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Cartographic materials as a source of information about landscape change related to urban-sprawl on the example of Czuby residential district, Lublin, Poland

MSc thesis under the supervision of

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MSc thesis submitted in the framework of, and according to the requirements of the UNIGIS Master of Science programme (Geographical Information Science & Systems).

Jagiellonian University, Kraków, Paris Lodron University of Salzburg

2013
I declare that all sources used in the thesis were properly acknowledged. The thesis is fully my work and it was not and will not be submitted as a thesis elsewhere.

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Introduction

The map is a medium of informing about spatial relations and one of its qualities is depicting the most recent situation. In the digital era, life of information is very short and maps are no exception here – digital products (for example car navigation datasets) need constant update to reflect the changing world and to win market competition. Can old maps\(^1\) be of any interest or value then? Is outdated information stored in paper maps from the 20\(^{th}\) century or earlier useful? The answer is “yes” and the key word is a change. A change cannot be analysed with modern, up to date data only. One need past to compare it with present. Knowing both, changes can be traced, causes can be found and solutions or plans can be derived. This improves our life quality and enrich our knowledge.

This work concentrates on using topographic maps of the second half of the 20\(^{th}\) century to analyse changes in an rapidly altered post-war urban environment. The answer to be found is what kind of maps can be used, what is their reliability level and, most of all, what were the spatial changes caused by an urban-sprawl and if there are any remains of the past environment. With serious reshapes of space structures, demolishing villages, replacing them with constructing block of flats, maps is one of very few sources that can tell a big story from the past. This work tries to answer what are the limits of this message.

\(^1\) “Old map” is defined as an outdated map, “early map” is also outdated, but is treated as an historic object. An old map can become an early map not only with time, but also with situation change. The early map documents past map-making techniques and circumstances.
1. Cartographic sources and cartographic method of research in the past environment analyses

Maps, as it was mentioned in the introduction, are the source of information not only about up-to-date topics, but also about the past. Even modern maps present state of an environment from its past, but early maps present it to more extent, which is obvious. They contain historical information of various kinds and transmit it on various levels. How they are being read and what information is gained from them depends mainly on the reader and his/her attitude and scope. For historians early maps contain data about the past in a strict historical way – they are additional materials to support and supplement texts, showing spatial relations, human activity in the past etc. (Aleksandrowicz 2008, Skrycki 2011). For researchers dealing with life sciences, early maps show past state of both natural and anthropogenic environment (Pearson 2006, Gregory, Healey 2007, Nasiłowska 2008, Wolak 2008). Last, but not least – they are an evidence of science development and part of the heritage for cartographers, interested in methods of production and geometric qualities of maps (cartometry) (Beineke 2001, Gaspar 2010, Nieścioruk 2011a). All these aspects are important when using early maps in research. One needs not to forget about them when aims to understand a map well and get proper conclusions. A comprehensive approach to such studies is highly advised, with understandable shift toward main area of examination. For example, it is needed to know a cartographer's methodology and used land cover classification to convey right historical land use research and properly judge the author's goals (Nieścioruk 2011a).

No matter what research approach is used and what aspects are investigated, both source and outcome maps help to describe, analyse and study natural and anthropogenic phenomena. The process is called the cartographic method of research (Saliszczew 1998, p. 265) and is widely applied in the field of the Earth science. It is used as the main approach in this work, when environment changes are analysed with the use of maps, aerial photography and other sources.
1.1. Early maps and other materials in the analysis of environmental changes

This work concentrates on a 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 widely used (or not as widely as could be used) by historians recently, especially in Poland (Alexandrowicz 2008). The extensive use of maps by historical geographers (as presented below) and rapid spread of popularity of the Geographic Information Systems (GIS) in the last decade have changed the situation among historians as well. They use for great effect maps as a way to communicate and present research results and information about the past as well as source materials. The first case is not only popular school history atlases, but also more scientific publications, being the result of cooperation between historians and cartographers (Wnuk et al. 2007). Even strictly scientific publications on history begin to take advantages of maps as a medium to show results, analyse a topic and describe a spatial phenomena (fig. 1.1) (Szady 2010). Another case are historians (sometimes having history of cartography in their research scope) using maps as a source information of the same level as text or even a primary one (Gregory, Southall 2002, p. 120-121).

![Fig. 1.1. Religious diversity in Crown Poland (reduced), classes represent values of fractionisation factor (Szady 2010, p. 233)](image)

The most important aspect of analysing early maps, in regards to this work’s topic, is using them by the Earth scientist (geographers, environmentalist, ecologist) in processes of research on both natural and human-changed landscape. Such research are
based mainly on a series of map, while “series” may refer even to as little as two, when one just compares past state with current one. Not only a map can be used as a contemporary reference material – ortophotography or satellite imagery serves here as well. Of course the longer and/or more dense a series is, the better, with some needed remarks. Maps should not be selected accidentally (Plit 2007, p. 199), they should cover an examined area in an approximately the same scale and with similar scope of information, at least in aspects needed for given research. It is a serious problem when conducting analyses dealing with Polish environment – the 19th century maps are of very different scales, contents, mathematical basis and quality, depending on an area and country occupying Polish territories\(^2\). Maps published after the World War II are also not fully reliable due to censorship and political reasons, what will be further explained in more details.

Hydrography and land cover (especially forests) are among widely-analysed elements of the natural environment. Also landforms are examined, but often in connection with hydrography (river beds and plains). Stand-alone geomorphological analyses refers to characteristic features, e. g. dunes or gullies or, when more complex, are performed with extensive use of GIS.

The hydrography is an element of the environment which seems to be easily examined. A river (or more broadly – water) network can be simply compared and changes can be traced (Koziel 2010, Plit 2010). Rivers are also being analysed in an aspect of their relation to other elements in a very small (in a sense of area) scale, like for example spring locations on a base of (among other) early maps (Gołaski 2011). Superimposing two maps may give unreliable results however. The problem is – as mentioned before – mathematical base (projection). Even georeferenced maps from the 19th century may be hard to compare in an aspect of hydrography, as rivers are twisted 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. More complex analyses include for example 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 generalization level and presentation and classification methods used on each map, resulting in slightly different image of river network (Dawidek, Turczyński 2007, p. 181).

\(^2\) Partition of Poland lasted from the late 18th century to the end of the World War I.
Cartography supports geomorphological analyses of river bed changes (Maruszczak 1997). The past location of the river is often visible on topographic maps from pre-melioration and river engineering period in forms of oxbow lakes, abandoned meanders and meanders scars (Kowalik, Suchożebrski 2011). Similar analyses may refer to open water bodies changes as well – for example morphology of a coastline, a shallow water area or estuaries (van der Wal, Pye 2003).

Research on small areas often combine a few factors besides the hydrographic one – geomorphologic and anthropogenic, as changes in river network on limited (especially urbanized) territory are always a result of both human activity and natural conditions (Kociuba 2003).

Landforms are very often analysed together with river network (Maruszczak 1997, Pradela, Solarski 2010), but works concentrating on a geomorphology only are also conducted, including using both early maps alone and maps combined with a digital elevation model (Solarski, Pradela 2010).

