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Cartographic source materials and cartographic method of research in the past environment analyses

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Abstract. The article reviews a methodology of using early maps and other cartographic materials in the past environment studies. The application of the cartographic method of research is presented on examples from different research fields, but cases from the Earth Science are analysed deeper – from hydrography, through geomorphology to many aspects of economic geography. What is broadly described is a detection of human interaction with the nature: all traces that are marked by settlement, land use, communication, etc. This paper shows that the past environment, with its ways of use and topology can be recreated using early maps. These materials help finding hidden marks from the past, saved in abandoned orchards, old roads composed into modern network, toponyms storing past spatial relations, etc. It is also shown that analyses of early maps have to be conveyed with great care and responsibility, especially when it comes to geometric properties of old cartographic materials. The Geographic Information System (GIS) is helpful in such a situation, but its use is more profound. In this paper GIS is described as a tool being a great step forward in the applications of cartographic method of research and many examples of such applications in the field of a landscape analyses are given – from simple yet informative numeric outcomes of research to 3D virtual creations of long-gone landscapes.

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Contents:

1. Introduction

Maps are a source of information not only about a modern state and condition of the environment, but also about its past. Early maps contain various kinds of historical information and present it on many levels. The way they are read and the kind of information gleaned from them depends mainly on a reader's needs and scope. For historians, early maps contain data of a strict historical sense – they are additional materials supporting and supplementing texts, showing spatial relations, human activity in the past, etc. (Alexandrowicz, 2008; Skrycki, 2011). For environmental science researchers, early maps show the past state of both the natural and anthropogenic environment (Pearson, 2006; Gregory, Healey, 2007; Nasiłowska, 2008; Wolak, 2008). Last, but not least, they are evidence of map-making science and technology, as well as being a part of the heritage for cartographers that are interested in methods of maps production and their geometric qualities (Beineke, 2001; Gaspar, 2010; Nieścioruk, 2011a). All these aspects are important and none can be omitted when using early maps in research if one aims to understand a map well and obtain proper conclusions. A comprehensive approach is highly advised, with a sensible shift towards a main area of examination. For example, the cartographer's methodology and land cover classification usage needs to be understood in order to convey the historical land use research right and properly judge the author's goals (Nieścioruk, 2011a).No matter what research approach is used and what aspects are investigated, both source (early) and outcome (resulting) maps help to describe, analyse, study and understand natural and anthropogenic phenomena. The process is called the cartographic method of research (Saliszczew, 1998: 265) and is widely used in the field of the Earth Science including all environmental changes research.

This paper concentrates on the methodology of the past environment analysis. However, it is worth mentioning that early maps, being a great information source about the past, especially transmitting spatial and topological context absent in text-sources, were not recently widely used (or not as widely as they could be) by historians (Alexandrowicz, 2008). In the last decade the extensive use of maps by historical geographers (as presented below) and rapid spread of popularity of GIS (Geographic Information Systems) has changed (and still changes) the situation among historians as well. They use for a greater effect maps as a way to communicate and present research results and information about the past as well as a source material. The first case is not only popular school history atlases, but also more scientific (but still popularising the subject among wider recipients) publications, being the result of cooperation between historians and cartographers (Wnuk et al., 2007). Even strictly scientific publications on history take advantage of maps as a medium to show results, analyse a topic and describe a spatial phenomena (Szady, 2010). The second case is application by historians (sometimes having history of cartography in their research scope) using maps as a source information of the same level as a text or even a primary one (Gregory, Southall, 2002: 120–121).

The aspect of analysing early maps stressed in this paper is using them by Earth scientists (for example geographers, environmentalistand and ecologist) in a processes of research on both natural and human-changed landscape. Such researches are based mainly on a series of maps, while 'series' may refer even to as little as two. In such case, one just compares a past state with a current one, i.e. using a modern map. An ortophotography or a satellite imagery serves well here too. Of course the longer and/or the more denser a series is, the better. However, some additional remarks are needed. Maps should not be selected randomly (Plit, 2007: 199), as they should cover an examined area in approximately the same scale and with similar scope of information, at least in all aspects needed for the given research. It is a serious problem when conducting analyses dealing with the Polish environment – 19th century maps are of very different scales, contest, mathematical basis and quality, depending on an area and country occupying Polish territories during the over-century partition of Poland. Maps published after World War II are also not fully reliable due to censorship and political reasons.

