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Land cover and land use change in the Italian central Apennines: A comparison of assessment methods

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A B S T R A C T

Analyses of land-use cover changes (LUCC) are fundamental to the understanding of numerous social, economical and environmental problems and can be carried out rapidly, using either cartographic or census data. However, the trends of the two methods differ in direction and quantity.

For this study, a historical and a recent remote sensing-derived map were homogenized to reduce misleading changes and to assess spatial aggregation errors. This was carried out by means of a data integration procedure based on landscape metrics, allowing cartographic and census trends to be compared. Discrepancies between data were thus highlighted, both in absolute surface value and in evolution.

The methodology presented, and the results obtained, could be employed to evaluate and improve LUCC analyses aimed at assessing landscape identity, both in the case of analyses based only on LU census data, or of those based only on LC cartographic data. This could lead to benefits for both biodiversity conservation and environmental planning on a large scale.

Introduction

Land-use and -cover change (LUCC) are among the most important alterations of the Earth's land surface (Lambin et al., 2001). Moreover, since the Second World War, LUCC and landscape transformation processes have accelerated (Antrop, 2005; Ewert, Rounsevell, Reginster, Metzger, & Leemans, 2005). Consequently, understanding and predicting the causes, processes and consequences of LUCC has become a major challenge to anyone involved in landscape ecology, regional land-use (LU) planning, biodiversity conservation (Etter, McAlpine, Pullar, & Possingham 2006), or protecting water resources from non-point pollution (Ripa, Leone, Garnier, & Lo Porto, 2006).

Accurate methods of LUCC assessment have been developed, and are currently used, by the scientific community. In contrast, governance agencies and local administrations responsible for the planning of territories often rely on LU and land-cover (LC) information without understanding its inherent characteristics. As a result, they are not aware of its suitability, or of its limitations, for the analysis of territorial dynamics. LU and LC are not identical. A knowledge of LC does not necessarily define LU. The LU function of an LC type needs to be known in order to understand changes in LC (Lambin & Geist, 2001).

Abbreviations: LC, land cover; CLC, CORINE land cover; LU, land use; LUCC, land-use cover change; LUM 2000, Land-Use Map of 2000; GAC, general agricultural census; TCI/CNR, Land-Use Map of 1960; FSY, forest statistics yearbooks; ISTAT, Italian National Statistics Institute; SAU, area used for agriculture; I.N.F.C., National Forest and Carbon Reserve Inventory.

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There are many definitions of LU (Jansen, 2006) and LC. For this paper, LC is defined as "the observed (bio) physical cover on the earth's surface" (Di Gregorio & Jansen, 2000); while LU refers to the manner in which people use these biophysical assets (Cihlar & Jansen, 2001).

Among the many concerns about global environmental change today, there is an increasing awareness of the importance of issues involved in LU and its changes over time, since LU is a key descriptor of human influence. The fundamental problem in mapping LU is that it does not typically leave a distinct signature that can be discerned without a site investigation, possibly including socio-economic and cultural surveys. As site visits are not feasible, except for limited research and field-checking purposes, the production of LU maps for large areas (i.e., $>10^3$ km^2) can only be achieved using other means. The primary (and often only) generally available sub-national LU data are collected through census statistics, and do not show the spatial distribution of LC within the administrative unit (Cihlar & Jansen, 2001).

Nevertheless, because LC maps are more diffuse and easier to prepare, LC information is a key dataset for many LUCC research projects and LU planning (Cihlar & Jansen, 2001) and studies (e.g., Cousins, 2001; Falcucci, Maiorano, & Boitani, 2007; Hietel, Waldhardt, & Otte, 2004; Lasanta-Martìnez, Vicente-Serrano, & Cuadrat-Prats, 2005; Petit & Lambin, 2002; Schneider & Pontius, 2001; Vasconcelos, Mussá Biai, Araújo, & Diniz, 2002). These studies combine different data, such as historical LC maps or remote-sensing derived maps (generally from aerial photographs or satellite images), to analyze LC change in a spatially explicit way, with the support of a Geographic Information System (GIS).

