Urban growth scenarios – is the aim to fit into urban spaces or live in them?

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Abstract: Predictive urban growth models are used to assess impacts on transport and housing issues, but they may also be used to assess impacts on natural ecosystems within urban areas. This paper uses a spatial allocation model to predict the growth distribution of households across a major metropolitan region in Australia. We examine the implications of planning controls for urban growth management boundaries and transit-oriented developments to the year 2026. The model may be applied to a number of pressing urban issues, but the paper focuses on the particular issue of urbanisation pressures on remnant vegetation within the urban footprint. We present the results of different scenarios for urban growth boundaries and draw the conclusion that planning controls are needed to harmonise natural landscape elements with future urban development.

1. Introduction

Many Australian cities have introduced urban growth boundaries (Song and Knaap 2004) to contain sprawl and limit new infrastructure development. If administered properly they do reduce sprawl and achieve smart growth benefits (Song and Knaap 2004), but they are also criticised as being a blunt planning instrument indifferent to fundamental market forces and reducing the standard of living for urban populations (Brueckner 2000; Forster 2006). South-east Queensland introduced a regional plan in 2005 with an urban footprint to contain development to 2026 (SEQ 2005). Over time the urban footprint will consume available greenfield land and refocus development as infill within existing urban areas. This places great development pressure on all land, including land we would ideally like to preserve for landscape amenity and/or biodiversity values. These 'green' areas can be the centre piece of new development to promote desirable living qualities for natural settings and passive recreational activities. While the urban footprint upholds protected areas for parks, forests and wetlands; there is still a large amount of forest not explicitly protected. For instance, we found about 80% of remnant vegetation within SEQ's urban footprint is not protected. Urban growth boundaries are rarely imposed on their own; they are usually aligned with other planning schemes and initiatives. For instance Portland in the U.S. is a well known city that established urban growth boundaries in the 1980's; it has additionally managed growth pressures with transit-oriented developments to encourage high-density housing and accessible employment centres (Song and Knaap 2004).

Our research (Pullar et al., submitted) shows that an imposed urban footprint in SEQ places great development pressure over the region. Questions arise as to whether added development pressures threaten 'green' areas by over-riding conservation actions or not allowing public/private partnerships to form that utilise areas for their natural character. It is difficult to answer these questions because of the complex nature of urban growth, but in this paper we attempt to examine some indicators of urban growth pressure and the effects of plans. The literature supports the claim that transit-oriented developments achieve their purpose for concentrating growth, but to what extent do they relieve pressure on other areas to preserve historical neighbourhoods or allow green urban design. To explore this question in SEQ we will analyse growth forecasts in relation to remnant vegetation within the urban footprint.

The outline for the paper is as follows. The next section gives an overview of how our growth projections are made. Section 3 describes the approach used to analyse remnant vegetation in relation to levels of urbanisation. The final section reports the results of this analysis and our conclusion that growth models should incorporate indicators to control growth to conserve or utilise urban green space.

2. Method of Urban Growth Prediction

Predicting urban growth patterns is a complex process due to the diverse factors shaping cities such as human spatial behaviour and land economics (Golledge and Stimson, 1997). Urban growth models may be broadly classified on the underlying assumptions used to make predictions by: i) tracing an evolutionary pathway over time, or ii) fitting growth to expected patterns. In the former case a direct relationship is modelled between urban processes and urban growth patterns, whereas in the later case the models rely upon empirically observed patterns to infer changes. In practice most urban modelling applies a combination of process-based and empirical models. Ideally it is better to make predictions based upon a good understanding of urban processes, but in reality this is difficult to do because of the complex nature of factors defining growth and the availability of data to adequately support the models. Our growth model is similar to the second approach, we disaggregate regional demographic forecasts based upon observed socio-economic patterns and land use trends. The method is fully explained in Pullar et al. (submitted) and is summarised below.

The context for our research is a large scale metropolitan region for South East Queensland (SEQ) in Australia. It includes two major cities, Brisbane and the Gold Coast, and many smaller cities. The region covers 22,244 km^2 and the urbanised areas cover 2,945 km^2, or about 13% of the region. The model input are yearly forecasts for the period 2005 to 2026 of regional population and jobs for SEQ; these forecasts are provided from state demographic and economic models (Stimson et al., submitted). Our model spatially allocates these input forecasts to disaggregate areas based upon predicted growth patterns. We will first describe spatial representations used in the models and then explain the allocation model.