2. Environment features analysed with early maps

Of the natural environment elements, hydrography and land cover (especially forests) are among the most widely-analysed. Landforms are examined also, but often in connection with hydrography (riverbeds and plains). Stand-alone geomorphological analyses refer to characteristic features, e.g. dunes or gullies and – when more complex – are performed with extensive use of GIS.

Hydrography is an element of the environment that seems to be easily examined. A water network can be simply compared and changes can be traced (Kozieł, 2010; Plit, 2010). Rivers are also being analysed in an aspect of their relation to other elements in very small (in a sense of area) scale, e.g. spring locations on a base of early maps (Gołaski, 2011) Superimposing two maps may give unreliable results however. The problem is already the mentioned mathematical base (map projection). Even georeferenced maps from the 19th century may be hard to compare in an aspect of hydrography, as rivers are twisting line elements, what makes it difficult to decide which meander change is the result of change in nature and which is just a lack of georeferenceing control points. Analyses that are more complex include, for example, a comparison of density factor of rivers on different maps. Again, the scale has to be the same or closely similar and still there is a problem of generalisation level as well as presentation and classification methods used on each map, resulting in a slightly different image of river network (Dawidek, Turczyński, 2007: 181).

Cartography supports geomorphological analyses in river valleys in case of riverbed changes (Maruszczak, 1997). The past location of the river is often visible on topographic maps from pre-melioration and river engineering periods in the forms of oxbow lakes, abandoned meanders and meanders scars (Kowalik, Suchożebrski, 2011). Similar analyses may refer to open water body changes as well, e.g. morphology of a coastline, a shallow water area or estuaries (van der Wal, Pye, 2003).

Researches on small areas often combine a few factors besides hydrographic one – geomorphologic and anthropogenic, as changes in river network on limited (especially urbanised) territory, are always a result of both human activity and natural conditions (Kociuba, 2003). A river network analyses are quite frequently accompanied by landforms studies (Maruszczak, 1997; Pradela, Solarski, 2010), but works concentrating on a geomorphology only are not rare, including cases of using both early maps alone and maps combined with a digital elevation model (Solarski, Pradela, 2010).

The other important environment feature analysed with series of cartographic materials is the land use and land cover. Due to a nature of maps and the process of generalisation it is not always easy as it can be in the case of previously mentioned water bodies. The generalisation of rivers is often mainly quantitative as some smaller meanders, lakes or streams are omitted. In the case of land use the generalisation can be to the same extent both qualitative and quantitative. Smaller fields may be joined together, small orchards may be removed, but also land use classes may be joined. ‘Crop fields’ and ‘meadows’ classes on one map may be turned into ‘agriculture areas’ on another one. This is the reason why land use analyses often take advantages of aerial photographs and satellite imagery, as they have no pre-classified categories. Such studies are, however, time limited – broad access to these images is possible for period after World War II, especially since 1990s, when it was not as restricted as before (Sanecki, 2006: 155). A longer, covering pre-war period time series analyses mix maps with images or rely on maps only.

Probably the most popular land use studies deal with general land use, combining built-up areas (residential and industrial), arable land, forest, communication, waters, etc. The territorial extent of areas being an object of interest differs significantly, from large, mainly rural regions (Bielecka, Ciołkosz, 2000; Skocki, 2001; Nasiłowska, 2008), with a domination in agriculture (Fig. 1) to smaller areas (van Eetwelde, Antrop, 2004). Even tiny areas of local habitats, villages, hamlets and fields are being analysed using topographic maps, aerial images (Pabjanek, 1999), topographic or similar large- (Zachariasz, 2012) and medium-scale maps (Pearson, Collier, 2002) or cadastre maps (Wolak, 2008; Sobala, 2012). Urbanised areas of modern towns and agglomerations are also being selected as a research topic (Nowocień, 2011) as well as suburban agriculture areas, both past rural, incorporated into cities

(Nieścioruk, 2011b) and modern rural or semi-rural areas (Ichikawa et al., 2006). Some of such works concentrate on results shown on final maps only, others include quite complex statistics of change (Nasiłowska, 2008). A group of researches combine land-use with extensive analyses of other environmental factors, for example hydrography (Hildebrandt-Radke, Przybycin, 2011).

