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Environmental & Socio-economic Studies

environ

DOI: 10.2478/environ-2020-0010

Environ. Socio.-econ. Stud., **2020, 8, 2: 32-44**

Review article

Outline of the development of research on the impact of Neolithic settlements on the transformation on loess landscapes in southern Poland

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ABSTRACT

During the last few decades, many case studies have focused on landscape transformations in response to water erosion, human impact, and climate changes. This article presents a review and comparison of the current state of knowledge on conducted research on the impact of the activities of early humans on the relief and forms of loess areas in Poland based on the results of a variety of dating methods (OSL, TL, C^{14}, ^{137}Cs, palynology, dendrochronology etc.). The influence of land-use activity since the first permanent settlements (8,000–5,200 BP) played a major role in the development of certain sand sediment terrain forms: gullies, river terraces, the filling of isolated depressions and alluvial fans in the loess areas. As a result, a simplified scheme of landscape evolution was created along with a map of the most investigated areas by authors. The main problem was to differentiate the influence of anthropogenic factors from natural ones occurring either simultaneously or alternatively. The developed deposits form a geo-archive which has recorded the history of environmental changes. A detailed analysis of the sedimentary structures provides the possibility to reconstruct and understand past functional responses in natural systems. It is important to consider the impact of climate change and human influence over the course of history on a specific geomorphological system. This can help to predict future land changes and likely hazards.

KEY WORDS: loess, geo-archive, human impact, land use change

ARTICLE HISTORY: received 11 February 2020; received in revised form 3 May 2020; accepted 14 May 2020

1. Introduction

Climate changes in the Holocene associated primarily with a rise in temperature and the emergence of permanent vegetation (forest) have influenced changes in the transfer of sediments from slopes to valley bottoms. Climate warming has contributed to the stabilisation of slopes and the transformation of riverbed systems from braided to meandering (STARKEL ET AL., 1996; STARKEL, 1997). These natural processes occurring in the slope-valley system, although stimulated by climatic processes, have also been modified and disturbed by human activity (DOTTERWEICH, 2008). The emergence of hunter-gatherers did not fundamentally affect the modification of these natural processes. It was only human activity in the Neolithic, characterised by sedentary lifestyles, deforestation, cultivation of plants, animal husbandry, and permanent settlements, which significantly transformed the natural flow of water and sediments in valley ecosystems.

The Neolithic colonisation of Europe was a transitory process that began in the south and gradually spread, along with climatic changes, to the north (KRUK ET AL., 1996; KRUK & MILISAUSKAS, 1999). Humans migrated from the south through the Moravian Gate and other passages in the Sudetes and Carpathians in search of fertile soils and new areas for cultivation. Deforestation and land use resulted in increased soil erosion (ŚNIESZKO, 1985). Anthropogenic changes have been observed mainly on the loess plateaus of southern Poland (KRUK ET AL., 1996). Colluvial sediments, contributing to alluvial fans, can be found in systems of small, dry valleys as a result of anthropogenic activity from the Neolithic period (ZYGMUNT ET AL., 2006; ZYGMUNT, 2009; SUPERSON ET AL., 2014). The range of the first Neolithic cultures in the first phase of expansion (8,000–5,200 BP) mainly includes areas of loess (Fig. 1): the Głubczyce Plateau, the Carpathian Foothills, and the Sandomierz and Lublin Uplands (KRUK, 1972, 1987; KRUK & MILISAUSKAS, 1999). In the resulting forms and sediments, one can often find a record of changes in the use of land by humans. Sedimentary structures and soil levels contain a record of temporal and spatial transformations of relief, creating a kind of geo-archive, which, along with thorough analysis and simultaneous comparison with archaeological and palaeogeoecological data and the history of a given region, will show the degree of interaction between humans and the environment on a regional scale (DOTTERWEICH ET AL., 2012).

The aim of this article was to review and compare the existing literature on the influence of settlements and activities of Neolithic settlers on the transformation of the relief of loess areas from the point of view of sedimentological and geomorphological research.

