Chapter 10

Discussion

Sugar Refinery, Broadwater

The world is full of people whose notion of a satisfactory future is in fact, a return to the idealized past.
Robertson Davies

CHAPTER 10 DISCUSSION

This project developed a new 'hybrid' methodology based on refining and combining future landscape trend simulation techniques with a landscape future scenario design and evaluation framework for understanding social-ecological change across landscapes and regions. This novel approach was further developed and tested on a case study region, which was one of the largest spatial applications of this kind to date and the only application alternative landscape future (ALF) scenarios encompassing urban growth within Australia (The only other landscape futures application in Australia was focused on dryland agriculture in Southern Australia undertaken concurrently with this project; see Bryan *et al.* (2008).

The Northern Rivers region provided the broad spatial extent and location as well as a diversity of landscape and social contexts, which provided additional research challenges. The land use, demographic, social and patterns across the region have high rates of population growth and extensive urban development. However over such a large region there is considerable spatial variation in this growth. Some areas will be affected very little, while in others linear growth has turned into exponential growth. This change in land use is severely impacting the social, economic and/or ecological aspects of many areas. To increase the degree of accuracy in spatial modeling and analysis within such a diverse regional context, this research incorporated a novel multi-scalar and multi-zonal approach to landscape scenario design, model building and analysis.

Furthermore, this work demonstrated the capacity of current technology and techniques to provide a more holistic, landscape ecology driven, approach to long term regional planning in Australia. Finally, through the case study application to the Northern Rivers region of New South Wales, Australia the research contributed new knowledge and insights into likely trend and plausible alternative futures for that region.

10.1 REVIEW OF SCENARIO RESULTS

The application of the adopted, new hybrid methodology produced a future trajectory scenario and a number of possible alternative future landscape scenarios for the Northern Rivers region. The research also evaluated and compared land use / land cover (LULC) change of scenarios. However, the suite of feasible and plausible landscape future scenarios produced is only a fraction of all possible futures of the Northern Rivers region. In direct policy and planning applications of this methodology, extensive stakeholder and focus group participation and feedback should be included throughout the process, in an iterative cycle to refine scenarios and develop others for evaluation. The scenarios produced through such interactions would cycle back through the scenario development process and would be placed back into the community for perusal, discussion and modification. Due to the size of the study area, such iterative stakeholder interactions were beyond the scope of this projects available time. For this project the stakeholder input was simulated in the initial stages by examination of publicly accessible documents and information such as those produced from extensive consultations under the Northern Rivers Regional Strategy (NRRS 2000; NRRS 2005). From this information a basic framework for priorities was created (Chapter 3). This method was a valuable surrogate for stakeholder involvement. It is hypothesized however, that a longer interactive stakeholder process would pave the way for active implementation of a desired, more sustainable future. Project length active engagement of stakeholders is also likely to help prime capacities for further adaptive management as that future is pursued and other (unforeseen) change pressures come to bear.

Without actively re-designing and influencing the future landscape, it is most likely the current trends of minimal and localised building constraints will continue. This trend follows the situation described by the minimal constraints scenario of Chapter 5. While population growth was minimal in inland areas, high growth rates coupled with a decreasing population density in coastal areas will effect a major loss of agricultural land, ecosystems, coastal wetlands and heath, and other natural areas important, for example to climate change storm surge resilience or conservation of species with narrow habitat ranges. The continuing trend in the future trajectory scenario model indicates considerable areas and numbers of rare, threatened and vulnerable vegetation will be put at risk. In most cases these are represented by vegetation communities and ecosystems that are major part of the aesthetic appeal and uniqueness of the area.

Population density could have been modeled with the preconception that with encouragement over many years for a shift from traditional "quarter-acre blocks" to higher density housing (ABS 2008) that population density would be increasing. However it was found that despite this shift, population density is decreasing and that throughout the region, areas with little population growth are continuing to grow spatially by several fold (see Chapter 4). In the northern coastal areas this density based urban expansion together with an increasing population meant that there was no longer the spatial capacity to apply moderate levels of protection for conservation and agriculture and still meet urban development requirements (see Chapter 8).

