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Landscape dynamics on the Ljubljana Moor

Dimitrij Mlekuž
Department of Archeology, University of Ljubljana, Slovenia
dimitrij.mlekuz@kiss.uni-lj.si

ABSTRACT – *A geographical Information System (GIS) based dynamical model of streams migration was constructed in order to gain insight into the dynamics of the palaeo landscape. Model implications related to the settlement patterns and perception of the landscape by the mid-Holocene men and women dwelling in it are discussed.*

IZVLEČEK – *Članek predstavlja uporabo geografskega informacijskega sistema (GIS) pri rekonstrukciji dinamike poplavne ravnice na Ljubljanskem barju. Predstavljen je model dinamike krajine Ljubljanskega barja v srednjem holocenu in model nastanka poselitvenega vzorca.*

KEY WORDS – *Ljubljansko barje; Mesolithic; Neolithic; Eneolithic; Geographical Information System; alluvial geoarchaeology; landscape dynamics*

The purpose of modeling is insight, not numbers.
(Hamming 1962)

INTRODUCTION

The aim of the present paper is to access the palaeodynamics of the Ljubljana Moor landscape in the period between 6500 BP and 4000 BP. My intention is to take one step beyond the traditional debate concerned mainly with the description of the static site environs and the detection of the human impact on the landscape and which is – at least in my opinion – unable to access long-term co-evolutionary dynamics of human groups and landscape on the Ljubljana Moor. The following text aims to suggest that Geographical Information Systems (GIS) can provide not only a sophisticated cartographic tool, but a flexible environment within which the dynamics of the past landscapes can be modelled and explored.

Using an on-going case-study focused upon the landscape dynamics of the Ljubljana Moor, a dynamic GIS model was constructed in order to explore the dynamics of the floodplain and its implications in the context of the Mesolithic/Neolithic/Eneolithic occupation of the Ljubljana Moor.

BACKGROUND TO THE STUDY AREA

Ljubljana Moor or Ljubljansko barje (Fig. 1) is a large wetland in the extreme south of the Ljubljana basin in the central part of Slovenia. It is a tectonic depression, with an extensive alluvial floor and flat surface, fringed by three major topographical regions: the Alpine foothills, carstic Dolenjska region and northern tip of carstified Dinaric mountains. The bottom can be generally divided into three basic topographic units, the most extensive being a marshy flood-plain, then alluvial fans and, finally, isolated hills. The whole area is characterised by dynamic tectonic activity taking forms from long-term subsidence and uplift to catastrophic earthquakes, the last one in 1895. The main water-courses are Ljubljanica, Ižica and Iška rivers, with extensive carstic watersheds in the Dinaric Mountains, and the River Gradaščica from the Alpine foothills. Prior to the major regulation works and commercial peat extraction in the 19th century, parts of the area were covered by up to 6 m of peat and characterised by predictable cyclical annual floods nested within an unpredictable cycle

