
10. Simulation of future urban growth based on multicriteria evaluation models

This stage completes the development of this sort of simulation box which we hope will enable us to test realistically different planning strategies for future urban development projects. On the basis of this second approach using normative-type models, we aim to draw up a future proposal for urban land assignation (residential, commercial and industrial) based on the principles of sustainability and social and environmental equity by means of the combined use of multi-criteria evaluation (MCE) techniques and GIS.

Given the availability of real data for land occupation, education and health infrastructures, communication networks, etc. for 1990 in the two areas of study, before simulating future scenarios we did some research to establish the potential of this combination of techniques when assigning the most suitable uses of land for a present situation (in this case, the year 2000) on the basis of data relating to a more or less recent past (1990). We were thus able to determine what would be the most convenient land occupation situation at a given date and to compare the results with what actually happened.

After gathering data for the year 1990 for a total of 15 variables encompassing the three dimensions (economic, bio-physical and social) of sustainable development and after determining their relative weight (by way of example, table 7 shows the weights of the factors for the Madrid region), the variables were combined using weighted linear combination, after which a fit-map was obtained for each of the modelled land uses (residential, industrial and commercial). From these maps the most suitable plots of land were obtained—land which met certain requirements in terms of area. These three maps were then used to perform a Multi-Objective Land Allocation procedure (MOLA) so that we could obtain a final map assigning to each part of the territory the most convenient use of the three, depending on the individual suitability for each of them. It was therefore possible to carry out a detailed analysis of the situation in 2000 in relation to what would have been the most convenient situation from the perspective of the territory's capacity or vocation to accommodate that activity.

Factors	Innovation and sustainability scenario (Weights for each factor and for each scenario)		
	Residential	Commercial	Industrial
1. Land uses (CLC1990)	0.14	0.15	0.21
2. Distance from hydrography	0.07	0.06	0.10
3. Vulnerability to contamination of water-carrying levels	0.03	0.02	0.04
4. Distance from natural spaces	0.05	0.04	0.08
5. Protection of highly productive land	0.07	0.06	0.10
1. Land slope	0.02	0.02	0.02
2. Accessibility to roads	0.12	0.10	0.11
3. Accessibility to urban areas	0.16	0.25	0.08
4. Accessibility to commerce	0.09	0.11	----
5. Accessibility to industries	----	----	0.05
6. Geotechnics	0.06	0.05	0.05
1. Distance from undesirable installations	0.02	0.06	0.10
2. Accessibility to hospitals	0.10	0.05	0.06
3. (Weighted) distance from population	----	----	----
4. Visual basins	0.02	0.02	----
5. Orientation of land	0.05	0.01	----
Sum =	1.00	1.00	1.00

Table 7. Factors included in the optimal urban, commercial and industrial land assignment model in the Madrid Region, and their weighting

We can say that in general terms more sustainable and compact proposals for urban territorial occupation have been obtained in the vicinity of medium and intermediate-sized municipalities, thus protecting spaces of greater agricultural production; commercial zones are situated at a considerable distance from each other but close to those new urban zones with highest percentages of population with purchasing power, while the new industrial zones are distant from the places with the highest density of vulnerable population.

On the basis of the same factors updated to the year 2000, the three scenarios planned in the simulation project for urban growth in the Madrid region and in the metropolitan area of Granada for the year 2020 were created. The combination and use of these factors was carried out differently for each scenario with a view to reproducing as faithfully as possible the logic behind each of them.

Figure 3 show the results for the three scenarios for the three simulated uses (residential, commercial and industrial). Our first conclusion is that the normative models based on the combined use of GIS and multi-criteria assessment techniques may also be of great use when carrying out prospective simulations. This method is not usually used for this kind of simulations, but our work has shown that it not only enables a possible future territorial situation to be obtained, but also allows us to generate different images of that future if the input factors are processed properly; and this, in contrast to other prediction models, permits economic, social and environmental variables to be included as well as the three fundamental dimensions of sustainable development.

All this information may be used to open a debate about the disparities, imbalances or benefits that might accrue to the Madrid region if the development hypotheses regarding different future scenarios are assumed or not. They can provide valuable information about the potential impacts

if current planning policies are continued, if there is a situation of economic recession, and if the alternative of sustainable development is implemented.

