Historical Mapping for Landscape Reconstruction
Examples from the Canton of Valais (Switzerland)

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Abstract

Alpine landscapes have evolved rapidly over the last two centuries. River embankments and urbanization have affected most of the large alluvial plains, agriculture has radically changed and its relative landscapes also. Forests are gaining space in most of the Alpine countries and tourism has modified landscapes in several areas, both in alpine forelands and high valleys. In Switzerland, the availability of accurate topographic maps since the middle of the 19th century has allowed us to reconstruct historical landscape change. Former landscapes were reconstructed using historical maps in a Geographic Information System (GIS) in two different contexts in the Canton of Valais (Switzerland). The evolution of the Rhone river alluvial plain and the history of vineyard landscapes were analysed. This paper presents the methodological aspects relating to the study of old maps.

1. Introduction

Over the last two centuries, landscapes have changed very fast and in this context landscape planning is becoming more and more important. It is now agreed that today's landscapes are part of the legacy from the past and analysing historical landscape changes is essential to predict the development of future landscapes (Grangirard, 1997; Marcucci, 2000; Bender et al., 2005). Long-term change may be explained by describing past landscapes and by understanding the driving forces of landscape change (Marcucci, 2000; Bürgi et al., 2004; Bürgi et al., 2007). Maps as a historical source provide important information about landscape change especially when they are used in a Geographic Information System (GIS) (Kienast, 1993; Gurnell et al., 1994; Simpson et al., 1994; Marston et al., 1995; Gurnell, 1997; Vuorela et al., 2000; Winterbottom, 2000; Petit & Lambin, 2002; Gurnell et al., 2003; Paulmier, 2004; Bender et al., 2005; Poirier, 2006; Domaas, 2007). The Canton of Valais is an alpine region formed by two mountain ranges – the Bernese and Pennic Alps – separated by the Rhone river alluvial plain. Today's landscape of the Rhone river valley is the result of important changes since the first Rhone river corrections, which occurred from 1864 to 1893. The hydraulic works completely modified the geomorphological behaviour of the river, which allowed the development of intensive agriculture and more recently the spatial diffusion of commercial and urban zones in the formerly flooded areas (Stäuble & Reynard, 2005; Stäuble & Reynard, 2007). The canton of Valais is the principal wine producer in Switzerland with more than 5,000 ha vineyards. The vineyard surfaces evolved differently from one site to the other: in some places, agriculture was replaced by other activities, whereas in others, viticulture became the main agricultural activity (Martin & Reynard, 2007; Reynard et al., 2008).

This paper presents how former landscapes were reconstructed by analysing historical maps within a GIS. It describes the methodological aspects relating to digitalisation, spatial treatment and analysis of landscape features from historical maps. Problems relating to changes in map characteristics and to the accuracy of former maps as well as several examples of landscape evolution are presented.

2. Study area

Both studies are located in the canton of Valais in Switzerland (Fig. 1). Transformations of the Rhone river landscape were studied in two specific sections of the Rhone river in order to analyse the changes on a large scale. One site is located downstream to Sion in the so-called plain of Conthey on the right bank of the Rhone river and the other one is located downstream to Sierre on the left bank of the river (Chalais – Grône – Granges). The study of historical changes of vineyard landscape focuses on six sites, which show typical features of evolution trend.

3. Maps

Landscape reconstruction was undertaken using historical maps as a main source. Thus, the quality of the research depends on the accuracy of the historical maps and their potential to be integrated in a GIS. Indeed, the oldest map that could be used is the "Napoleon map". It is the only one used in this study that was not drawn by the Swiss topographical Bureau (today's Federal Office of Topography Swisstopo). We used also the topographic surveys for the Dufour map, the Dufour map, the Siegfried atlas and the National maps. The maps are briefly described here and the characteristics of each kind of map are summarized in Fig. 2. An example of each map is illustrated in Fig. 3.