The other important environmental feature analysed with series of maps is the land use and land cover. Due to a nature of maps and the process of generalization (areas joining, different land use classes), land use analyses often take advantage of aerial photographs and satellite images (as they have no pre-classified categories). Such studies are however time limited as broad access to these images is possible for period after the World War II, especially since 1990s, when it is not as restricted as before (Sanecki 2006, p. 155). A longer time series analyses mix maps with images or rely on maps only.

![Fig. 1.2 Changes in land use in Szczecin (Poland) area (from left: second half of the 19th century, 1975, 1992, reduced), colours represent different land use classes (Bielecka, Ciołkosz 2000, p. 101)](image)

Probably the most popular land use studies deal with a general land use, combining build-up areas (residential and industrial), arable land, forest, communication,
waters etc. A territorial extent of areas being the object of interest differs significantly. There are works concentrating on large, mainly rural regions (Bielecka, Ciolkosz 2000, Skocki 2001, Nasiłowska 2008), with domination of agriculture (fig. 1.2). Others take smaller areas into consideration (van Eetvelde, Antrop 2004). Tiny areas of local habitats, villages and hamlets are being analysed using topographic maps and aerial images (Pabjanek 1999), topographic or similar large- and medium-scale maps (Pearson, Collier 2002) or cadastre maps (Wolak 2008). Large urban areas of modern towns and agglomerations are also being selected as a research topic (Nowocień 2011) as well as suburban areas, both past rural, incorporated into cities (Nieścioruk 2011b) and still rural or semi-rural (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 research combine land-use with extensive hydrography analyses (Hildebrandt-Radke, Przybycin 2011).

![Fig. 1.3. Long time-series based on topographic maps in forest changes analyses (map of types, reduced) (Meksula 2001)](image)

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 landscape element. Even early topographic maps show forest boundaries in an acceptable way, hence it is possible to combine maps to create a long time-series to analyse (fig. 1.3). Such series usually consists of both maps and aerial/satellite images, as images give more detailed and non-generalized information for more recent times (Wilson 2005). In case of some last
50 years many analyses rely on satellite images only (Krawczyk 1993, Kozak, Troll 1994).

The last statement about exclusive satellite images use describes a tendency in environmental change analyses of many aspects in recent times: land use (Sochacka 2008), land use in an industrial changed landscape (Szaryk 1983) and changes in build-up areas (Szczypek, Wika 1990, Nowakowska 2008).

Many of the detected changes are of an anthropogenic origin. The land use tends to change 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, like in mining areas (Pradela, Solarski 2010).

Urbanized areas are of course these, where anthropogenic changes occur in high rates. They involve both urban-sprawl as well as changes in long-established urban areas. Main forces causing natural and cultural landscape changes are man-associated: transportation mode and infrastructure, urbanisation and globalisation (van Eetweld, Antrop 2004, p. 80).

Early maps confronted with modern space can serve as a tool to restore past relations and (above all) discover if any of these relations are still vital, visible and if they shape a landscape till now.

Buildings are typical as they are characteristic spots. Even shallow interest in a history let one identify main buildings, like churches, town-halls, nobles’ mansions etc., present on early plans. Identifying more hidden features needs both better knowledge of an early cartography and a history of a place. A good example of such features are fortifications elements. 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(d) a space of a city, conserving spatial relations. It refers mainly to bastions of big stronghold works, with well-visible characteristic points (Benavides 2004), but even smaller features, like flèches can be of use however. They serve as a reference points (Nieścioruk 2011a, p. 144), but they can have other functions too. Being a part of municipal grounds, they remained unbuilt even long after fortifications themselves virtually disappeared (fig. 1.4), preserving ownership and structural relations (Nieścioruk 2005, p. 53). The question of using quite complicated constructions like fortifications needs more investigation then in case of a regu-
lar building – the nature of them and (sometimes) a perspective or a semi-perspective depiction on a plan make it hard to select a proper reference point (Benavides, Koster 2006).

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

Fig. 1.4. Unbuilt areas of the 17th century fortification preserving a land property relations in a modern cityscape (Nieścioruk 2011a, p. 144)

The identification of all of the above is based on maps which store information from the past, even if this information is sometimes hard to interpret or understand and deterring due to technical reasons (Chías, Abad 2009). Maps can help conducting mul-
ti-aspects analyses too, like general spatial arrangements (Chojnacka, Wilkaniec 2009) or abandoned villages environment research (Affek 2011). Maps can also transmit a cultural-only or a non-material information, which are – in general – elements forming cultural landscape, together with man-made 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 votive, thanksgiving or just ritual cross-roads shrines (Marszałek 2008, Pawłowski 2011) often packed with personal stories, regional incidents or national history (Garbacz 2009, p. 274). The latter refers to, for example, toponyms. Names can store information about the past, about human interaction with landscape, naming things to make them more common, friendly, humanized (Lipińska 2003, p. 132-133), to communicate clearly and to commemorate. Toponymic research are done on different scale, but small areas investigation can show information not available in other scales and maps come in handy here, preserving names and their changes even when gone-names users are no longer living (Chylińska, Kosmala 2010). However, the most useful cartographic material are maps from the 19th and the 20th century, showing a relatively recent past (Makarski 2005, p. 119). Names can stay in cultural landscape even after serious changes of it – when former villages become part of a city, some toponyms are adopted into a new space, losing their reference objects, 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).

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

It has already been mentioned a few times how important is the analysis of early maps also in context of geotransformation such materials into a modern reference system. It allows further analyses and let one discover relations not seen in other materials or other way. The base of transformation is set of already described stable points (GCPs), which are used as referencing elements between an early and a modern map. Proper selection of them is a critical part of cartometric analyses as well as decision on transformation method is, no matter what scale or geographic extent is dealt with (Ba-
Modern technologies in form of hardware equipped with software of GIS can help conducting transformation process with selected points and method. It is, however, not the only advantage of GIS – there are many more, even in a context of research on early maps, past landscape and its analyses.

Recently, in the last decade, it has been used so widely in research related to the past (both natural and anthropogenic aspects) that a new term referring to this activities and possibilities has emerged: historic GIS, often shortened to hGIS (Gregory, Healey 2007, p. 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 a new use for a map (which some of them was already familiar with) and approaching them to spatial database with all its possibilities of analyses and technical aspect (Gregory, Healey 2007, p. 638-639). It gives new possibilities for scientist related more to Earth science too, although the methodology is better known to them. However, this group already forms new specialists, looking at the past through space-oriented window, creating, managing and analysing databases of the world that no longer exist (Knowles 2005, p. 7).

The most obvious use of GIS with early maps is superimposing them on a modern space and analysing changes, as mentioned above. The analysis can be based on the raster image only (see chapter 1.1) or combined with digital vector data of different kinds. The scope of analyses is the same as in classic early maps use, the difference in this aspect is the tool only – the subject of research can be land cover change (Wilson 2005), water network (Pradela, Solaraki 2010), land use and its change (Bigler 2005, Pearson 2006), non-material human activity, for example boundaries change (Chías, Abad 2009) and many more, similar to described in the chapter 1.1. What makes GIS-powered research unique, is its ease in quantitative statistic outcome. Computer tools of data processing can perform many computation faster and – what is more important – some of them are not possible to make in other ways or can be done with very limited scope.

