Land-use in the Macaronesian islands of Portugal and Spain

Michael Rodrigues

Department of Human Geography, Faculty of Geography and History, Complutense University of Madrid, Madrid, Spain

ABSTRACT

This article outlines the method used in designing a thematic map of land-use. The aim is to depict the main land-use categories and changes, across the Macaronesian islands of Portugal and Spain, between 1990 and 2006. The map presents a novel technique of summarizing land-use/land-cover (LULC) data into a custom-made 2D static graph-based display. The method proposes depicting the region of interest inside a hollow circle chart, commonly known as ‘doughnut chart’. The void inside the chart allows placing a complete cartographic representation, whereas the circle chart itself allows displaying statistical data of the encircled cartographic representation. To convey the temporal dimension, the method positions the graphics following a timeline. This custom display provides a framework to study and represent LULC data, overcoming common visual effectiveness issues. The proposed approach is flexible and suitable for application elsewhere, making it possible to draw visual impressions and comparisons in a straightforward manner.

1. Introduction

Although land-use/land-cover (LULC) studies are diverse (Levine & Kaufman, 2008; Nigel, Rughooputh, & Boojhawon, 2015; Vorel & Grill, 2015), there is still a field that can be greatly improved: LULC representation and visualization methods. As researchers have an increasing amount of LULC data, there is a continuous need for tools and methods to synthesize information (Rodrigues, 2016). On this matter, a dominant approach relies in coupling geographic information science (GIS) techniques, with the use of geo-visualization, to accelerate the process of visual geospatial exploration (Gugl, 2009). As an interdisciplinary area, geo-visualization integrates approaches from several scientific fields to provide theory, methods, and tools for visual exploration, analysis, synthesis, and presentation of geospatial data (MacEachren & Kraak, 2001). In addition, research acknowledges that there is a growing need for novel approaches to represent geospatial data in a visual form that can improve pattern recognition and hypothesis generation (Bodum, 2005).

In recent decades, human-induced landscape changes were profound at a global scale (Foley et al., 2005); these changes have also affected the small and isolated Macaronesian islands of Portugal and Spain. Due to the islands’ ecological importance (Sundseth, 2009), land-change studies are of particular significance to this region. In fact, despite representing only 0.2% of the EU territory, these islands host over a quarter of EU’s most endangered and vulnerable flora (Sundseth, 2009). Therefore, the supplemental Main Map discussed in this article encompasses the 18 inhabited Macaronesian islands of Portugal and Spain. The study aims to analyze and measure, the main land-use categories and changes, between 1990 and 2006. A period marked by a rapid increase in land development, which ended with the 2007–2008 financial crisis. The results, deducing landscape proportions and rates of change, are presented in a single map using the proposed method.

In land-change assessment, change matrices are the main technique used to show changes across a landscape. A change matrix represents transitions among LULC categories, keeping track of area shifts among categories. It is a technique widely applied in land-change research (Fuchs, Herold, Verburg, Clevers, & Eberle, 2015). Nonetheless, when dealing with several study cases, change matrices may turn out too extensive, thus becoming impractical and ineffective. On the other hand, cartographic methods such as choropleth maps (Sun, Kronenfeld, & Wong, 2013), flow maps (Guo, 2009), and cartograms (Li & Clarke, 2012), are the prevailing techniques used to depict geospatial data thematically. Contrary to tabular displays, these methods are spatially explicit, though to varying degrees, and symbols can be combined and overlaid to further enrich the depiction of data. However, a common drawback among cartographic methods occurs when data items overlap in the data-view, making patterns hard to perceive due to occlusion. This drawback is known as the visual effectiveness problem (Guo, Chen, MacEachren, & Liao, 2006). In order to address clutter and over-plotting, several views can be represented alongside the main data-view, a common design strategy, where the geographic

CONTACT Michael Rodrigues mikemrbr@gmail.com

© 2016 Michael Rodrigues
data-view is presented alongside further data of interest, such as data plots and tables. Alam, Kobourov, and Veeramoni (2015) classify this approach as augmented map visualizations.

In addition, besides tabular and cartographic representations, LULC data may also be presented in standard static displays, such as graphs and charts. Despite being non-spatially explicit, these methods are well-fitted to display multivariate data. For this reason, the supplemental Main Map discussed in the present article showcases the coupling of cartographic representations and charts, adapting circle and bar charts to aid the representation of LULC data.

The main goal of the supplemental Main Map discussed in this article, is to propose a method of representing multivariate LULC data, in a meaningful and concise manner. First, a GIS-based spatial analysis was employed, deducing statistical data of land-use categories across eighteen islands. Second, the results are visualized in a custom-made 2D static graph-based display. Overall, this article provides an original contribution to the ongoing debate about land-change and LULC dynamics, by means of the development of a novel method of analyzing and representing LULC data. The remainder of this article is organized as follows. The next section presents the study area and data sources. Section 3 presents the map design, whereas Section 4 concludes the article.