2.1 Spatial Representation

A gridded data representation is preferred for analysis as it provides a uniform spatial structure to represent land use classes. The disadvantage of a grid is that the scale of urban activities varies across space and a single resolution does not capture the level of details for high-frequency activities in urban areas versus low-frequency activities for rural landscapes. To overcome this shortcoming we represent space with a grid having multiple resolution and attribution. The resolution of the grid is varied to be sensitive to spatial scales between urban (500 meters squared) and rural areas (1 square kilometer), see Fig. 1. To represent variation within cells we attribute data as component values based upon the proportion of area occupied by each land class, see Fig. 1. Another feature of attribution is that we use designated land transformation classes instead of land uses to better reflect growth processes. Transformation processes are differentiated at one level by: i) *expansion* which occurs at the urban fringe, and ii) *intensification* which occurs within urban areas. Finer levels of expansion further distinguish increases in rural only housing, conversion of rural properties to urban, and greenfield development. Finer levels of intensification further distinguish transformation of vacant land, existing urban areas, and brownfield sites. These land allocation classes better reflect planning terminology and also relate well to other land use qualities for urban growth capacities and accessibility. For the base year of 2005 we obtained upper capacities for housing densities from planning regulations and preferential development locations from a quality-of-life survey (Chhetri et al., 2007).