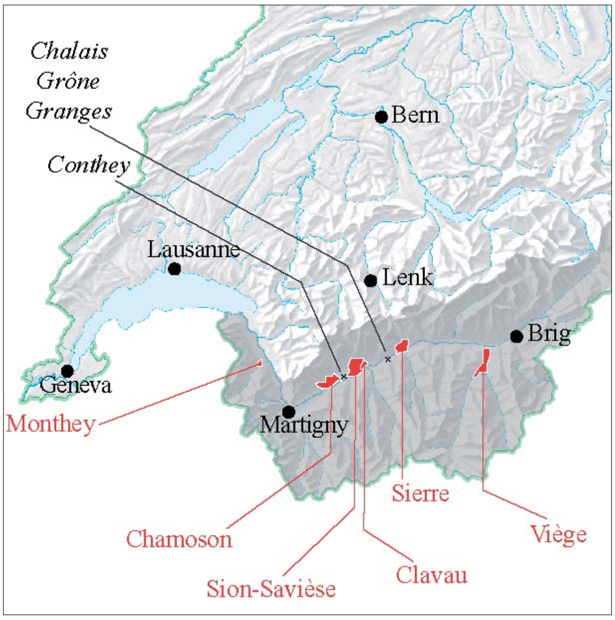

Fig. 1: Study sites. In red: vineyards. In black and italics: Rhone river alluvial plain. Reproduced by permission of swisstopo (B081074).

The "Napoleon map" was ordered by the French government under Napoleon in 1802 to provide a basis for the improvements of the road that leads to Italy over the Simplon pass (Lechevalier, 2005). Four cartographers mapped the entire Rhone river valley from Lake Geneva to Brigue on 65 different sheets.

The first topographic surveys for the Dufour map were drawn in the 1830's. In the Alps the maps were drawn at a 1:50,000 scale. For the Rhone river study we used three maps dated between 1839 and 1841.

The Dufour map is based on the topographic surveys but it was published at a smaller scale (1:100,000). The sheet we used for the Rhone river study was published in 1845. The topographic surveys and the Dufour map were not used for the study on vineyards, because vineyards are not indicated.

The Siegfried atlas is the first publication of surveys at a 1:50,000 scale (in the Alps) and 1:25,000 (in the rest of Switzerland). The first edition of the maps was published between 1870 and 1926 and each map was then revised several times until 1949. Several editions of the Siegfried maps were used for both studies.

From the beginning of the 20th century, as new geodesic measurements were being performed, the accuracy of mapping increased and new maps could be drawn. The National maps were first published at a 1:50,000 scale between 1938 and 1964 and then, between 1952 and 1979 at a 1:25,000 scale. Both of them are completely revised every six years. National maps are still in use nowadays. From the 1940's to the 1950's we used the 1:50,000 scale National map and from the 1960's until today we used several editions of the 1:25,000 scale maps.

4. Method

Each map was scanned and integrated in the GIS using a minimum of four ground control points with ArcMap (9.1)[1]. Two different methods were used to integrate the maps into the GIS: the coordinates were integrated manually using a printed map, or they were integrated using a reference map already present in the GIS with a coordinate system. Territorial features such as churches or farms that already existed on the oldest maps were used as ground con-

Map name	First edition	Revision	Scale	Point of origin for height measurements	Method of ground representation	Ellipsoid	Projection
Napoleon map	1802	-	1:5,000	No height indication	-	-	-
Topographic survey for the Dufour map	1839-1841	-	1:50,000	Repère Pierre du Niton (R.P.N.): 376.2 m	Contour lines: 30 m	Schmidt 1828	Equivalent conical projection
Dufour map	1845-1865	Until 1939	1:100,000	R.P.N.: 376.2 m	Obliquely luminated hachures	Schmidt 1828	Equivalent conical projection
Siegfried map	1870-1926	Until 1949	1:50,000	R.P.N: 376.86 m ("old horizon")	Contour lines: 30 m	Schmidt 1828	Equivalent conical projection
Siegfried map	1870-1922	1949	1:25,000	R.P.N: 376.86 m ("old horizon")	Contour lines: 10 m	Schmidt 1828	Equivalent conical projection
Swiss National map	1938-1964	Every six years	1:50,000	R.P.N.: 373.6 m ("new horizon")	Contour lines: 20 m	Bessel 1841	Conformal oblique cylinder projection
Swiss National map	1952-1979	Every six years	1:25,000	R.P.N.: 373.6 m ("new horizon")	Contour lines: 10 m; Alps: 20 m	Bessel 1841	Conformal oblique cylinder projection