2. Study area and data

Macaronesia is a bio-geographical region comprising several archipelagos extending outwards from the coast of Europe and Africa (Fernández-Palacios et al., 2011). The archipelagos belong to three countries: Portugal, Spain, and Cape Verde. The supplemental Main Map discussed in the present article encompasses three archipelagos: Azores, Madeira, and the Canary Islands. The Azores and Madeira belong to Portugal, whereas the Canaries belong to Spain. Climatically, the Macaronesian islands of Portugal and Spain span a transition zone between temperate and subtropical climate. However, a rugged volcanic orography originates a diversity of microclimates and landscapes, ranging from arid environments to humid evergreen forests.

The most important ecosystem in the Macaronesia bio-geographical region is the Atlantic laurel forest, which develops in the archipelagos’ areas with very low seasonal temperature variation and high precipitation. The ecological importance of the laurel forest relies in the fact that its vegetation is composed of the remnants of Palaeotropical geoflora (Fernández-Palacios et al., 2011), a flora that thrived in the Paleogene Period (c. 64–25 Ma) after the Cretaceous-Paleogene extinction event. Having been wiped out from the mainland, because of the Quaternary glaciation, Europe’s last impoverished remnants of Palaeotropical geoflora survived in these archipelagos, subsisting where the impact of the Quaternary climate change was moderated by the oceanic influence (Fernández-Palacios et al., 2011).

The data used for this map is available from public domain sources. CORINE land-cover (CLC) data sets were the map’s primary data source. CLC are geospatial datasets of the European landscape deduced from remote sensing. These public domain data sets (www.eea.europa.eu/data-and-maps) provide an inventory of LULC categories organized hierarchically in three levels as a comparable cartographic product. CLC level1 corresponds to the main categories of land-use (artificial, agricultural, forests and semi natural, wetlands, water bodies), CLC level2 covers land-cover entities at a higher level of detail (i.e. 15 categories), whereas the disaggregated CLC level3 is composed of 44 land-cover categories. Therefore, the aggregated CLC level1 allows characterizing land-use, whilst from CLC level2 onward the CLC data sets characterize land-cover. The availability of comparable data sets using similar source data and having the same technical characteristics (e.g. 25 ha minimum mapping unit), allows a quantitative characterization and assessment of land-change, over a period of two decades. The first iteration of CLC data covered the reference year of 1990 with subsequent releases covering the years 2000 and 2006. The latest 2012 update is still under production. Finally, in order to depict bathymetry, the map uses ‘Natural Earth’ data, another public domain map data source (www.naturalearthdata.com).

3. Map design

A GIS-based analysis was performed to determine changes in the areal extent of land-use categories by comparing land-use data from two points in time: 1990 and 2006. Through this approach, the goal was to measure the islands’ main land-use categories and change, based on two years of CLC level1 data. This analysis allowed establishing the difference of land-use areas, to deduce the arithmetic calculation of change in total land area, and the rates of change across CLC level1 categories. In these islands, CLC level1 is represented by three land-use categories (artificial; agricultural; forest and semi natural), whereas due to the 25 ha minimum mapping unit, the remaining CLC level1 categories are absent (i.e. wetlands; water bodies).

In order to frame a discussion about land-use, map design was one of the most challenging task in the study. There was the need to display eighteen islands in a single map. Nonetheless, a balanced map design was achieved, and visual relationships were designed to achieve appropriate visual hierarchy and optimize visual contrast. Due to the approach followed, the supplemental Main Map discussed in the present
article can be categorized as an augmented map visualization (Alam et al., 2015), because several data-views are simultaneously represented to depict the eighteen inhabited Macaronesian islands of Portugal and Spain.

Because the map was intended to individually depict eighteen islands, it has an ISO standard A0 (841×1189 mm) page format. As for color, the map uses the CMYK color model. Nonetheless, color is used sparingly, as the map only illustrates three land-use categories. For the typography, the map uses the Calibre font in sizes ranging from 6 to 50 pt.

The map’s novel approach is the custom-made 2D static graph-based display. As shown in Figure 1, this approach allows representing each island and its associated data individually. The region of interest is depicted inside a hollow circle chart, commonly known as ‘doughnut chart’. Thus, the void inside the chart allows placing a complete cartographic representation, whereas the circle chart itself allows displaying statistical data of the encircled cartographic representation (Figure 1).

In order to convey the temporal dimension, Figure 1 positions the graphics following a timeline. In this study, the first year under analysis is 1990, whereas 2006 ends the timeline. Although in the supplemental Main Map discussed in the present article, only two years are depicted, the method allows placing more years as needed. This design follows the multiple-static-maps strategy (Monmonier, 1990), which juxtaposes graphics for a simultaneous visual comparison of time units. The multiple-static-maps strategy suits particularly well LULC assessments, because each graphic presents a snapshot for a discrete period. Thus, if two or more graphics are juxtaposed, the reader can visually compare LULC data (Rodrigues, 2016). As shown in Figure 1, this method allows inferring trends over time, including LULC gains and losses.