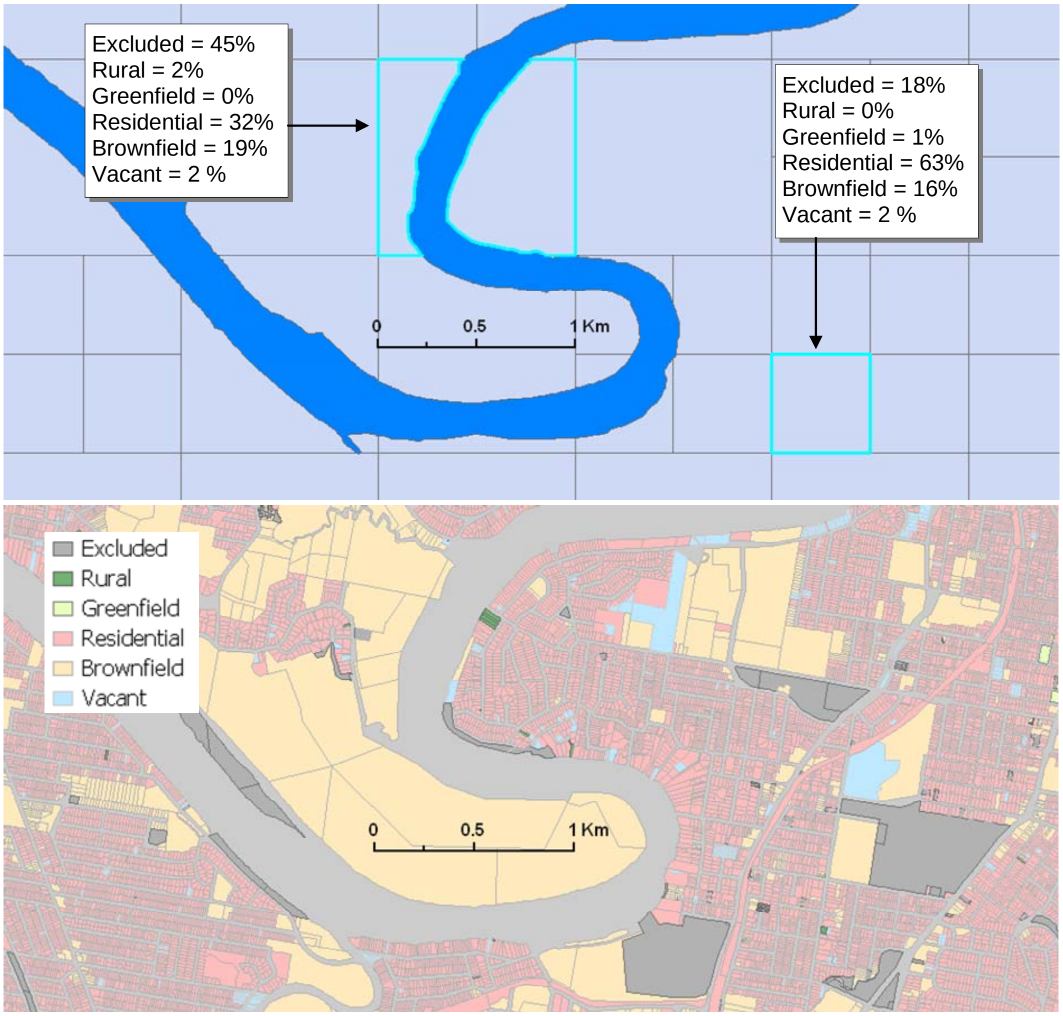


Fig. 1: Space representation using multiple resolution and attribution grid. Example component values are given for two cells.

Table 1: Urban allocation classes

Expansion	
1. Rural Housing Only	**2.5%**
2. Rural & Urban Potential	**2.5%**
3. Greenfield for Urban Dev.	**20%**

Intensification	
4. Residential to Higher Density	**10%**
5. Brownfield to Residential	**15%**
6. Vacant Lot	**50%**

2.2 Allocation Method

Our model spatially allocates regional forecasts from 2005-2026 on population, housing and jobs to the grid based upon predicted growth patterns. Allocation rules reflect residential location choice and land availability given by growth capacities. We formulate the allocation problem as an optimisation by specifying objective criteria and constraints. In our model, the constraint is that a specified number of additional households are allocated across the region within a year. There is an infinite number of ways to do the allocation, so we search for an optimal solution that maximises a set of suitability objectives. Suitability is a natural way to express allocation in planning problems (Malczewski, 2004). To make comparisons between objectives compatible we standardise suitability to a common scale, i.e. from 0 to 1. The optimisation for a yearly allocation is specified as:

Maximise:

$$F = \sum_{x=1,n} \{ \sum_{i=1,m} (w_i \cdot s_i(x) \cdot a_x) \} \qquad (1)$$

where:

F is the total suitability over all cells

x is the index for cells, $x=1..n$ cells

s_i is the i^{th} suitability objective, $i=1..m$ as scalar value $s_i \in [0,1]$

w_i is the weight of the i^{th} objective such that $w_i \in [0,1]$ and $\sum_{i=1,m} w_i = 1$

a_x is the number of households allocated to the cell x

subject to the constraint:

$A = \sum_{x=1,n} a_x$

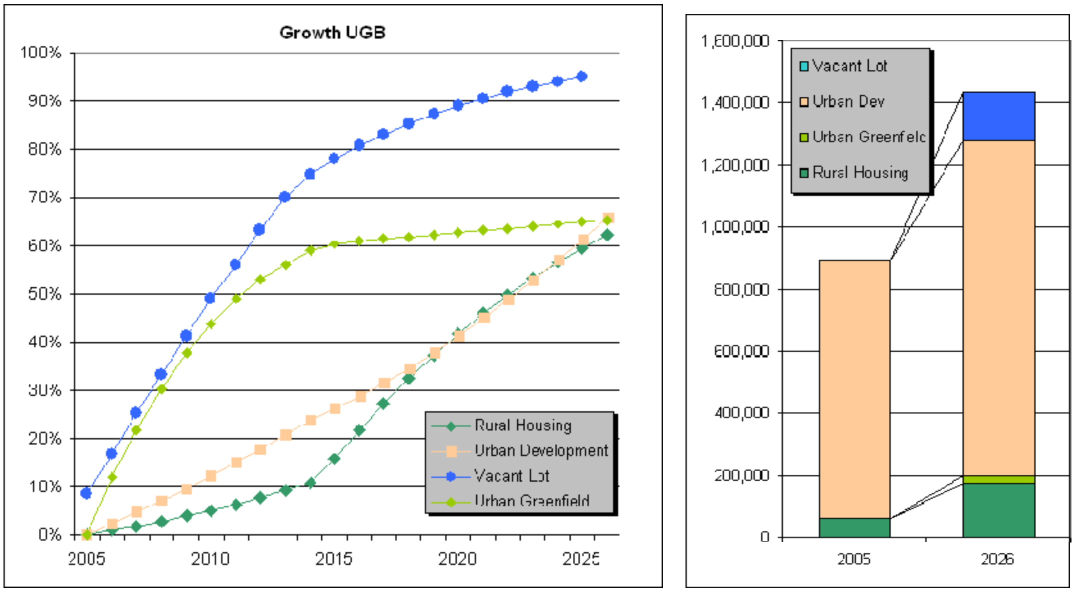
where:

A is the total number of household to be allocated.