As the agricultural protection constraints are government policy and traditionally there have been very few restrictions on development, it is likely this growth will be at the further expense of native vegetation and 'low value' agricultural land and further jeopardise the ecological sustainability (e.g. ecosystem viability and connectivity) of the area (see Chapters 7 & 8). However applying restrictions on development or actively moving development further south and inland (Chapters 8 and 9) spatially increased urban growth due to the lower population density. This again is to the detriment of native vegetation (outside reserves) and low value agriculture. However, less protection is afforded to the greater diversity of ecosystem types on the coastal fringe and hinterland, suggesting that more extensive areas of urban growth within inland areas would have less detrimental impacts on ecological systems, viable natural populations and landscape connectivity and therefore arguably, improved long term social-ecological sustainability (Chapter 9).

The reduced fragmentation and impact on coastal vegetation and agriculture by shifting urban development inland is shown in Figure 10.1 The figure places the north coast area of the 'future trajectory minimal constraints scenario' next to the 'coastal protection with agricultural and environmental constraints scenario' for visual comparison.

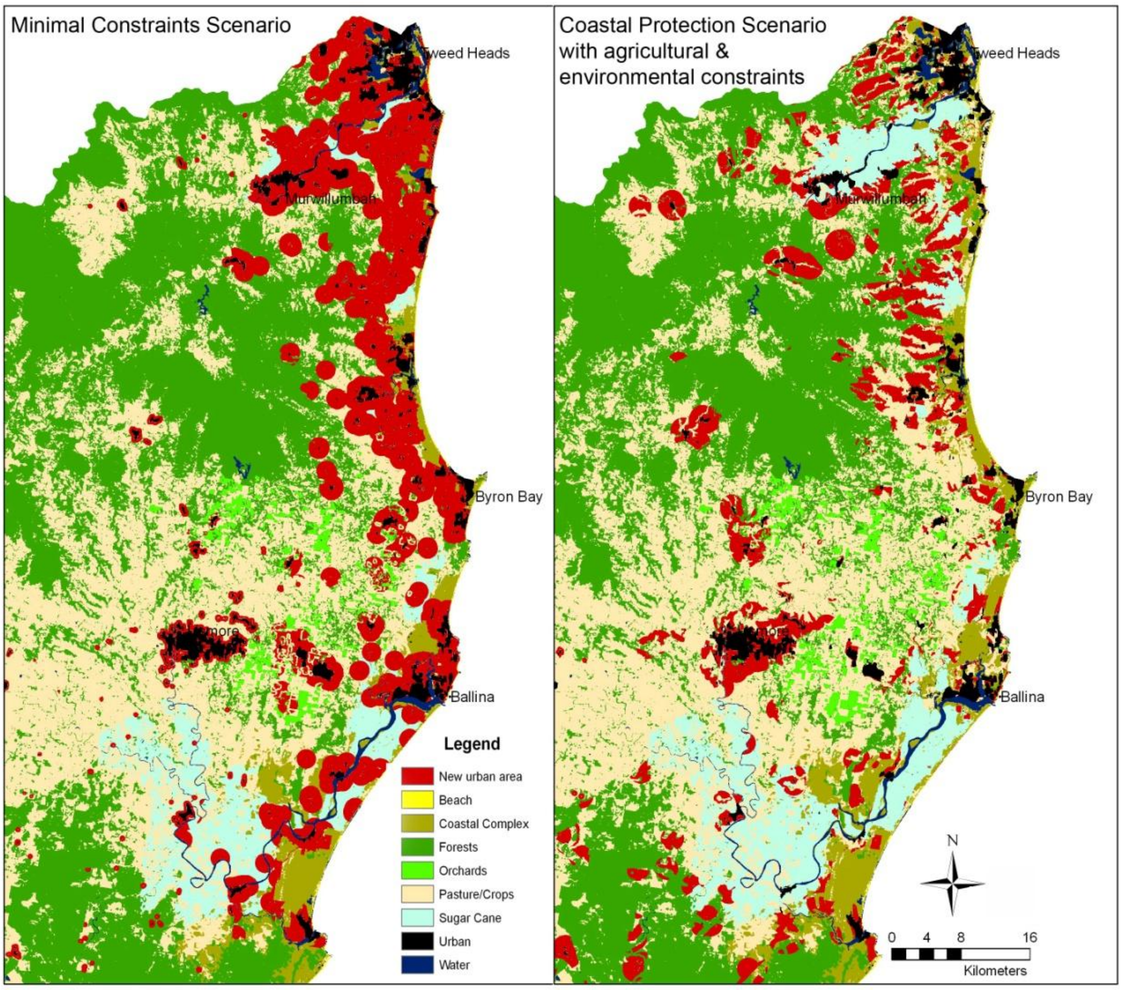


FIGURE 10.1 REDUCED FRAGMENTATION AND IMPACT OF COASTAL AREAS

While coastal vulnerability assessment under various climate change, sea level rise and increasing storm surge were not a component of the present study, Figure 10.1 indicates such additional analysis would be useful.

10.2 THE FUTURE OF AGRICULTURE IN THE REGION

Many of the changes in land use were fragmentation impacts, spatially localised within smaller areas and likely to have much greater effects on communities than otherwise represented by the whole regional overview.

For example, as the population approached a million people, the loss in sugar cane reached 31% of its extent for the entire region. Such a loss is likely to be beyond the critical economic viability for sugar mill operations. While a change in land use and loss of an industry at this level would have considerable impact on the region, the area that produces sugar cane is actually relatively small. Numerous towns such as Broadwater are located within the main sugar cane growing areas and have a strong economic reliance on sugar refining. The loss in sugar cane within the area would put considerable strain on related industries, service industries, local employment and therefore economic and social viability of these small towns.