These statistics can be a simple outcome of environmental change analysis, e.g. land use and land cover (van der Wal, Pye 2003, Bigler 2005, Wilson 2005, Hildebrandt-Radke, Koziel 2010, Affek 2011, Przybycin 2011, Skaloš et al. 2011) or more complicated, based on a created model and with spatial illustration in form of maps (fig. 1.5) being result of cartographic method of research (van Eetwelde, Antrop 2004, Pearson 2006, Nasiłowska 2008) or data characterizing not only the subject of a map,
but a map itself as a source material and historic monument, both in form of coefficients and of graphics (including maps) (Dunajski, Sieczka 2008, Gaspar 2010, Nieścioruk 2011a). 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 by comparison of ground-based photography from different periods (Kaim, Kolecka 2010).

Fig. 1.5. The change map for dominant land use and number of fields. Classes show land use change, bars show number of fields (van Eetvelde, Antrop 2004, p. 91)

The numbers show a more mathematic image of the past. One can not only evaluate past environment in terms of absolute (how much) and relative (less or more) values, but also compare it with current state, finding information about qualitative (meadows turned into fields) and quantitative change (20% decrease in forest areas).

This is, however, still a statistic. 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 full potential when it comes to third dimension. Even the simplest 3D models give new quality to early maps – georeferenced imaged draped on a modern digital elevation model (DEM) can help to “feel” and understand early maps easier (Rumsey, Williams 2002). Such an effort is a step toward finding more data in early maps. Analyses and visualisations can be combined and the result can be a visualization of past terrain analysis outcome in form of historical relief with proper land cover added (Harris 2002). It is not the limit of visu-
alizations in GIS. Final step so far is recreating a past landscape as three-dimensional model with both natural and anthropogenic features, based on – mainly – early maps analyses, plus field works, iconography studies etc. (Brumana, Achille 2007), even combined with constructing 3D models of objects using laser scanning of existing historical buildings (Visintini et al. 2007) and full landscape generation (fig. 1.6) (de Boer 2010), leading to almost virtual reality of the past, as this aspect of visualization, on the border of hardware, media, IT technology is more and more present in GIS world (Batty 2008).

Fig. 1.6. A rendered virtual historic landscape (de Boer 2010, p. 55)

Such works are goals of analyses, leading to new results or are a part of research of other kind, when comparing past views with modern is a part of broader analysis (Oleński 2012). The end-user is not always a specialist, he/she can be everyone interested in some (often only visual) aspect of research results. Virtualisation is even more user-oriented, when it is available to everyone. Hence some projects combining early maps, historical data, reconstructions and knowledge end up as the internet websites (fig. 1.7), where users can not only see 3D past and use it object-oriented database, but also fully navigate through a past landscape on his/her own, using any internet-connected computer (Przewodniki Lublin 2.0).

Fig. 1.7. Internet-based, 3D virtual reconstruction of historic city environment (Przewodniki Lublin 2.0)
Technically, visualisation is a graphic outcome of data gathered in a database. It is an important part of research to create such a database (Gregory, Healey 2007). It makes understanding database approach easier, when one keep in mind early (in facts, each) map is a database itself, sometimes even having attribute tables, like “analogue GIS” (Pearson, Collier 2002, p. 108).

Gathering materials is one, visualisation is other aspect, but digitizing data and making them sensitive to analysis in GIS is another serious part of work. This introduce historians and historical geographers to the – mostly – unknown: 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 make this subject even more fascinating, demanding and interdisciplinary. There is a growing number of such interdisciplinary projects, combining early maps, historical data, cartographic visualization and database, supplying all this and more information to an end-user (Ray 2002, Szady 2008, Micalizzi et al. 2012).
2. The goal and the subject of the study

2.1. The goal

Early maps are historic documents and materials showing past spatial relations. They are in the scope of interest of many different specialists dealing with history, history of technology (cartography, printing) and art, historical geography etc. as it was shown in the previous chapter. In many cases maps created after the World War II are not treated as an interesting historic source, while they should be, as these almost 70-year period is the time of rapid changes in the environment. The goal of this work is to evaluate if and with what information outcome post-war materials can be used to recreate a past space from the time just before an intensive spread of urbanisation process. It happened in many Polish cities that suburban areas and villages were destroyed and included in new residential blocks of flats districts. The remains of these past spatial relations are hard to find now. This work tests if maps and other cartographic materials are of any help in searching for these remains and if it is possible to use them in analyses of recent environmental changes as well as in an attempt toward building virtual reconstructions of non-existing past.

2.2. Case study

As the study area the south-western (Rury district) part of the Polish city of Lublin was selected. The reason to select this part of Lublin was that – after the World War II – Lublin became the biggest city of the eastern Poland with rapid development. The population rose from about 80 thousands in 1944 (50 thousands less than before war) (Wójcikowski, Wójcikowski 2000, p. 320) to over 350 thousands nowadays. It resulted in new areas for residential building needed. These changes are still young, so it is fairly easy to observe remains compared with areas more changed by cumulative settlement processes. The other important fact is that cartographic materials for big cities are easier to obtain than for areas of smaller population, which can even lack proper cartographic representation.
In 1959 the area of Lublin was doubled to over 93 km² (Wójcikowski, Wójcikowski 2000, p. 410) and one of incorporated areas were Rury villages, now forming Rury district (the name is used as an administrative one only). The name Rury (Polish “pipes”) comes from the late medieval period (15th/16th century) water supply system. Pipes were crossing church and cloister lands, hence later land names were formed using both elements – pipes and religious order name. Rury Wizytkowskie (of Visitation Order) was one of few that remained as a separate village till the 20th century. Even after its incorporation into Lublin's administrative boundaries, it was untouched by multi-family block of flats. It changed in the late 1970s, when the new residential district and housing cooperative Czuby was established. The areas selected for research is located in the former central and western part of Rury Wizytkowskie, now forming “osiedle” (sub-district) Ruta (established in 1982) and Łęgi (est. 1984), both – especially Ruta – spreading along main village road.

Fig. 2.1. The research area marked with the red line on the modern topographic map

The exact boundary of the research area is shown on fig 2.1. It is an upland between two dry valleys formed in loess (it is the eastern part of the Nałęczów Plateau mesoregion, with up to 30 m thick, easily eroded loess layer (Kondracki 1998, p. 281)) and having their outlets in the Bystrzyca river valley. They are locally called “wąwozy” (gullies), but in terms of geomorphology they are much larger erosive and accumulative
dry forms. The area contains mentioned Łęgi and Ruta plus Widok (southern art) and Błonie (north-western part) sub-districts. The figure 2.2 clearly shows the boundary corresponds with former Rury Wizytkowskie western and central part.

Fig. 2.2. The research area marked with the red line on the the 1970s aerial photography showing village of Rury Wizytkowskie

The reason for selecting this exact territory (beside general ones mentioned earlier) is also a personal one – it is a place of living of the author what makes it easy to investigate in field, but also gives the research a unique attitude, as it is not only a test polygon, but also a place with personal memories.
3. Source materials and their preparation

The precise delimitation of the research area allows a selection of cartographic materials and their territorial extent. The definition of goals results in scale range of materials that can be used for certain task, i.e. containing information that can lead to answering research questions and solving defined problems.

