HUMAN IMPACT AND VEGETATION CHANGE AS TRIGGERS FOR SEDIMENT DYNAMICS IN THE RIVER RHINE CATCHMENT

With 2 figures and 2 tables

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Zusammenfassung: Anthropogener Einfluss und Veränderungen der Vegetation als Auslöser für die Sedimentdynamik im Einzugsgebiet des Rheins

Das internationale LUCIFS-Projekt fragt nach den Haupteinflussfaktoren auf die fluviale Dynamik, die sich im Sedimentbudget der Flüsse niederschlägt. Grundannahme ist, dass der wirtschaftende Mensch spätestens seit seiner Sesshaftigkeit und dem damit zusammenhängenden Beginn des Ackerbaus einen entscheidenden Einfluss auf das Abflussverhalten und den Sedimenttransport des Flusses hatte. In diesem Zusammenhang ist der Rhein als ein Fluss mit einer sehr langen Überprägung durch anthropogene Einflüsse anzusprechen. Der vorliegende Beitrag fasst dazu einige der aktuellen Forschungen und Fragestellungen zusammen. Neben einer Darstellung der wesentlichen Schritte in der wachsenden Mensch-Natur-Wechselwirkung am Beispiel des Sedimentarchivs und der in den Pollenprofilen konservierten Veränderungen der Vegetation wird am Beispiel des Neolithikums und der Periode vom Mittelalter bis heute der Frage nachgegangen, wie sich dieser wachsender Einfluss durch verschiedene Quellen, wie das Bodenarchiv oder archivalische Quellen nachweisen lässt. In der Tendenz lässt sich sagen, dass bereits im Neolithikum der Einfluss des Menschen wichtig war, der aber mit einigen Unterbrechungen, die sich unter anderem in Pollenprofilen nachweisen lassen, weiter zunimmt. Nach dem Ende des Mittelalters nimmt der Einfluss weiter zu, um in den letzten 300 Jahren noch einmal dramatisch zu steigen.

Summary: The main goal of the international LUCIFS project is to analyse the human impact on the hydrological dynamics of the river and the sediment budget. The main thesis is, that earlier human societies shaped the fluvial system and the sediment transport in a fundamental way since the beginning of agriculture. The River Rhine can be seen as a typical river, which is shaped by humankind over a very long period. This paper gives an overview over the current knowledge and research situation. In a first chapter several major steps of a growing human impact on fluvial dynamics will be identified in the sediment archives and the pollen profiles, which contain information of the vegetation change. In case of the Stone Age and the period from the medieval age onwards the aim is to look for other sources like archaeological remains or archival sources. The main thesis is, that the human impact became more and more important throughout this period and especially during the last 300 years.

Introduction

The main goal of the global LUCIFS framework is a better understanding of the fluvial dynamics, the variations of water and particulate fluxes at various times since the beginning of agriculture. For this purpose a sample of about 20 "big rivers" will be compared. The fundamental hypothesis of the project is that humankind has become a major geological and ecological agent on a global scale (Turner 1990). The project seeks to get a better understanding of the interaction of ecosystems and the human society. Rivers are key features because of their importance in human history as settlement and agricultural areas but also as important links within global biogeochemical cycles. All the rivers represent certain types of historical and actual influence of humankind. Within this sample the River Rhine is an example of a river, which is influenced by strong human impact throughout the last 10,000 years.

The human impact itself can be divided in two parts, a direct and an indirect one. The direct impact comprises all the way of hydraulic engineering, e.g. the change of the river course or the change of the water discharge. The indirect ones are caused by the change of land use during time. Different types of vegetation, the ratio of open land and forested ecosystems are the trigger of different types of sediment fluxes and water discharge to the riverine system.

To reconstruct the land use history and in a second step to connect this information with the question, how these changes had had an influence on erosion and water discharge, it is necessary to analyse a broad range of archives.

The following article demonstrates which kind of information can be provided by different archives. With this perspective Schirmer analyses sediments and other geomorphological information for a reconstruction of river history and the probable human impact. It was also in the River Rhine catchment, that GERLACH (1990) could verify the human impact (e.g. forest clearances, extension of arable land) on the development of riverine terraces. More recent studies show the impacts of agriculture on the development of (soil-)erosion (BORK 1998). A second very important field is the reconstruction of the vegetation history by a geobotanical perspective. There is a lot of information especially in the River Rhine catchment. KÜSTER presents a detailed overview on the link between our current palynologic knowledge and the land use history in the River Rhine catchment from the Holocene to medieval times. ZIMMERMANN presents some methods to get a better link between the population development in the early stages of agriculture and its impact on water and sediment fluxes. But it is quite obvious, that the human impact became stronger in historic times due to an increasing population and changes in agricultural techniques. From medieval times until today, archival sources like maps and other written evidences, mostly produced for administrative purposes, become more and more important. BURGGRAAFF and KLEEFELD give a short insight on the current work in the Lower Rhine area. Some of the considered historic maps are published (BURGGRAAFF 1992) and for selected regions give a first impression on land use change and the change of natural structures since medieval times. Current research projects related to RhineLUCIFS indicate, that the last 250–300 years are the critical time period for the change and intensification of the human – nature interaction. There is a lot of information about the agricultural land use (BUSCH 1985; HAHN 1973; WEIß 1992) specially along the branches of the Middle and Lower Rhine, but it is still a remaining task for the future to get more detailed information for certain areas and to create a link between the wide range of methods, which are presented in the following paper. This is necessary to be able in the future to get a more precise overview of the human influenced sediment flux within the entire River Rhine catchment on the large time scale of the entire Holocene.

1 *Steps of human impact in the River Rhine floodplains*

1.1 *Human impact into the valley ground*

The steps of evolution of the valley ground have been described above in Schirmer et al. The coincidence of gravel deposition, V gravel as well as L gravel, in all bigger river valleys of the Rhine River catchment (as well as of all major rivers in Central Europe) testifies their common climatically controlled origin (SCHIRMER 1978, 154; 1993, 579, cf. Fig. 8 in SCHIRMER et al. (2005), this issue).

Since the Neolithic period man is interfering in this rhythmic process. Thus, the question of human impact into this climatic controlled system is of major interest. This impact is visible, e.g. by augmentation of flood sediment in areas rich in loess. From this it becomes evident that man's impact does not effect the formation and number of accumulations, but it affects their dimensions and their material composition (SCHIRMER 1983, 40).

On the Upper Rhine the Ebensfeld Terrace is the first to exhibit thicker flood sediment. On the Lower Rhine the input of loess material indicating first important slope clearance starts by 6,500 a BP (SCHIRMER 1993; SCHIRMER a. SCHIRMER 1995). In contrast the Ebensfeld Terrace of the Upper Main area is very poor in floodloam (SCHIRMER 1980, E5f.); this indicates the landscape on the Upper Main being not yet stronger effected by clearance activity at that time. However, the gravel bed of the Ebensfeld Terrace exists on all rivers. From this follows a natural origin for the Ebensfeld Terrace body. From the time of the formation of the Zettlitz Terrace within the Subatlantic period glacier advance periods are well investigated. A comparison between glacier advance periods in the Alps and phases of river activity exhibits a good synchronism between both (cf. SCHIRMER 1978, 154, 1988, 33 and Fig. 8 in SCHIRMER et al. (2005), this volume) – a testimony for natural control of the reworking phases even in the very times of strong human influence. It becomes evident that man's impact does not effect the formation and number of accumulations, but it affects their dimensions and their material composition (SCHIRMER 1983, 40).