The use of agricultural constraints could help alleviate localised economic loss caused by new urban development. In this project the agricultural constraints used were supplied by NSW Department of Planning and represented properties that had a high agricultural or historical value. Protection of prime agricultural land is important as it is a limited resource and under pressure for conversion to other uses such as residential development, hobby farms and tourism facilities as noted by the Tweed City Council (Tweed CC 2004). In a number of areas within the region and throughout Australia there are an increasing number of people purchasing whole farms solely as a country estate or weekend retreat and not for use of the land as a productive agribusiness. Alternatively farms are purchased and used as hobby farms, alternative businesses, or for private revegetation and restoration aims. This has the effect of increasing land values disproportionately to the agricultural economy (Tweed CC, 2004; Barr 2007).

The 'prime agricultural lands' data is to be used by Council planners to protect the region's most productive and culturally important areas, however it does not ensure the viability of areas of contiguous farms or that enough area is protected to ensure the continuation of related industries. The Tweed council state "Apart from sugar cane the Tweed no longer has the potential for large-scale profitable production" (Tweed CC, 2004, p17). This is due to high land prices and small producers finding it increasing difficult to generate the income necessary to finance debt and invest in new equipment and practices, or expand for greater efficiency so as to compete with larger companies in a global economy (Barr 2007). In areas facing a similar agricultural crisis in Victoria a number of farmers are changing from the socially welcome, but unviable agriculture industries to more profitable, but socially unwelcome (particularly in a increasingly urbanised and lifestyle aware communities) operations such as intensive animal production (Barr 2007).