3.1. The selection of source materials

The defined goal was achieved with the use of a few cartographic (and not only) source materials. They were as follows:

- maps,
- aerial photography,
- terrestrial photos.

3.1.1. Maps

As the rural landscape to discover in this research has disappeared in the late 1970s/early 1980s (when Czuby residential district has been constructed), the archive maps have to be no later than this period. On the other hand – reference materials should be as contemporary as possible, for example modern topographic maps.

The large scale (1:25,000 and bigger) 20th century maps are limited to post-war topographic maps done in the period of People’s Republic of Poland. It brings about serious consequences to accessibility and reliability of sources and influences results (the importance of this influence is one of this work’s research question). The maps of 1:50 000 and smaller scales are available more widely (still with reliability remark however), but they can only be used as supporting documents because of selected territorial extent of the research (one village, two modern districts, less than 2 km in length).
Maps in coordinate system (“układ”) “1942”\(^3\) were not available for Lublin area, but resultant maps in system “1965”\(^4\) were. Two adjacent sheets were used. Quite new and well-designed coordinate system “1992”\(^5\) maps were available for Lublin (they do not cover all the country) and one sheet was used as the reference in this work.

Two sheet of system “1965” based on 1:10 000 maps were used together with one sheet of so-called “obrębówka”\(^6\) map (part of one sheet).

The additional info can be – if needed – obtained from geodetic large-scale maps. In case of this work and for selected area of research 5 sheets of 1:1000 maps were found. All sheets were created around 1959 and were later updated till early 1970s. They show situation on Rury Wizytkowskie before building of block of flats with aerial photo described below. All sheets have reference system graticule crosses of system “1965”, but closer examination shown they are misleading – they were drawn either in

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3 Coordinate system “1942” was used for the Warsaw Pact military topographic maps. It is the Gauss-Krüger projection using Krasovsky ellipsoid. From the late 1950s to the early 1970s a whole territory of Poland has been covered with 1:10 000 maps of “1942”. They were, however, confidential.

4 The censorship and legislative regulations on state and military secrets reduced, especially since 1950, the public access to cartographic publications. Society was struggling to get maps, even as basic as city plans (Grygorenko 1991, Konopska 2010), so a civil-use coordinate system was introduced in 1976. It has 5 projection zones (4 quasi-stereographic and 1 Gauss-Krüger, all using Krasovsky ellipsoid) not matching at zone boundaries. 1:10 000 maps were based on works done for “1942” system and were used (together with military “1942” 1:25 000) to produce 1:25 000 maps (Siwek 2006, p. 262-263).

5 The system was devised after political changes of 1989, modifying not only mathematical base of the map, but also its content and graphic design. “Układ 1992” is based on GRS80 ellipsoid and is in Gauss-Krüger projection.

6 The oldest post-war civil use map. Based on military maps, it was seriously distorted with glue and scissors, it has no topographic nor cartographic parallels and its quality is very low. It was published in sheets showing only powiats (units of territorial division of Poland), with no data outside their borders, hence the name (“obręb” can be translated as “selected area”). The fact of censorship, limited access and falsification of maps in post-war Poland stands as a serious problem in the environment research analyses, as many aspects of it have to be additionally treated with care due to low reliability of both contents and topology of maps. The other, side effect of all this limitation is lowered trust in maps and their contents among regular users (Konopska 2011).
Map sheets selected as cartographic source materials are – according to explanations above and area of research – as follows:

- 1:1000 local coordinate system: 5 sheets,
- 1:10 000 system “1965”: sheets 136.311 “Lublin” and 136.313 “Lublin-Abra- mowice”,
- 1:25 000 system “1965”: sheets 136.31 “Lublin” and 135.42 “Konopnica”,
- 1:25 000 “obrębowka – Powiat Lublin”: sheet IV.

3.1.2. Aerial photography

The very basic definition of a map contains information that map contents is generalized (Ostrowski, Pasławski 2006, p. 16), hence it shows only a selection of features, depending on scale, subject, classifications etc. In a process of recreating past landscape, some features omitted on a map can be of great use. This is where aerial photography and satellite images come in handy.

The modern ortophoto images used in this work were incorporated into database via Web Map Service (WMS) of Polish National Spatial Data Infrastructure portal (www.geoportal.gov.pl). For research area, the date of acquiring data is 2010. The archive aerial photography used in this work has been selected on a base of scale and date of acquisition. Photos should not be taken later then early 1980s and the best solution was 1:16 000 scale scenes of 1976.

3.1.3. Terrestrial photography

The photographies of the research area were taken by the author of the work during introductory field works and later field analyses. Some of them were taken earlier during works for other tasks. All the mentioned works took place in summer months of 2010, 2011 and 2012.
3.2. Rectification and geotransformation of raster data

The reference topographic maps and aerial photos are available in system “1992” coordinate system, which is the currently used system in Poland. Hence all the data in the project should be in this system, including produced vectorised information, research outcome and other (older) raster data. It means these rasters have to be georeferenced and transformed into system “1992” in a final workspace.

Sheets of 1:10 000 maps in system “1965” were obtained with georeferencing. They were loaded into ArcGIS data frame having system “1965” set and then – after checking quality of sheets contact zones meeting, exported as one geotiff (storing spatial reference) file. The flat-scanned sheet of 1:25 000 map in “1965” system has been rectified in the same (above) data frame using its topographic graticule. After successful quality check with 1:10 000 sheets, it has also been exported to geotiff format.

The 1:10 000 sheet of “1992” system has been registered in the proper data frame based on topographic graticule as well as exported as geotiff again.

The three remaining materials had no information about their geometric quality, spatial reference etc. – for ortophoto it was missing (only scale and date of acquisition were available), for “obrębówka” such data are invalid, as the map is seriously distorted. There was a need to transform and georeference these materials.

The used ortophotography has good quality and quite reliable geometry with typical for aerial photography circular scale change towards the edges. The “obrębówka” has no geometric quality to trust. Both materials lacked any graticule, which resulted in fact that they have to be georeferenced using topographic features. Ground Control Points used for georeferencing should be distributed regularly and refer to object with maximum possible reliability (Nieścioruk 2011, p. 148). It is not always possible – for aerial photo points were easier to define in northern part, showing build-up areas with many characteristic features (buildings). Southern part, with large open areas of crop fields only got less points and most of them use field-roads crossroad and similar. The distribution of 28 GCPs for aerial photo is shown on fig. 3.1 (good transformation needs over 20 GCP).

“Obrębówka” map, being a modification of normal (correct in geometric sense) map, could be georeferenced and transformed on basis of clear topographic features visible on both maps. The distribution of GCP was not as regular as for aerial photo. The
reason was a different distortion factor. Aerial photography is regularly distorted and more or less regular (as described above) distribution of points can correct this. “Obrębówka” is distorted in unpredictable, random way, hence a process of correcting it should be most intensive in areas of special interest (in this case – of Rury Wizytowskie village). Most of 20 the GCPs for this map concentrates in the village plus Bystrzyca valley and neighbouring villages of Rury Jezuickie and Rury Bonifraterskie.

