Applied Geography 90 (2018) 115–122

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Using high-resolution multitemporal imagery to highlight severe land management changes in Mediterranean vineyards

Fabrice Vinatier*, Ana González Arnaiz

INRA, UMR LISAH, F-34060 Montpellier, France

A B S T R A C T

Mediterranean vineyards are subjected to drastic changes due to socio-economic, physical and environmental drivers. Whereas global trends affecting the evolution of Mediterranean land cover are well-known, their descriptions at a fine spatial scale, i.e., a plot level of several decametres, and over long time periods are still underexplored. This lack of exploration persists despite the increase in multitemporal imagery at fine resolutions. As scale and stakeholders are often correlated, we hypothesize that monitoring land cover at fine spatial and temporal scale would help understanding the local drivers shaping landscapes. To that end, we exploited a database of aerial pictures to obtain classified and vectorized land uses at the field level during the past five decades of a large watershed. The land uses were analyzed to detect changes at the field level considering the evolution of vineyard management. Changes in land management were synthesized in transition matrices expressing gains, losses and swaps for each land use category and illustrated using chord and Sankey diagrams. The results showed both a change in land management through a severe transformation of vineyards areas, from goblet to trellised vineyards, during the 1980s and a progressive evolution of land uses from vineyards to urban areas, arboriculture areas and arable lands. This transformation resulted from the local policies on vineyard replanting and the arrival of mechanization.

1. Introduction

Landscape organization, in terms of land uses and management, is the result of centuries-old interaction between man and the environment (Agnoletti et al., 2011; Lieskovský et al., 2014). By definition, the land use encompasses the intentional role of people to adapt the natural land cover to their benefit (Verheye, 2004) whereas land management defines the way in which a given land use is administered by people (Foley et al., 2005). Among the variety of landscapes on Earth, vineyards are excellent case studies, as they represent a strong cultural legacy and support a crucial socioeconomic sector in European countries (Salome et al., 2014). Historical maps of vineyards were widely studied because they have faced several crises (Lieskovský et al 2013, 2015, 2017; Pazúr, Lieskovský, Feranec, & Ot'aheľ, 2014; Incze & Novák, 2016). In Europe, the phylloxera aphid caused a total collapse of vineyard production in 1860s, until the grafting onto American vines finally succeeded. In France, the introduction of the Common Market in 1970, which allowed the Italians and Spanish to invest in the French interior market, caused a decrease in the growing of table grapes (Galet, 2008) in conjunction with a decrease in pesticides used in agriculture. In 1990, the arrival of vines "du nouveau monde" from the United States, Australia and Chile influenced vine production (Touzard & Laporte, 1998). As the global drivers affecting evolution of vineyards are well known, their monitoring at landscape scale to understand their driving forces is an essential step still under investigation (Houet, Verburg, & Loveland, 2010).

The driving forces shaping landscapes are both socio-economical and physical. Landscape consolidation is driven by political forces because it helps making large fields more suitable for industrial agriculture (Lieskovský et al., 2014). Landscape composition in land uses is also affected by social forces and particularly the land abandonment (Incze & Novák, 2016). Physical forces drived also landscape architecture and composition in land uses. For instance, geomorphological variables drived land use changes such as slope that affects field accessibility with machinery (Sluiter & Jong, 2006; Lieskovský, Lieskovský, & Piscová, 2017). Altitude gradient can also affect the loss of natural areas in favour of agriculture expansion (Tovar, Seijmonsbergen, & Duivenvoorden, 2013). The pedological factors are also important to understand land settlement on fertile soils for example (Lieskovský et al., 2014, 2015). As explained below, land management is also affected by socio-economical and physical forces.

Historical evolution of vineyards in regards to other land uses have

* Corresponding author.
E-mail address: fabrice.vinatier@inra.fr (F. Vinatier).

https://doi.org/10.1016/j.apgeog.2017.12.003
Received 16 October 2017; Received in revised form 4 December 2017; Accepted 4 December 2017

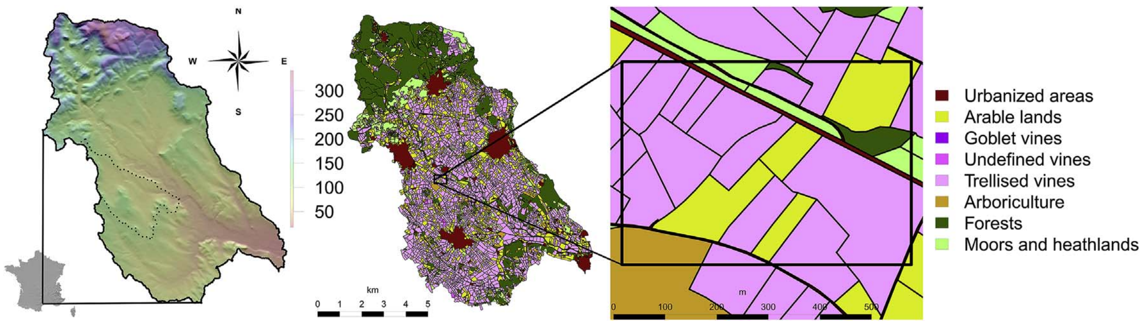

Fig. 1. Localization of watersheds in the zone. Borders of the Peyne watershed and Bourdic subwatershed are symbolized by plain and dotted lines on the altitude map, respectively. Land use categories are also represented with white crosses indicating the locations of towns.