Fig. 2: Characteristics of the maps used in this study (after Grosjean, 1996; Gurtner, 1997 and www.swisstopo.ch, modified).

[1] The Napoleon map was photographed by Michel Lechevalier and the team of the Third Rhone river corrections integrated it in the GIS. The Siegfried maps were scanned by ourselves or by Swisstopo, who edited some maps on a CD-ROM. The topographic surveys for the Dufour map were scanned by Swisstopo. Scanning of the National maps was done by ourselves. We georeferenced all the maps except the Napoleon map.

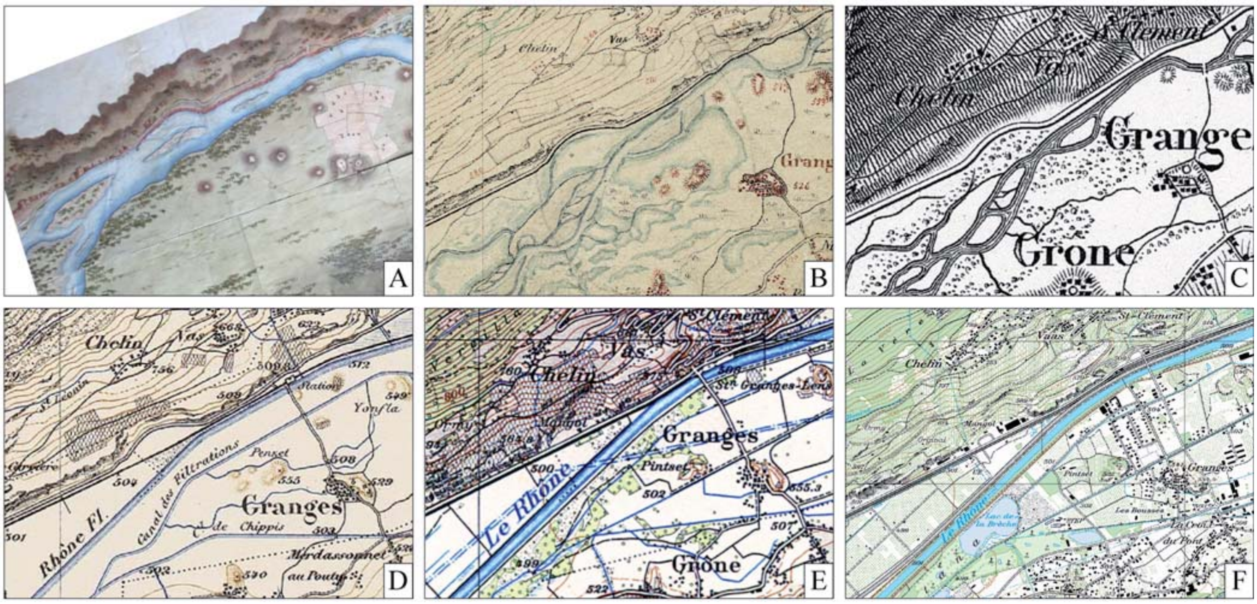

Fig. 3: Examples of maps used in the Rhone river study. A: Napoleon map (1802). B: Topographic survey for the Dufour map (399 Saint-Léonard, 1839). C: Dufour map (XVII, 1845). D: Siegfried map (481 Saint-Léonard, 1880). E: National map 1:50,000 (273 Montana, 1943). F: National map 1:25,000 (1286 Saint-Léonard, 2001). Reproduced by permission of swisstopo (B081074).

trol points. For the more recent maps the squaring of the coordinates could be used.

