table 2. Results of the statistical analyses of forest cover

<table>
<thead>
<tr>
<th>Area 1 (total: 264.58 square kilometres)</th>
<th>year</th>
<th>total of all forest areas [km²]</th>
<th>forest area ratio [%]</th>
<th>total number of forest areas</th>
<th>average forest areas size [km²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1790</td>
<td>80.65</td>
<td>30.48</td>
<td>20</td>
<td>4.0324</td>
</tr>
<tr>
<td></td>
<td>1830</td>
<td>97.91</td>
<td>37.01</td>
<td>53</td>
<td>1.8474</td>
</tr>
<tr>
<td></td>
<td>1890</td>
<td>81.27</td>
<td>30.72</td>
<td>60</td>
<td>1.3545</td>
</tr>
<tr>
<td></td>
<td>1936</td>
<td>50.19</td>
<td>18.97</td>
<td>81</td>
<td>0.6196</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1790</td>
<td>16.91</td>
<td>34.96</td>
<td>5</td>
<td>3.3818</td>
</tr>
<tr>
<td></td>
<td>1830</td>
<td>22.94</td>
<td>47.43</td>
<td>11</td>
<td>2.0855</td>
</tr>
<tr>
<td></td>
<td>1890</td>
<td>20.57</td>
<td>42.54</td>
<td>15</td>
<td>1.3716</td>
</tr>
<tr>
<td></td>
<td>1936</td>
<td>11.42</td>
<td>23.61</td>
<td>22</td>
<td>0.5189</td>
</tr>
<tr>
<td></td>
<td>1959</td>
<td>10.97</td>
<td>22.68</td>
<td>51</td>
<td>0.2150</td>
</tr>
<tr>
<td></td>
<td>1982</td>
<td>12.67</td>
<td>26.20</td>
<td>202</td>
<td>0.0627</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area 2 (total: 48.36 square kilometres)</th>
<th>year</th>
<th>total of all forest areas [km²]</th>
<th>forest area ratio [%]</th>
<th>total number of forest areas</th>
<th>average forest areas size [km²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1790</td>
<td>16.91</td>
<td>34.96</td>
<td>5</td>
<td>3.3818</td>
</tr>
<tr>
<td></td>
<td>1830</td>
<td>22.94</td>
<td>47.43</td>
<td>11</td>
<td>2.0855</td>
</tr>
<tr>
<td></td>
<td>1890</td>
<td>20.57</td>
<td>42.54</td>
<td>15</td>
<td>1.3716</td>
</tr>
<tr>
<td></td>
<td>1936</td>
<td>11.42</td>
<td>23.61</td>
<td>22</td>
<td>0.5189</td>
</tr>
<tr>
<td></td>
<td>1959</td>
<td>10.97</td>
<td>22.68</td>
<td>51</td>
<td>0.2150</td>
</tr>
<tr>
<td></td>
<td>1982</td>
<td>12.67</td>
<td>26.20</td>
<td>202</td>
<td>0.0627</td>
</tr>
</tbody>
</table>

References


Maps

Topographic map of Miechów [Nr. 3864] 1890: scale up of the German map 1:100.000, Abteilung der Königlich Preußischen Landesaufnahme (ed.) 1914: Karte des westlichen Russlands 1:100.000, based on Neue Topographische Karte des westlichen Russlands 1:84.000 and 1:42.000 (survey: 1890), (location of source: library of the Faculty of Geography and Regional Studies, University of Warsaw).