Another way to check the relationship between man's impact and river activity is to compare historical records of man's impact into the valley with the response of the river. The River Main yielded the following evidence: Where rich historical data tell about affection by man's impact, the river does not react by activity rhythms (GERLACH 1988, 210). But it reacts by the type of sedimentation: floods carry increasingly suspension load.

Since the middle 19th century in Central Europe river courses become to a large extent canalised by stabilizing the banks and rectifying the course. Thus, the tendency towards branching and flattening of the channel has been stopped in favour of one only river file. However, the clearance conditions that had caused the branching and flattening before, now remain the same: namely sudden and high water discharge due to prevention of seepage, moreover high suspension load from soil erosion. Consequently, the bracketing of the river results in big flooding of our valleys with smoothening of the relief by flood sediment deposition. In former times these big floods carrying fresh lime to the floodplain meadows were the bless of our ancestors. Nowadays they are regarded as catastrophes since man had occupied the floodplain using it by fields, settlements and main veins of his traffic (cf. SCHIRMER 1995a).

1.2 Floodplain loam under natural and human conditions

There was a research period when floodplain loam was thought to origin from land clearance activity only (MENSCHING 1957). This view existed prior to the knowledge of the multiple number of floodplain terraces and their genetic structure. Under natural conditions floodplain loam ranges from sandy loam (Reundorf Terrace) under periglacial conditions to silty loam (Schönbrunn Terrace, Lichtenfels Terrace) under vegetated conditions of the Late Glacial resp. the Preboreal. Land clearance caused augmentation of fines, i.e. sand in the sandy catchments of sandstone areas especially that of Rotliegend, Buntsandstein and Keuper bedrock, silt and clayey silt in the clay areas, especially that of Devonian shale, Jurassic bedrock and in areas of thicker loess cover. Generally floodloam under natural and vegetated conditions is finer in grain size than that under human influence. The reason is that human influence with its land clearance and soil erosion effects tendency towards periglacial conditions. The more clearance, the more sediment flux, the more floodplain sediment is there.

1.3 Acts of human impact in the River Rhine floodplain

Considering the course of man-floodplain interaction there are four major acts of human interference in the valley ground:

Act 1: man visits the river for fishing and boat travelling and is collecting gravel for tools. Floodplain and rivers offer a good place for hunting. The oldest human traces found in an ancient valley bottom of the River Rhine catchment are three quartzite pebble tools of about Jaramillo age (ca. 1 Mio a) (BOSINSKI et al. 1995, 844, 886). In this first act of human being man is mere part of nature sometimes leaving tools behind. He may alter the animal composition, as was the case with the extinction of the mammoth towards the end of the last glaciation. However, the main valley context remains untouched by man's sporadic presence.

Act 2: from the Neolithic period on, about 7,300 a cal. BP, man's settling and land clearance activity initiates the second step of the relationship of man and valley. Land clearance, agriculture and early forestry changes the vegetational composition (KALIS a. MEURERS-BALKE 1988). Since then increased soil erosion within the catchment causes infill of fine clastic deposits via hillwash, gully erosion, alluvial fans into the valley ground. Consequently the floodplain changes its character:

Prior to this impact increased flooding activity caused gravel accretions (floodplain terraces) the surface of which was covered by thin mostly silty flood deposit. During quiescence periods of flooding on top of these flood deposits a black AC-soil developed. The whole floodplain surface was strongly undulated due to a dense network of floodplain channels that are genetically abundant palaeomeanders of the river (primary floodplain channels) or chute channels formed during floods (secondary floodplain channels).

Starting with the human interference the natural process of alternating flood activity and quiescence phases is superimposed. Flood sediment increases. It commences to veneer the floodplain and to fill the floodplain channels more than before. Consequently the level of the floodplain is growing up quicker. Thus, its undulated relief with its network of floodplain channels starts to get drowned in sediment. The floodplain becomes more even than before. Moreover, it gets more fertile. The soil material eroded at plateau and slope now augmenting the flood freight is preweathered. Thus soil formation in the floodplain can better proceed than before. Floodplain soils on carbonaceous parent sediment change from AC-soils to ABC-soils.

All these changes of the floodplain are the result of an indirect human impact into the valley. Though the Neolithic man settled in the valley ground, he chose areas on the low terraces that lie outside the floodplain free from flooding, e.g. in Cologne (BERNHARDT 1986; SIMONS 1993; SCHIRMER 1993). During this second act man provides the valley ground with distinct imprints. Nature incorporates these effects into its course that mainly remains unaltered.

Act 3: with the decline of the Subboreal period and the beginning of the Iron Age in Central Europe, at about 2,700 a BP, land clearance is enhanced substantially. The relief within the valley ground is widespread and completely evened, as demonstrated in Cologne-Blumenberg (SCHIRMER 1993) or Düsseldorf-Rath (SCHIRMER a. SCHIRMER 1995). Now the floodplain offers new possibilities being used by man. A great amount of the floodplain channels showing open water or swamp before now became dry. Marsh fever should recede. Flattening of the floodplain allows better access to the floodplain. Improved soil fertility offers proper land use.

As consequence during the Iron Age/Roman period forest clearance in the floodplain enhances and first settlement is known. The river course has been affected. Increasing growth of the floodplain allows floodwater to rise higher than before, evening of the floodplain enables it to extend laterally wider than before (Schirmer 1990b) (Fig. 1). Hence rivers could change their course easier than before. On all rivers the river channel alters in shape and dimension of accumulation. This process intensifies until the early modern times.

The clearance activity inferred conditions towards braiding. These conditions start with the Zettlitz phase. One result is the fill-in-fill texture of the younger Holocene terraces commencing with the Unterbrunn phase. The reworking areas of these rivers tend to widen. Consequently, the preceding older terraces become more eroded. The river splits up into a lot of branches. Old seam channels become reactivated by flooding and are filled with floodplain channel sediments and floodplain sediments. However, despite of all these changes in river dynamics the river continues being meandering and the gravel continues being deposited as clear L type gravel.

During this third act man has essentially influenced the natural processes in the valley. He triggered indirectly the change of the river texture from row terraces lying side by side with equal base and top to fill-in-fill-texture and transformed the wooded undulated floodplain into a widespread cleared and rather evened floodplain that offered agricultural use. Though he still is completely subdued to the course of nature he modified its face and action by far.

Act 4: during the course of the 19th century man's technical era opens the last and forth act of the man-valley relation. River courses become stabilized to fix the landed property and the waterway. Thus, bigger rivers were transformed into canals. In places there courses are drawn artificially. Floodplain and low terraces are modified as required. As the valley ground is the most important place and vein of man's life he intends to control all natural processes in the valley.

The river serves as sewer and waterway. Its function as fertilizer of floodplains has ceased. Long valley stretches, as the so-called Goldene Meile in midst of the Middle Rhine, a stretch of a mile named for its favoured climate and fertility, are now used for gravel exploitation and technical plants. The flood, one of the last testimonies of the living river, changed into an uncomfortable evil.