The suitability objectives are a combination of static and dynamic functions. A dynamic function means that as the intermediate allocations are made this changes the decision criteria for making subsequent allocations. Static objectives include allocating households to cells based upon: i) land allocation classes, and ii) location choice and accessibility preferences. For instance, an area of vacant land with high location preference and accessibility is rated as highly suitable for new households. The data used for assessing static criteria do not change within the allocation period, but values may be adjusted for the next allocation cycle. More details on the allocation method are given in Pullar et al. (submitted).

The results of allocation are given in Figs 2 and 3, they show growth summed up over all grid cells as a ratio to planned capacity and absolute household counts. The allocation scenario with an imposed urban footprint and existing planning schemes (Fig. 2) shows steady growth until 2014 consuming available greenfield and vacant lands, then broad transformations with intensification of existing urban and brownfield sites. The urban footprint limits where growth can occur and this reflects the convergence of land class curves in Fig 2 as trade-offs occur between land classes.

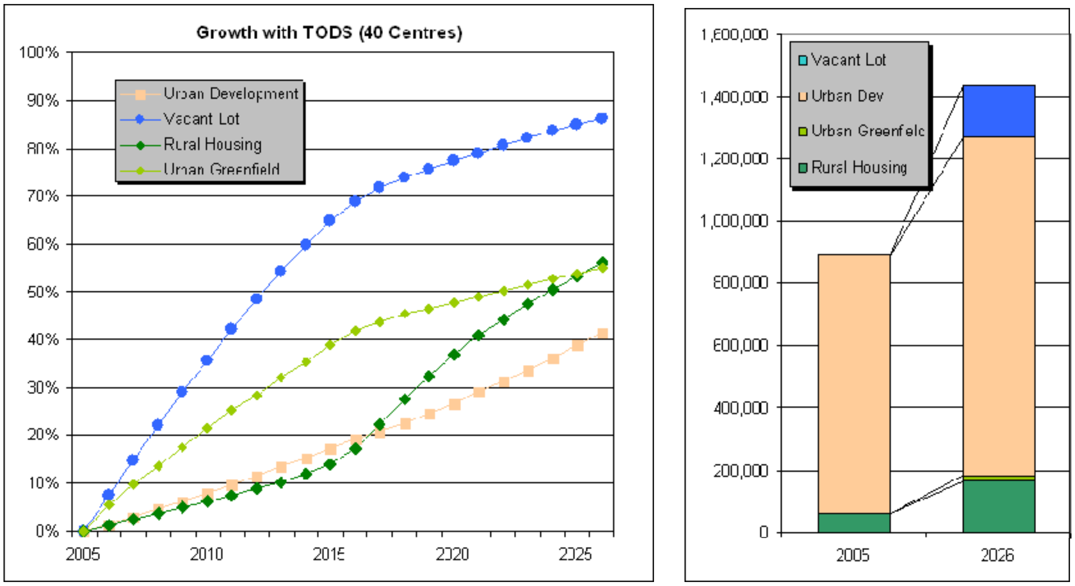
We are able to try different scenarios by changing any of the controlling variables in the optimisation. One scenario of interest is to add transit-oriented developments (TOD) to the model by raising the capacities near selected transport hubs. The purpose of TOD’s is to increase urban densities and specific activities (retail, education and other service industries) at key locations along transit systems. The SEQ growth plan (SEQ 2005) identified principle and major activities centres throughout the region, and our TODs scenario simply changes the household capacity to 200 dwellings/ha within 750m from principal activity centres and 100 dwellings/ha within 750m from major activity centres. Our interest in TODs was to investigate if they reduce growth pressures to areas where we wish to conserve remnant vegetation. Results of allocation for a TOD’s scenario (Fig. 3) show steady land utilisation to 2020 before available greenfield and vacant lands are exhausted and further growth occurring through intensification of existing urban and brownfield sites. It also shows prolonged capacity for growth and less intense growth pressure.



a) Growth as relative percentage of capacity

b) Growth in household counts

Fig. 2: Composition of growth for allocation classes with an urban growth boundary.



a) Growth as relative percentage of capacity

b) Growth in household counts

Fig. 3: Composition of growth for allocation classes with increased capacity at TODS.