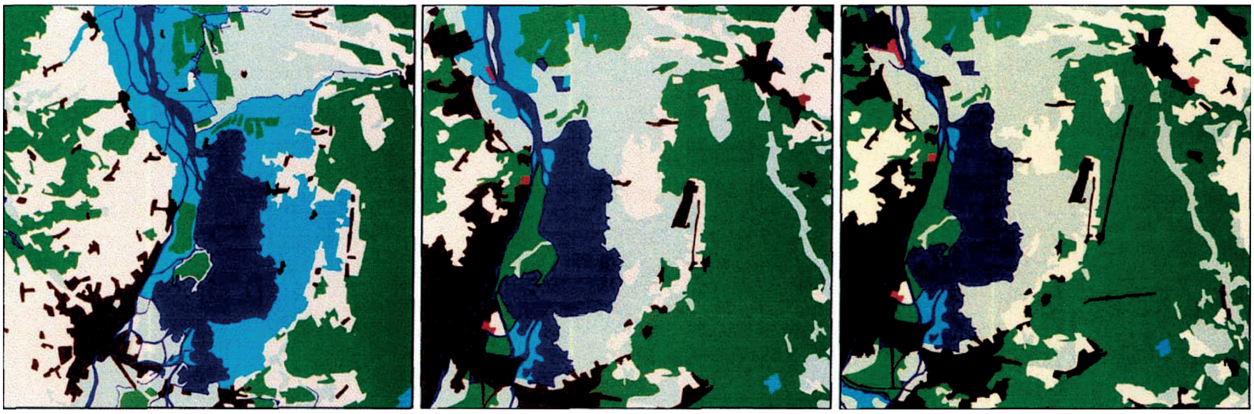

Fig. 1. Changes in land use in Szczecin (Poland) area (from left: second half of the 19th century, 1975, 1992), tones of grey represents different land use classes

Source: Bielecka, Ciołkosz, 2000: 101

Of one-category land use analyses, forest cover change detection is among most widely conducted. These areas are always depicted as an easily distinguished class on early maps (no matter how old), as forests are a significant and an important landscape element. Even early topographic maps show forest boundaries in a clear way, hence it is possible to combine maps to create a long time-series to analyse (Fig. 2). Such series usually consist of both maps and aerial/satellite imagery, as these images give more detailed and non-generalised information (Wilson, 2005). In case of about last 50 years many analyses rely on satellite imagery only (Krawczyk, 1993; Kozak, Troll 1994).

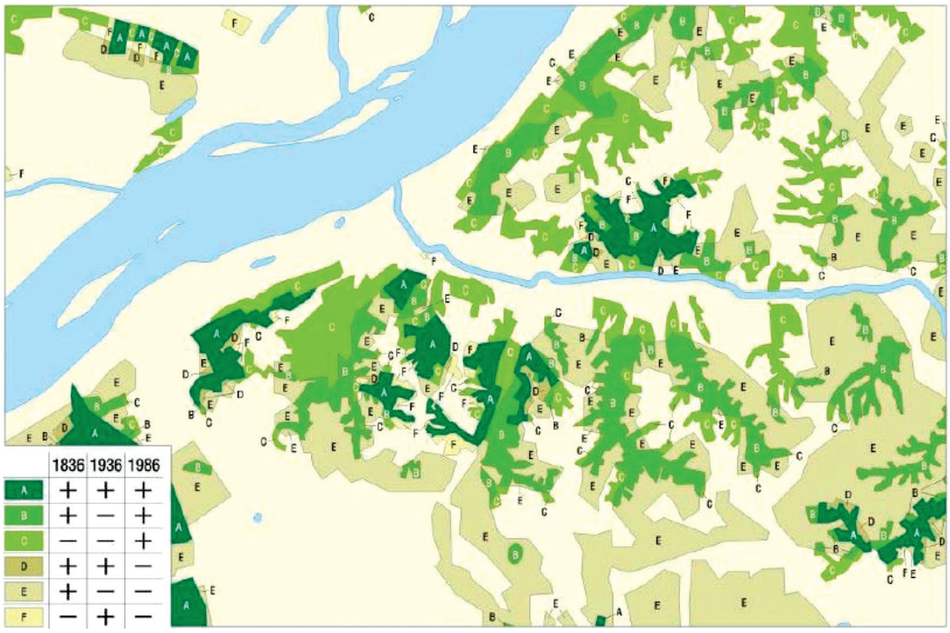

Fig. 2. Long time-series based on topographic maps in forest changes analyses (map of types, Kazimierz Dolny (Poland) area)