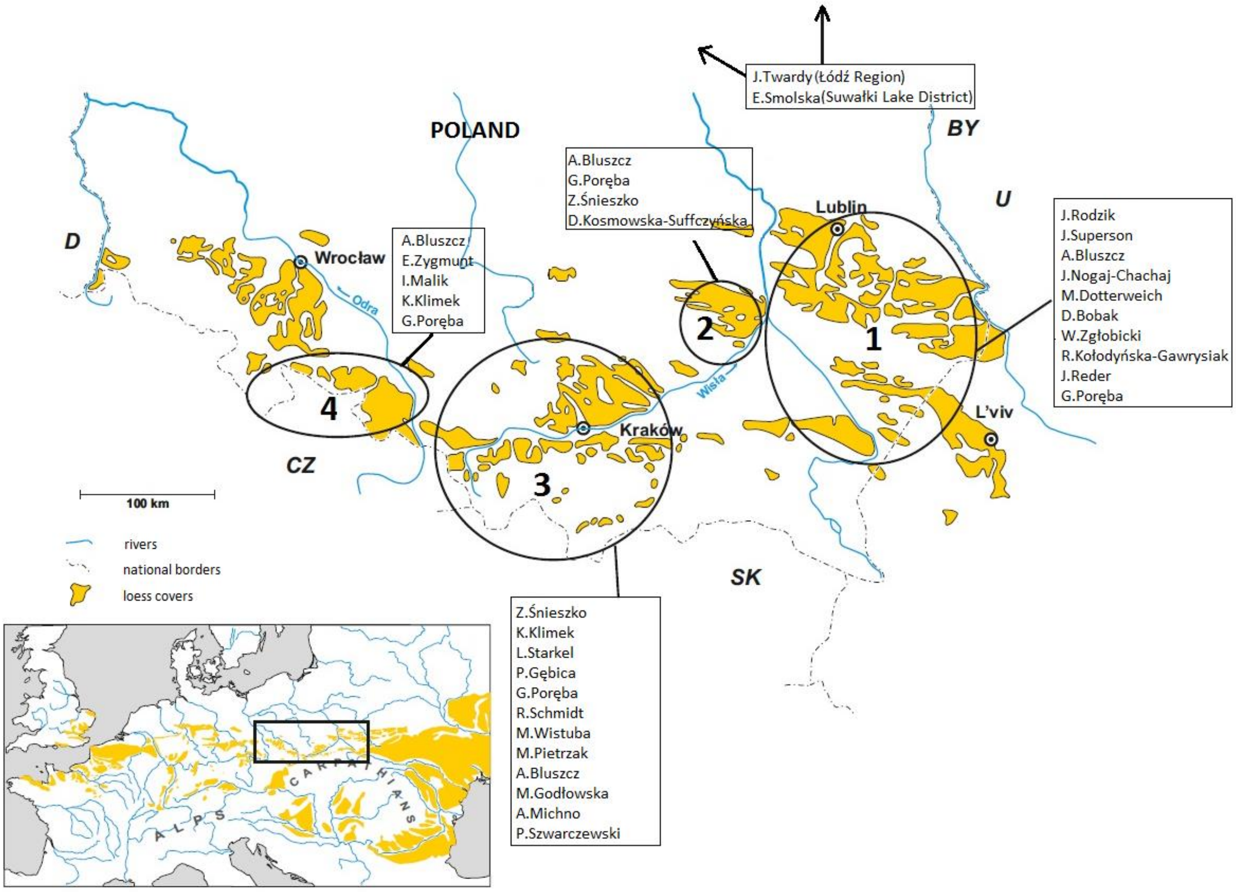

Fig. 1. The localization of the study areas described in the reviewed literature: 1 – Lublin Upland; 2 – Sandomierz Upland; 3 – Carpathian Foreland; 4 – Głubczyce Plateau (after Mroczek, 2013, modified)

1.1. The issue of the Neolithic Age

The term *Neolithic*, from Greek *neolithos*, means ‘new stone’, and is used in this case to mark a chronological age whose beginning is associated with the appearance of the first agricultural and peoples in the area or their direct influences (WIŚLAŃSKI, 1979a, b). Someone wishing to locate the Neolithic period in Poland in terms of time should review the entire chronology and periodisation of prehistory and early-historical times established to date. Based on the elaboration of time frames (Table 1), after GODŁOWSKI & KOZŁOWSKI (1985) and KACZANOWSKI & KOZŁOWSKI (1998), changed by ZYGMUNT (2007) it can be seen that the periodisation of Polish history covers three epochs: Stone, Bronze, and Iron Age. The basic criteria of periodisation were the main resources for tool production and food acquisition (economy), which are of a universal character. In addition to the basic criteria, so-called additional criteria of regional significance included raw materials (e.g., the production of ceramics and the beginning of metal-copper use for the production of tools), regional changes in the natural environment/climate (Ice Age) but also important historical events that have been written down (e.g. the influence of the Roman Empire and the Migration Period after the fall of the Empire) (Kozłowski & Kaczanowski, 1998).

In the past few decades, researchers have taken up the problem of relationships between prehistoric settlements and economy and the geomorphological development under the conditions prevailing in an environment increasingly transformed by humans. However, it is difficult to distinguish the impact of natural factors (e.g. climate fluctuations in the Holocene) from anthropogenic factors (Starkel, 2005b, 2006), which very often synchronously affected the evolution of the relief (Twardy, 2013).

Geoarchaeological and palaeogeographical studies of all kinds make it possible to correlate sediments of alluvial fans, dry valleys, slopes, and river terraces of loess areas with human activities from the Neolithic period (Klimek, 2002, 2003; Kruk, 1972, 1987; Kruk et al., 1996).