Since the Neolithic period man's impact into the valley happens only locally and subtly. Since the late Subboreal period this impact caused more and more severe consequences. Since the 19th century man controls and transforms the valley bottom at his own discretion. The anthropogenic events cause widening, branching and flattening of the riverbed, moreover augmentation of flood sediment and eventually elevation of flood levels. This is a tendency towards braiding. A further human input into floodplain deposits as well as channel deposits is the fluvisoliment (soil material reworked into fluviatile deposits) (Schirmer 1983, 27; 1991), likewise the input of heavy metals. Rectification of the river with shortening of the river course gives rise to subsidence of the ground water table. This as well as the dyking of the floodplain has the aim to augment the area for agriculture, settlement and traffic lines. However, all these impacts cause prevention of water filtration and rise of flood level. Floods extend in the last millennium to levels of that of the Lichtenfels, Ebing and in places the Schönbrunn Terrace (Schirmer 1978, 28; Schirmer et al. 1988, 4).

Though man's impact into the floodplain since the Neolithic period is evident and increasing it, even when strong, only modifies the natural development of the valley (Schirmer et al. 1988, 34). Nature's footprints remain visible.

2 Land use

Along the River Rhine, there are a lot of well-known excavation sites, where many aspects of human life in former times could be researched very well. Various aspects of former land use could be reconstructed. There are regions along the River Rhine where exemplary results could be collected which help us to understand the development of land use on an European, if not worldwide scale. But intensive research has been conducted only in some regions and by far not in the total region, which means that research in this field should be intensified.

Each change in land use practices had consequences for the development of the landscapes along the River Rhine, and the landscape of the present day is the result of very long-lasting land use practices in former and more recent times.

2.1 Palaeolithic and Mesolithic

Remnants of Palaeolithic Hominidae have been found near Heidelberg (Homo erectus heidelbergensis), in Steinheim near Stuttgart (Homo erectus steinheimiensis) and in the Neandertal near Düsseldorf (Homo erectus neanderthalensis). These early men, living in the Mid Pleistocene, used fire, collected plant food and predated animals, but they certainly did not practise any land use in a more modern sense (MÜLLER-KARPE 1998). Land use in a more marked way started in the late Würmian, when hunting techniques developed very rapidly. Remnants of Late Palaeolithic camps have been found in the volcanic areas of the Hegau near Lake Constance in southern Germany and in the western German Eifel mountains. Volcanoes were ideal sites for camps, as hunters could detect game from far away, and it was also convenient to hunt down-hill (ADAM 1984; ALBRECHT a. WOLKOPF 1990; BOSINSKI 1990; KOENIGSWALD a. HAHN 1981). Late Palaeolithic hunter stations at the Middle Rhine area were covered by ash during the volcanic eruption in the Laacher See volcano during the Würmian Late Glacial (BOSINSKI 1979). This fact offers very good opportunities to detect daily life of the ancient hunters.

During the Mesolithic the environment changed dramatically, as the former open land was covered by woods. Dense woodlands are not an ideal environment for reindeer and other animals living in big herds; therefore the animals possibly migrated to the north. Hunters still living in the River Rhine area had to change their foraging methods; fishing played an important role in the Mesolithic economy and land use. but possibly also the use of hazelnuts. Well-documented Mesolithic sites are known from the shores of Lake Constance and in northern Switzerland (ALBRECHT a. WOLKOPF 1990; WYSS 1968).

2.2 *Early Neolithic*

The preconditions for the establishment and development of agriculture were excellent in Central Europe. On the one hand very fertile soils were available on substrates, which had developed during the Ice Age, i.e. rather recently before the beginning of agriculture; they had been prohibited against erosion by dense woodlands in the Early Holocene. On the other hand a lot of cultivated plant and animal species were introduced to Central Europe. Therefore a great variety of crops could be grown, more than at other places in the temperate zone of the world, on soils, which were and are more fertile than elsewhere. Central Europe is therefore a unique area; hardly anywhere else in the world agriculture could be practised for millennia without any big crisis. This certainly contributed for the rapid development of European culture.

The establishment of agriculture was not possible on each stand at the same point of time. Along the River Rhine, there are more or less fertile soils, containing more or less pebbles and stones; in some areas the climatic conditions are better than elsewhere. During the early Neolithic, in the phase of the Bandkeramik culture, which is dated to the period around 5500–5000 BC, nearly exclusively loess soils have been selected for practising agriculture (CLARK 1952). These stands are among the most fertile ones in Central Europe, but it is more likely that loess soils have been selected by early farmers because stones are lacking there (KÜSTER

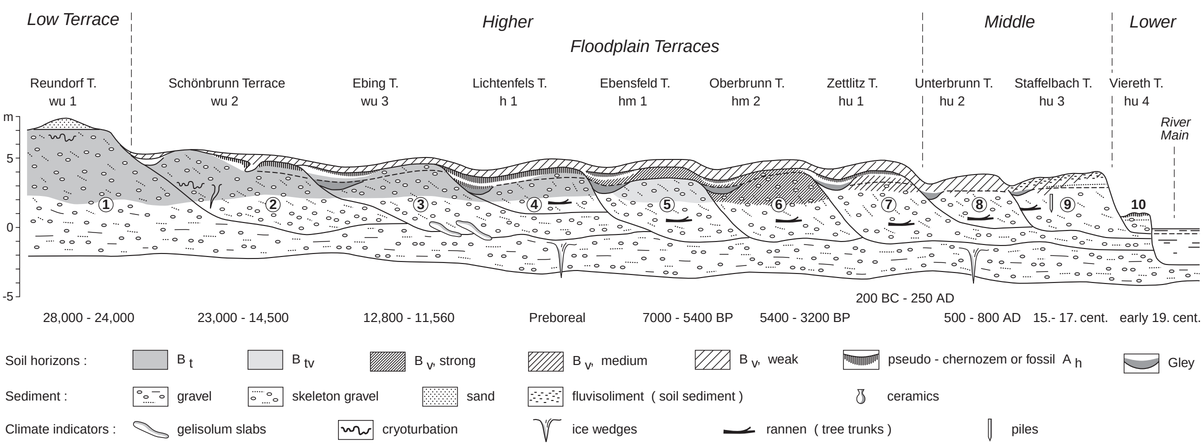

Fig. 1: Terrace sequence of the valley bottom of the River Main (SCHIRMER 1995b, 1447 slightly modified)
Talgrundterrassen des Mains (SCHIRMER 1995b, 1447)

1995b). Settlements were typically founded on the middle of the valley slopes, near the borderline of the loess plateaux and the valley itself, where loess has been removed by water erosion in the millennia before. This typical situation of settlements could be researched in a very detailed way in regions near the River Rhine, especially in the area between Cologne and Aachen (STEHLI 1989; LÜNING 1997). The settlements were situated just on the borderline between fertile and easily cultivable soils for agriculture and a damper area in the valley where possibly still trees were growing and cattle could browse. Cattle had access to running water in the creek in the middle of the valley, and the farmers could supervise the cattle from the settlements.