Territorial features, such as rivers, isles, wetlands, roads, houses, vineyards, orchards, etc. were digitized on each map on which they appeared. Digitalisation gives a representation of the historical landscape and allows quantification (for example: wetland surfaces in 1880, 1906, 1933 and its disappearance trend and velocity; see Fig. 5). On the other hand the overlaying of two different layers allows us to analyse the spreading and shrinking of some particular features (for example: appearance and disappearance of forest). The GIS integration also allows 3D representations of the landscape (see below).

5. Limitations

Using historical maps for the analysis of landscape change cannot be undertaken without an awareness of the problems relating both to the survey and to the integration in the GIS. Indeed, the accuracy of maps increased through time as is discussed below. Moreover, one has to keep in mind that maps are not reality but a representation of it (Kienast, 1993). Furthermore, as maps are static, they do not take into account the landscape dynamics with precision. This is especially the case of alluvial landscapes that may have changed several times between the images given by two successive maps. The period in which the field survey was carried out is also important as high and low water levels influence the extension of some features such as wetlands, forest cover or gravel bars.

The integration of old maps in a GIS enables 3D representations of historical landscapes that may be considered as closer to the natural landscape – as seen by an observer – than maps. Consequently, they could be an appropriate way to communicate with the public. Nevertheless, 3D views lead to a loss of information: surface deformation, absence of localisation, reduced vision of the area (depending on the chosen view point). 3D views should, therefore, be reserved for cases where the object of study is closely connected with the physical landscape or used to complement information given by maps.

In addition to these general limitations, each kind of map may present some problems. The Napoleon map was drawn for the improvement of a road. Even if the accuracy is good enough to be integrated in the GIS, the precision of the cartography is unequal depending on the distance to the road. Indeed, if the road is on the right bank of the Rhone river, the section of the left bank will have very poor information about land cover and land use. The map gives, therefore, indications for qualitative analysis of the landscape at the beginning of the 19th century, but it cannot be used for quantitative analysis (Stäuble & Reynard, 2007). Furthermore, we have no information about the projection used to draw the map. As the French cartographers usually used the Flamsteed modified projection at the beginning of the 19th century, we may suppose that it was also the case for the Napoleon map, but no further investigation has been carried out until now (Bureau topographique fédéral, 1898).

On the topographic surveys for the Dufour map the ground is represented with contour lines with an equidistance of 30 meters. Nevertheless, to draw the maps, the cartographers used only 400 to 500 spot elevations and drew the contour lines on sight, which means that the relief may not be completely exact (Grosjean, 1996). On the Dufour map, the relief is represented with obliquely luminated hachures, which does not give much information about the elevation. Anyway, we consider that the accuracy of the topographic surveys for the Dufour map is good enough to perform quantitative analyses and that they are the oldest maps that can be used for the quantification of landscape change.

To be able to overlay the maps, all of them were integrated in the CH1903 reference system. As the Dufour and the Siegfried maps were surveyed with a different projection system (Fig. 2), distortion and inaccuracies may be important in the GIS. The number of ground control points was therefore increased in order to reduce distortions, but an important shift still exists between the Siegfried maps and the National maps. Moreover, one has to bear in mind that the techniques of mapping improved over time, especially with the progress in geodesy and photogrammetry. Even if the accuracy of old maps is high, it is therefore not equal to the more recent ones. Finally, the point of origin for height measurement of the Dufour and Siegfried maps is approximately three meters above today's point of origin (Fig. 2) (Grosjean, 1996; Gurtner, 1997). For all these reasons, the layers had to be manually or automatically rectified and lined up sometimes.