Where LC maps and/or GIS support are not readily available, territories are frequently interpreted using census data, due to its greater ease of access and immediacy. However, the results of such studies are not entirely satisfactory, as cartographic information derived from remote sensing is discordant, i.e., the census and cartographic surfaces do not match. As a result, the dynamics of evolution are also not clear.

To illustrate this, let us consider a specific case of remote-sensing data versus census data. A comparison of LC, as observed in CORINE CLC2000 and CLC1990 (APAT, 2005), shows that at a national level in Italy, there was a general increase in wooded areas (Code CLC 3.1) of 1.07%, and a decrease in areas of natural pastures and meadows (Code CLC 3.2.1.) of 2.07%. In contrast, the Italian National Statistics Institute (ISTAT) data indicate that, on a national level, there was a notable decrease in wooded areas (-16.9%) and meadowland (-17.2%), in the period 1990–2000. The discrepancy with cartographic data is evident.

This discrepancy is due to the aim and methodology of production of the two sets of data. The woodland transition dynamics reported above can be explained by the abandonment of the weakest agroforestry farms (Di Gennaro, Innamorato, & Capone, 2005). As the latter were no longer included in the ISTAT census, they determined a decrease in the area declared as wooded. On the other hand, the forest recovery can be explained by the abandonment of the less productive fields and pastures in places with decreasing populations, such as mountainous regions (Falcucci et al., 2007; Rudel et al., 2005). This took place over a period of about 30–50 years (Pignatti, 1998; Rocchini, Perry, Salerno, Maccherini, & Chiarucci, 2006). Although LC can generally be said to be a consequence of LU, when LU modifications generate relatively modest changes in LC (i.e., if the change is not large enough to cause a shift from one cover type to another), then comparing and linking the two sets of data becomes complicated (Cihlar & Jansen, 2001). This is due to the difficulty in defining the real use, type and intensity of management of the LC by remote sensing methods. For example, in a largely irrigated territory, diffused or isolated crops may not be irrigated. Grassland and open areas may or may not be used as pasture, or may have been used as crops for a large part of the year and used as pasture for the remaining time. Therefore, besides the quality of the sensor, also the period of the year in which the images were collected can influence the resulting land classification. Site visits may be necessary to discriminate some LUs (e.g., to identify irrigation channels and the presence of irrigation equipment, or to verify the presence of animal grazing).

Some authors have discussed the relationships between LC and LU and proposed a methodology to derive LU maps from LC maps (Cihlar & Jansen, 2001). However, as a result of pressure to achieve immediate results simply, analyses of change continue to be performed based on census data or non-homogeneous LC maps. Consequently, erroneous conclusions are drawn and inappropriate decisions are made, which are ineffective and open to criticism. To improve LUCC analyses based only on LU census data, or those based only on LC cartographic data, it is necessary to highlight these misleading results.

Comparing two different sets of data requires that they should be as homogeneous as possible. Since census data cannot be improved, given that it was collected in the past by means of a questionnaire and is not characterized by spatial distribution, the only option is to improve the homogenization of LC maps.

In order to detect long-term changes, all the available information is needed. However, since the type of data varies greatly, this poses a series of problems. For example, aerial photographs and satellite images may not have the same spatial and spectral resolutions, and thus may not yield the same level of detail in LC classification. Furthermore, the LC information displayed on certain old topographic maps is even more difficult to integrate with LC maps derived from remote sensing. Indeed, the geometric and thematic characteristics of historical maps are not always perfectly known (Petit & Lambin, 2001). Moreover, historical maps may have been derived from a cartographic generalization whose primary aim was to convey a clearly readable image that is esthetically pleasing. Thus, the formation and displacement of "placeholder" objects (e.g., a building representing a group of buildings) are tolerated (Weibel & Jones, 1998). In short, the detection of LC change between such different data is contaminated by imprecision and inconsistency.

In order to reduce these problems, a map (or database) generalization is commonly realized. This consists in a process of informed extraction, emphasizing the essential while suppressing the unimportant, in which logical and unambiguous relations between map objects are maintained. At the same time, the accuracy and legibility of the map image are preserved as far as possible (Weibel & Jones, 1998).