Fig. 3.1. Distribution of aerial photo GCPs

Geodetic 1:1000 map sheet has also been transformed. There was a methodological problem here. The base reference material is in 1:10 000 scale and final geobase has quality and accuracy inherited from these maps, hence no bigger than 1:1000. These large-scale sheets were used incidentally only in a process of cross-checking aerial photographs and in distinguishing the use of buildings (geodetic maps clearly states if a building is a residential or a farm building). It is – in some way – scale independent. It theory a whole database could be relied on this 1:1000 maps as they – again: in theory – assure the best accuracy and the rest of materials should be georeferenced to these sheets. It is not true however. As mentioned previously, these maps were made in local reference system with “Układ 1965” coordinates only marked. Closes analysis shown these coordinates are false – they are (for unknown reasons) shifted about 120 metres east and 30 metres north. It disqualifies these maps as geometric reliable base. Having all this in mind, it has been decided to georeference 1:1000 on a base of 1:10 000 maps and aerial photos. It is against the rule of using larger scale as more reliable, but it is
justified in this case. 1:1000 sheets were transformed on a base of over 20 GCPs each, so buildings (most important elements of these maps) fits ideally those of aerial photo and can be used to create a three dimensional models for example.

The transformation used to correct and georeference materials with no coordinate system was the spline method. It is a method that secures a precise location of selected points – received accuracy is local (in the contrary to minimising global accuracy error and receiving not precise location of GCP in polynomial transformations, which was tested with a little unsatisfactory results even for aerial photography). The method can be compared to warping a map on a rubber – selected points get located in they counterpart GCPs, so the points on the early map we know real location for are located in proper coordinates. This method is ideal for georeferencing materials of unknown geometric qualities and properties, like “obrębówka” especially.
4. Landscape analyses – introduction

The two dimensional visual landscape comparison is the most basic one. It can be done on a very simple level, just by setting two maps from different periods aside and pointing differences. Geographic Information Systems software let us go further however – working on layers and superimposing one map on another. That enriches visual comparisons and gives an extra value – all kinds of elements (geometries) can be vectorised and compared this way in GIS, using linear, areal (polygons) and points (points-alike) vector classes along with raster data (maps and aerial photos).

The gathered raster data were georectified and transformed into one reference system. Before vectorising and analysing data, rasters were organized, together with other feature data in one storage container – file geodatabase. For a small project, separate files could be used and this work could be handled with such a solution. Geo-database is, however, the most efficient and easy way to gather one project data together (Ormsby et al. 2008, p. 372).

4.1. The visual comparison – defining exact topics of investigations

Having all the raster (cartographic) data gathered, georeferenced and overlaid in one project, it was possible to compare elements of the past and the modern environment and to find potential areas and subject of interest, which are listed below:

- the main village road now partly serves as the district street Jutrzenki (on Ruta) and partly as Tatarakowa street (on Łęgi), but mostly lost its connection with a current road network toward the west of the analysed area. Exact relations should be analysed deeper;
- most of the local field and less important village roads are now defunct with a few exceptions of paths in dry valleys;
- the past road network should be vectorised and compared with current streets and paths on a modern map;
- most of the area in the past were fields, now being invisible. It is possible they boundaries are still shaping the area, but there were no modern geodetic large scale map with boundaries to compare with and analyse;
orchards and building were lined along the main village road. Some of them are still existing. There are two houses still being inhabited, with completely changed environment around. Orchard areas should be vectorised and compared with a modern map and field works results, what could give the answer if, for example, single fruit trees are the remains of the Rury Wizytkowskie village;

- some cultural elements are also preserved. The mentioned space organization defined by road network is one, while the other is more material – crossroad shrine together with trees defining its sacrum-zone.

All of the above items were examined in details in next chapters, where vectorisation of elements was conducted and results were compared with a modern map and field works findings.

4.2. Feature extraction

4.2.1. Linear features – roads

The analysis of the road network was based on a comparison of the past state with the modern one by means of overlying roads vectorised from the old material onto a modern map. The source material was the 1970s aerial photography. The reason for this are listed below:

- an aerial photography is not generalised, what means every (potentially) road is visible on it. A map is, on a contrary, generalised and the criteria for this are not ensuring the roads needed for the analysis are included (roads were generalised to show network of the time, with no relations to then non-existing (what is obvious) modern network);

- the modern map is 1:10 000, while the early map of the same scale shows the 1980s situation, with – partially – blocks of flats instead of village. Earlier maps are in the scale of 1:25 000, so roads on them are not only generalised according to different road system, but also to a smaller scale.

The roads were digitised as a linear feature class being a part of the feature dataset containing land use information. In the next step, they were displayed on the modern map and – according to this topographic map and field works knowledge – split (when needed) into smaller segments. Of 65 segments, each was assigned a numeric
value in its attribute table. The attribute described a modern state of the selected segment, as follow. Number “0” was assigned to these segments which are defunct in current road network. “1” was given to these which are now asphalt streets (of different importance), “2” – to these which function as pedestrian pavements (in some cases accompanied by bike roads) and “3” to former roads now being unpaved paths used by pedestrians.

4.2.2. Areal features – fields and orchards

The introductory analysis showed that most of the study area was occupied by crop fields in the past. The village was spread along main road(s) and so most of other than cereal crops agricultural activities, like near-farm gardening, fruit orchards and vegetables fields.

Crop fields were turned into the sub-districts build-up areas and there are no clear evidences of them, mainly because they were areas of seasonal vegetation, contrary to orchards, where fruit-trees were long-term plantations. It is quite likely the only evidence of fields pattern can be hidden in parcels maps. It was mentioned land-ownership rights were not exactly abided during People's Republic of Poland, but some traces can still be seen. However, there is no parcel map to compare a past state with.

Much easier feature to analyse were orchards. Hence they were, as it was said, lined along the main road, they were easy to correlate with the modern environment. Beside this, cultivated fruit trees, garden plants and even some topography marks are often remaining of the past that can be quite easily traced (Vujaković 2012).

The first step was a vectorisation of the past state. This time, contrary to the road analysis, two sources were used – aerial photography and 1:25 000 map in system “1965” coordinate system. The reason for using photography was as before: it is a quantitatively non-generalised source plus it lets distinguishing different types of near-farm gardening (no qualitative generalisation). The map is generalised in both way, which can also be an advantage – not all areas can be easily detected on an aerial photo, as it requires both knowledge and sometimes remote sensing skills.

Orchards were digitised as polygon feature classes included in the feature dataset with land use information, one class for the aerial photo data and one for the topographic map.
4.2.3. Point features

Beside linear (roads) and areal (orchards) features, point features can be analysed as well. Orchards, of course, consists of point elements too – single fruit trees – but these are insignificant unique features. As far as natural elements are concerned, there are fair-sized trees, which were “guarding” properties, giving shadow, serving as meeting points, sacralising the space by themselves or by accompanying shrines (Cała 2007). Some past village trees were left untouched and they are still growing along the former main road. The only way to discover such remains is to use field works (plus GPS measurements to increase locations accuracy) together with photographic documentation. Topographic maps are of no use here, as they do not record single trees in general. The aerial photography however, can be of some help.