Fig. 4 illustrates the problems that can occur by georeferencing old maps. The western map (St-Léonard 1880) and the eastern map (Sierre 1886) do not fit completely: the width of the Rhone river is not the same and a forest is represented on the Sierre map but not on the St-Léonard one. It does not seem possible that the forest developed in only six years. This is an example of cartographic imprecision and of the shifting that can occur with georeferencing, even if it is done as precisely as possible (using many control points). It is, therefore, important to use other sources of information, such as historical records, to understand historical landscape change.

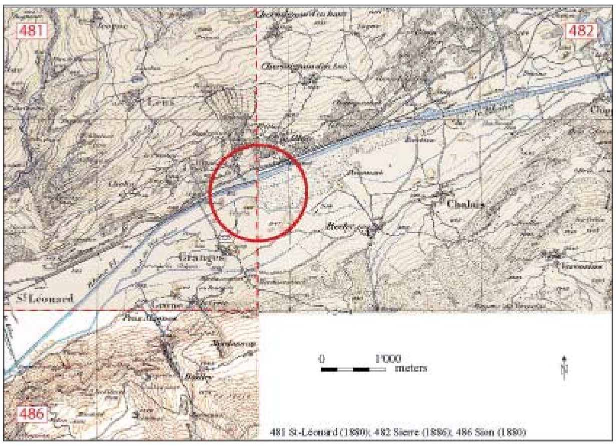

Fig. 4: Problems with fitting two Siegfried maps (Stäuble & Reynard, 2007 modified). Reproduced by permission of swisstopo (B081074).

6. Examples

The analysis of historical maps in the Rhone river valley highlighted four stages in the landscape evolution. Until the middle of the 19th century the Rhone river and the valley may be considered as close to a natural state. Since the 1860's, the landscape of the valley changed rapidly: the First Rhone river corrections allowed the development of intensive agriculture and more recently urbanization (Fig. 7). The study of six vineyard areas showed different evolution trends. We present here only a few examples taken from the two studies (for more details, see Stäuble & Reynard (2005, 2007), Martin & Reynard (2007) and Reynard et al. (2008)).

The draining of wetlands in the plain of Conthey was mapped and analysed. The First Rhone river corrections were performed between 1864 and 1893. The aim of the hydraulic work was not only to reduce flood risk, but also to increase agricultural surfaces by building canals, which would drain the wetlands. Fig. 5 illustrates the retreat of wetlands in the plain of Conthey. Its quantification helps to analyse the reasons for the disappearance of wetlands in this area. Even if the canals were in use since 1877 (Pasche, 2004), only half of the area was drained before the 1930's. Indeed, during the 1930's, the so-called "Wahlen Plan" aimed at increasing the agricultural surfaces in order to improve food availability in Switzerland. The analysis of maps and the quantification of changes permit us to understand the importance of the "Wahlen Plan" in the drainage process in the area. Moreover, the development of roads

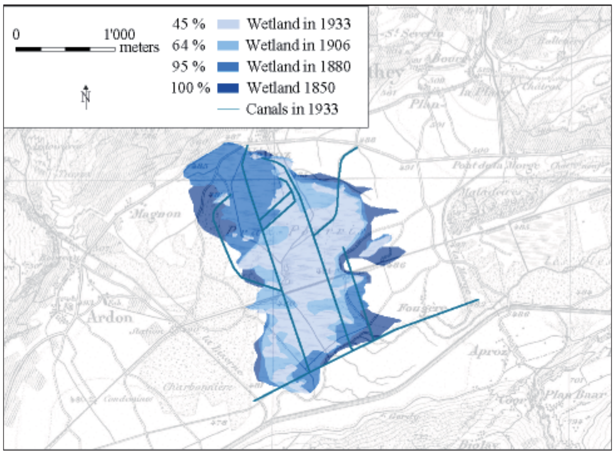

Fig. 5: Retreat of wetland in the plain of Conthey. On the map of 1943, all the land is drained (Stäuble & Reynard 2005 modified). Reproduced by permission of swisstopo (B081074)