Table 1. Periodisation of the history of Poland (after Godłowski & Kozłowski, 1985; Ostoja-Zagórski, 1998)

<table>
<tr><th>Chronology</th><th>Geological period</th><th>Epoch</th><th>Period</th><th>Economy</th><th colspan="3">Main raw materials</th></tr>
<tr><td>First half of the 10th century AD</td><td rowspan="14">Holocene</td><td>Historical centuries</td><td>Middle Ages</td><td rowspan="13">Manufacturing; agricultural (farming, breeding)</td><td rowspan="13">Ceramics: production of dishes/vessels</td><td rowspan="6">iron</td><td rowspan="10"></td></tr>
<tr><td>570 AD</td><td rowspan="5">Iron Age</td><td>Early Middle Ages</td></tr>
<tr><td>375–450 AD</td><td>Migration Period</td></tr>
<tr><td>1 AD</td><td>Roman influences/Roman</td></tr>
<tr><td>400 BC</td><td>La Tène/Pre-Roman</td></tr>
<tr><td>700–650 BC</td><td>Hallstatt</td></tr>
<tr><td>800 BC</td><td rowspan="5">Bronze Age</td><td>V</td><td rowspan="4">bronze</td></tr>
<tr><td>1000 BC</td><td>IV</td></tr>
<tr><td>1200 BC</td><td>III</td></tr>
<tr><td>1400 BC</td><td>II</td></tr>
<tr><td>1900–1700 BC</td><td>I</td><td rowspan="5">stone</td><td rowspan="2">copper</td></tr>
<tr><td rowspan="2">5200 BC</td><td rowspan="4">Stone Age</td><td>Eneolithic</td></tr>
<tr><td>Neolithic</td><td rowspan="3"></td></tr>
<tr><td>8000 BC</td><td>Mesolithic</td><td rowspan="2">Absorbable: hunting-gathering, fishing</td><td rowspan="2"></td></tr>
<tr><td>250,000–180,000 BC</td><td>Pleistocene</td><td>Palaeolithic</td></tr>
</table>

2. The purpose and scope of the research

The aim of this article was to analyse and compare previous articles on the impact of anthropogenic activity on the transformation of loess areas of Poland since the Neolithic period in terms of sedimentology and to point out the absence of this type of research in loess areas of south-western Poland (Niemcza-Strzelin and Trzebnica Hills), previously analysed only for archaeological purposes. This article focuses on the issue from the geomorphological and sedimentological viewpoint, that is, the role of human activity in modifying the course of natural geomorphological processes that led to the creation of specific landforms and of the sediments that built them.

The migration of peoples from the south to the north was facilitated by the relatively low altitude of the Sudetes and their relief: flattened mountains, gentle slopes, passes, numerous valleys and valley depressions, and above all the passages of the Eastern Neisse and the Moravian Gate (Kulczycka-Leciejewiczowa, 1993). The nearest areas in which palaeogeographical studies related to the Neolithic were carried out are the Głubczyce (ZYGMUNT, 2004, 2009; ZYGMUNT ET AL., 2006; PORĘBA & MURRAY, 2006) and Proboszczów Plateaus and the Raciborz Basin (KLIMEK, 1996; MALIK, 2006; PORĘBA ET AL., 2011, 2012, 2014). The articles published previously on the subject of the transformation of relief by humans since the beginning of neolithisation in Polish territory omit the area of Lower Silesia, which has become in this respect a so-called 'white spot' among other loess areas.

3. Impact of human activity on the transformation of loess highlands

Many researchers have attempted to analyse and describe the problems of human influence on the development of the relief of loess areas. A series of discussions has been undertaken in relation to the problems of human influence on landscape transformation and definition of the time frame of the beginnings of Neolithic agriculture, especially in loess areas (JERSAK & ŚNIESZKO, 1987; ŚNIESZKO, 1995; KRUK, 1972, 1987; KRUK ET AL., 1996; KLIMEK, 2002, 2003) and other regions of Poland (TWARDY, 1995, 2008, 2009; SMOLSKA, 2007, 2012). The forms that have been studied are mainly alluvial fans, valley bottom sediments, loess colluvium, slope covers, and river and lake sediments. In order to determine the age of sediments, radiocarbon dating has been used, mainly with the support of other methods such as palynology, dendrochronology (MALIK, 2006), geochemistry (ZGŁOBICKI, 2008), and OSL and ^{137}Cs (BLUSZCZ ET AL., 2007; PORĘBA & BLUSZCZ, 2006 a, b; PORĘBA ET AL., 2011, 2012, 2018, 2019) (Table 2).

Table 2. Comparison of conducted research on impact of human activities on the loess landscapes in Poland