Source: Meksuła, 2001: 326

The above statement about exclusive satellite imagery use describes a tendency in changes analyses of many environment aspects in recent times: land use (Sochacka et al., 2008), land use in an industrial changed landscape (Szaryk, 1983), and changes in build-up areas (Szczypek, Wika, 1990; Nowakowska, 2008). Many detected changes are of an anthropogenic origin. The land use tends to differ over time as people deforest area to plough fields, turn swampy river valleys into meadows through melioration, plant new forest on abandoned fields, etc. Some changes are of more rapid and unplanned nature, e.g. in mining areas (Pradela, Solarski, 2010).

Urbanised areas are of course these where anthropogenic changes occur in high rates. They involve both urban-sprawl (new roads, including ring roads and new districts along them) as well as changes in long-established, relatively stable urban areas. Main factors causing natural and cultural landscape changes are man-associated: transport and its infrastructure, urbanisation and globalisation (van Eetwelde, Antrop, 2004: 80).

The latter change analyses are often parts of cartometry studies as stable, unchanged landmarks are a base of such (Benavides, Koster, 2006: 197; Nieścioruk, 2011a: 143). To define control (base) points, one needs to analyse an early plan and compare it with a contemporary environment and confront any possible changes with other materials, including texts, to ensure that the selected point is really stable – it has not changed and what is shown on a map is what exists in a modern space.

3. Past spatial relation preserved with maps

Changes are a documentation of our environment history. Early maps can be used to 'time-travel', in discovering the past and comparing it with a modern situation. As shown above, such studies are popular and they allow an evaluation of the environment change, human pressure, development of urbanised areas, shifts in land-use proportion, etc. Hence early maps and results of analyses based on them are important factors in environment sciences. Most of the changes leave some artefacts of the past, as none of them totally recreates a landscape. One can discover some of these remains with ease, based on photographs or on our common society-shared memories (old building preserved in modernised district, monuments of architecture, communication tracks, etc.). Some are more hidden, however, and stay secret for one using only non-spatial materials, especially if they deal with objects of different kinds then easily-noticed buildings. Maps show their unique character here as they preserve spatial relation between objects, not their look. Early maps confronted with a modern space can serve as a tool to restore past relations and, above all, discover if any of these relations are still vital and visible and if they shape a landscape until now.

Good examples of such less typical features from the past are fortifications elements. Some are long-defunct and almost unidentifiable, the others are massive and stand as an important part of a cityscape. Both can serve as good reference points and both have hidden secrets and traps. As mentioned, cartometric analyses and geotransformations of early plans into modern space are based on stable GCPs (Ground Control Points). Fortifications are useful, as they often shape the space of a city, conserving spatial relations. It refers mainly to bastions of large stronghold works, with well-visible characteristic points (Benavides, 2004), but even smaller features like flèches can be of use. They serve as reference points (Nieścioruk, 2011a: 144), but they can have other meanings too. Being a part of municipal grounds, they remained unbuilt even long after fortifications themselves have virtually disappeared (Fig. 3), preserving ownership and structural relations (Nieścioruk, 2005: 53). The question of using quite complicated constructions like fortifications needs more investigation than in a case of a regular building, when the only possible error refers to using part of the building that has been modified. A detailed view of fortifications, quite common on early plans, the nature of these constructions and (sometimes) a perspective or a semi-perspective depiction on a plan make it hard to select a proper, reliable reference point (Benavides, Koster, 2006).

The mentioned spatial relations and land ownership traces are visible in a case of other features too, especially roads and former rural areas incorporated (mainly in the 20th century) into city built-up zones. The land boundaries are very stable – even if they are not easily visible in a modern space, they preserve former relations and act as a reminder of power or authority (Plit, 2011), they are also sometimes remarked with artefacts like stones, posts, and local roads along them (Jop, 2011). Local roads (or roads in general) are great landscape elements storing past information. They shape and create the space together with interconnected inhabited areas (Fig. 4). Any change in an importance, a delicate shift or serious re-valuation in a road network can heavily influence a role of a settlement, leaving former important and bustling villages a bit out of a way (de Mezer, 2009) An ex-village road can be, on the other hand, adopted to a modern network. It is of course typical with transit roads going through and out of towns and gathering settlement along them, but can also happen in a case of a demolished village replaced with a modern residential area, leaving the former village road as the one of a few remains of a previous landscape (Nieścioruk, 2011b).