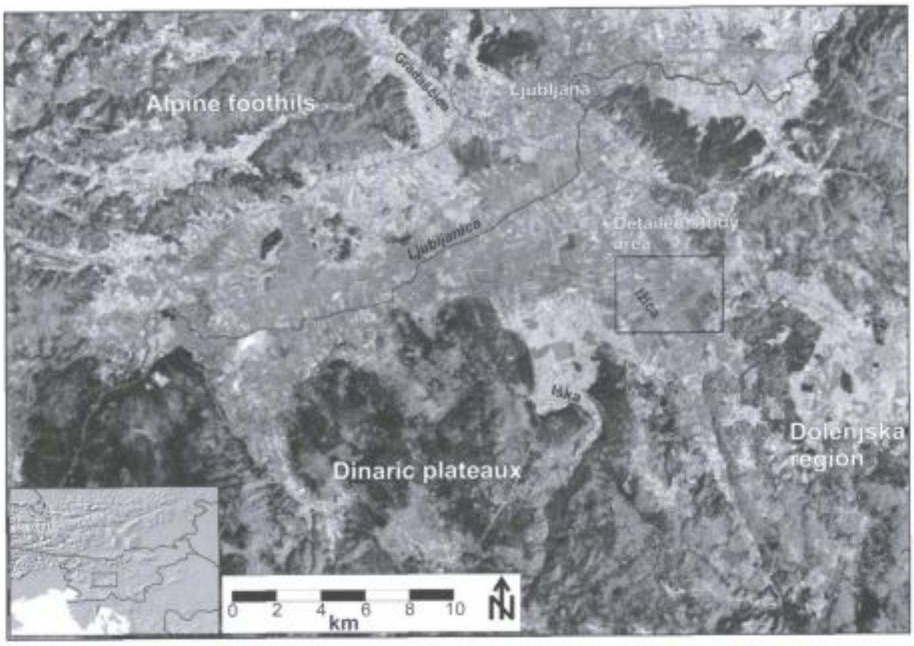


Fig. 1. False colour sattelite image of Ljubljana Moor with the places mentioned in the text. Landsat TM, channels 2,5,7. Source: EURIMAGE, Frascati, Italy. Owner of the data: Joint Research Centre, Ispra, Italy. Owner of the georeferenced mosaic: Zavod Republike Slovenije za Statistiko, Slovenia.

of major flood events. Today, as a result of flood control works, the landscape is effectively controllable and stable.

RECENT ARCHAEOLOGICAL RESEARCH

Archaeological interest in the region started in the second half of the 19th century when the first pile dwellings were discovered. This discovery was a part of the wider cultural historical context in the second half of the 19th century, when a chain reaction of pile-dwelling discoveries was triggered by the initial discovery of the pile dwelling on the Lake Zurich (*Greif 1997.72*). The peaceful landscape of a pile-dwelling situated at the edge of a lake surrounded by mountains served as a model for interpreting Neolithic settlement patterns and palaeo environment (*Keller 1854*). In the case of the Ljubljana Moor this romantic picture was supported by the generalised stratigraphic sequence of chalky lacustrine clays and marls followed by organogenic muds and finally peat, interpreted as a result of linear hydroseral succession from lake to swamp and raised bog (*Melik 1946; Šercelj 1966.443*). A vicious circle was formed when archaeological data was used to support environmental data and vice versa.

The model created in the mid-19th century was applied to the archaeological and palaeo environmental data at the Ljubljana Moor until the 1990s. This was a period when the search for pile-dwellings was fashionable and intensive – although poorly documented – excavations were important for the institutional promotion of Slovenian prehistoric archaeology (*Budja 1995.176*). The floor of Ljubljana Moor was privileged and other parts of the Ljubljana basin and background hills were neglected until the 1980s, when the discovery of Mesolithic lithic scatters (*Josipović 1985*) focused research interest on – and only on – the fringes of the Moor and at edges of isolated hills. But new data was still collected unsystematically and researchers ignored the Moor's hinterland. The Mesolithic settlement pattern was interpreted as an indicator of lakeside activities and was used to support the model of gradual and linear succession from lake to swamp and raised bog.