In the absence of readily available data designating agricultural protection priorities, landscape suitability analysis could be used in future research to provide surrogate assessment and identification of important agricultural production areas. This analysis could then be coupled with conservation style reserve selection techniques integrated in an ALF scenario analysis to protect, even "covenant" large contiguous areas of highly productive agricultural land. Further research would be required however to determine the amount of area to be protected for specific industries to ensure their ongoing continuity along with measures to identify and protect agricultural land contiguity for future farm viability (Tweed 2004).

10.3 THE CONTRADICTION OF WATER SCARCITY AND ABUNDANCE

One surprising, but clear message which emerged early in the study was that accessibility and supply of water is not a limiting factor to urban development, despite apparently being a key concern of many local governments (ALGA 2004). Questioning of international colleagues confirmed the same finding in all of their landscape futures studies elsewhere in the world, even in deserts such as found in Saudi Arabia, Israel and Nevada (Pers. Comm. Mouat, D., Bassett, S. 30 August 2007). Jared Diamond in *Collapse* (2005) also noted that for many societies water scarcity did not seem to be taken into account in the decision making process, leading to over development including excessive water infrastructure development.

In addition to increased consumption by a growing population, building an average small to medium home uses 125 cubic metres of concrete which requires approximately 4800 litres of water per cubic metre (Harris 1999, Morel *et al.* 2001). Despite this vast drain of water resources, Brisbane and South east Queensland's massive population increase (averaging 700-1000 new homes / week during 2006-2007) was sustained for many years even in the midst of a drought. This consumption by a single sector of the building industry multiplies out to over 600 Million litres of water a week in new home construction, which continued through extreme 1 in 100 year drought conditions and severe domestic water use restrictions.

In contrast to drought conditions, some parts of the region, in particular large areas around Murwillumbah and Lismore are very prone to flooding. However this also does not seem to be a constraint to new development. Within Lismore council's development control plan (Lismore CC, 2007) there are five categories of flood prone lands.

The "High Flood Risk Area" is described as

> "High Flood Risk Area is the area in which there is a potential for flooding to cause danger to personal safety and/or loss or damage to light structures. Able bodied adults could have difficulty wading to safety…" (Lismore CC, 2007, Ch 8, p4)

While there are numerous restrictions to development in this area, in general terms multi-story residential, commercial and industrial development are allowed provided evacuation plans are created and some percentage of floor space is higher than expected flood levels (Lismore CC, 2007).

The Lismore CC is a local government example of a typical policy towards development in an area that over years has gained notoriety for flooding. The council however, has decided that flood level would not be used as a constraint to development. This policy also reinforces the general finding (Chapter 5) that restrictions to development by local governments are generally based on the suitability of the type of development rather than an overall restriction of new development for a location. Local governments in Australia and many other countries rely on residential rates for the Council income. As irrational as it might seem, water in scarcity or abundance is rarely a constraint on placement or use of space in development planning.

10.4 FUTURE DEVELOPMENT OF ALTERNATIVE FUTURES METHODOLOGY

10.4.1 ZONING AND POPULATION DENSITY

To increase the capacity of the methodology to other areas, a number of factors could be improved. The introduction of an approach to multi-scaling via multiple zones was a valuable methodological advance, and required due the large spatial extent of the region and the spatial diversity in population growth across the region. Multi-scaling was accomplished through an iterative process to balance population growth with sample size and change in urban area. While this worked well with relatively few boundary affects for this region, the process was very slow and has room for improvement through further research.

Other methods for multi-level zoning have recently been developed for integrating resource governance and environmental planning, for example 'Eco-civic' regionalisation (Brunkhorst *et al*. 2006, 2008). This technique creates a nested, multi-scalar framework that is spatially based on the 'community networks' and area of civic interest to residents. Having a strong basis in natural resource management, bioregional planning and socio-ecological systems theory, the eco-civic method can also be calculated mathematically using surrogates for civic representation. This creates a 3D surface of community interest or "social-civic" topography. By spatially integrating a "community surface" with past trends of population growth, this method could be incorporated into the alternative futures procedure. Such an approach would prove beneficial in increasing community civic engagement in scenarios and transferability of the methodology while reducing zoning issues and calculation overheads.