Authors (dates of publications)	Region, investigated area	Type of sediment, processes	Methods to determine the age of the sediment	Neolithic influence on the transformation of relief forms
Śnieszko, 1985, 1987, 1995; Śnieszko & Gygierczyk, 1991	Miechów Upland (Sancygniówka), Malopolska Upland	Loess diluvium	C^{14}, palynology	Valley bottom sediments, gullies, river sediments, mud
Klimek, 1987, 1988, 1996, 2002, 2003; Klimek & Latocha, 2007; Klimek et al., 2001, 2006	Carpathian and Sudeten Foothills, Upper Oder Valley, Rybnicki Plateau	Alluvial sediments	C^{14}, OSL, palynology	Valley bottom material, slope covers, alluvial fans
Twardy, 1995, 2008, 2013	River valleys of central Poland, Łódź, Rawska, and Piotrków Uplands	Alluvial sediments, slope diluvium	C^{14}, ceramic	River and slope sediments
Starkel, 1991, 2005, 2006, 2011	Carpathian mountain areas	Lake sediments, alluvial sediments, slope diluvium	C^{14} dendrochronology	River valleys bottom sediments, lake sediments
Gębica, 2013; Gębica et al., 2013	Carpathian Foreland	Slope sediments	C^{14}, palynology dendrochronology,	River valleys bottom sediments, terraces
Rodzik, 2010; Rodzik et al., 2014	Nałęczów Plateau, Lublin Upland	Loess diluvium	C^{14}, OSL	Gullies, alluvial fans, palaeo-depressions
Dotterweich et al., 2012	Nałęczów Plateau, Lublin Upland	Loess diluvium	C^{14}, artefacts	Natural gullies, road gullies, soil development
Superson & Zgłobicki, 2005; Superson et al., 2003, 2011, 2014, 2016	Lublin Upland, Nałęczów Plateau	Loess diluvium, alluvial sediments	C^{14}	Gullies, alluvial fans, valleys
Zgłobicki & Zgłobicka-Baran, 2008, 2010, 2015; Zglobicki et al., 2014, 2015	Lublin Upland (the intersection of the Vistula and Bystrzyca)	Loess diluvium, slope and alluvial sediments	C^{14}, ^{137}Cs, geochemistry statistics, cluster analysis	Gullies, alluvial fans
Bobak et al., 2017	Carpathian Foreland, Nałęczów Plateau	Loess diluvium	C^{14}, TL, OSL, Flint artefacts	Colluvium
Kołodyńska-Gawrysiak & Bienia, 2010; Kołodyńska-Gawrysiak et al., 2011, 2015, 2017	Nałęczów Plateau, Lublin Upland	Loess diluvium, colluvium	C^{14}, OSL, palynology, maps	Closed depressions
Poręba & Bluszcz, 2006 a, b; Poręba & Murray, 2006; Poręba et al., 2011, 2013, 2014, 2018, 2019	Carpathian, Raciborz Cirque, Proboszczowicka Plateau, Sandomierz Upland, Głubczyce Plateau, etc.	Loess diluvium,	OSL, C^{14}, ^{137}Cs, ^{210}Pb, dendrochronology	Colluvium, soils, valley bottom sediments
Zygmunt, 2004, 2007, 2009; Zygmunt et al., 2006	Głubczyce Plateau	Loess diluvium	C^{14}, palynology	Alluvial fans
Michno, 2002, 2004, 2008, 2013	Upland, Proszowicki Plateau, Małoszowka Catchment, Nidzica Valley	Slope and river sediments	Sediment analysis and comparison with archaeological data, C^{14}	Valley bottom sediments

Szwarczewski, 2007, 2009	Miechów Upland, Proszowicki Plateau, Wodzisław Hump (Chroberz)	Loess diluvium	C^{14}	Alluvial fans
Schmidt et al., 2011	Nidziańska Basin	Loess diluvium	Surveys, maps, GiS, archaeological analysis, comparison	Gullies, soil development
Smolska, 2007, 2012	Suwałki Lake District	Slope sediments	C^{14}, geochemistry	Erosion slits, gullies, fans
Malik, 2006	Silesian Upland (Tarnogóra Hump, Proboszczowicka Plateau, St. Anna Mt,)	Loess cover	Dendrochronology	Gullies, erosion slits
Wistuba et al., 2018	Carpathian Mts	Alluvial sediments	C^{14} , ^{137}C, ^{210}Pb, dendrochronology	River terraces
Bluszcz & Pietrzak, 2001; Bluszcz et al., 2007	Lublin Upland, Sandomierz Upland, Malopolska Upland, Glubczyce Plateau	Loess diluvium, slope sediments	C^{14} , ^{137}Cs, OSL, TL	Slope, valleys
Pietrzak, 1998, 2000, 2002	Carpatian Foothils	Deluvial sediments, slope	Historical and archaeological data	Valleys, slopes
Reder et al., 2010	Nałęczów Plateau, Lublin Upland	Alluvial sediments	Historical and archaeological data, C^{14}	River valley sediments
Nogaj-Chachaj, 1998, 2004, 2006	Nałęczów Plateau	Deluvial sediments	Archaeological data, C^{14}	Valley bottoms sediments, burial forms
Godłowska et al., 1987	Malopolska Upland, Pleszow	Fluvial/ alluvial sediments	Palynology, C^{14}	River valley bottom sediments, terrace
Kosmowska-Suffczyńska, 1983	Sandomierz Upland	Fluvial/alluvial sediments	C^{14}	Dry valley bottom

3.1. Loess areas

Loess deposits occur in Poland in the upland and foreland regions of the south. The distribution of Polish loess is characterised by various regularities which have been analysed by many authors, including JAHN (1950), JERSAK (1977), MARUSZCZAK (1991), JARY (1996, 2007, 2010), MROCZEK (2008) and MOSKA (2018). The most important regularity is an increase in the thickness and extent of loess patches from west (approximately 10 m deep) to east (up to 40 m deep). Accordingly, the term loess relief refers mainly to the eastern region of Poland. Areas of loess in Poland can be divided into three regions within the belt of the south-western highlands (Lublin, Sandomierz, and Cracow) and two in the foothills of the Carpathian and Sudeten Mountains (MARUSZCZAK, 1991).