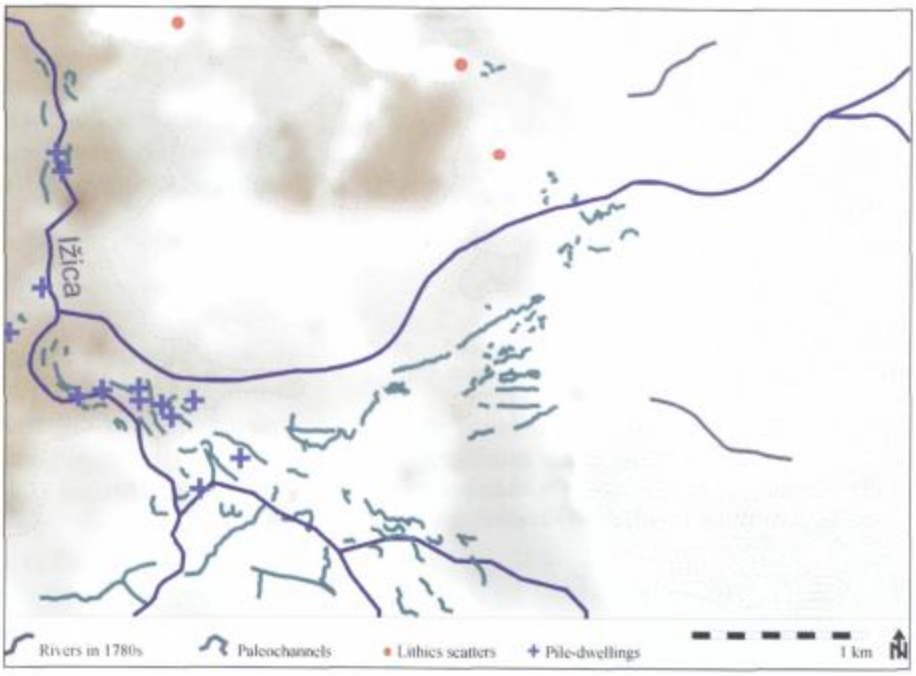
In 1995 Budja proposed an alternative scenario for the landscape dynamics and settlement patterns based on Šifrer (*1984*) flood-plain hypothesis. Šifrer interprets chalky silt and clay deposits as the sign of erosion of various soils in the Dinaric Karst region at the beginning of the Holocene. These sediments are interpreted as indicators of climate changes and past flooding of the Ljubljana Moor, rather than as proofs of a lake existence. Budja (*1995*) explained Neolithic and Eneolithic sites as riparian settlements and their pattern as a human response to flood-plain evolution.

ACCESSING PALAEO DYNAMICS

Detailed study area

The eastern part of the Ljubljana Moor was chosen for intensive research into floodplain dynamics. A

Fig. 2. Detailed study area. Shaded area between 288 m (dark shaded) and 291 m (light shaded).



detailed digital elevation model (DEM) was generated and floodplain features such as lakes, oxbow lakes and palaeo channels were identified from aerophotos and DEM. The pre-regulation hydrological network was reconstructed from historical maps (Fig. 2).

Settlement patterns

The remnant settlement pattern shows a clear preference for the floodplain by the Neolithic/Eneolithic "pile-dwellings" and a position just next to the palaeo channels. The distribution of the Mesolithic/ Early Neolithic lithic scatters is limited to the edges of the floodplain.

Spatial statistics tests were performed in order to observe the relationship between sites and environmental variables, in this case, distance to the nearest river and palaeo channel.

Firstly, the relationship between sites and the pre-regulation hydrological network was tested using Kolmogorov-Smirnov two sample test (*Hodder and Orton 1976.226–229*).

Samples of the 32 pile dwellings and 19 lithic scatters was used in the analysis. The difference between distributions of pile-dwellings and streams proved to be significant at well below the 1% level. Pile-dwellings show a marked preference for proximity to water, with about 90% of the sites located less than 500 m from the nearest stream.

Lithics scatters display a similar, but less marked preference, and the difference between distributions was proven not to be significant at the 5% level (Fig. 3).

Another test was performed to observe the relationship between the location of pile-dwellings and palaeo channels in the detailed study area (Fig. 4). 13 pile-dwellings were used in analysis and the difference between two distributions was proven to be significant well below the 1% level.

Possible interpretations of the observed pattern are:

- There were no large scale river migrations since the Neolithic/Eneolithic.

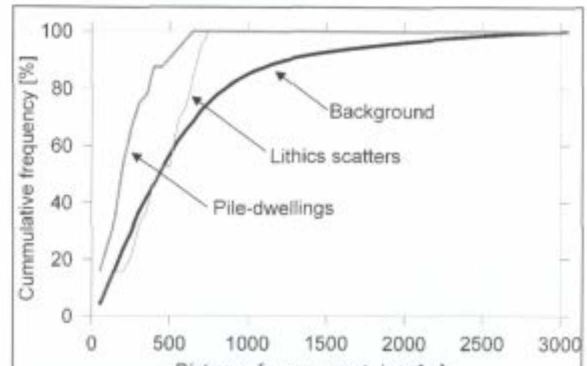


Fig. 3. Relationship between number of sites and background (expected number of sites) at distances from nearest river (obtained from historical map) on a regional (Ljubljana Moor) scale.