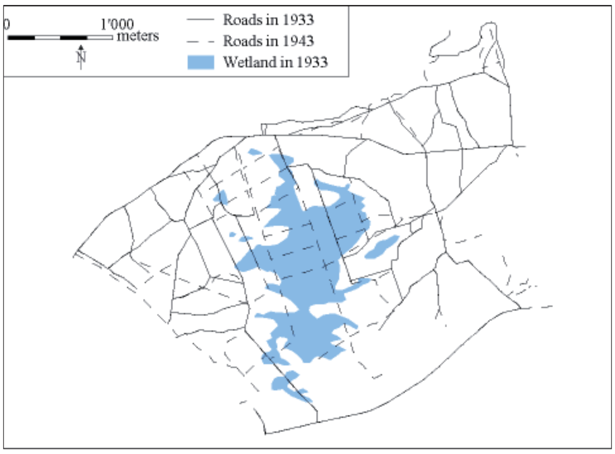

Fig. 6: Retreat of wetland in the plain of Conthey and development of roads for agriculture (Stäuble & Reynard, 2005 modified).

(Fig. 6) shows that as soon as the land was drained off, the land was used for agriculture. Before the first national maps at a 1: 25,000 scale, orchards were not drawn on maps; the analysis of the road development helps understanding the transition between wetland and agriculture.

Mapping historical landscapes allows us to highlight the increase in vulnerability of the Rhone river alluvial plain, which is currently very high: in case of a hundred year return flood, almost 7,000 ha of the valley could be flooded. The potential damage is estimated at 2.8 billion Swiss francs for the current state of the valley (Canton du Valais, 2000).

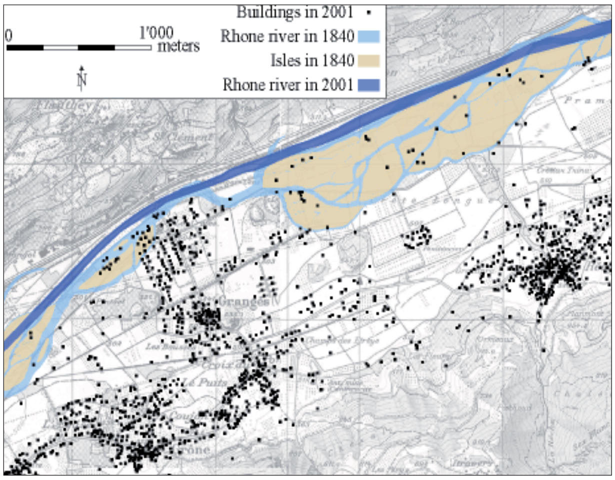

Fig. 7: Today's buildings in relation to the Rhone river before the first river corrections. Houses have been built on the old braids of the Rhone river (Stäuble & Reynard, 2007 modified). Reproduced by permission of swisstopo (B081074).