The settlements were certainly constructed in densely wooded areas because timber was needed to construct houses; Early Neolithic houses are as long as oak trunks which can mean that the length of available timber caused the size of the houses (KÜSTER 1998a, b). Neolithic farmers in Central Europe were familiar with timbering, which can be demonstrated by constructions like that of a deep well at Kückhoven near Aachen (WEINER 1991). From the early Neolithic onwards, most rural sites have been principally founded in the same situation: on the valley slopes, between fields on dry soils and the valley region with running water and damper soils. Below the settlements, grasslands have been designed and even meadows in later periods.

The oldest rural culture in Central Europe was not uniform in an economic sense. This can be demonstrated along the River Rhine in an excellent way. Loess soils on the one hand were and are available north of the region which was covered by the alpine glacier, in the Hegau west of Lake Constance and in the upper Rhine plains between Basel and Frankfurt; on the other hand great loess areas exist just north of the Central European hilly landscapes, where they are called "Börde". Near of the River Rhine, Börde areas can be found in the Cologne area, e.g. in the Jülicher Börde. Loess can also be found in so-called intra-montane situations; there it has been deposited between the hill chains. This is the case e.g. in the Wetterau north of Frankfurt and in the basin around Neuwied and Koblenz.

2.3 Later Neolithic cultures

During the middle and younger Neolithic agriculture was continued on loess soils, but the settlements were partly also funded higher or lower on the valley slopes. In the Lower Rhine region, settlements of the Rössen culture could be found. From the examination of the cereal grains from these settlements it became obvious that barley was introduced to the Lower Rhine region in this period (SCHIEMANN 1954; BAKELS 1990; BAKELS et al. 1993). This can be regarded as an influence from the Mediterranean region as barley was possibly introduced from the Near East via the Mediterranean area to Central Europe.

In the younger Neolithic, agricultural settlements have been founded also outside the loess areas. From this period onwards, about the 4th millennium BC, also stands on ice age moraines were cultivated which are fertile as well but contain more pebbles and stones than loess stands. Along the River Rhine, these stands can be found in the Lake Constance region. At the lake borders, so called lake dwelling settlements ("Pfahlbau-Siedlungen") have been constructed. The "lake dwellings" from Lake Constance belong to the most well-known and researched younger Neolithic settlements in the world (e.g. SCHLICHTHERLE a. WAHLSTER 1986; SCHLICHTHERLE 1991). By looking at the crop inventories, again a Mediterranean influence on their composition is evident. This is obvious from several records of tetraploid free-threshing wheat (*Triticum turgidum*) in this area, which came there via the Mediterranean area (MAIER 1996). Also several Mediterranean spices could be found in younger Neolithic settlements in SW Central Europe, such as dill (*Anethum graveolens*), parsley (*Petroselinum crispum*) and celery (*Apium graveolens*; JACOMET 1988; KÜSTER 1999).

Settlements also expanded to sandy stands in the Rhine-Meuse delta; barley and emmer were grown in the settlements at Hazendonk (BAKELS 1981). Instead of emmer, naked wheat was present in the late Neolithic settlement of Vlaardingen (ZEIST 1968).

2.4 Bronze and Iron Ages

During Bronze Age, agriculture was introduced mainly to limestone areas, where fields could be designed in the relatively damp lowlands, whereas agriculture was not possible on flat grounds and drier soils on the hills. Typical areas where agriculture was established mainly during Bronze Age are not present along the River Rhine, but farther away (Jura Mountains in Swabia and Frankonia). There are pollen analytical and archaeological evidences that summer farming in the Alps started approximately during Bronze Age, perhaps even a little bit earlier (ZOLLER 1983; WICK 1994; KÜSTER 1994a). But we have only very few plant macrofossils from alpine settlements so that we cannot describe how summer farmers were supplied with plant food.

In the same period, the introduction of spelt (*Triticum spelta*) is evident in settlements in the area north of the

Tab. 1: Table of the size of Bandkeramik settlement areas and the number of households per square kilometer on different scales
Größe der bandkeramischen Siedlungsareale und geschätzte Anzahl der Haushalte pro km^2

Area	Key Areas Östliche Aldenhovener Platte	Key Areas Mörlener Bucht	Geschichtlicher Atlas der Rheinlande Isolines 3 km	Geschichtlicher Atlas der Rheinlande Isolines 5 km	Rhine Catchment Isolines 3 km	Rhine Catchment Isolines 4 km
sq km	38	28	927	3,469	8,193	11,429
Households	41	22	927	3,469	8,193	11,429
Households/sq km in settlement areas	1.1	0.8	1	1	1	1
Households/sq km in total mapped area	–	–	–	0.11	0.07	0.09

Tab. 2: Table showing the size of Bandkeramik settlement areas in the Rhine catchment from South (below) to North (upper end of the table). For the Upper-Rhine sizes are cumulated for an area as far as Bingen and than again for the Middle Rhine and the "Rheinische Bucht". According to observations made on the Aldenhovener Platte 2% of the area can be expected to have been open land.
Größe bandkeramischer Siedlungsareale im Rheineinzugsgebiet

Geographical areas	Size of areas in 3 km-isolines (km^2)	cumulated km^2	Size of areas in 4 km-isolines (km^2)	cumulated km^2
North				
Hellwegbörden	149	2,438	224	2,947
Rheinische Bucht	853	2,290	1,580	2,723
	189	1,437		
	490	1,248		
Middle Rhine Basin	632	758	808	1,143
Mosel (middle sect.)			18	335
Luxembourg	28	127	317	317
	99	99		
Bingen area	451	5,755	795	8,482
Wetterau/Mainebene	10	5,304	1,670	7,687
	990	5,294		
Dieburger Becken	147	4,304	275	6,017
Südl. Maindreieck	195	4,157	1,508	5,742
	374	3,962		
	320	3,588		
Neckar area (without internal empty areas)	2,584	3,268	3,219	4,234
Upper Rhine area	495	648	670	1,015
			14	345
Kaiserstuhl	150	153	272	331
	3	3	59	59
South				

Alps and in southern Germany (KÜSTER 1995a; KARG 1996). In connection with the introduction of spelt possibly winter cropping started (KÜSTER 1995a). Mixed winter and summer cropping resulted in a prolongation of working phases in agriculture, and greater areas could be managed per farming person. Therefore it was facilitated that a number of persons inside the farming community could leave the agrarian settlement for either summer farming or mining, which both became more important since the Bronze Age.

From Iron Age onwards, agriculture was introduced to areas with stony soils, e.g. on sandstone and granite. During this period, the hills of the "Rheinisches Schiefergebirge" and its environs became settled for the first time. In the Hunsrück and Eifel hills a specific culture group was recognised and named, the "Hunsrück-Eifel-Kultur" (HAFFNER 1976). But also in other hilly landscapes of this area land use started in this period, which could be evidenced by pollen analysis (POTT 1985; SPEIER 1994). Only very few plant macrofossils are examined from this interesting period; it should be examined whether farming was practised in the hills or exclusively mining and metal smelting, which is evident from the pollen diagrams (POTT 1985) and archaeological excavations (e.g. JOCKENHÖVEL 1995).