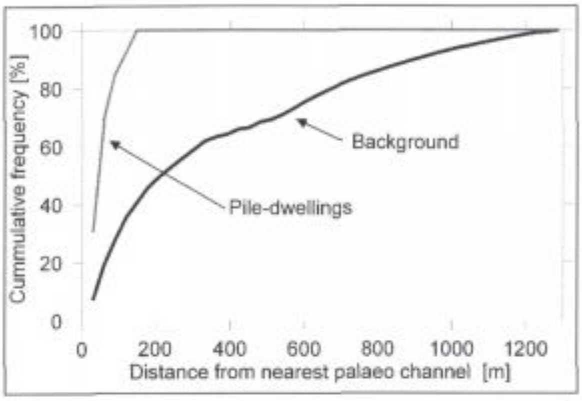


Fig. 4. Relationship between number of pile-dwellings and background (expected number of sites) at distances from nearest palaeo channel on a catchement (Detailed study area) scale.

- Pile-dwellings show a preference for riparian environments.
- Proximity to running water was not the key factor for choosing the location for activities, observed today as lithic scatters or
- drastic landscape restructuring (drying up of the lake and formation of the floodplain) took place in the Late Mesolithic.

However, this is a modern, quantifiable and first of all static landscape, and the next step is to access the dynamics which shaped it in the past.

Processes that shaped the floodplain

Looking at the long-term structuring of the Ljubljana Moor landscape it is obvious that floods are the main factor which contributed to the shaping of the floodplain. However, it was high magnitude, unpredictable floods that changed the floodplain dramatically.

There are four interlinked processes which are the consequences of flood events of different magnitudes and which can be read from the modern landscape.

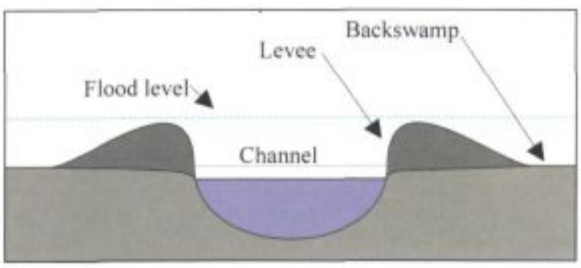


Fig. 5. Levee formation.

Levee formation

Levees (Fig. 5) are linear features located just next to a channel. They are formed by the deposition of sediment when flood-water exceeds bank height and its velocity drops abruptly (*van Andel and Runnels 1995.485; Brown 1997, Table 1.1; Knighton 1998.145*).

Meander migration

In meandering systems (as most of Ljubljana Moor rivers are) the most common type of channel change is meander migration (Fig. 6). This can be classified into a number of different forms, such as rotation, translation, extension, enlargement and combinations of these (*Brown 1997.26–27; Knighton 1998. 226–227*).

Meander neck cutoff

High energy flood water can find a shorter route and cut-offs meander into neck (Fig. 7). Result is a distinctive oxbow lake or swamp (*Brown 1997.28*). Meander neck cut-off can also be caused in a low magnitude, cyclical flood event.

Avulsion

The most dramatic process is called avulsion (Fig. 8). The gradual rise of the river bed and adjacent levees causes the river to seek a new course lower down in the flood-plain. Avulsion can be triggered by a high magnitude flood. Ribbon lakes or palaeochannels are typical result of this process (*Brown 1997.28; van Andel and Runnels 1995, Fig. 2, 484*).