been largely analyzed in Europe, but a change in land management of the vineyards is still lacking. Tracking subtle changes in land management is sometimes more difficult than for land uses because it necessitates a resolution of the historical maps higher or equal to the metre to distinguish between vineyard types (Delenne et al., 2008). In the same way, changes in land management acted at a smaller scale than for changes in land uses. For example, weeding practices in vineyards were mainly governed by local government areas (Biarnes, Bailly, & Boissieux, 2009). As scales and stakeholders are often correlated (Hein, van Koppen, de Groot, & van Ierland, 2006), monitoring the evolution of vineyard management help us explain the role of local stakeholders in a given area. There is now a large number of available images (Wulder, Masek, Cohen, Loveland, & Woodcock, 2012) to create diachronic maps but they have not always a sufficient resolution to detect changes in land management at field scale whereas the field scale is the main unit on which most decisions on the land management operate in agricultural landscapes (Thenail et al., 2009).

A large amount of research has been conducted on the study of land cover in various fields from LANDSAT images: urban expansion (Chen, Zhao, Li, & Yin, 2006; Qin, Jianwen, & Yun, 2006; Yuan, Sawaya, Loeffelholz, & Bauer, 2005), urbanization of agricultural zones (Liu, Liu, Zhuang, Zhang, & Deng, 2003; Stefanov, Ramsey, & Christensen, 2001; Yang & Lo, 2002), forest disturbance (Gibbs et al., 2010; Huang et al., 2010; Mertens & Lambin, 2000; Tovar et al., 2013), desertification monitoring (Dawelbait & Morari, 2012; Symeonakis, Calvo-Cases, & Arnau-Rosalen, 2007) and several ecological applications (Cohen & Goward, 2004). However, image classification for determining land cover categories is limited by satellite resolution (higher than 30 m) for these series, and changes in land use or land management operation at the field scale cannot be evaluated by LANDSAT images.

The texture of the field entity could provide information about the type of land use (Trias-Sanz, 2006) and even the land management of vineyards (Delenne et al., 2008; Wassenaar, Robbez-Masson, Andrieux, & Baret, 2002). Furthermore, spatial segmentation is driven by the raster dataset, which is composed of regular squared cells from one to several decametres, and is different from the irregular shapes that form the field entities, the latter being studied using object-based image analysis (OBIA).

By extracting valuable information from various satellite images at different spatial resolutions, from 50 cm to several metres, OBIA is well suited for performing land change studies at the field scale (Benz, Hofmann, Willhauck, Lingenfelder, & Heynen, 2004; Blaschke, 2010). A large number of studies has been devoted to ecological applications (Xie, Roberts, & Johnson, 2008; Yu et al., 2006 for example) or urban features (for a review, see Blaschke (2010)), but only few OBIA studies have been conducted at the field level (Karakizi & Karantzalos, 2015; Qiu, Wu, & Miao, 2014; Zhou & Troy, 2008), and never during long time periods.

The difficulty in studying land use changes at the field scale for large spatial and temporal extents is mainly driven by dataset resolution. The availability of remotely sensed data over long time periods (Wulder et al., 2012) and the constant improvements of photogrammetric and digitalization tools for such spatial database analyses make these studies possible (Grekousis, Mountrakis, & Kavouras, 2016). Arnaud et al. (2015) realized historical geomorphic analysis over 80 years in France thanks to the release of aerial photographs from the Institut Geographique National (IGN), for instance.

The study reported land use changes at the field scale over a time period of 50 years using aerial images of Mediterranean vineyards. We hypothesize that a high-resolution database could provide information about changes in land management of vineyards, providing that the time period encompasses the wine crises periods with sufficient temporal resolution. We aim to determine changes in land use categories at the field level using both field number and field area.

2. Materials and methods

2.1. Composition and configuration of the dataset at the field scale

The study area corresponds to the Peyne watershed, which covers approximately 76 km^2 and is located in Languedoc-Roussillon in southern France (43° 35′N, 3° 19′E). The smaller enclosed watershed is called the Bourdic subwatershed and covers 7 km^2. Both the Peyne and Bourdic watersheds were used for further analyses depending on the temporal richness of the dataset. The area of the Peyne watershed is mostly covered by perennial crops (mainly vineyards), and five towns are present in the zone (Fig. 1). The climate is submediterranean subhumid with a long dry season, an average annual temperature of 14 °C, an annual rainfall varying between 400 and 1400 mm and an altitude varying between 0 and 350 m.

In 2012, the IGN released a large, open-access database of aerial black-and-white photographs from 1937 until the present. We selected a sample of images from the IGN database covering the Peyne watershed from 1962 to 2003 with a time interval between 4 and 5 years. We completed the series by taking orthophotos from 2005 to 2012 processed by the IGN from colour photographs (see Table 1 for more details on the imagery database). The time period was chosen in accordance with the major changes in vineyard composition. Because the goals of our study focused on change detection at the field scale, the diachronic dataset used for retro-observation needs to be processed at a fine resolution to distinguish field unit limits and their land use or land cover. The aerial photographs were orthorectified using structure-from-motion approach (Midgley & Tonkin, 2017) and corrected from vignetting effects (Lebourgeois et al., 2008) to get orthophotos defined at pixel resolution of less than 1 m. The satellite images were also sampled at the same resolution.

The raster database was then transformed into polygons with a minimal area of approximately 200 m^2 using manual digitizing and classification procedures to separate field entities and their associated land use categories using QGIS software (QGIS Development Team, 2016) and GRASS (GRASS Development Team, 2016).

Land uses of each homogeneous polygon were classified according