2.5 *Roman age*

For the colonisation of Central Europe, the formation of permanent states and stable economic structures, the River Rhine was very important from Roman times onwards. The Romans were the first who utilised the Rhine as trading route, which was protected by the Limes. Along the river, crops were not only produced for local consumption but also for trade which is normally established together with the colonisation and the formation of stable settlement structures which are absent in prehistoric times. Trading goods were transported on the river. This is evident for wine and wine vessels (ULBERT 1959; GILLES 1995), crops such as naked wheat (KÜSTER 1993), spices and Mediterranean fruits (e.g. KUČAN 1984; KNÖRZER 1966) and timber (KÜSTER 1994b). The settlements and their agricultural areas became more stable but were still situated in the same topography as in the early Neolithic (HAVERSATH 1984).

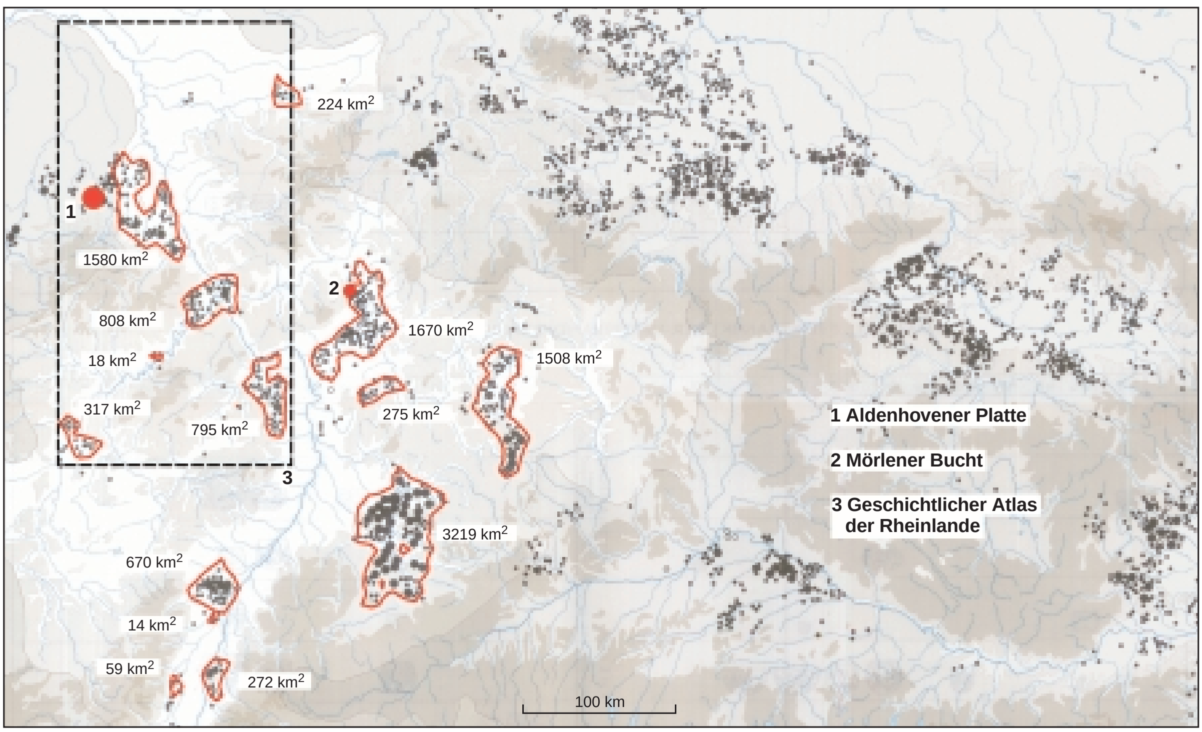

Fig. 2: Distribution map of the Bandkeramik in the River Rhine catchment (area outside catchment shaded) with 4 km isoline in red colour. Isolines are calculated according to the map published by PREUß (1996), Karte 1

Verbreitungskarte der Bandkeramik im Einzugsgebiet des Rheins

The stabilisation of the settlements had interesting effects on the development of woodlands. In prehistoric times, settlements shifted from time to time, which resulted in new clearings of woodlands, but also secondary successions of woods on abandoned farmland. In the course of secondary successions trees could more easily expand than in areas where they did not take place. By this process, possibly the spread of beech was favoured in Central Europe (KÜSTER 1997). The stabilisation of the settlements caused that secondary successions of woodlands did not take place. Therefore beech did not continue to spread in the area occupied and colonised by Romans but outside. After the end of the Roman Imperium the agrarian landscape became more unstable again, settlements shifted and secondary successions of woodlands could take place again. Beech expanded again up to the beginning of early medieval colonisation, which again resulted in more stability of the settlements. The changing phases of immigration and retreat of beech can be most typically seen in pollen diagrams form the Rhine-Meuse delta region (e.g. GILOT et al. 1969).

The interactions between changes of both land use and woodland are far from being totally understood and should be examined more intensively.

2.6 Middle Ages

Central Europe was colonised again in the medieval period. The River Rhine was the very important trade axis from which colonisation started in the North Sea and Baltic regions, but also to the regions east of the river, which had not been colonised during Roman times. All goods, which had been traded in Roman times, again were transported on the River Rhine. But the area, which could be explored for ores and timber, became greater in Middle Ages because also the regions east of the Limes with rivers contributing to the River Rhine, too, were easily accessible. The availability of a great variety of timber at the River Rhine mouth was one precondition for the rapid development of Dutch and Lower Rhine cities in the Middle Ages; fir and spruce was transported from the southern German mountains, whereas oak timber was cut along the Middle Rhine. In the coppice woods along the River Rhine only relatively small trees were occurring with bend wood. Bend wood was highly desired by ship constructors. Some medieval cities are intensively examined by archaeobotanists to reconstruct the urban nutrition, such as Cologne (KNÖRZER 1987) and Neuß (KNÖRZER 1975), and also crops from rural settlements are examined (KNÖRZER 1979; PALS 1987). But it is important to work more intensively on these materials as it should be tried to find out, how it became possible to support citizens living in towns with crops; the Lower Rhine area would be a very good model region where this interesting problem could be examined intensively. But it will also be necessary to work more intensively on medieval plant remains from other regions along the River Rhine.

2.7 Concluding remarks

It is evident that there are regions along the River Rhine from which we have rather detailed knowledge about the conditions of land use. We know a lot about late Palaeolithic hunters from the Neuwied area and about early Neolithic farming in the Lower Rhine area. We have rather detailed knowledge about late Neolithic and Bronze Age farming practices in the Lake Constance region. And we are quite well informed about Roman and medieval land use in the Lower Rhine area. But – apart from single problems discussed in this text – we are not familiar with the history of land use practices along the entire river.

3 Vegetation change

The River Rhine passes across all different Central European vegetation areas. Nevertheless, there is a general basis for the development of vegetation, which was outlined first and foremost by FIRBAS (1949, 1952). A "basic Central European succession" of woodlands during the Holocene was described: in the Early Holocene trees invaded an open landscape, so that more or less open birch and pine woodlands evolved. After that hazel and later the trees contributing to the "Quercetum mixtum" became frequent. The "Quercetum mixtum", which is not a plant community existing as a uniform type was regarded as a mixed deciduous woodland formed by oak, lime, elm and ash. The mixed deciduous woodlands were later replaced by beech or mixed woods of beech, spruce and/or fir. In recent phases of the Holocene hornbeam became more frequent, whereas beech and fir became rarer; and in the most recent phase of the Holocene spruce and partly also pine were planted to establish new forests.