Towards the end of the Pleistocene, grass and forests began to grow in loess areas along with the warming of the climate. Currently, proof of these conditions is furnished by degraded chernozems that occur locally on the surface of loess. In dry valley bottoms, they can be found as fossil soil under sediments associated with water erosion and mass movements (ŚNIESZKO, 1995). This erosion began in the Neolithic period as a result of the felling of forests and the cultivation of the land.

The soils covering the loess areas were among the first to be used agriculturally due to their fertility and ease of cultivation. However, they were very susceptible to water erosion processes (STARKEL, 1991). Loess areas are characterised by specific terrain relief. Characteristic features of a loess landscape may include dry or temporarily dry valleys intersected by networks of gullies created as a result of episodic rainfall events (ŚNIESZKO, 1995).

The oldest well documented traces of agricultural use of loess areas in Poland are dated from 5,000 to 4,000 BC (PORĘBA ET AL., 2011). Practically the entire loess region of southern Poland is contained within areas intensively colonised and constantly used by the first farmers and breeders. In connection with long-term human and natural influences on changes in relief and sediment formation, loess areas have long been an important field for research in archaeology, geomorphology, sedimentology, and geochemistry (ŚNIESZKO, 1995; KRUK & ŚNIESZKO, 1998; KRUK ET AL., 1996; KULCZYCKA-LECIEJEWICZOWA, 1993; NOGAJ-CHACHAJ, 1998, 2004, 2006; KLIMEK, 2002; KLIMEK ET AL., 2003; ZGŁOBICKI ET AL., 2003; STARKEL, 2005 a, b; SZWARCZEWSKI, 2009; ZGŁOBICKI ET AL., 2014). Thanks to interdisciplinary research, it is possible to correlate any changes taking place in the chemical composition, structure, and texture of sediments with the intensity of human activity from the Neolithic period (forest cutting, settlement, farming, grazing of animals) through the Bronze and Iron Ages (metal smelting) and the Industrial Revolution at the turn of the eighteenth and nineteenth centuries (increased production of heavy metals, contaminants) to the present day (^{137}Cs) (PORĘBA & MURRAY, 2006; SMOLSKA, 2007; ZGŁOBICKI & RODZIK, 2007; SZWARCZEWSKI, 2009).

3.1. Lublin Upland

The Lublin Upland is a region almost entirely covered by dense loess; therefore, research of this type is commonly conducted here. This area has already been described in terms of the characteristics of loess sediments (JERSAK, 1977; MARUSZCZAK, 1991; JARY, 2007; ŁANCZONT ET AL., 2014; MOSKA ET AL., 2018). In an interdisciplinary context, there have been numerous papers on gully systems within the Lublin Upland and the Naleczów Plateau (NAKONIECZNY, 1967; DOTTERWEICH ET AL., 2012; ZGŁOBICKI ET AL., 2014; SUPERSON ET AL., 2011, 2014, 2016) (Fig. 1, Table 2). RODZIK ET AL. (2014) and BOBAK ET AL. (2017) presented the influence of a hunter-gatherer culture on the loess of the Magdalenian (seasonal) settlement. According to the previously mentioned researchers, the transformation of the relief caused by humans in this area began during the Neolithic revolution, approximately 7,500 years ago; the subsequent phases of agricultural expansion (logging) and regression (reforestation) were recorded in the properties of sediments such as changes in grain size structure, geochemistry (e.g. heavy metal content), or organic matter content. The results of these studies are based on a detailed analysis of processes, sediments, and terrain forms along with historical, archaeological and palaeoecological data (NOGAJ-CHACHAJ, 1998, 2004, 2006; SCHMITT ET AL., 2006; REDER ET AL., 2010; RODZIK, 2010; DOTTERWEICH ET AL., 2012; SUPERSON & ZGŁOBICKI, 2005; SUPERSON ET AL., 2014). Several papers have been devoted to terrain forms such as closed depressions, which, according to the relevant analyses, were created by natural and anthropogenic processes in loess e.g. piping (KOŁODYŃSKA-GAWRYSIAK & BIENIA, 2010; KOŁODYŃSKA-GAWRYSIAK ET AL., 2011, 2017; RODZIK ET AL., 2014). Research was also aimed at analysing sediments from the bottom of the valleys in terms of the content of heavy metals, which, apart from natural factors, are also strictly related to human activity (ZGŁOBICKI & RODZIK, 2007; ZGŁOBICKI, 2008). These sediments constitute an excellent so-called sedimentological geo-archive reflecting past processes occurring there in (ZYGMUNT, 2009; DOTTERWEICH ET AL., 2012; ZGŁOBICKI & ZGŁOBICKA, 2011; WISTUBA ET AL., 2018).

3.2. Sandomierz Upland

Another loess region included in the Polish eastern Highlands is located on the west bank of the River Vistula near to Sandomierz. In this area mainly two sites were investigated: Czyżówka valley (KOSMOWSKA-SUFFCZYŃSKA, 1983; Śnieszko, 1995; Bluszcz et al., 2007) and Sieradowice (ŚNIESZKO, 1995; BLUSZCZ ET AL., 2007) (Table 2). A few dating methods were used on deluvial, proluvial deposits for a good comparison and to achieve a better interpretation of results. BLUSZCZ ET AL. (2007) indicate how important it is to compare the results dated with historical and archaeological data. KOSMOWSKA-SUFFCZYŃSKA (1983) highlights that the most extraordinarily rapid rate of deposit accumulation (in comparison to other periods) in the Czyżówka valley occurred in the modern period.