The model

A simple GIS based dynamic model of stream behaviour was constructed in order to access the long-term structuring of the floodplain. It simulates the

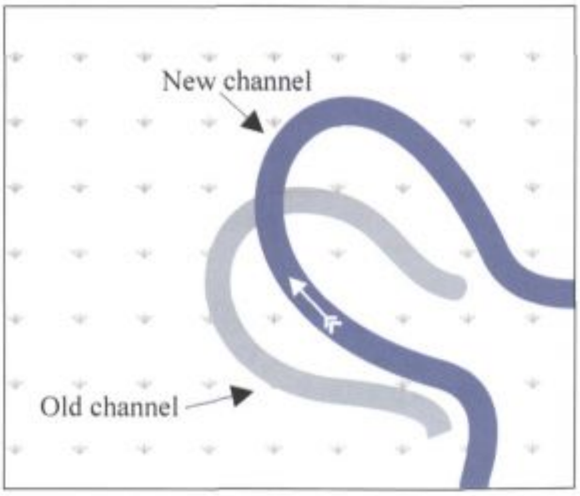


Fig. 6. Meander migration.

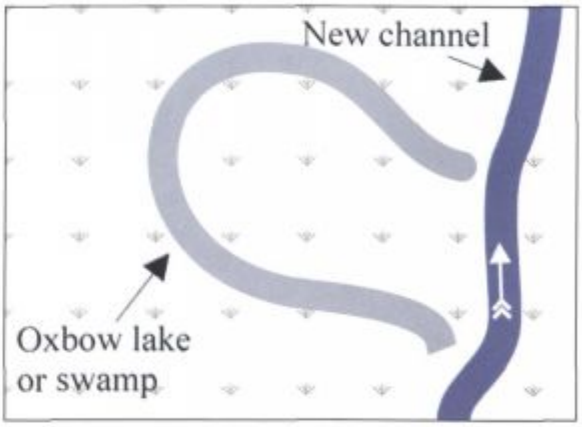


Fig. 7. Meander neck cutoff.

effect of various permanent alterations inflicted upon a landscape by the action of floods events of different magnitudes. GIS was then used to apply a group of hydrological modelling algorithms to the post-flood topographical data in order to simulate the movement and behaviour of water flows across the post-flood landscape. The modelled landscape has it own history as topographic changes of previous flood events are inherited and contribute to the shaping of subsequent events. Stream course data obtained after each run of the model were overlaid to observe the long-term effects of floodplain dynamics. The resultant map (Fig. 9) can be seen as a fuzzy set, with different levels of probability (uncertainty) for fluvial activity at each grain of the floodplain. A by-product of the model is an animation of stream migration which offers a truly dynamic view of the floodplain and replaces the static abstraction of the map.

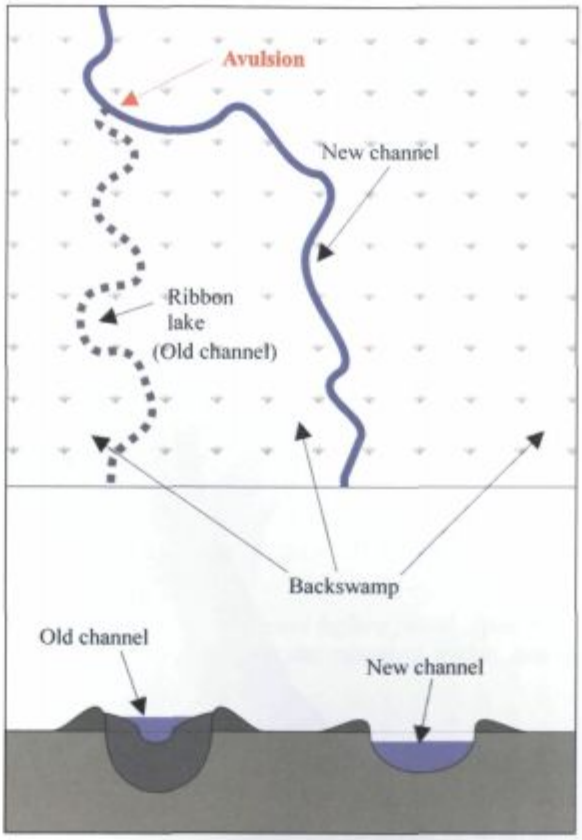


Fig. 8. Avulsion.