4.3. Application and results – the road network analysis

The linear road feature class was displayed on the modern map with qualitative colour distinction according to attribute values described in the methodology section. The result is shown on fig. 4.1.

It can be clearly seen that the main village road (central WNW – ESE line, with long black-coloured segments), as it was discovered during the introductory comparison and analyses, partly serves as the in-district street now. It forms a part of Wiklinowa street (most western) and then long part of Tatarakowa street, crossing main two-roads-ways street (Armii Krajowej) and continues as Jutrzenki street (fig. 4.2, 4.3) east toward a former crossroads, where there is an interesting deviation. It turns NE, not copying former road in a sense of exact track, but in a sense of general shape, which is observed some 280 m to the east. That change could have been caused by a few factors. A land ownership is less probable (during People's Republic of Poland private land were, when needed, easily taken over by the local governments), a topography is more. The village road was lined along an edge of a dry valley, what could end up with street collapsing, so it was shifted a bit, not going on a village road path on that segment till the second bend, when it starts copying the former road again. The other factors of such a situation could be (a few years older) sub-district Skarpa pavement going along a smaller village road, entering the analysed area from the east and continuing for over 100 metres or
plans to build a sport hall in the area.

Fig. 4.1. The result of the road network analysis

The other segments of roads now being streets are on the edge of the research area. These are: a part of small Poznańska street, part of important sub-district Ułanów street and Zwycięska street, separating the sub-district from a commercial area. The two
latter used to be village roads of higher rank, but not as high as the main Rury Wizyt- 
kowskie road described above.

Fig. 4.2. The small sub-district street Tatarakowa continuing as the more important  
Jutrzenki street, seen in the background; linear arrangement of both streets emphasized  
with arrows

Fig. 4.3. Jutrzenki street (part of the former village road) as seen from  
the eastern end of Tatarakowa street
Smaller sections of the mentioned main road are now paved and serve pedestrians. It is a case of a part of the analysed deviation of Jutrzenki street. The same situation in more to the north, when the other road, parallel to the mentioned, is partly used as a pavement now. The longest paved section of the former village road is on the south edge of the research area. For many years it was a path in wild-wasteland dry valley, but it was turned into a park in 2009, with bike and pedestrian alleys going side by side on a line of former path (fig. 4.4).

Fig. 4.4. The bottom of the dry valley, now with park function; bike road goes (on this section) on old village road, pedestrian walkway is above

Going east, the pavement turns north and leaves the old village road track, which becomes almost unused, natural path, as seen on fig. 4.5.

Fig. 4.5. The unpaved path up the dry valley (red arrow), paved track turning north and leaving the old road system (blue arrow)
The other significant in-grass path (former road of quite high importance) can be seen on the east edge of the Łęgi sub-district, going south along old, but still visible (see next chapter) orchard (fig. 4.6) and joining a path in a main dry valley.

What is interesting, none of old linking roads, going (in general) north – south and joining two long, parallel village roads are used nowadays. The only NS road is Zwycięska street, which was a linkage to a main street at the end of the main village road.

![Fig. 4.6. Old orchard separated from block of flats by the former village road](image)

To sum up this analysis, the modern system is based solely on the former west – east roads which are highly topography-depndant: Jutrzenki street goes along the former main village road on the upland, between two dry valleys, park path is in one of these valleys and none of the roads goes crosswise “valley – upland” system.

4.4. Application and results – the land use (orchards) analysis

Both polygon feature classes of land use feature dataset were displayed on the modern map, as seen on the fig 4.7.

It became a base for the field works – the map was used to discover and validate remains of the past village, mainly fruit trees. Vectorised areas were investigated in field and a few interesting cases are described below.
Fig 4.7. Former orchards, near-farm gardening and properties area in the current environment

Most of the remains are single fruit trees near unbuilt sub-district areas, as these of Łęgi, shown on fig. 4.8. They were left untouched as they were not occupying large areas. Their form suggests wildering now (they are no longer taken care of), but there
are a few reasons to treat them as past near-farm elements. One is that they fits in areas selected during analysis and shown on fig. 4.7 above. The other is they are cultivars – for example plums, in the case of photographies on the fig. 4.8.

The groups of trees also exists. The fig. 4.9 shows such, which remained because this exact area was unbuilt and destined for small green, grassy square with pedestrian paths only. The remaining trees are plums and pears.

Fig. 4.8. Single fruit-trees in the space of sub-district (left: so-called “węgierka” – “hungarian” (domestic) plum, right: a mirabelle plum, both typical for private, countryside gardening)

Fig. 4.9. A group of fruit trees
The brims of districts are mainly unchanged in some aspects, what allowed larger orchards areas to be untouched. The one example was mentioned in the previous chapter and is shown on the fig 4.10 again, from different angle. The other is more interesting and is located on an empty area west of Szaserów street on Błonie sub-district. The land-ownership problems resulted in this space being unbuilt for many years. Now the situation changed a little and commercial buildings was constructed, but the large group of wildered fruit-trees, self planted trees and shrubs still exist, forming a “jungle” surrounded by the city (fig. 4.11).

Fig. 4.10. Previously described orchard on the brim of Łęgi sub-district

Fig. 4.11. Area of problematic land-ownership – just-built (2011) commercial enterprise next to brushwood-trees area and temporary grassy car-park, forming a landscape dissonance
4.5. Application and results – the point feature analysis

The field reconnaissance results and object GPS locations were confronted with aerial photo. Fig. 4.12 shows two examples of old trees in the modern sub-district environment.

![Modern view of two old trees together with their 70s aerial image](image)

Fig. 4.12. Modern view of two old trees together with their 70s aerial image

A special case of point features that survived total environment changes are shrines. There are two cross-shrines of Rury Wizytkowskie village still existing, but only one is located in the selected research area. It used to be a shrine on crossroads, guarding roads, showing directions and serving as an “open-air church” for locals. It is on a small hillock now, between the main road and a large parking place, surrounded by trees (see fig. 4.13) Most of its functions are now gone, but it still serves as silent witness of the past environment.

Shrines, as characteristic features, are present on topographic maps, so it was possible to locate the described above one on maps used in this analysis. Aerial photography gives no info this time. Quite contrary – because of surrounding trees it is impossible to see the shrine (only the trees themselves mark that space).
The other interesting point features are wells. It is an important element of human dwelling activities, as living is not possible without water. In areas with water shortages, wells value cannot be overestimated. Wells used to have a cultural meaning too – for example rituals and holy springs (Głuski, Kryjak 2010). Rury Wizytkowskie village spread west from the Bystrzyca river valley and the research area is from 1 to 3 km away from the river. Topographic maps show one important well in the analysed area. It can be seen on both system “1965” maps – 1:10 000 (together with well water efficiency) and 1:25 000 and on modern system “1992” map. It is hard to interpret the aerial photography, but the area of well is unbuilt and well-alike object can be seen.
Closer investigation showed this is not a village concrete-ring dug-well, but an abyssal (deep) well of 80 meters deep, probably drilled. It was dug in 1973, with future Czuby district construction work needs in mind. The well is defunct now and the current state is shown on fig. 4.14.
5. Topographic analyses – introduction

The previous chapter contained a multi-feature analyses of the past environment which was, however, limited to two-dimensional relations. Although a land relief was included in the research, especially with relations to a road network, no further volume analyses were conducted. Maps contain a lot of information and relations – flat (2D) “far – close” or “big – small” are easily noticed. The third dimension is encoded by means of (in case of topographic maps) contour lines. This chapter concentrates on a possibility of using these features in analyses.