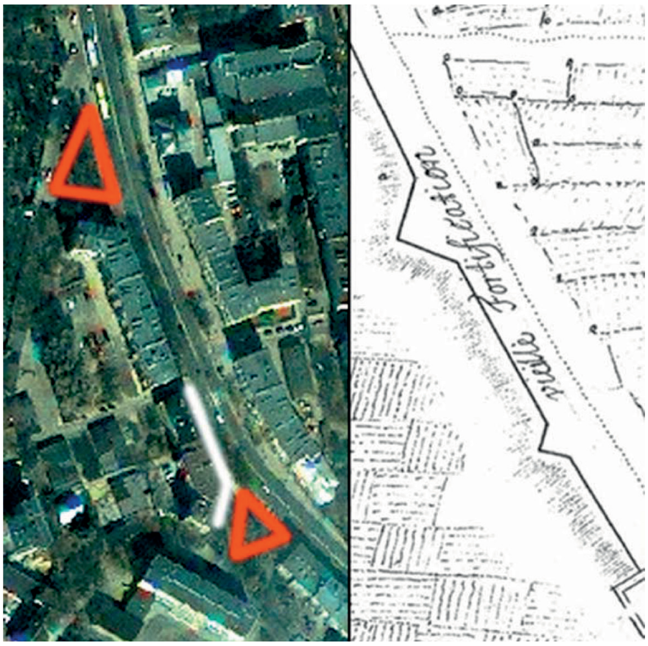

Fig. 3. Unbuilt areas of the 17th century fortification in Lublin (Poland) preserving a land property relations in a modern cityscape

Source: Nieścioruk, 2011a: 144

The identification of all of the above is based on maps that store information from the past, even if this information is sometimes hard to interpret or understand and a bit deterring due to technical reasons (Chías, Abad, 2009). Maps can help conducting multi-aspect analyses too, like general spatial arrangements (Chojnacka, Wilkaniec, 2009) or abandoned (Affek, 2011) and deserted (Soszyński, 2012) villages environment research. Maps can also transmit a cultural-only or a non-material information, which are, in general, elements forming cultural landscape, (together with manmade features). The former are all aspects of human non-commercial activities like commemorating persons or events important for locals or sacralising a space by means of crossroad shrines (Marszałek, 2008; Pawłowski, 2011). Shrines were votive, thanksgiving or just ritual, but for their users, members of a local society, they were filled with and based on personal stories, regional incidents or national history events (Garbacz, 2009: 274). The latter (non-material) refers to, for example, toponyms. Names can store information about the past, about human interaction with landscape, naming phenomena and objects to make them more common, friendly, humanised (Lipińska, 2003: 132–133), to communicate clearly and to commemorate. The nation (society) lives as long as its language is alive; hence, names store and serve for more than just a georeference for locals – they keep the spirit of a place alive together with its former users. Toponymic research are done on a different scale, but small area investigation can show information that is not available in other scales. Maps come in handy here, preserving names and their changes even when their users, who understood them, are no longer living (Chylińska, Kosmala, 2010). However, the most useful cartographic material are maps from the 19th and 20th century, showing a relatively recent past and quite a high number of toponyms (Makarski, 2005: 119). Names can remain in the cultural landscape even after when there has been serious changes in it – when former villages become part of a city, some toponyms are adopted to a new space, losing their reference objects and some are copied to a new object, being names of streets or districts (Nieścioruk, 2005). Names also record process of settlement changes and spread, together with their legislative and demographic background (Janicki, 2011).