3.3. Carpathian Foothills (Małopolska and Niecka Nidzianska)

Loess in Małopolska and the Carpathian foothills has been an interesting area of research for geomorphologists and archaeologists for many years. In this area, links have been described between the impact of climate change and agricultural activity on the processes of soil erosion on the slopes and accumulation processes in the bottoms of river valleys (KLIMEK, 1987, 1988, 1996, 2002; KLIMEK ET AL., 2006; GODŁOWSKA ET AL., 1987; STARKEL, 1991, 2005a, b, 2006, 2011; PIETRZAK, 1998, 2000; BLUSZCZ & PIETRZAK, 2001; GĘBICA ET AL., 2013; PORĘBA ET AL., 2018, 2019) (Table 2).

STARKEL (1991, 2005, 2006) focused primarily on the interpretation of relationships between human activity, climate, and fluvial activity. KLIMEK (1987, 1988, 1996, 2002, 2003) and KLIMEK ET AL. (2001, 2006) described human expansion into mountain areas affecting all environmental components, while primarily analysing river sediments, slope diluvium, and alluvial fans. In areas north of Cracow, SCHMIDT ET AL. (2011) analysed loess colluvium in terms of human influence on the evolution of the present-day landscape, using no dating methods other than comparisons of maps and archaeological analyses. Nevertheless, their assumptions were similar, and they focused on how the gullies were created. Sediments were examined at their outlets for a record of human activities (felling of forests, agricultural use, soil degradation). They concluded that the increase in population over the past 200 years, along with significant changes in land use and subsequent deforestation, caused increased soil erosion.

The Miechów and Proszowice Plateau region can be regarded as a classic area of research on the human influences on the transformations of loess landscapes. Several researchers have attempted to describe the impact of human activity on the transformation of relief and the development of the diluvial deposits of this region (Table 2). Śnieszko (1985, 1987) addressed this issue as early as the 1980s, describing the sediments of the Sancygniówka Valley. Michno (2002, 2004, 2008, 2013) focused primarily on comparing the results of long-term archaeological research with analysis of slope cover and transformation of relief in terms of the impact of Neolithic humans in the region of the Małoszowka and Nidzica valleys. According to the author, the period of greatest human influence fell in the middle Neolithic. However, Szwarczewski (2007, 2009), investigating loess alluvial fans of the Wodzisław Hump (Chroberz) region, distinguishes several periods of intense human activity which were recorded in the form of changes in the type of sedimentation rate: the Neolithic period, the Iron Age, and the early Middle Ages.

3.4. Silesian Lowland

3.4.1. Głubczyce Plateau

The fertile loess areas of the Głubczyce Plateau were colonised by Neolithic peoples migrating northward quite early, due to the proximity of the Moravian Gate and other mountain passes. This colonisation was also associated with exceptionally favourable climatic and soil conditions in the region. The plateau was described by Klimek et al. (2001) and Klimek (2002, 2003) in terms of human impact on the development and acceleration of erosion processes and transfer of sediments between slopes and the bottoms of valleys (Table 2). However, Zygmunt (2004, 2007, 2009) and Zygmunt et al. (2006) conducted a thorough analysis of the sediments that built alluvial fans at the outlets of loess valleys and gullies. The results of alluvial fan analysis confirmed by archaeological findings proved that settlement has been continuous on the Głubczyce Plateau since the Neolithic Age. In light of the dating of sediments using the OSL and C^{14}methods, it was found that the colonisation of the Głubczyce Plateau began about 7,000 years ago, but soil erosion began later, as a result of the cultivation of arable land outside the river valleys (Poręba & Murray, 2006; Poręba et al., 2011, 2013).

3.4.2. Eastern Sudetes

The area of the Eastern Sudetes and their foothill rivers possesses its own separate research history (Table 2). As humans arrived, crops occupied slopes with greater inclinations in the upper sections of the catchment. In order to reduce soil erosion, agricultural terraces were formed (Klimek & Latocha, 2007). Due to the mining of raw materials, and under the influence of changes in climatic conditions, the structure of afforestation also changed, which had a direct impact on erosion and sedimentation processes within river valleys (Klimek et al., 2003).

3.5. Other areas

Research on the impact of human activity on the transformation of relief is not carried out exclusively in loess areas; for more than 30 years, this relationship has been analysed in detail and described by Twardy (1995) in the so-called Łódź Region as well, focusing primarily on analysis of the development of the bottoms of small river valleys and their slopes, including the issue of prehistoric human settlement and economic activity (Table 2). The author emphasises that there is a time offset between the initiation of transformations of slopes and aeolian geosystems to the previously described loess areas, due to the relative unattractiveness of natural features (numerous aeolian dunes fields) for Neolithic settlers seeking fertile soil for cultivation (Twardy, 2008, 2013).

