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LAND USE CHANGE INTENSITIES IN THE REGION OF MADRID BETWEEN 1982 AND 2006

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I. INTRODUTION

In the last decades the Region of Madrid has undertaken an artificialization process, showing high rates of urbanization (López de Lucio, 2003; Naredo and García-Zaldivar, 2008). This increase in urban land use is related to a greater accessibility, linked with the road infrastructure development (Gago et al., 2004, García Palomares and Gutiérrez Puebla, 2007), but also with an abandonment of agricultural lands (Plata Rocha et al. 2009). This phenomenon is considered as one of the main driving forces in land use change (Wu et al., 2006). Land artificialization is related with potential problems such as landscape degradation and fragmentation (Alig et al., 2003), forest fires occurrence increase (Gallardo et al., 2016), heat islands (Zhang et al. 2013), greenhouse and other pollutants emissions (Chen, 2002, Peña et al., 2007), urban pressure inside or near natural protected areas (Mallinis et al., 2011; Pérez-Hugalde Et al., 2011; Hewitt et al., 2016; Gallardo and Martínez-Vega, 2017), among others.

Transition matrices or so-called cross-tabulation matrices (Bell, 1974; Pontius et al., 2004), allows to obtain quantities of total land use change, net change, exchange, gross gains and gross losses, analyzing data of two different points in time and performing a pixel-to-pixel comparison. Nowadays, there are few studies which use these matrices to develop land use intensities analysis. Aldwaik and Pontius (2012) present this methodology and study the intensity of land use changes during 1985, 1991 and 1999 for seven different land uses in Massachusetts, USA; Huang et al. (2012) study urban, agricultural and natural land uses intensities during 1986, 1996 and 2002 in the Juilong River Basin, southeast of China; Raphael et al. (2014) analyze land use changes intensities for seven land uses during 1976, 1987 and 2008 in the Arusha region, Tanzania, and relate them to perceptions and community responses to such changes; Rufin et al. (2015) study the changes that have occurred in pastures and arboreal vegetation between 1985 and 2012 in Novo Progresso, Brazil, relating them to phenology; and Farfán et al. (2016) observe the intensities in thirteen land use changes in the Biosphere Reserve Sierra de Manantlán, Mexico, during 2000, 2004 and 2008.

The intensity of land use change is expressed in this work as the speed of one type of land use to change to another assuming that in the whole study period land use changes would have been uniformly distributed over time. It is interesting to know which land uses are more dynamic in different time periods, comparing them with a uniform annual rate of change.

For this purpose, a hierarchical analysis of intensity of land use changes in the Region of Madrid, at time interval level, category level and transition level, is carried out. The aim is to show the evolution of the Region since it was created as an Autonomous entity in 1983. The methodology developed by Aldwaik and Pontius (2012) is used. Analyzing cross-tabulation matrices between 1982-1990, 1990-2000 and 2000-2006, three questions are solved: a) how does the size and rate change varies among different time intervals; b) how the size and the intensity of gross gains and gross losses of each category varies across categories in each time interval; and c) how the size and the intensity of each category transition varies across other categories that are available for that transition.

II. DATABASE AND METHODOLOGY

Four maps of four points in time are used. The initial land use data is a vegetation and land use map of the region of Madrid from 1982. It has a 1:50,000 spatial scale and a thematic legend of 63 categories. Three CORINE Land Cover (CLC) products are used: CORINE Land Cover 1990 (CLC90); Image & CORINE Land Cover 2000 (CLC2000); and CORINE Land Cover 2006 (CLC2006). These maps have a 1:100.000 spatial scale, with a minimum unit of 25 ha and a minimum 100 m linear width. It has a hieratical legend with 5 levels of detail. In this work, level 2 has been used, this is, 13 land use classes in the Region of Madrid. As thematic and spatial scale between 1982 map and CLC maps does not match, a reclassification of 1982 map to CLC level 3 legend was made. Spatial scale was also generalized to 1:100,000. Aerial photography, orthophotos and remote sensing images close to the date were used. All this information was converted to raster format, 50 m. pixel size.

Intensity in land use changes is analyzed between years 1982-1990, 1990-2000 and 2000-2006. These time intervals do not have the same time scale (the first one covers 8 years, the second, 10 years and the third, 6 years) and therefore the information regarding to total gains and losses between periods are not comparable. For that reason, it is important to perform a year-on-year rate of change analysis, rather than just considering the total change.

The time interval-level analyzes the total change for each time interval; it shows how the size and the annual rate of change vary. Results are compared with a uniform rate that would exist if annual changes were uniformly distributed over time.

The category-level analyzes the intensity of each category within each time interval regarding to the total rate of change shown by the interval-level analysis. Each category is examined to measure how the intensity and size of gross losses and gross gains varies in the territory. These intensities are also compared with a uniform annual exchange rate that would exist if the change in each interval were uniformly distributed in the study area.

The transition-level shows the intensity of the transition related to the size of the categories and in relation to the results obtained from the category-level analysis. Each transition is analyzed to show how the size and intensity of such transition varies among the other categories available for that transition. When a category gain or lose, this analysis can identify

which other categories are being intensively avoided or intensively directed by comparing the observed intensity of each transition with a uniform intensity that would exist if the transition were uniformly distributed among the categories available for that transition.