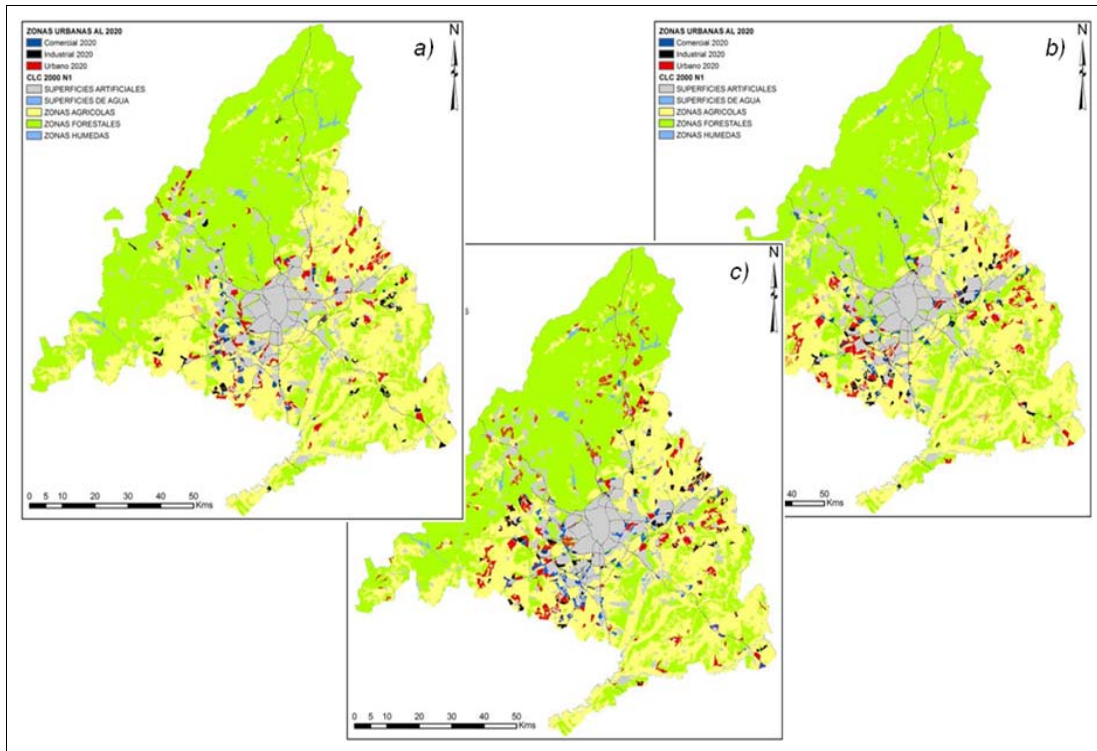


Figure 3. Result for the three urban growth simulation scenarios for the Madrid region in 2020. A) Business as usual scenario; b) Crisis scenario and c) Innovation and sustainability scenario

A first visual analysis confirms that the spatial patterns for land use proposed for the year 2020 correspond to the hypotheses assumed for the scenarios. Figure 3a shows how the growth of residential areas in the business as usual scenario is dispersed throughout the territory, mainly taking up land suited for agricultural and livestock activities. This generates new needs for communication networks and an increase in the use of private transportation—all accompanied by greater fragmentation of the landscape and an increase in environmental pollution. If these results are compared with those for the crisis scenario shown in figure 3b, the latter shows a less dispersed spatial distribution of residential areas, concentrated in the main in the metropolitan area of Madrid. At the same time, the productive areas are basically assigned to the south-west of Madrid in an attempt to rebalance the state of affairs in the area, compensating its socio-economic disparities with respect to other parts of the region by means of housing estates and productive centres in highly accessible locations and abandoned agricultural land. Figure 3c shows land occupation in a context of innovation and sustainability, where the pattern is one of compact development with growth in the new residential zones close, in the main, to medium and intermediate-sized urban centres and with a socially, economically and environmentally efficient use of the territory which satisfies sustainable territorial planning policies.

An initial quantitative evaluation of the impact of each scenario's results has also been carried out, which shows, for example, what type and what quantity of uses have been swallowed up by each of the urban developments simulated. The distribution of each has also been analysed on the basis of its location relative to the BCD (Madrid) or the distance from pre-existing medium or intermediate-sized municipalities. We offer here a schematic interpretation of the results for each of the simulated future scenarios.

Points of view	Causes	Scenarios		
		Business as usual	Crisis	Innovation and sustainability
Environmental	Dispersed urban growth	+++	--	--
	Consumption of land and landscape fragmentation	++	-	-
	Pressure on natural spaces	++	-	--
	Urban contamination	++	-	-
	Sealing and contamination of land	++	-	--
Economic	Demographic growth	=	=	=
	Economic growth	++	--	+++
	Use of new technologies	--	-	++
Social	Quality of life	---	-	++
	Conservation of rural areas	---	+	+++
	Accessibility to services	---	+	+++

Table 8. Approximation to impacts deriving from simulated urban growth in each of the scenarios

More information in:

Plata Rocha, W.; Gómez Delgado, M. and Bosque Sendra, J. (2010): "Desarrollo de modelos de crecimiento urbano óptimo para la Comunidad de Madrid aplicando Métodos de Evaluación Multicriterio y Sistemas de Información Geográfica"; *GeoFocus (Revista Internacional de Ciencia y Tecnología de la Información Geográfica*, Vol.10, pp. 103-134.

Available at: http://geofocus.rediris.es/2010/Articulo5_2010.pdf

Plata Rocha, W.; Gómez Delgado, M. and Bosque Sendra, J.: "Simulating urban growth scenarios using GIS and Multicriteria Analysis techniques. A case study of the Madrid Region, Spain", *Environment and Planning B* (in press).