Another area that has been distinguished in the context of the impact of former settler cultures on transformation of the terrain is the Suwałki Lake District, analysed by Smolska (2012). The author's work in this respect is mainly devoted to cuts, which create single, not very long v-shaped forms and ravines. In the majority of cases, these were formed in the para-Neolithic by Balts due to gully erosion, which occurred along with the deforestation of the area and the beginning of agricultural operations and road gullies. The author's aim was to 'identify the morphological features of cuts and sediments associated with gully erosion and determine their age' (Smolska, 2007, 2012).

4. Discussion

The history of the development and transformation of the relief (proximity of human settlements, vicinity of farmland, presence of roads) of each area is unique. The intensity of change varies, depending on the historical period (less in the Neolithic, Bronze, Iron, and Little Ice Ages, greater in the Middle Ages and the Industrial Era), in an investigated region (SUPERSON ET AL., 2016).

Depending on the area being studied, there are several phases of erosion and accumulation which correlate with periods of increased human settlement and climate change (KLIMEK ET AL., 2006; KACZANOWSKI & KOZŁOWSKI, 1998).

All of the analysed areas of southern Poland share a similar history of settlement development and its impact on changes in the landscape. This area was uninhabited and covered with forests until the Neolithic (around 7,000 BP). The process of soil erosion began much later, when cultivation of agricultural fields began in areas other than the bottoms of river valleys.

The oldest well-documented traces of the agricultural use of loess areas in Poland date from 5000 to 4000 BC. After the Neolithic, loess areas in Poland were probably used several times by farmers during agricultural activity between 3500 BP and 1000 AD (ZYGMUNT, 2009). It is assumed that most of the sediments covering Holocene soil accumulated at different periods over the past millennium (PORĘBA ET AL., 2011).

Analysis of the evolution of a given area's relief over various periods is based on lithological studies of differentiated landforms, mainly of alluvial fans, gully bottom sediments, and river terraces. In contrast to the case of slopes, or the evolution of the fluvial landscape, the sediment sequences in the gullies are incomplete, which is attributed to alternating erosion and accumulation processes. General periods of intensified erosion can be identified indirectly on the basis of the degree of soil transformation in a given catchment, correlated with the history of its agricultural use. Sedimentological features of bottom sediments and the soil separating them indicate several phases of transformation of a given region's relief (RODZIK, 2010; DOTTERWEICH ET AL., 2012).

Erosional processes may be combined with increases in human agricultural activity, whereas accumulation and syngenetic soil development occurs during reduced (or none) human activity in a given area. Material created during the erosion of slopes was moved with water along gullies into larger valleys, where it was deposited in the form of alluvial fans and subjected to further fluvial transport. The simplified schema of relief development (Fig. 2) includes three main features of the development/transformation stages of the relief common to all analysed areas and the forms appearing there in. In the beginning (Fig. 2A), before human economic activity started, following the end of loess accumulation, a steppe was formed, under which Holocene chernozem soil was formed. Subsequently, after a change in climatic conditions to warmer and wetter, the forest grew gradually. With the first arrival of humans in the area, anthropogenic changes in the landscape were negligible and not detectable in the resulting sediments; however, as settlements developed (Fig. 2B), mainly due to trees being cut down for cultivation and breeding, the exposed area was subjected to water erosion (rainfall and melting snow) and the formed material moved with water down along the slopes to the gulley bottoms and river valleys, sometimes settling at their outlets to create alluvial fans (Fig. 2C). Sometimes loess diluvium fills already existing natural depressions in the area to create sedimentary basins, so they became geo-archives (KOŁODYŃSKA-GAWRYSIAK ET AL. 2011, 2015, 2017). The chernozems underlying the deposits of the valley bottoms probably developed throughout the Holocene and have been covered in the last few centuries by colluvial deposits several metres thick (ŚNIESZKO, 1991). Each area, or form, studied by the authors has its own individual history in terms of the development of local human settlements, but all share common elements that determine the phases of increased human activity in a given area as well as of regression and permanent, or temporary, disappearance. These elements have been correlated with historical and archaeological data; however, their number varies from area to area and they may be related to other periods of the development of settlements in Poland. Individual authors distinguish approximately 7 stages of development of alluvial fans on the Głubczyce Plateau (ZYGMUNT, 2004, 2009); 6, 8, and 11 phases of alternating erosion, accumulation, and soil development in the Lublin region (RODZIK, 2010; DOTTERWEICH ET AL., 2012; SUPERSON ET AL., 2014); 7 phases of transformation of aeolian, slope, and river geosystems in central Poland under anthropopressure (TWARDY, 2008); 4 phases of sediment development in the Nidzica Valley (MICHNO, 2008); at least 8 or 9 more humid and relatively colder phases alternating with drier phases (STARKEL, 2006); and 4 phases of sediment particle transport in surface runoff (rainwater, thaw) in the Sancygniówka Valley, involving change in the hydrological regime, formation of agricultural mud, flattening of the valley bottom, formation of alluvial fans, and filling of the bottoms of gullies and valleys with mineral-organic material (ŚNIESZKO, 1985).