Fig. 4. Former village road (map of 1961 and aerial photography of 1976) becoming path on a brim of contemporary residential area in Lublin (modern map and photography)

Source: Nieścioruk, 2011b: 451

4. Application of Geographic Information Systems in environmental change analyses using early maps

It has been mentioned a few times above that analysis of early maps is important also in the context of geotransformation of such material into a modern reference system. It allows further analyses and lets one discover relations not seen in other materials or in other ways. The base of transformation is a set of already described stable points (GCPs), which are used as referencing elements between an early and modern map. Proper selection of this is the critical part of cartometric analyses as well as a decision on the transformation method, no matter what scale or geographic extent is dealt with (Baletti, 2006; Gaspar, 2010; Nieścioruk, 2011a). Modern technologies in the form of a hardware equipped with GIS software can help conducting the transformation process with selected points and method. It is, however, not the only advantage of GIS. There are many more, even in context of researches on early maps, past landscape and its analyses.

In the last decade, GIS has been used so widely in researches related to the past (in both natural and anthropogenic aspects) that a new term referring to these activities and possibilities has emerged: historic GIS, often shortened to GIS (Gregory, Healey, 2007: 638). It is an application of spatial methods in the field of history. A new tool and a new approach to some scholars in history, defining it as a new use for a map (which some of them had been already familiar with) allowing them to use spatial databases with all the possibilities of analyses as well as technical aspects (Gregory, Healey, 2007: 638-639). For a scientist related more to Earth Science the tool and the approach haves given new possibilities, although the methodology is often known to them. However, this group already forms a new speciality, looking at the past through a space-oriented window, creating, managing and analysing databases of the world that no longer exists (Knowles, 2005: 7).

The most obvious use of GIS with early maps is superimposing them on the modern space in order to analyse the changes, as mentioned above. This analysis can be based on a raster image only (scanned maps) or combined with a digital vector data of different kinds. The scope of the analyses is the same as with no GIS – the difference is the tool only. The subject of research can be land cover changes (Wilson, 2005), water network (Pradela, Solarski, 2010), land use and its changes (Bigler, 2005; Pearson, 2006), non-material human activity, for example boundaries changes (Chías, Abad, 2009) and many more, similar to previously described.

What makes researche with GIS unique is its ability to produce an easily quantitative outcome. Computer tools of data processing can perform many computations faster and – what is more important – some of them are impossible to conduct in other ways or can be done with a very limited scope. Such numeric statistics can be a simple result of an environment change analysis, e.g. land use/land cover (van der Wal, Pye, 2003; Bigler, 2005; Wilson, 2005; Kozieł, 2010; Affek, 2011; Hildebrandt-Radke, Przybycin, 2011; Skaloš et al., 2011) or more complicated, based on a created model and with a spatial outcome in the form of maps (see Fig. 5) being the result of a cartographic method of research (van Eetwelde, Antrop, 2004; Pearson, 2006; Nasiłowska, 2008). Other numeric features are these characterising not only the subject of the map, but the map itself as a source material and historic monuments, both in the form of coefficients and of graphics (including the resulting maps) (Dunajski, Sieczka, 2008; Gaspar, 2010; Nieścioruk, 2011a). Maps can be assessed also in terms of proper land use recognition and land classification error propagation (not only what is shown, but also how true it is), which is not always taken into consideration (Nita, Myga-Piątek, 2012). Such techniques like fuzzy logic classification can be used here (Zachwatowicz, 2012). Land cover change statistics in GIS can be computed not only on maps solely – aerial photography can be used as well as more original approaches, for example coverage change in a comparison of ground-based photography from different periods (Kaim, Kolecka, 2010).

The numbers show a more mathematical image of the past. One cannot only evaluate the past environment in terms of absolute (how much) and relative (less or more) values, but also compare it with its currents state, finding information about qualitative (meadows turned into fields) and, most of all, quantitative changes (20% decrease in forest areas).

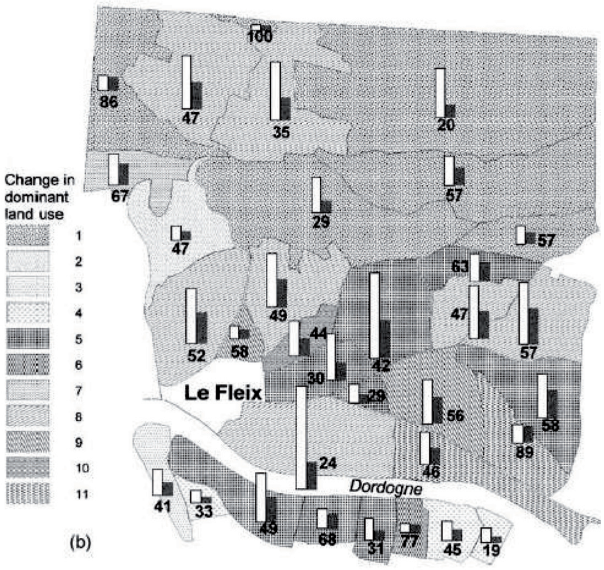

Fig. 5. The change map for dominant land use and number of fields in Le Fleix – Monfaucon (France). Classes show land use change (for example: 4 is arable land and grassland changed to fruit orchards), bars show number of fields

