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Does MOLAND work as a tool for the assessment and/or as a predictor of the distribution of urban biodiversity in Dublin city?

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Abstract

The MOLAND project's aim is to provide spatial planning tools that can be used to assess, monitor and model the development of urban and regional environments. To date it has been applied to an area of over 70,000km^2 across Europe. MOLAND's use as a tool for the assessment and forecasting of biodiversity is examined with Dublin city as a case study. It was found that, in its current form, the MOLAND model's use as a biodiversity assessment tool was limited. Several recommendations are made for improvements to its capability in this area.

Keywords: *MOLAND, biodiversity, land-use modelling, urban, ecology.*

1 Introduction

1.1 The Urban Environment Project (UEP)

The UEP is an EPA funded, multi-disciplinary, inter-institutional research project that aims to better understand the link between development, land-use change and associated economic and environmental impact within urban regions. The project is based at UCD's Urban Institute Ireland and includes academic partners in TCD and NUI Maynooth as well as a specialist GIS company, ERA-Maptech and the local authorities in the Greater Dublin Region.

At the core of the project is MOLAND, a land-use computer model which includes socio-economic and demographic information. The UEP focuses on 6 new strands which will be incorporated into the existing decision-support tool. These are air quality, urban transport, urban sprawl, climate change, green city and biodiversity. This paper will focus on MOLAND's application to the biodiversity strand.

1.2 What is MOLAND?

MOLAND's aim is to provide spatial planning tools that can be used to assess, monitor and model the development of urban and regional environments. The project was initiated in 1998 (under the name of MURBANDY - Monitoring Urban Dynamics) with the objective to monitor the developments of urban areas and identify trends at the European scale. The work includes the computation of indicators and the assessment of the impact of anthropogenic stress factors (with a focus on expanding settlements, transport and tourism) in and around urban areas, and along development corridors (JRC, 2008).

1.3 How does it work?

MOLAND is implemented using GEONAMICA, a bespoke modelling framework. At its heart, there are dynamic spatial models that operate at both the micro and macro-geographical scales (Lavalle and Barredo, 2004).
The model takes five digital maps as inputs

- actual land use types;
- accessibility of the area to the transport network;
- inherent suitability of the area for different land uses;
- zoning status (i.e. legal constraints) of the area for different land uses;
- socio-economic characteristics (e.g. population, income, production, employment) of the area.

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On a macro scale, the modelling framework integrates several component sub-models, which typify the natural, social, and economic sub-systems of the area studied. These are interconnected into a network of mutual reciprocal influence. At the micro scale, cellular automata (CA)-based models determine the fate of individual parcels of land based on their individual institutional and environmental characteristics as well as on the type of activities in their neighbourhoods (Lavalle and Barredo, 2004).

Unlike conventional CA, these models are defined with larger neighbourhoods, and more cell-states representing socio-economic land-uses and natural land (Barredo et al., 2003). Overall dynamics of the CA-based models are constrained at the macro level. This approach permits the straightforward integration of detailed physical, geomorphological and institutional variables, as well as the particulars of the transportation infrastructure.

1.4 What has it been used for in the past?

The uses to which MOLAND has been put are many and varied.

MOLAND has been used on the following four specific applications:

- Spatial Planning and Hazards' Mitigation
- Indicators of sustainable urban and regional development;
- European Spatial Development Perspective and sectoral policies with spatial impact;
- Strategic Environmental assessment and EIA;
- Creation of network of cities and regions.

Since 2004, MOLAND is contributing to the evaluation and analysis of impact of extreme weather events, in the frame of research on adaptation strategies to cope with climate change.

To date, the MOLAND methodology has been applied to an extensive network of cities and regions (see Figure 1), for an approximate total coverage in Europe of 70,000 km^2.

2 Application of MOLAND-like models to environmental factors

RIKS has developed two other products, both based on the GEONOMICA framework, for the assessment of environmental factors. These are Catcher, aimed at river basin management and Coaster, for coastal zone management.

RamCo was the first prototype of the Catcher system, which is intended to evolve into a Generic Decision Support System for the integrated assessment of sustainable coastal zone management problems. It was applied to the Ujung Pandang in south-west Sulawesi, Indonesia. RamCo predicted a number of adverse environmental events, such as increased river pollution, deforestation and accompanying soil erosion, would occur over the next twenty without policy intervention (http://www.riks.nl/projects/RamCO). It is important to note that although these outcomes have obvious consequences for biodiversity, the RamCo model focuses on the human implications such as food shortages, lack of drinking water and inundation of the coastal zones. The specifics of these effects on biodiversity, such as species loss, displacement and adaptation to the new conditions are not addressed by the model and would require further research and development to incorporate into the model.