A more or less strong connection was assumed to exist between climatic and vegetation development. Climatic change was regarded as the principal reason for each vegetation change. But from an ecological point of view it must be stressed that climate change is only one out of many different reasons, which can cause vegetation change. It is possible that some changes of the climate did not cause vegetation change, whereas many changes of vegetation can be caused by very different reasons such as vegetation development and succession as biological phenomena alone, but also soil development, changing hydrology, animal and especially human interference. Apart from the general model of vegetation development, which has been presented by FIRBAS and others, it must be clear that there are important differences in the vegetation history of different areas along the River Rhine. This is in accordance with the fact that the present vegetation types, which can be found along the river, are different as well. Therefore some main characteristics of the specific vegetation developments in different areas along the River Rhine shall be analysed in the following sections.

3.1 The Alps and its environs

FIRBAS (1949, 1952) excluded the region of the Alps from his classic description of the Central European vegetation history, because in the middle of the 20th century it was still very complicated to deal with the vegetation history of these high European mountains. After intensive research during the last decades detailed compilations of the vegetation history of the Alps were published which belong to the most important descriptions of vegetation history in specific areas of the world. Among others, the books by KRAL (1979), WELTEN (1982), LANG (1985) and BURGA a. PERRET (1998) shall be mentioned here. According to the fact that very many azonal and extrazonal vegetation stands can be found inside the Alps (patches with high Alpine related to arctic and boreal vegetation types can be found just in the neighbourhood of areas with sub-Mediterranean vegetation) vegetation history differs a lot from site to site.

In Switzerland, the development from open to wooded land started as early as in the Bölling period (ca. 13,000 a BP). There was only a slight delay in the expansion of woodlands from lower to higher elevations. The climatic deterioration of the Younger Dryas period led in higher elevations more to a drawback of woodlands, whereas in lower elevations pinewoods were replaced by birch, which again developed to pine woodlands after the Younger Dryas (BURGA a. PERRET 1998). According to BURGA and PERRET (1998) the alpine timberline shifted from ca. 1,600 m at about 12,000 a BP to 1,400 m during the Younger Dryas. After this, it established at about 2,200–2,400 m. In the subalpine woodlands *Larix decidua* and *Pinus cembra* became dominant. During the second part of the Holocene *Larix-Pinus cembra*-woodlands were more or less replaced by *Alnus viridis* shrubs, but also *Picea* woodlands. Both changes were influenced by summer grazing of cattle in connection with summer farming. In the mountainous woodlands on the northern border of the Alps conifers were prevailing throughout the Holocene. Scots pine (*Pinus sylvestris*) was dominant up to about 7,000/6,000 a BP, when it was more and more replaced by mainly fir (*Abies alba*) and also Norway spruce (*Picea abies*), as summarised by BURGA a. PERRET (1998). Norway spruce perhaps was introduced with the help of prehistoric man (MARKGRAF 1970, 1972); during secondary successions after clearings of the woodland the spread of spruce might have been favoured. Hazel woods were established at about 9,000 a BP both in low and mountainous elevations, where they were more and more replaced by deciduous woodlands dominated by either oak or elm (BURGA a. PERRET 1998). It is obvious that elm, probably *Ulmus glabra*, became more important near to the border of the Alps, as this tree was possibly better adapted to high precipitation rates which are typical for this area; oak became dominant more in woodlands farther away from the mountains, where the precipitation rates are smaller (KÜSTER 1990). Beech spread mainly in those areas where oak was important before; at some places the beech spread might be favoured by similar mechanisms as the spread of spruce (KÜSTER 1996, 1997).

During the Neolithic, human impact on the vegetation started in the lowland areas inside and outside the Alps and in the broad valleys, which were shaped by glaciers during the Quaternary. Very early also woodlands near to the timberline were influenced by human impact as well; possibly grazing and summer farming in high elevations of the Alps started as early as about 6,000 a BP (BURGA a. PERRET 1998).

In the Lake Constance area, which can be included to the alpine environs as it was also formed by Quaternary glaciers, pine woodlands were nearly completely replaced by broad-leafed trees very early (about 9,000 a BP). Hazel became very important especially in the west (e.g. LANG 1973a) whereas possibly spruce arrived in the eastern part of the area during this period (KÜSTER 1990). Woodlands were influenced by prehistoric men since about 6,000 a BP when the famous so-called “lake dwellings” on the Lake Constance embankments were constructed. This influence was intensively studied by RÖSCH (e.g. 1990, 1992) in connection with dendro-archaeological research (BILLAMBOZ 1990).

3.2 The Southern Mountains: Black Forest and Vosges

After leaving the area formed by glaciers originating from the Alps the River Rhine passes the Upper Rhine plains, which are a part of a tectonic separation zone between the west, and the east, where high mountainous areas are situated. Both of them, the Vosges to the west and the Black Forest to the east, have a timberline, which is only developed locally at the highest summits. The precipitation rates are higher in the Vosges than in the Black Forest, which is partly situated in the rain shelter of the Vosges. Therefore broad-leafed trees were favoured in the Vosges and conifers in the Black Forest to some respect. Nevertheless, hazel became frequent both in the Vosges (e.g. EDELMAN 1985; DE VALK 1981; KALIS 1984a) and in the Black Forest (e.g. LANG 1954, 1955; FRIEDMANN 1999; RÖSCH 2000). After 9,000 a BP hazel was mainly replaced by fir and later by beech, which became more frequent in the Vosges and at the western rim of the Black Forest, whereas fir was more frequent in the other parts of the Black Forest. Spruce invaded both mountains only very lately and became established naturally only on some special stands as upland regions around the highest summits of the Black Forest (LANG 1973b) and in the Vosges (KALIS 1984b).

In the lowlands of the upper Rhine plain only very little research was done in the field of pollen analysis. FRIEDMANN (1999) published interesting data about pollen analysis from an old riverbed of the Rhine near Freiburg, and some data have been published by LESSMANN (1983). Pine (*Pinus sylvestris*) obviously was locally an important component of the lowland vegetation along the Upper Rhine during nearly the entire Holocene.

Recent pollen diagrams from the hills north of the Black Forest and the Vosges, the Odenwald and the Pfälzer Wald, which cover the total vegetation development of the Holocene, are not available, so that it should be tried to fill this gap of knowledge during the planned project; and it is also obvious that it would be good to get more pollen diagrams from the Upper Rhine lowlands, where possibly extrazonal stands of thermophilous plants developed during the Holocene.

3.3 The Western Mountains: Rheinisches Schiefergebirge

North of the Upper Rhine lowlands the river turns to a narrow valley, which is incised into the hilly chains of the mountains. Some of them are summarised as the Rheinisches Schiefergebirge.