III. RESULTS

At time interval level, it is observed that the biggest percentage of change is registered in the first period, between 1982 and 1990. If the annual change rate is observed, this period is also the one with the highest intensity rate; it is above the uniform rate of change (1.03), which means that, although the duration of this period is less than the duration of the second period (1990-2000), the intensity of the changes is bigger. This annual change take place in fact, fairly rapidly, whereas between 1990-2000 and 2000-2006 the change is relatively slow, taking into account the uniform rate of change.

The exchange rate is not uniform throughout the whole period. If the rate of change had remained constant for the whole time set, that is, at a rate of change of 1.03, lower exchange rates should have been recorded for the period 1982-1990 (8.20% compared to 12.80% obtained), much higher values for the period 1990-2000 (10.25% with respect to 6.61%) and relatively higher values for the period 2000-2006 (6.15% with respect to 5.19 %).

At category level, mine, dump and construction sites show intensive gains compared to other categories. This intensity occurs in the three time intervals, which indicates that this category is stationary. It also shows an increasing intensity in time. Industrial, commercial and transportation units, and artificial non-agricultural vegetated areas also experience gains more intensely than other categories in the three time periods. In fact, the latter is the one which shows the greatest intensity in the first period, 1982-1990.

In terms of losses, the category mine, dump and construction site is also more intense regarding to the other categories in the three time periods, indicating that this category is stationary, both in intensity of gains and in intensity of losses. It is the one with the highest intensity loss in the periods 1990-2000 and 2000-2006, while in the first period, 1982-1990, the highest intensity loss is shown in heterogeneous agricultural areas.

There are categories that remain dormant comparing to the rest of categories. In the period 1982-1990, the inactivity is shown in arable land and forest (in terms of gains) and in shrub and/or herbaceous vegetation association, in terms of losses. Between 1990 and 2000, gains in arable land remain dormant (as in the period 2000-2006) and, in terms of losses, are the forests which remain dormant. In the last period, 2000-2006, the greatest inactivity in losses occurs in open spaces with little or no vegetation. Inland waters and wetlands do not show any gain or loss since they do not undergo any change during 1982-2006.

Regarding to results obtained at the transition level, only two transitions are shown (there are 42 possible transitions): from other land uses to urban fabric and from arable land to other uses.

Urban areas grow more intensively from mine, dump and construction sites and from other artificial uses, than from agricultural uses. The category mine, dump and construction sites target the gains in urban areas in the three periods of study, which means that this process is stationary. Between 1982 and 1990, artificial non-agricultural vegetated areas, follow by shrub and pastures, record intensity in land uses in terms of their replacement by urban areas. Between 1990 and 2000, shrub and pastures and arable land stand out, although far below the areas of

mine, dump and construction sites. In the last study period, 2000-2006, industrial, commercial and transport units, as well as shrub and pastures, are shown more intensely, but also, much less active than mine, dump and construction sites.

On the topic of intensity of changes from arable land to other uses, it is shown that the first period, 1982-1990, this land use tend to be intensively replaced by heterogeneous agricultural areas, permanent crops, mine, dump and construction sites, and industrial, commercial and transportation units. In the second period, 1990-2000, highlight the land uses mine, dump and construction sites, follow by industrial, commercial and transport units, and urban areas. In the last period, it also highlight mine, dump and construction sites and, to a lesser extent, industrial, commercial and transportation units, artificial non-agricultural vegetated areas, and urban areas. Categories mine, dump and construction sites, and industrial, commercial and transportation units can be considered as stationary.

In summary, it can be said that the period of biggest land use change intensities is during 1982 and 1990, follow by years 2000 and 2006. The most intense gains happen in mine, dump and construction sites category for the three periods studied, follow by industrial, commercial and transport units and artificial non-agricultural vegetated areas. Concerning the intensity in losses, mine, dump and construction sites register also the biggest intensities. Within this category, the land use which caused these results is, in fact, areas under construction, which appears as a previous step to the occupation by urban, industrial, commercial or transport uses. Forests stand out due to inactivity or stability.

IV. DISCUSSION AND CONCLUSIONS.

Results obtained are related to the join of Spain in the European Union in 1985, with an economic recovery which entails the introduction of hyperconnections in large cities (de Santiago, 2008). Actually, the region of Madrid appeared as a strategic enclave for the installation of new industries, activities and tertiary equipment and also for urban promotion.

Land use changes have been mainly based on the growth of artificial areas related with the loss of agricultural uses. The most dynamic and intense change in land use has been the changes from and to construction sites. The basis of the transformation of the Region of Madrid has been the development of transport infrastructures in these last decades (Serrano Cambronero, 2002; Lopez de Lucio, 2003), linked to the interest of the regional administrations to build high-capacity infrastructures for private transport (Fernández Güell, 2008; Valenzuela, 2010). This infrastructure has entailed a fast occupation of areas near the metropolis. New toll roads construction and the Barajas airport expansion accounts for 80% of land formation by equipment between 1980 and 2005 (Naredo and García Zaldivar, 2008). As Verburg et al. (2004) said, accessibility, measured in terms of distance and transport time, is one of the factors that most influence land use changes, especially in highly urbanized regions.

The urban and infrastructures development taking into account in this last period has led to negative environmental impacts. Transport infrastructures have caused fragmentation of natural environments. Urbanized land and secondary and/or unoccupied housing have been oversized, causing an over-destruction of ecosystems and natural landscapes. This has carried out an important ecological deterioration (Naredo, 2009). In spite of this, the region still conserves a significant number of natural spaces of unquestionable ecological value, under various protection figures.