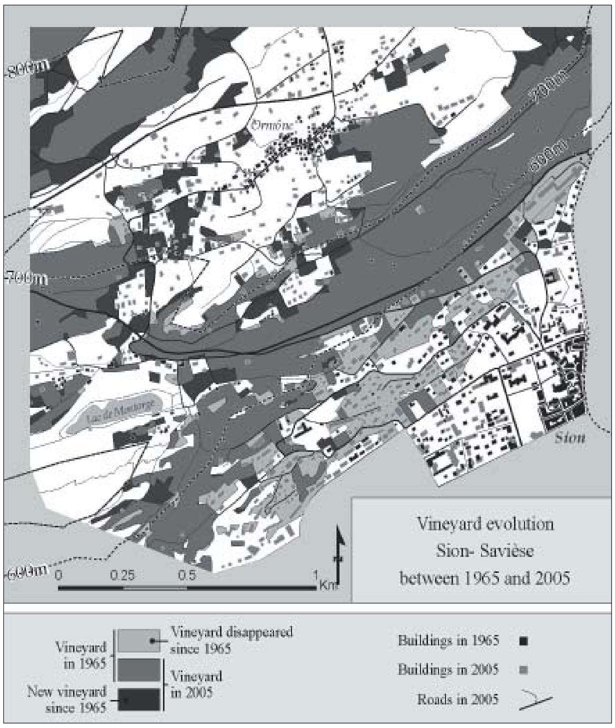

Fig. 8: Vineyard landscape change between 1965 and 2005 in relation to urbanisation in the surroundings of the town of Sion (Martin & Reynard, 2007, modified). Reproduced by permission of swisstopo (B081074).

Since 2000, the Canton of Valais has undertaken the Third Rhone river corrections, which aims at increasing the security of the valley and its ecological and socioeconomic state. Figure 7 shows the recent development of buildings in sectors where the Rhone used to flow before the First Rhone river corrections.

Fig. 8 shows how historical maps were used to analyse the relationship between vineyard landscape change and urbanization. The growth of Sion (capital of the Valais canton) during the last decades caused the disappearance of most vineyards at the foot of the hillside and on the plain, which were replaced by buildings. Between 600 m and 700 m, no important change is observable. Above 700 m, unlike around Sion, the vineyard has stretched everywhere, sometimes higher than 800 m. At the same time, numerous new houses were built all around the village of Ormône, but mostly at the detriment of meadows and not of vineyards. This evolution has now almost stopped the possible development of vineyards.

7. Conclusions

GIS allows dealing with heterogeneous spatial information such as historical maps whose accuracy and scale vary over time (Joliveau, 1996). We have pointed out some important methodological problems, such as changes in mapping characteristics (scale, projection system, reference point for elevation calculation, etc.), precision during the field survey, and accuracy of some important natural elements – forests, wetlands – in relation to the season that the survey was carried out. Moreover, some landscape elements, such as agricultural surfaces like orchards, meadows and cereal fields, that may change from one year to the next, are not represented on maps, even on the more recent ones. The reconstruction of historical landscapes is, therefore, always partial. Nevertheless, the integration of maps in a GIS environment allowed us to reconstruct some aspects of past landscapes and helped us to understand the driving forces of landscape change by crossing territorial features such as urbanization, building of infrastructures and changes of some natural elements like forests or wetlands. Maps represent, therefore, a first step in understanding landscape change by allowing us to formulate hypotheses on landscape driving forces. Further investigations – such as interviews of actors, consultation of archives – have yet to be carried out to confirm the hypotheses.

Acknowledgements

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References

Bender, O., Boehmer, H. J., Jens, D. and Schumacher, K. P. (2005): Using GIS to analyse long-term cultural land-scape change in Southern Germany. Landscape and Urban Planning, 70, 111–125.

Bureau topographique fédéral (1898) : La topographie de la Suisse - 1832–1864. Histoire de la carte Dufour. Bu-reau topographique fédéral, Berne.

Bürgi, M., Hersperger, A. and Schneeberger, N. (2004): Driving forces of landscape change - current and new di-rections. Landscape Ecology, 19, 857–868.

Bürgi, M., Hersperger, A., Hall, M., Southgate, E. and Schneeberger, N. (2007): Using the past to understand the present land use and land cover. In: Kienast, F. P. D., Wildi, O., Ghosh, S.: A changing world. Challenges for landscape research. Springer, Dordrecht, 133–144.

Canton du Valais (2000) : Troisième correction du Rhône. Sécurité pour le futur. Rapport de synthèse. Canton du Valais, Service des routes et cours d'eau, Sion.

Domaas, S. T. (2007) : The reconstructing of past patterns of tilled fields historical cadastral maps using GIS. Landscape Research, 32, 1, 23–43.

Grandgirard, V. (1997) : Du paysage au lieu de mémoire. Annales fribourgeoises, Tomes 61 et 62, 41–48.