Source: van Eetwelde, Antrop, 2004: 91

5. 3D visualisations and animations in GIS

This is, however, still a numeric presentation. The important function of GIS (in terms of early maps and their analyses) is visualisation – turning numbers into images. The cartographic methods can be applied in GIS, but the system shows its potential when it comes into third dimension too. Even the simplest 3D models give new quality to early maps – georeferenced imaged draped on a modern digital elevation model (DEM) can help us in understanding and 'feeling' early maps (Rumsey, Williams, 2002). Such an effort is a step toward finding more data in early maps. When it can be analysed and visualised, why not to combine both? The result can be, for example, a visualisation of past terrain analysis outcome in the form of a historical relief with proper land cover added (Harris, 2002). It is not the limit of visualisations in GIS of course. The final step so far is recreating a past landscape as a three-dimensional model with both natural and anthropogenic features, based on, mainly, an analyses of early maps supported by field works, iconography studies etc. (Brumana, Achille, 2007). This can even be combined with constructing objects' 3D models using laser scanning of existing historical buildings (Visintini et al., 2007) and full landscape generation (see Fig. 6) (de Boer, 2010), leading to an almost virtual reality of the past. This aspect of visualisation, on the border of hardware, media, and IT technology is more and more presented in the GIS world (Batty, 2008).

Fig. 6. A rendered virtual historic landscape of Naaldwijk area I the Netherland

Source: de Boer, 2010: 55

Such works are the goals of analyses, leading to new results or a part of research of other kind, when a comparison of past views with the modern is a part of a broader analysis (Oleński, 2012). The end-user of a virtual image is not only a specialist, it can be one that can have an interest in some (often only visual) aspect of the research results. Virtualisation is even more general-user-oriented, when it is available to everyone, not only as a single-machine research outcome. Hence some projects combining early maps, historical data, reconstructions and knowledge are prepared and finalised as internet services (Fig. 7), where users can not only see the 3D past and use it object-oriented database, but also fully navigate through the past landscape on their own, using any internet-connected computer (Przewodniki Lublin 2.0).

Fig. 7. Internet-based, 3D virtual reconstruction of historic Lublin city environment

Source: Przewodniki Lublin 2.0

Technically, visualisation is a graphic representation of data gathered in a database, so it is an important part of a research to create such a database (Gregory, Healey, 2007). It makes understanding a database approach easier, when one keeps in mind that map is a database itself, sometimes even having attribute tables, like 'analogue GIS' (Pearson, Collier, 2002: 108).

Gathering materials is one, visualisation is another aspect, but digitising data and making them sensitive to analyses in GIS is another serious part of the work. This introduces historians and historical geographers to the mostly unknown area of expertise, the IT world. It is not using software alone now, it is sometimes creating software solutions and fully digital data management environments, including DBMS (database management system). All this can make the subject even more fascinating, demanding and interdisciplinary. There are a growing number of such interdisciplinary projects, combining early maps, historical data, cartographic visualisation and databases supplying all this and more information to an end-user (Ray, 2002; Szady, 2008; Micalizzi et al., 2012).

6. Conclusions

The examples above show a great diversity of use of cartographic materials in an area of environment change analyses and assessments. This profusion of cases shows how informative and important source maps are. It was also stressed that their use is sometimes limited due to specific map language (for example generalisation), geometric quality problems (caused by methods of early maps creation or political reasons) and lack of proper, similar scale time series. All this have to be taken into consideration during a research process.

The use of maps may be very broad and the cartographic method of research outcomes may be interesting. Modern technology gives a tool to apply that method in a more convenient way and broaden its use among users from many fields, from hardcore science applications to popularising its results and building up spatial awareness of environment change problems among society.

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