The positioning of a bar chart between the circle charts allows further depicting data. In the case of this study, the bar chart illustrates the land-use midpoint percentage change between 1990 and 2006. Moreover, the lower-most section of Figure 1 allows enriching the data-view with contextual information, in the case of this study, demographic statistics for each year under analysis, total land area, and the altitude of the highest peak. Overall, the proposed method was devised with a graphical hierarchy that makes it intuitively easy for the reader to discover the key concepts and relationships of the data portrayed.

3.1. Software

Spatial analysis and data manipulation were accomplished with ArcGIS® Desktop 10, and map layouts exported to the Illustrator® file format. Land-use statistical analysis was performed with Excel® 2013. Finally, map composition, charting, and labeling were all made with Illustrator® CS6.

4. Conclusion

This article presented a map using a novel method of analyzing and representing LULC data in a meaningful and concise manner. By presenting a technique summarizing LULC data into a graph-based display, this method can simplify complex LULC data in a single data-view. As shown in the supplemental Main Map, the method can be used to: (1) depict the overall LULC patterns; (2) facilitate visual comparisons among study areas and/or time-series; and (3) facilitate the identification of LULC gains, losses, and trends. Ultimately, the method makes it possible to easily draw visual impressions of LULC data, establishing the difference of land-use areas in order to deduce landscape proportions and rates of change.

Figure 1. Example of the custom-made 2D static graph-based display.
Acknowledgements

The author would like to express his sincere gratitude to Professor Javier Gutiérrez Puebla for his valuable suggestions on the previous drafts of this map.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

Financial support for this research from the Portuguese Foundation for Science and Technology is greatly acknowledged [grant number SFRH/BD/69396/2010].

References

Alam, M. J., Kobourov, S. G., & Veeramoni, S. (2015). Quantitative measures for cartogram generation techniques. Computer Graphics Forum, 34(3), 351–360.

Bodum, L. (2005). Modelling virtual environments for geovisualization: A focus on representation. In J. Dykes, A. M. MacEachren, & M. J. Kraak (Eds.), Exploring geovisualization (pp. 389–402). London: Elsevier.

Fernández-Palacios, J. M., de Nascimento, L., Otto, R., Delgado, J. D., García-del-Rey, E., Arévalo, J. R., & Whittaker, R. J. (2011). A reconstruction of Palaeo-Macaronesia, with particular reference to the long-term biogeography of the Atlantic island laurel forests. Journal of Biogeography, 38(2), 226–246.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., … Snyder, P. K. (2005). Global consequences of land use. Science, 309(5734), 570–574.

Fuchs, R., Herold, M., Verburg, P. H., Cleverson, J. G., & Eberle, J. (2015). Gross changes in reconstructions of historic land cover/use for Europe between 1900 and 2010. Global Change Biology, 21(1), 299–313.

Gugl, C. (2009). Mapping and analysis of linear landscape features. In O. Bender, N. Evelepidou, A. Krek, & A. Vassilopoulos (Eds.), Geoinformation technologies for geo-cultural landscapes: European perspectives (pp. 275–290). London: Taylor & Francis.

Guo, D. (2009). Flow mapping and multivariate visualization of large spatial interaction data. IEEE Transactions on Visualization and Computer Graphics, 15(6), 1041–1048.

Guo, D., Chen, J., MacEachren, A. M., & Liao, K. (2006). A visualization system for space-time and multivariate patterns (vis-stamp). IEEE Transactions on Visualization and Computer Graphics, 12(6), 1461–1474.

Levine, N. S., & Kaufman, C. C. (2008). Land use, erosion, and habitat mapping on an Atlantic Barrier Island, Sullivan’s Island, South Carolina. Journal of Maps, 4(1), 161–174.

Li, L., & Clarke, K. C. (2012). Cartograms showing China’s population and wealth distribution. Journal of Maps, 8(3), 320–323.

MacEachren, A. M., & Kraak, M. J. (2001). Research challenges in geovisualization. Cartography and Geographic Information Science, 28(1): 3–12.

Monmonier, M. (1990). Strategies for the visualization of geographic time-series data. Cartographica: The International Journal for Geographic Information and Geovisualization, 27(1), 30–45.

Nigel, R., Rughooputh, S. D., & Boojawon, R. (2015). Land cover of Mauritius Island. Journal of Maps, 11(2), 217–224.

Rodrigues, M. (2016). Representing coastal land use in the island of Gran Canaria. Journal of Maps, 12(2), 311–315.

Sun, M., Kronenfeld, B. J., & Wong, D. W. (2013). Cartographic techniques for communicating class separability: Enhanced choropleth maps of median household income, Iowa. Journal of Maps, 9(1), 43–49.

Sundseth, K. (2009). Natura 2000 in the Macaronesian region. Luxembourg: Publications Office of the European Union.

Vorel, J., & Grill, S. (2015). Land use change propensity maps. Journal of Maps, 11(2), 225–230.