All contour lines from the maps were vectorised as line feature classes of the project geodatabase, one class for each map. Artificial forms of terrains, such as głębocznice and terraces across slopes directions were included as proper contour lines shifting (no lines of breaks were used).

5.1. The volume comparison – defining exact topics of investigations

Terrain analyses is based on the mathematical representation of topography which is the goal in itself, but also leads to delineation of landscapes and to define or examine relationships between terrain and other factors and processes, in both spatial and temporal aspect (Deng et al. 2008, p. 417). Among many digital elevation models (DEM) uses, a few were selected.

Visualisation of a relief is obvious and of so-called primary topographic attributes: slope, aspect and curvature (Urbański 2011, p. 148-150) only the first one was used. Aspect and curvature have less meaning in temporal analyses. They, just like slope, are attributes that can change significantly during reshaping of the landscape (like building sub-residential areas), but the slope gives most information about it (levelling ground, flattening gullies etc.).

Terrain models for different periods are also useful in case of map algebra computations – subtraction can demonstrate and delimit areas of positive and negative

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7 Głębocznica is a local name for an anthropogenic gully, formed in a loess terrain. It is a form with almost vertical walls and road on its bottom. The origin of it is a constant communication use, increasing surface run-off and washout of loess, leading to lowering a road base and deepening the form.
changes, which can be supplemented with algebra of slope values as well.

5.2. Feature extraction

All three sets of contour lines corresponding to three maps were vectorised and used as basis for digital elevation models. DEM is the raster representation of landforms (on the contrary to digital terrain model, containing elevation plus on-surface objects like buildings, vegetation etc.), hence it is – in general – equal to a surface represented by contour lines.

The 1:10 000 system “1992” map was a modern reference material, with contour lines partially highly modified by levelling works and construction of blocks of flats. The interval of contour lines is 1.25 metre on this map, with solid line every 5 and bold line every 10 metre.

The 1:10 000 system “1965” map could not be used, as it shows too modern situation, with sub-distRICTS partially built. The 1:25 000 map was used instead. Its interval is 1.25 metre as well, but not on a whole area. More flat areas has 2.5 metre interval, while steeper slopes are shown with additional lines of 1.25. Solid line goes every 5, while bold every 15 metres.

The “obrębówka” 1:25 000 map was also used, but its quality has been taken into consideration (see below). The interval of contour lines on “obrębówka” is 2.5 metre with solid line every 5 and bold every 25 metres.

The next pre-analyses step was a creation of DEMs on the base of these contour lines. ArcGIS “Topo to raster” 3D Analyst tool was used with the output cell size set to 5 and the output spatial extent equal to the extent of contour lines (the research area).

5.3. Application and results – visualisation

The vectorisation of contour lines was a good way to assess maps reliability. In the previous chapter it was mentioned the “obrębówka” map can be used – when correctly georectified – mainly for point features analyses, while areal features are far more distorted. The terrain information is a good example to confront this theory with
practice. The figure 5.1 shows all the three types of contour lines on one map. It can be clearly seen that the “1965” coordinate system map depicts relief (red contour lines) in general in very similar way to the modern “1992” map (green contour lines). The differences are not big and some of them are result of real topography changes. The blue contour lines representing “obrębówka” map run – in many areas – completely different than these of both “1992” and “1965”. It is caused by topography changes only to a small extent, the rest is the result of deliberately poor quality of this map.

![Contour lines vectorised from three maps used in this work](image)

**Fig. 5.1.** Contour lines vectorised from three maps used in this work

5.4. Application and results – elevation algebra

The interval of contour lines is 1.25 metres. When subtracting digital elevation models, it is quite likely that differences smaller than this values are not significant. Such interval cannot show little artificial forms, like small hillocks for example, which forms a landscape of modern districts. This is why the result of subtraction shown on fig. 5.2 concentrates on differences larger then mentioned 1.25 metres.
The figure shows the result of subtraction of DEM created from “1965” system map from DEM of modern, “1992” system map. Most of the area falls into classes between -1.25 and 1.25 metres – smaller than single contour line interval, hence it is hard to assess the origin of these changes. Values larger than ±1.5 metres are more significant. Positive values are observed in a few areas. The one to the south of a cross-road of main streets is a large artificial earth work of no special use (waste land), raised and flattened to a level of nearby car park. The westernmost is strengthened slope along small sub-district street. The most interesting area is located in the north eastern corner. It is a part of sub-district Ruta near the dry valley. The task of constructing blocks of flats there required serious levelling. It is the reason why significant changes are observed there, both positive and negative. South eastern corner of the research area shows other serious negative change. This was caused by construction of a north abutment of a viaduct. The only change which is not easy to explain and may be a serious error in contour lines distribution between two maps is over 2.5 metres negative change at the western brim of Łęgi sub-district. It is an area of little valley and previously mentioned old orchard, rather untouched by construction works.

As far as contour lines image is concerned, it was worth testing if “obrębówka” map can be trusted, based on the comparison with “1965”. Both maps and digital
elevation models show topographic situation before sub-district construction works, hence any ground level changes should be small, at least smaller than these observed on fig. 5.2, when pre-construction terrain level is compared with modern, changed elevation. The result of subtraction is shown on fig. 5.3.

![Image](image_url)

**Fig. 5.3. The result of DEMs subtraction (1970s minus 1960s)**

It can be clearly seen that the image is false. The area of positive changes is huge with high share of classes of almost 4 meter and more which is very unlikely, according to what was said before. Also negative changes (mainly in northern part) are not true. This figure supports the conclusion which could be based on contour lines images themselves (fig. 5.1): the quality of “obrębówka” map is very low, especially as a source of areal information. Even quite good georectification of this map cannot change its overall poor reliability. As a source of planar and metric information this map should be used only in well justified cases and with very high margin of trust.