Coaster is a GEONAMICA-based tool coupled with a set of software libraries, specifically tailored for developing a Decision Support System (DSS) for Integrated Coastal Zone Management. This DSS represents the ecological and the economic functions of the Wadden Sea (a sea extending from the North of the Netherlands into Northern Germany and Western Denmark). Unlike both Catcher and MOLAND, Coaster has a dedicated ecological component, which calculates the effects of abiotic and biotic interactions on an appropriate timescale, in this case one tidal cycle.

3 Limitations of the MOLAND methodology

The limits of the MOLAND methodology in general have been outlined by Twumasi (2008), and will not be dealt with here. However there are two linked limitations that are particular to the biodiversity strand, namely spatial resolution and inadequacy of land use categories.

3.1 Spatial resolution

The cell size used by the UEP is 200m on a side; the resulting cell represents 40,000m^2. The minimum cell size that the MOLAND framework supports is 50m on a side. This represents 2500m^2 which is clearly too large an area to be considered homogenous, considering that such an area can contain up to 3-4 terrace houses, adjoining front and back gardens and adjacent roads. This results in a massive loss of information regarding small scale conditions, which is needed to adequately explain local species

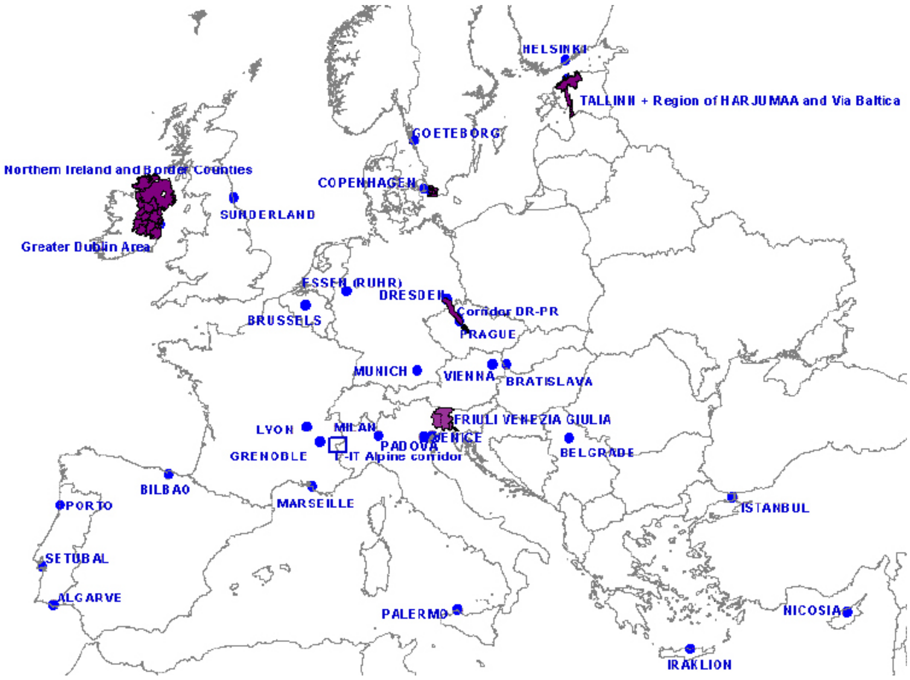

Figure 1 – Urban areas to which the MOLAND methodology has been applied (JRC, 2008).

variations (Jokimäki, 1999).

4 Inadequacy of land use categories

4.1 Flora

The study area of the UEP covers 783,916 ha of land, of which some 92% (720,652 ha) is 'habitat', habitat hereby defined as vegetated area. Habitat is made up of seven land use classes (see Table 1) but the dominant two are Arable Land and Pasture. Together these two classes comprise nearly 80% of habitat and over 72% of the total area as of 2006. To consider over 80% of the vegetated area as belonging to one of only two possible categories is unrealistic for the purposes of assessing biodiversity. The rural land around the city is a mosaic of various habitat types, for example grasslands alone are made up of improved agricultural grassland, amenity grassland (improved), dry calcareous and neutral grassland, dry meadows, grassy verges, dry-humid acid grassland, and wet grassland, and . Each habitat has, by definition, a different assemblage of species associated with it and thus the effects of development must be considered on an individual basis.

4.2 Fauna

As noted above the land use classes used to describe habitat types are limited. However there are almost triple the number of land use classes describing the built environment as there are to describe habitat (seventeen versus six). It was possible that the increased number of classes would facilitate assessment of urban faunal biodiversity. To investigate this, bat surveys were carried out across Dublin city during the summer months of 2006 and 2007. Bats were chosen as they are a significant component of Ireland's mammalian fauna, comprising about a sixth of all recorded species, and half of all recorded terrestrial species (Dower, 2007). Bats were chosen because they are mobile K-strategists, and hence it is reasonable to assume their distribution and activity would vary depending on many abiotic and biotic factors, i.e. with land use (Walsh and Harris, 1996). However, in both years, bat distribution and activity were poorly correlated with MOLAND land use classes (Dower, 2007; Simkins, 2006). When the survey sites were reclassified according to habitat type, the variance between points was explained, with riverine habitats displaying especially high bat activity.