3. Threats to remnant vegetation

To assess threats to natural areas we used vegetation mapping that is part of the biodiversity planning framework for the state (Sattler and Williams 1999). The framework is based upon an ecological hierarchy of bioregions and regional ecosystems, and their biodiversity assessment. Bioregions are mapped areas with similar bioclimatic ranges, land forms and geology. They reflect changes in biodiversity at a regional scale. Regional ecosystems are mapped communities within bioregions and are identified by a unique combination of plant species and landscape ecosystem functions. We used the ecosystem mapping which shows these remnant vegetation patches down to a hectare scale. The biodiversity assessment examines the unique qualities of these vegetation patches for supporting plant and wildlife locally and within the broader landscape defined by bioregions. Biodiversity status is assessed as: i) endangered, ii) of concern, or iii) not of present concern based upon the biodiversity values, their uniqueness in the landscape and exposure to threatening processes (such as land clearing and urbanisation).

To assess urbanisation threats to these regional ecosystems we identified unprotected areas and associated population pressures near these areas. This included areas: i) within the urban footprint, ii) that are not protected reserves or parkland tenure, and iii) have a biodiversity status of endangered or of concern. To measure urbanisation pressure we used the proportion of households within 250 of these areas. The analysis results are shown as household counts and percentage of the base count for 2005 in Table 2. There are three scenario analysed with household projections to 2026 obtained from the allocation model above: i) projection with imposed urban footprint, ii) projection with TODs and counting those areas away from TODs, iii) projections with new development forced to TODs. The last scenario is based upon forcing all new development within 10km of a TOD to that TOD, which shows the least increase in urbanisation pressure, and illustrates a situation where new housing if forced to utilise TODs.

Table 2. Urbanisation pressure expressed as households within 250 meters of a regional ecosystem. Scenarios are given for the base housing count at 2005, within the urban footprint at 2026, with TODs in 2026, and forcing all new housing within 10km of a TOD[†] to a TOD.

Projection (Scenario)	2005 (Base)	2026 (UF)	2026 (TODs)	2026 (TODs[†])
Household counts	26200	55400	47200	30700
Percentage of 2005	100%	210%	180%	110%

4. Discussion

The paper has explored the impact of future urban development in a spatially explicit manner on remnant vegetation within the urban footprint. The benefits of conserving remnant patches may be questioned within urban areas, but there are many good reasons for protecting these areas. First they are significant biodiversity areas that have unique ecosystem benefits within the broader landscape. Second there is growing appreciation of urban ecology by society for not only the functional benefits of natural systems, but also its social status and awareness of environmental problems (Pickett et al 2008). We have used relatively crude indicators of the influence on urbanisation on remnant vegetation within an urban footprint. Imposing an urban growth boundaries may be beneficial for protecting areas outside the urban footprint, but it increases urbanisation pressure on housing and other functions within the urban footprint. For instance, it make no sense to increase threats to important ecosystems within an urban footprint when desirable land for development that has a lower ecological impact exists outside the urban footprint. The establishment of urban footprints needs to coexist with other responsive planning controls such as transit oriented developments. Our results show that a TOD does relieve some of the pressures of urbanisation near remnant vegetation, and further development control can significantly reduce urbanisation pressure.

These results are preliminary and embody many assumptions. However there is an argument that special attention should be afforded to the remaining patches of natural land that exist within urban areas. While governments are keen to impose urban growth boundaries on Australian cities, the general public may be less enthusiastic (Forester 2006). We believe, even with crude modelling, that there are opportunities to better harmonise urban green space with urban development (Ahern 1999). Future work will focus on explicitly incorporating landscape planning concepts into urban growth scenarios.

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