The slope analyses was conducted for both modern and based on “1965” system map DEMs. The results were quite similar in general picture with steeper slopes in northern part of modern terrain, where buildings were constructed near the dry valley slope, which needed strengthening of earth works. The result for modern terrain is shown on fig. 5.4.
Fig. 5.4. The result of slope analysis for the modern DEM

The figure 5.5 shows an attempt to compare both slope surfaces. It is a result of subtracting slope analyses result for 1970s map (“1965”) from the modern one. What can be seen here, is a confirmation of previous conclusions – quite significant changes (positive – increasing slope degree and negative – decreasing) are being observed in the northern part, along the dry valley, when scarp and levelling works has been done as well as serious change in the areas of flat hillock in a southern part. This figure shows one more interesting case, best seen here, but also observed on the previous figures. Smaller, isolated areas of certain values are clearly contour lines dependant. It is no surprise, as digital elevation models (and – consequently – topographic attributes as slope) rely on a terrain image created by contour lines. The problem is what is really analysed then – real terrain changes or contour line distribution. It was already showed that “obrębówka” map cannot be treated as a reliable source. Are other maps reliable then? The fig. 5.1 shows contour lines of three maps used it this work. “1965” and “1992” systems are very similar. It is safe to claim the general image of the phenomena is right as well as larger values observed. Changes and values smaller than single contour line interval can – in many cases – be a result of little shift of contour lines, for example during cartographic editing process (drawing lines).
Fig. 5.5. Slope surfaces subtraction results (modern minus 1970s)

Fig. 5.6. A fragment of slope surfaces subtraction results (modern minus 1970s) with contour lines added

The figure 5.6 presents an enlarged portion of slopes subtraction result with contours added. It is an area which did not changed significantly – an unused dry valley seen on fig. 4.5. It has been reshaped for allotment gardens, but with no intense level-
ling. Maps reveal that contour lines differences are not big, but they use generated two slightly different DEMs and – consequently – more different slope surfaces. Even a little dissimilarity generates here a cumulative error on lower values. In case of higher values, the influence of error seems to be less important.
6. Discussion of results and conclusions

6.1. The visual comparison summary

The results are more than satisfactory, especially with features easily distinguishable in the field. Vectorising an old road network and overlaying it on a modern one is a step toward finding which segments still serve as a communication mean. The conducted analysis showed the main village road is still active on many parts. A few other segments changed their mode of use and importance, becoming pavements or recreational paths in the park. What is topographically interesting – no single short segment going orthogonal to “dry valleys – upland” system exists nowadays.

The areal features are less visible. Due to a serious environmental changes during sub-districts construction process, areas (orchards) were far less likely to stay untouched compared to linear elements of roads. Hence the only one still existing orchard is located on the west end of Łęgi, at the brim of built-up area. The rest is just a scrappy left-overs of past human activities. A few interesting cases of point-features were also analysed, most of which were anthropogenic as well – cross-roads shrine, single human-plant trees, wells.

The goal of that part was to analyse the rural landscape, but also to evaluate if and what early materials can be used in such works. Maps are of great value, but in some aspects aerial photography seems to be better. There are two main advantages of from-plane images. They are not quantitatively generalised, so there is no risk of omitting an element which could serve as an important evidence when compared with the modern state, for example a then-less important segment of the road, which is now used as a pavement. Beside this, they show the whole situation (lack of qualitative generalisation) – let one compare single non-unique elements not available on maps, like bigger trees. On the other hand – maps show special single point elements which are hardly or not possible to distinguish on a photo. Interesting topographic features can be mentioned here, like analysed wells or special-use buildings (fire brigades stations, mills) not always clearly seen on aerial photos and small point features of orienteering importance, like cross-roads shrines (often hard to see on photos, because of trees or lack of shadows marking their locations). Both maps and aerial photos can be used to analyse and to compare with modern state areal elements. The analysis of orchards
shown some differences between both early materials (map and aerial photo), but
general image of phenomena was correct (similar). One should keep in mind that the
differences were also a result of slightly different age of these materials.

Both maps and photos should be georeferenced first, so it is highly advised to
use reliable materials. In case of any rectification problems, topographic elements can
serve as reference points. Even such unreliable source as “obrębówka” can be of some
use with good by-point spline referencing (especially when analysing point and – in
some cases – linear features, which are not distorted as much as areal features are).

6.2. The topographic analyses summary

The result of an attempt to use topographic (volume) information is satisfactory.
Created digital elevation models may be used in visualisations to shade maps, but
further analyses are also possible with – as could be seen – interesting results. DEM
algebra proved to be a good mean of determining areas of significant changes in
topography. Subtraction of two elevation models gave an image of general levelling
related to construction works. General, because more detailed picture is limited by
partly different contour line intervals on used maps and – mainly – by the inconsistent
forms of corresponding, unaltered contours. Topography changes smaller than interval
seem not to be reliable. The problem cumulates with further steps, when DEM is used to
generate other characteristic, as slope in case of this work. Here is where limiting a re-
sult to a general image is more true. While in case of elevation models subtraction
results showed true image even in more detailed scale (the only problem was areas of
little differences, smaller than single contour interval), in case of slope surfaces
subtraction result may be simply false in many areas, where forms of contour lines are
inconsistent, no matter what level of precision is taken into consideration (smaller than
an interval or even a few times larger than a single interval).

Vectorisation of contour lines and comparing created DEMs proved to be an in-
teresting and reliable way to assess the planimetric accuracy of maps also (or – indi-
rectly – accuracy of georectification), what was shown on an example of the “obrę-
bówka” map, used quite successfully in visual linear and point object analysis and failed
in topographic analysis.
6.3. Further steps

Georectified maps, aerial photography and land cover information together with 2.5 dimensional model in form of DEM and vectorised contour lines is a step towards creating a virtual landscape. This task is beyond the scope of this work, it seems however, it could be done as a next step. Aerial photography brings information about land use plus it can be used as a texture to wrap on shaded relief created on a base of digital elevation model. Ground level photos of past landscape remnants in forms of trees or shrine can also be used as graphic representations of single objects. Other elements can be obtained from maps. 1:25 000 or even 1:10 000 maps are not enough to construct a detailed image of buildings in 3D environment, however. Such a task requires a geodetic level, so for example 1:1000 maps (which were gathered as cartographic material for this work too) would be good for it, giving exact information about single buildings and they use, together with infrastructure (utility poles, wells etc.). All this should be sufficient to create a virtual representation of a past landscape.

6.4. Conclusions

The work showed that old maps can be treated as early maps – they have their own value and can be interesting in many aspects. The quality of these materials are very different, from interesting and trustworthy maps and aerial photos to poor paracartographic objects, which can be of very limited use. Examining and analysing them with proper attitude, knowledge and preparations, can lead to valuable results. The case study proved that post-war cartographic materials store a lot of information and – properly combined with field works and scientific tools – can reveal past spatial relation, which are very hard to discover using other materials or field reconnaissance only. The set of gathered maps defines a scope of conducted research from landscape analyses (possible with just topographic maps) to virtual presentation of a past environment, which needs much more cartographic information (geodetic and topographic maps combined with aerial photography).
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Zdjęcie lotnicze, będące treścią niniejszego opracowania, jest materiałem państwowego zasobu geodezyjnego i kartograficznego, prowadzonego przez Głównego Geodetę Kraju na podstawie przepisów ustawy z dnia 17 maja 1989 r. Prawo geodezyjne i kartograficzne (Dz. U. z 2010 r. Nr 193, poz. 1287). Osoby korzystające z tych materiałów nie mają prawa do ich wielokrotniania, sprzedawania, udostępniania lub w inny sposób wprowadzania do obrotu lub rozpowszechniania ich treści w całości bądź we fragmentach, w szczególności do ich przesyłania lub udostępniania w systemach i sieciach komputerowych lub jakichkolwiek innych systemach teleinformatycznych”.

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