The vegetation history in some of these areas is well documented by pollen analysis, which is especially true for the Eifel mountains (USINGER 1982; BRAUER et al. 2001) and the Siegerland and its environs (POTT 1985; SPEIER 1994). Much less data is available from e.g. the Taunus hills, the Hunsrück hills and the Westerwald.

All these areas have a more or less oceanic climate, which favours the spread of broad-leafed trees. Only in the Early Holocene pine was a major constituent of the woodlands in these areas, but birch was more frequent in these areas than in the regions farther to the east and south where the climate is and probably was more continental. Hazel became as frequent as in the Vosges and in the Black Forest. In some diagrams oak became the most important deciduous tree later on, in others elm, and there are also diagrams in which lime was a very important, if not the dominant part of the woodlands. It seems to be characteristic to the woodlands in these areas that hazel, oak, elm and lime were equally important in the pollen rain which probably means that all these trees were nearly equally important; in some cases the one of them turned out to be the most frequent, in some cases another one.

The dates on beech invasion in these areas differ a lot, about 2000 years (KÜSTER 1996; POTT 1989, 1992). This gives evidence for the fact that the beech expansion was not influenced by any climatic change or by climate alone; if climatic change would be the major reason for the beech expansion it should be expected that the data for this event are more or less equal. It is more obvious that the beech expansion was influenced by human interference. It is certainly not possible to assume that beech was planted by men or that men furthered beech on purpose. It is likely that beech was favoured during secondary successions of woodlands, which took place when men abandoned settlements and woodlands; in prehistoric times settlement localities were not totally stable and were abandoned after some decades.

Intensive woodland exploitation from the Iron Age onwards resulted in a drawback of beech in the Siegerland. In the intensively exploited coppice woods hornbeam expanded and partly replaced beech which cannot stand intensive and repeated cutting (POTT 1981, 1985; SPEIER 1994). Conifers obviously never invaded the area by natural mechanisms, but were planted during the last centuries.

3.4 The lowland areas in the Northwest

Pollen analysis has been practised recently in the Lower Rhine area where coal mining forced archaeologists to performance real "landscape archaeology", which means that not only settlements were excavated but also their environs (KALIS a. MEURERS-BALKE 1988). Hazel obviously was not as important as in the uplands, and later on woodlands were formed by oak, elm and lime. Beech invaded the area very lately, not very much before the Roman age. As additional landscapes will be totally excavated before the start of mining it will be possible to continue with intensive pollen analysis in this area; in the subsoil of valleys very good peat sections can be found which otherwise would not have been detected.

Intensive pollen analytical work was carried out in the Netherlands, along the river mouths of the Rhine. Peat sections have been taken from peat lands and from palaeochannels (e.g. Teunissen 1991; Hofstede et al. 1989; Janssen a. Tornqvist 1991). Working with depositions from palaeochannels is interesting from a methodological point of view. Normally the sections are not as long as those from "normal" peatlands, they do not span great time intervals, and hiatus phases are frequent. Therefore it is complicated to reconstruct the entire Holocene vegetation history from profiles taken from palaeochannel sections, and a lot of profiles must be analysed to reconstruct the vegetation history for one area. Furthermore, these pollen diagrams are difficult to interpret and to compare with diagrams from fens and bogs outside the river environs; in palaeochannels frequently alder carrs developed after they were abandoned by running water, so that the pollen accumulations are dominated by alder (*Alnus*) pollen.

Birch was equally important as pine in the Early Holocene, if not more important. Possibly pine grew first and foremost on higher (which means in this area dry) elevations, whereas birch carrs prevailed on low-lying locations where the groundwater table was very high. Pine was replaced by hazel and oak, which later was the major constituent of woodlands on sandy, dry soils during the greater part of the Holocene, whereas birch was mainly replaced by alder in the low lying, damp parts of the region. Beech invaded lately, partly before, partly even after Roman age, but not during the period of Roman occupation as obviously human impact on the woodlands was too intensive during this period. In the periods before and afterwards, in prehistoric times as well as in the Migration period, settlements were not stable so that secondary successions of woodlands could take place, which obviously favoured the spread of beech.

During the Middle Ages and early modern times most parts of the Netherlands were deforested to receive timber and firewood and to design additional areas for cropping and grazing. It was necessary to import timber and firewood from outside the area. The River Rhine was one of the most important routes to support the areas at its mouth with wood. Timber and firewood were cut in the areas farther up in the mountains and transported on the river to the Dutch cities, which belonged to the biggest and richest during centuries.

Cutting of wood and timber for the transport on the River Rhine took place already in Roman times (Küster 1994b) and was continued during the Middle Ages (Behre 1983; Küster 1998a), which is well documented by written sources, but also by pollen diagrams and macrofossil analysis of wood.

3.5 Concluding remarks

It must be stated that by pollen diagrams it is and will be possible to integrate a lot of different results from many subjects, as in a pollen diagram it is possible to find reflections of vegetation development, climatic change, human interference, river activity and forestry management to collect only a few reasons for possible vegetation change. Pollen diagrams are a very good tool to describe long-term vegetation change. They are basic to any ecological research, which examines environmental change.

4 Prehistoric land use and its impacts on water and sediment fluxes

In case of the River Rhine catchment with its very long history of human impact it is at the moment one of the main research goals to quantify this impact on a larger scale of time and space. Specially for prehistoric times it is necessary to work with certain index numbers like population density and the open land/forested land ratio.

On the basis of the geographical distribution of archaeological sites of a given time period estimations can be made with regard to the percentage of deforested land in different regions. The smaller the area exploited by humans during a specific period, the more water is retained within the forests and, consequently, the smaller the potential for erosion (Fig. 2). For several periods of prehistory our knowledge is adequate enough for estimations to be made with respect to the size of deforested land at the time. For the remaining time periods methods are to be developed based on pollen diagrams. In this way the gaps between the better-studied periods can be closed.

The Bandkeramik, the time of the first farmers in Central Europe between approximately 5500 a BC and 5000 a BC is one of the better-studied time periods. Due to the activities of lignite mining in an area known as the Aldenhovener Platte between Cologne and Aachen, a great number of large-scale excavations have been conducted over the last 30 years (Zimmermann 2003). The analysis of the material from these excavations has been subject of many MA-theses and a number of doctoral dissertations. These have resulted in the establishment of a chronologically differentiated reconstruction of settlement patterns for this region. For example, it can be shown that in an area covering ca 38 km? there existed approximately 41 contemporaneous Bandkeramik households in the middle of the 51st century BC (Tab. 1). A similar density of one household per square kilometre is also the result of an analysis by SCHADE of the reconstructed settlement history in the Mörlener Bucht, north of Frankfurt am Main (SCHADE 2004). In order to guarantee the production of sufficient foodstuffs each of the households would have required 2 ha of farmland.

When calculating the density of bandkeramik settlements using the map published in the *Geschichtlicher Atlas der Rheinlande* (RICHTER a. CLAßEN 1997), it becomes clear that the ratio of open land to forested land – as estimated for the Aldenhovener Platte – can be up-scaled and applied to other regions where distances between settlements are not smaller than 3 km to 5 km. These distances can be visualized using isolines. The 3 km isoline represents a minimal settlement area based on the sites known today. Based on the 5 km isoline for the 32,000 km? of the area encompassed in the above-mentioned map, a density of 0.11 households per square kilometre can be calculated (Tab. 1).