RESULTS

What strikes me most how dynamici the simulated floodplain is. Simulated streams change their course after each flood event. Small-scale stream migrations and large scale migrations also took place, but not

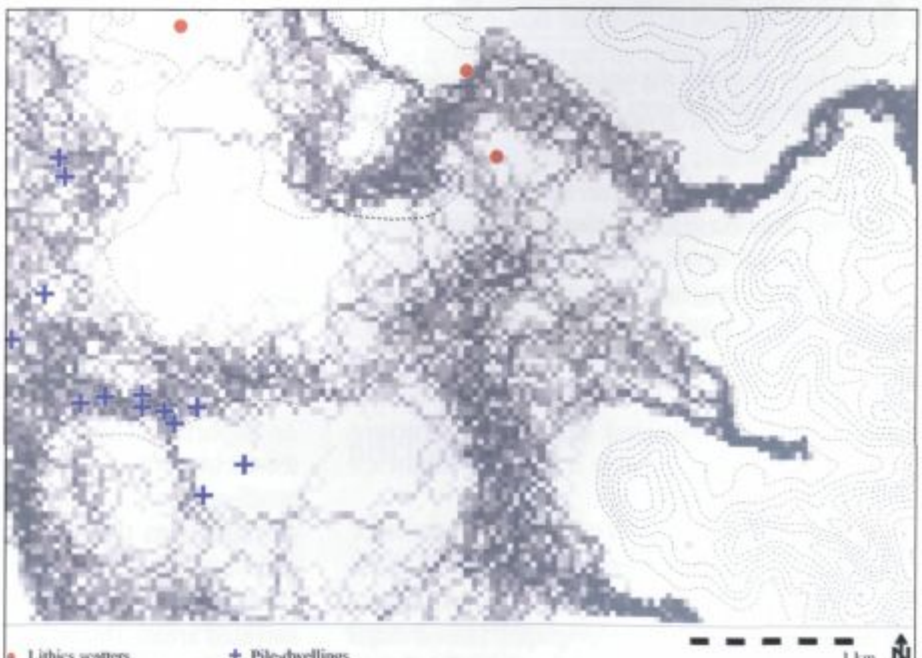


Fig. 9. Model results after 200 runs. Dark shaded areas indicate areas of high probability of fluvial activity.