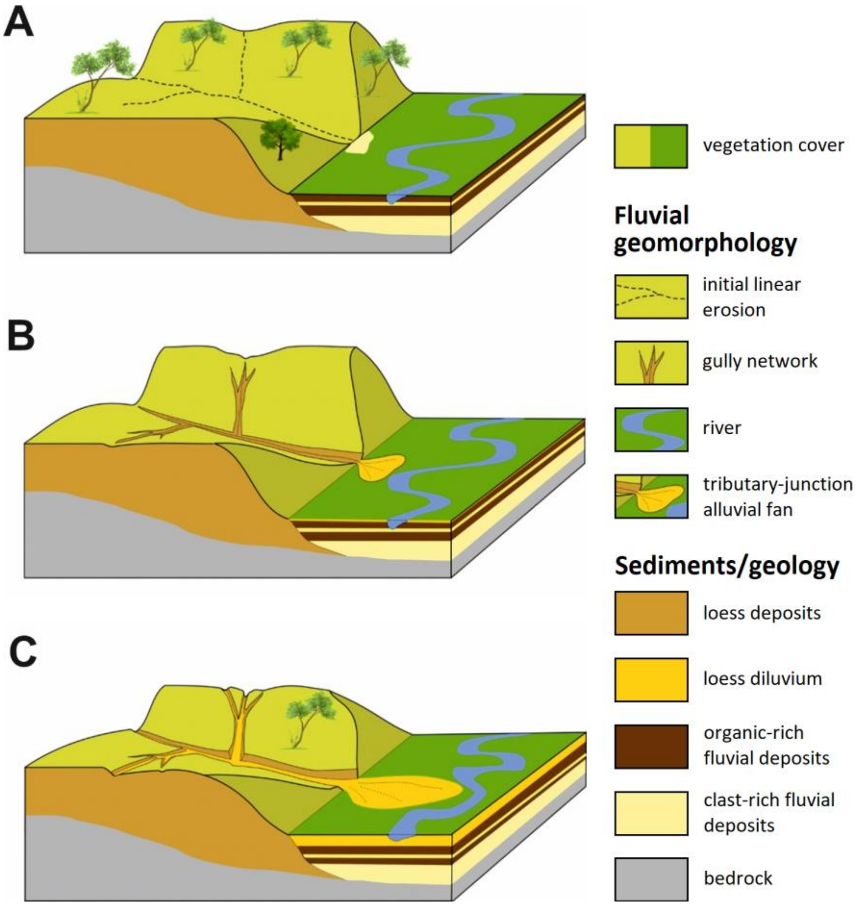

Fig. 2. Simplified scheme of landscape evolution
A – initial phase – early Holocene; B – phases of (erosional) anthropogenic activity, i.e. tree felling, cereal cultivation, and animal husbandry; various periods of valley indentation; transport of sediment from slopes to rivers (e.g. the Neolithic, Bronze, and Iron Ages, the Roman period, the Middle Ages, the Industrial Revolution); C – phases of accumulation in periods of reduced human activity: reforestation, withdrawal of agriculture, anthropogenic phase of erosion stabilization, formation of soils. Terming of alluvial fan as tributary-junction alluvial fan following the spatial scales according to Harvey (2010). The scale of this forms range from 10s to 100s of meters and occur where tributary streams join larger receiving rivers (Harvey, 2010)

5. Summary

From the beginning of the Neolithisation period in Poland, the influence of human activity began to appear in the natural environment in the form of alternating erosion of loess landforms and accumulation of sediments in the mouth of river valleys, slopes, foothills, outlets, and the bottoms of gullies. These sediments contain a nearly full historical record of these changes. Detailed analyses of sediment structures enable us to understand the functioning of the environment of the studied area from the past and to grasp the extent of human influence on these changes throughout history. Recognition of this impact, along with an understanding of the functioning of the environment, combined with changes in climatic conditions and land use, maybe useful in the future. The problem to be faced is the differentiation of the influence of natural factors from anthropogenic, as these very often co-exist.

In recent decades, more and more research has been conducted on the impact of human activity since the first agricultural cultures on the transformation of land relief and on the development of sediments. Thus, different models of Holocene landscape evolution in the loess areas of southern Poland have been proposed, varying primarily depending on the region and type of geo-archive investigated. Geo-archives investigated for this purpose are slopes, valleys, river terraces, alluvial fans, filled isolated depressions, and gully systems. In contrast to the larger fluvial depositional environments, gullies represent more challenging archives due to the incomplete preservation of sedimentary successions. However, although the models deviate from each other in detail, all indicate an earliest occupation in the Neolithic (~7000 BP) accompanied by minor to moderate anthropogenic impacts on landscape development; the first stronger effects did not occur before the Middle Ages. Based on the reviewed literature, a simplified three-phased scheme of landscape development has been introduced (Fig. 2) – encompassing a cycle of erosional (phase B) and accumulating (phase C) anthropogenic activity following an initial phase of the undisturbed landscape (phase A).

Main loess regions of southern Poland (Fig. 1) investigated for the influence of Neolithic settlements on the landscape were described in this article. However, loess coverage of Lower Silesia, the most western loess area in Poland, have a poor history of this kind of interdisciplinary research.

Therefore, it is worth supplementing the research that has already been carried out with investigations of additional regions. The Niemcza-Strzelin and Trzebnica Hills located in the loess area constitute an excellent area for research in this field.

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