These results, and those of other analyses for the complete River Rhine-catchment in Germany, are visualized on a large-scale map (Fig. 2). The isolines encompass Bandkeramik sites where a maximum distance of 4 km between sites is not exceeded. For the "Rheinische Bucht" only the part belonging to the River Rhine catchment is considered. There are of course some settlements situated outside of the areas depicted by the isolines (e.g. in the vicinity of Heidelberg), and it is also correct that further sites have been discovered since the map's publication in 1996.

If all such sites in the area covered by the Geschichtlicher Atlas (a total of seven) were to be considered with the maximum number of households as observed on the Aldenhovener Platte (each with 14 families), the resulting density of 0.11 households per square kilometre would not differ in the second digit behind the dot. Only if 26 or 27 settlements were to be found outside the 5 km isoline in the future, would the resulting density increase from 0.11 to 0.12 households per square kilometre. Therefore, this method of calculation would appear to be quite robust against such distortions.

It is yet to be decided which isoline in figure 2 is best appropriate to describe the settlement areas of the Bandkeramik. At present, the 4 km isoline in this map seems to correspond best with the 5 km or the 4 km isoline of the Geschichtlicher Atlas and to represent more of a maximum than a minimum value. It is clear that more general structures are better represented on this larger scale where they are more obvious. Consequently, an estimation of such maximal values would appear to be appropriate. In due course, the necessary reduction in the size of some percent of the area under study will be performed using a regression approach. Table 2 shows the results of the three-kilometre-isoline for the River Rhine catchment as well.

In the course of the study it has been noted that deviations can occur depending on whether settlement areas are calculated on the basis of small or large scale maps. At the moment only little experience has been made with errors of this kind. In certain cases differences of 20% to 30% of the estimated area seem to exist. Whether it will be possible to reduce this margin by statistical means is still to be resolved. Besides the improvement of the methods applied, it is also intended to produce maps of this kind for other pre- and protohistoric periods. These could help, together with the statistical analysis of pollen diagrams by means of spatial and temporal interpolation, to interpret the palynological measurement of human impact (KALIS a. ZIMMERMANN 1997) in terms of people per square kilometre (ZIMMERMANN 1996).

5 *The impact of historical land use and their changes on erosion and sedimentation processes in the Lower Rhine area from 1150 until today*

The research area of the Lower Rhine is located on the Dutch-German border and comprises the region between the cities of Kranenburg, Lobith, Emmerich, Rees, Kalkar, Kleve and Goch. In case of the human impact, this area has been intensively researched by geographers, archaeologists and historians, also including the authors of this paper (BURGGRAAFF 1993). As a result, relatively precise land surveys and topographical maps are available from 1740 onwards. These maps are very important for the research of the different forms of land use and land use changes, which in turn are a good starting point f or the estimation of historical erosion and sedimentation processes.

The oldest precise land survey (scale 1:2,500) of the 1730's had been made for a tax reform based on the land use ("Klevisches Kataster") (AYMANS 1986). This map contains detailed information about the land use (garden, arable land, pastures, forest, heath land), about the more extensive use of the commons and the more intensive use of the private land, settlements (villages and farmsteads), roads, the course of the rivers and so on. In addition, the following topographical maps are available (MÜLLER-MINY 1977):

1. the ‘Tranchot-Karte’ (1801–1813),
2. the Prussian ‘Uraufnahme’ (1840–1848),
3. the Prussian ‘Neuaufnahme’ (1890–1898),
4. different editions of the topographical maps (1950–1960) and
5. the latest edition of the topographical map.

Thus, it is possible to analyse the geographical patterns of land use change since 1740 until now.

For the period before 1740 the research has to be based on archival sources (both written and printed) and literature, which also contains information about the land use. For example, the “Klever Urbar” of 1319, which contains information about the land use for the “Zehnten” (i.e., for taxes), constitutes a useful source. Unfortunately, the maps of this period are not suitable, as they do not contain detailed information about the land use. This concerns for example thematic maps like border maps and general territorial survey maps of the 16th and 17th century. Medieval maps also are very rare (Aymans 1985).

5.1 Review on the area of investigation

Based on the geological development the research area has to be subdivided into two different natural areas (Brunnacker 1978; Klostermann 1992; Schirmer 1990b):

1. The area, which was shaped in the Pleistocene with terminal moraines, sandur areas and terraces
2. The area, which was shaped in the following Holocene with low lands (lower river terraces)

In medieval times large areas had been settled, but there were also large areas like wood and fen lands, which were not suitable for agricultural use. These areas were used by the farmers as commons. The intensive use of the woodlands and forests by cattle and a – not sustainable – timber production led to large heath areas; the forests were transformed into open heath areas. These areas were also used by farmers. In the late Middle Ages the fen lands were drained, cultivated and settled. Since the 18th century large areas have been cultivated and colonised within the framework of the Prussian colonisation. By this time the land use changed rapidly.

The Holocene part of the Lower Rhine area was a very dynamic low land area. The river played an important role in changing the landscape. Especially the continually changing course of the River Rhine led, on the one hand, to erosion of land on the outside of the meanders and, on the other hand, to the formation of new land. Cultivated lands had to be abandoned and new land had to be cultivated. This process continued until the fixation of the course of the River Rhine in the second half of the 19th century. Today, the Rhine resembles a canal, with a fixed course.

The annual floods of the River Rhine and the other rivers (Meuse and Niers) in winter and spring were also important for the arable land. These floods caused a natural fertilisation by sedimentation.

Another important effect on the land use were dikes, which were built to protect the settlements and arable lands against the summer floods. The dikes reduced the natural flood areas of the River Rhine and led to flood catastrophes, with erosion and sedimentation effects.

During the Middle Ages the arable land was situated around the settlements and farmsteads on the higher low land areas (Uferwälle) and the green lands were situated in the lower parts near the river and the old River Rhine courses. Typically, these green lands were commonly used by the farmers of a village or parish.

Some important historical events, which effected land use changes, include:

– Continuing settlement and cultivation activities since Neolithic times,
– Large scale settlement and enclosures during the Roman period
– Regression effects after the Roman period
– Merowingian and Carolingian settlement period
– Large scale medieval enclosures, cultivation and settlement activities in combination with regression by the deserted settlements
– The transformation of woodlands into heath lands through arable use (cattle), and uncontrolled timber production
– Colonisation activities during the 18th century
– Fixing the courses of rivers
– Large scale draining measures and
– The effects of the dynamic development of the cultural landscape (industrialisation, mining, urbanisation, suburbanisation, infrastructure, intensive agriculture etc.) since 1880.

The main purpose of the current research is the development of methods and instruments to understand land use as an important and underestimated factor of the fluvial dynamics of the Rhine since medieval times. This is not yet possible for the whole River Rhine area. Therefore, the well-researched area of the Lower Rhine was selected, to develop and to test methods and instruments for the research to establish long-term balances of land use forms in time and place. The evaluation of maps, the relation of written sources in combination with natural geographical, geological, hydrological pedological and sedimential processes as well as erosion information in the LUCIFS project will be tested.

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