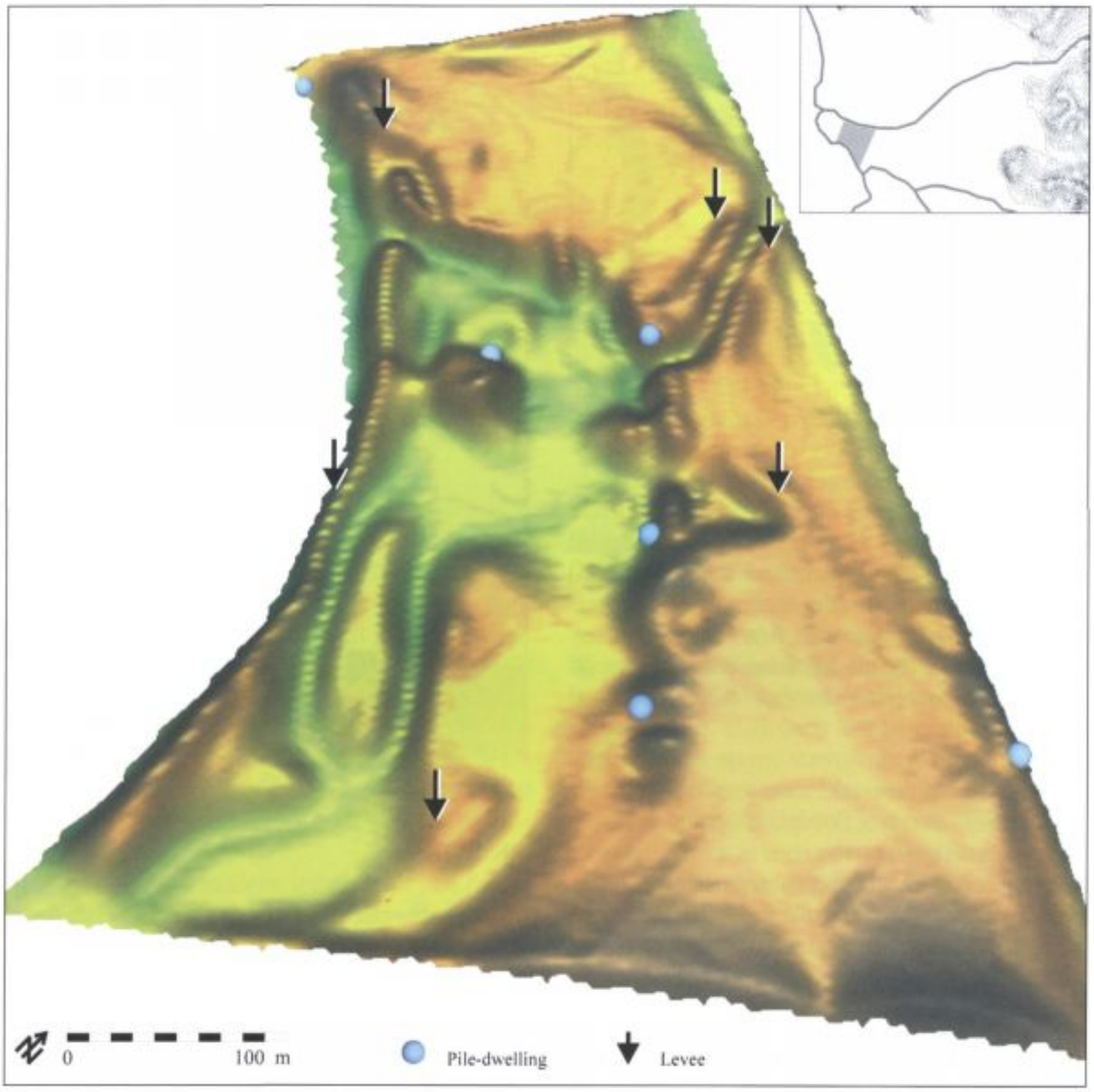


Fig. 10. Very detailed digital elevation model (DEM) of a small area of the floodplain. Several palaeochannels and adjoining leeves can be observed. Note the position of the pile-dwellings next to the palaeochannels.

randomly. Several possible corridors for each stream occur and flow oscillates between them.

If we translate this into the palaeo landscape, it means that the major consequences of the floods were not simply effects of the inundation, of high water, but the migration of water streams which reshaped the flood-plain and changed its structure. The floodplain was probably a dynamic landscape even on a human time scale.

Another feature is the enormous sensitivity of the simulated floodplain to disturbance. Simulating even the smallest changes in the topography caused major changes in the shape and structure of the floodplain. A corollary of this observation could be that human intervention in the drainage catchement of the floodplain or in the floodplain itself – forest burning, deforestation, grazing, cultivation – could have had a profound effect on the landscape and the future actions of the people inhabiting it.

An important feature of the simulated floodplain is the occurrence of isolated patches almost completely unaffected by fluvial activity. These are areas slightly elevated from the floodplain.

Lithic scatters are located on some of these slightly elevated areas. Absence of evidence of lithic scatters on the floodplain is, in my opinion, not evidence of