Grosjean, G. (1996) : Geschichte der Kartographie. Geographisches Institut der Universität Bern, Bern.

Gurnell, A. M., Downward, S.R. and Jones, R. (1994): Channel planform change of the river Dee meanders, 1876–1992. Regulated rivers: research & management, 9, 187–204.

Gurnell, A. M., Peiry, J.-L. and Petts, G. E. (2003): Using historical data in fluvial geomorphology. In: Kondolf, G. M. and Piégay, H.: Tools in fluvial geomorphology, Wiley, Chichester, 77–101.

Gurtner, M. (1997) : Lecture de carte. Manuel des Cartes nationales. Club alpin suisse et Office fédéral de topogra-phie, Wabern.

Joliveau, T. (1996) : Gérer l'environnement avec un SIG. Mais qu'est-ce qu'un SIG ? Revue de Géographie de Lyon, 71, 2, 101–110.

Kienast, F. P. D. (1993): Analysis of historic landscape patterns with a Geographical Information System - a me-thodological outline. Landscape Ecology, 8, 2, 103–118.

Lechevalier, M. (2005) : La mission des ingénieurs géographes français en Valais en 1802. Vallesia, 60, 411–432.

Marcucci, D. J. (2000): Landscape history as a planning tool. Landscape and Urban Planning, 49, 67–81.

Marston, R. A., Girel, J., Pauton, G., Piégay, H., Bravard, J.-P. and Arneson, C. (1995): Channel metamorphosis, floodplain disturbance and vegetation development: Ain River, France. Geomorphology, 13, 121–131.

Martin, S. and Reynard, E. (2007): Paysage viticole valaisan entre 1880 et 2005: cartographie géo-historique. Un-published report, Institute of Geography, University of Lausanne.

Pasche, L. (2004): Travaux de correction des cours d'eau en Valais et dans la région de Conthey (1860-1900). Vallesia, 59, 225–246.

Paulmier, E. (2004) : Evolution de la qualité écologique des paysages de la plaine du Rhône sur la base d'une ana-lyse spatiale de cartes historiques. Unpublished postgraduate diploma thesis, EPFL, Lausanne.

Petit, C. C. and Lambin, E. F. (2002): Impact of data integration technique on historical land-use/land-cover change: comparing historical maps with remote sensing data in the Belgian Ardennes. Landscape Ecology, 17, 117–132.

Poirier, N. (2006) : Des plans terriers au cadastre ancien: mesurer l'évolution de l'occupation du sol grace aux SIG. Le Médiéviste et l'ordinateur, 44, http://lemo.irht.cnrs.fr/44/plans-terriers.htm.

Reynard, E., Martin, S., Arlettaz, S. and Bessero, V. (2008) : Cartographie de l'évolution du vignoble valaisan entre 1880 et 2005. Vallesia, in print.

Simpson, J. W., Boerner, R. E. J., DeMers, M. N., Berns, L. A., Artigas, F. J. and Silva, A. (1994): Forty-eight years of landscape change on two contiguous Ohio landscapes. Landscape Ecology, 9, 4. 261–270.

Stäuble, S. and Reynard, E. (2005) : Evolution du paysage de la plaine du Rhône dans la région de Conthey depuis 1850. Les apports de l'analyse des cartes historiques. Vallesia, 60, 433–456.

Stäuble, S. and Reynard, E. (2007): Le Haut-Rhône et son bassin versant montagneux: pour une gestion intégrée des territoires transfrontaliers. Aménagement des cours d'eau et développement des sociétés. Une approche carto-graphique. Unpublished report, Interreg IIIA, Sion/Lausanne.

Vuorela, N., Alho, P. and Kalliola, R. (2002): Systematic assessment of maps as source information in landscape-change research. Landscape Research, 27, 2, 141–166.

Winterbottom, S. J. (2000): Medium and short-term channel planform changes on the rivers Tay and Tummel Scotland. Geomorphology, 34, 195–208.