The correlation of bird distributions with MOLAND land use classes across Dublin city is similarly poor, with massive variances of species numbers, species presence and species abundances within land use classes that are supposedly identical.

Thus the MOLAND methodology currently employed by the UEP is unsuitable for the assessment of flora or fauna across Dublin.

Table 1 – MOLAND land use classes and their contribution to the UEP study area. Bold denotes land classes that are 'habitat'

Land Use Class	Cells	ha
Arable land	31096	124384
Pastures	111882	447528
Heterogeneous agricultural areas	1605	6420
Forests	12405	49620
Semi-natural areas	1447	5788
Wetlands	18040	72160
Abandoned	9	36
Residential continuous dense urban fabric	27	108
Residential continuous medium dense urban fabric	48	192
Residential discontinuous urban fabric	5751	23004
Residential discontinuous sparse urban fabric	3952	15808
Industrial areas	1353	5412
Commercial areas	506	2024
Public and private services	622	2488
Port areas	54	216
Construction sites	492	1968
Road and rail networks and associated land	109	436
Airport	237	948
Mineral extraction sites	703	2812
Dump sites	124	496
Artificial non-agricultural vegetated areas	3688	14752
Restricted access areas	367	1468
Water bodies	1445	5780
Outside area	17	68
Total	195979	783916

5 Possible biodiversity applications of the MOLAND methodology in a Dublin setting

5.1 MOLAND methodology coupled with other maps

As stated earlier the MOLAND methodology that the UEP employs is unsuitable for the direct assessment of biodiversity in a detailed and meaningful way. However it could form part of a useful biodiversity assessment tool if coupled with detailed habitat maps, for example the habitat maps that have been produced or are being produced by the biodiversity officers of Local Authority councils. Combining these maps with MOLAND predicted changes in land use would allow a quick assessment of which habitats would likely be threatened in the short, medium and long term.

5.2 Expanding the land use classes

In addition to coupling the UEP GEONAMICA model with other maps, it would be useful to expand the land use classes so that a user would be able to immediately identify areas of biological significance. The UEP is in possession of the raw land use data used to create the model's land use map. This data contains descriptors of land use that are either absent or aggregated in the finished model (see Table 2). For the biodiversity strand, it would be useful if these land use classes were disaggregated.

5.3 GEONAMICA based biodiversity model

Exemplified by the Coaster model, the GEONAMICA framework can be applied to ecological factors. If funding could be secured for a project on the scale of the UEP, it would be possible to create a biodiversity model that would project changes in habitats over time under the influence of external factors, e.g. increased temperatures and decreased precipitation due to climate change, ground water abstraction, a- and reforestation. Indeed, modelling of this sort has been carried out in the past (Berry et al., 2003). This is however far beyond the scope of the biodiversity strand of the UEP.

6 Conclusion

There is no doubt that the MOLAND project has produced a useful tool in the GEONAMICA software framework. As a regional planning tool it can provide planners with the ability to forecast land use changes into the future and take appropriate action.

However, in its current configuration and used in

Table 2 – Biodiversity significant land use classes absent from the final UEP model

Land use	Code	Present as:
Beaches, Dunes and Sand Plains	3.3.1	Wetland
Broad-leaved forest	3.1.1	Forest
Coastal lagoon	5.2.1	Wetland
Complex cultivation patterns	2.4.2	Arable land/Pasture
Coniferous forest	3.1.2	Forest
Estuaries	5.2.2	Water bodies
Green urban areas	1.4.1	Artificial non-agricultural vegetated areas
Intertidal flats	4.2.3	Wetland
Mixed forest	3.1.3	Forest
Moors and heathland	3.2.2	Wetland
Natural grassland	3.2.1	Pasture
Peatbog	4.1.2	Wetland
Transitional woodland/shrub	1.4.2	Forest
Water courses	5.1.2	Water bodies

isolation from ancillary data such as detailed habitat maps of the area of study, the GEONAMICA framework faces considerable difficulty as a tool to forecast biodiversity change over time. As stated above the models minimum spatial resolution is too crude to be considered homogenous and the list of land use classes too few to accurately describe the region in a useful ecological context.

It is the author's opinion that if a GEONOMICA framework is to be used as a DSS for regional ecological/biodiversity planning then a new 'biodiversity model' should be created that operates on suitable temporal and spatial scales, e.g. months and tens of m^2.

However, in the context of the UEP, a number of recommendations can be made.

Firstly we suggest disaggregation of relevant land use classes, i.e. 'forests' to 'Broad-leaved forest', 'Coniferous forest', 'Transitional woodland/shrub', etc. Secondly decreasing the cell size to its minimum, while not ideal, may help in the identification of local features that affect biodiversity. Thirdly, MOLAND outputs should be used in conjunction with detailed habitat maps, in this way the effect of projected development on biodiversity could be better explored.

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