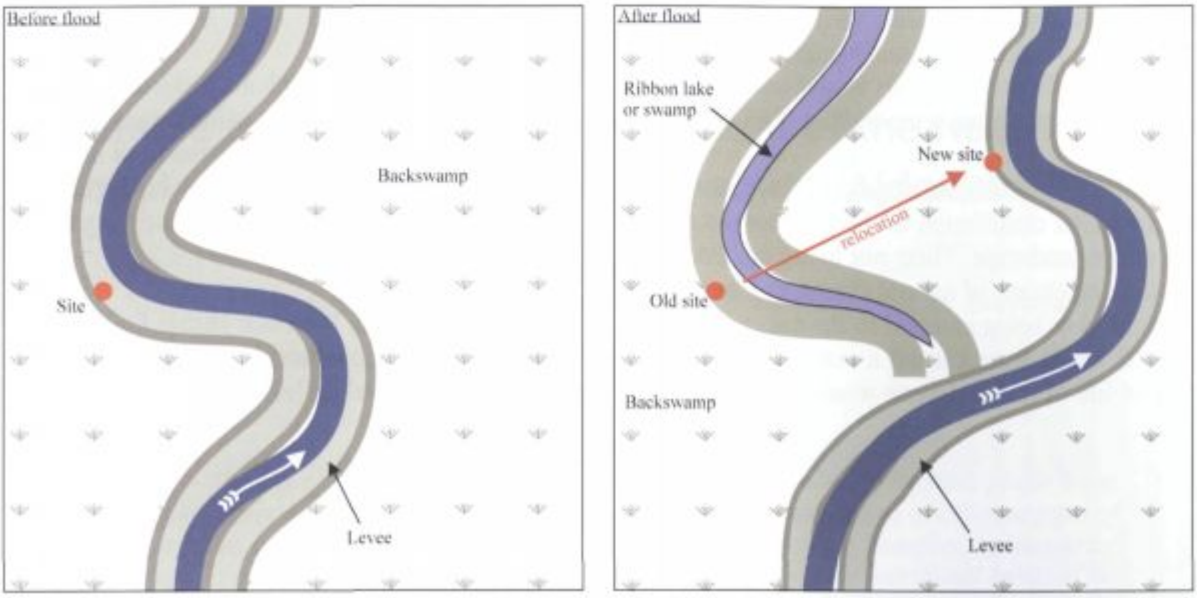


Fig. 11. Model of site relocation. Site located on a levee next to the active channel before flood. After high magnitude flood event, which restructures sites environ and cuts off site from the running water, site is relocated to the active channel.

absence. It is a result of a selective preservation of the sites with permanent structures (pile dwellings), whereas fragile Mesolithic/Early Neolithic sites of activities were washed away or rendered invisible by fluvial processes.

Neolithic and Eneolithic "pile-dwellings" display a different pattern. They are located just next to or in the stream corridors of the simulated flood-plain and just next to the identified palaeo channels in the real floodplain. As seen above, this pattern can be observed all over Ljubljana Moor. As suggested also by the stratigraphy of the excavated pile-dwellings (*Bregant 1975; Budja 1995*), sites were obviously located next to active channels on natural levees (Fig. 10), which were dry most of the time and never deeply submerged by flood-waters.

Flood can have several effects on the site:

- Inundation, which could have caused structural damage to the site. A human answer to that would be rebuilding of the site, probably at the same location.
- Bank erosion, which could have promoted undercutting of the levee and eventual bank collapse and damage to the site. A structure interpreted as a wave-break which was discovered at the Maharski prekop site could have served to protect the site from bank erosion (*Bregant 197. Fig. 1*).
- Stream migration and avulsion, as a result of catastrophic flooding which would have effectively changed the shape of the floodplain, restructured site environs and cut the site off from the active channel and running water. Human action would be the relocation of the site to the next active channel (Fig. 11). I believe that proximity to running water was a key factor in choosing a place to live.
- High density and number of sites can be seen in this perspective as a result of short duration of occupation and frequent relocation of the sites due to the effects of the catastrophic floods. Short duration of occupation was proved also by dendrochronological research on two sites to be about 50–80 years per site (*Čufar et al. 1998*). On the other side, long spans of radiocarbon data from sites Maharski prekop (*Budja 1995.174*) and Parti (*Harej 1978.74; Harej 1982.46*) suggest either long duration of occupation or more possibly, several re-occupation of the sites.

DISCUSSION

What can this exercise tell us about the perception of the flood-plain landscape by the people dwelling in it? I believe that cyclical, annual, predictable floods formed an integral part of the everyday lives of the people inhabiting flood-plain, just like the presence of enriched soils, reed beds, wild-fowl, fish, water chestnut and other malign and benign things that the flood-plain offers. The floods would have served to construct and maintain temporalities (*Gillings 1998*).

However, it was rare and unpredictable, catastrophic floods which contributed to the long term structuring of the landscape. Their not being embedded in people's taxonomy of natural events and their being thought of as being external to the natural order of events, would have caused a major change in the way of life of mid-Holocene women and men.

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