Similarly in this study, trends for population density followed the same zoning as population growth. While this increases the resolution of population density data from a whole of region scale, there would be the capacity to increase this information further. By cross matching information from CCD's with the LULC maps and, depending on growth rates within small areas, population density could then be used at a resolution of CCDs, irrespective of population zoning. Experimenting with various averaging algorithms may also allow an approximate continuous surface of population density to be applied.

10.4.2 LAND ALLOTMENTS

Throughout developed nations, land use planning typically uses allotments for decision making relating to future land use such as land releases, zoning and allocation to conservation. The use of grid cells and failure to utilise land parcels is a criticism of both landscape futures (Irwin & Geohegan 2001) and conservation planning approaches (Newburn 2005).

Using land allotments within the CA modeling framework could be accomplished by the selection of a land parcel that would be converted to urban. This area would then represent the creation of a new subdivision with an appropriate level of population depending on its extent and the population density of the area. While this would increase the realism of scenario models by representing current land use planning systems, it would also increase the computational overhead and increase the cost of the process due to the additional costs of data procurement and preparation.

10.4.3 CONSERVATION PLANNING AND ALTERNATIVE LANDSCAPE FUTURES

The key habitat and corridors data provided by NSW National Parks and Wildlife Service (NPWS) provides surrogate data for a simple method to prioritise conservation areas for ecological connectivity in ALF studies. On a landscape level this data represents a large number of nodes (many of which contain national parks or other reserves) with linkages throughout much of the region. However, the agricultural areas around Grafton, Casino and Lismore provide little in terms of natural vegetation when considered at this scale. Remnant vegetation patches within these areas should be considered a priority for consideration of protection for their role in the landscape.

Some considerable research effort has produced and refined methodologies and models to find the optimal suite of conservation reserves for a given area. The best known methods include Gap analysis (Scott *et al.* 1991,1993; Scott & Jennings 1997; Jennings 2000) and heuristic and linear algebra based algorithms for prioritising and placing reserves in a regional reserve network (for example see Rodrigues *et al.* 2000; Pressey *et al.* 2000, 2001, 2002, 2003; McDonnell *et al.* 2002; Cowling *et al.* 2003; Faith *et al.* 2003; Siitonen *et al.* 2003; Costello 2004; Sarkar *et al.* 2005). The development of future landscape plans, trajectories and scenarios has a number of similarities to conservation planning and reserve selection. In the absence of data such as that supplied by the NPWS the methodological procedure and framework of alternative landscape futures design for regions would benefit from the integration of reserve selection and conservation planning methods as a subset of the planning matrix of scenarios.

10.5 ALTERNATIVE FUTURES AND COMMUNITY INVOLVEMENT

The ultimate objective of alternative landscape futures research such as this are to create possible futures that can be implemented over many years in a decisive, but iterative and adaptive management context. The generation of a future trajectory was a novel intersection and integration with scenario based alternative landscape futures. Higher spatial accuracy is possible, however the focus is not on whether a specific, small parcel of land will be converted to urban development, but on landscape patterns of change (see Forman 2008). Within this methodology future trajectory modeling is a tool that contributes the capacity for the impact of the future growth of an area to be visualised and assessed, and in turn encourages the constituency to consider if there are more feasible alternative futures that are more desirable and sustainable.

Being able to visualise the future to some degree, increases the initial comprehension of change and subsequently, the capacity in decision making for the long term. In the ALF methodology, visualisation assists in design and testing of scenarios that reduce the undesirable outcomes of the future. This step would be extremely valuable in stakeholder involved development cycles as participants can modify outcomes based on their desires, beliefs and perceptions of what the future of their community should look like. This would likely see a greater commitment and participation in the community in regard to pursuing an alternative future.

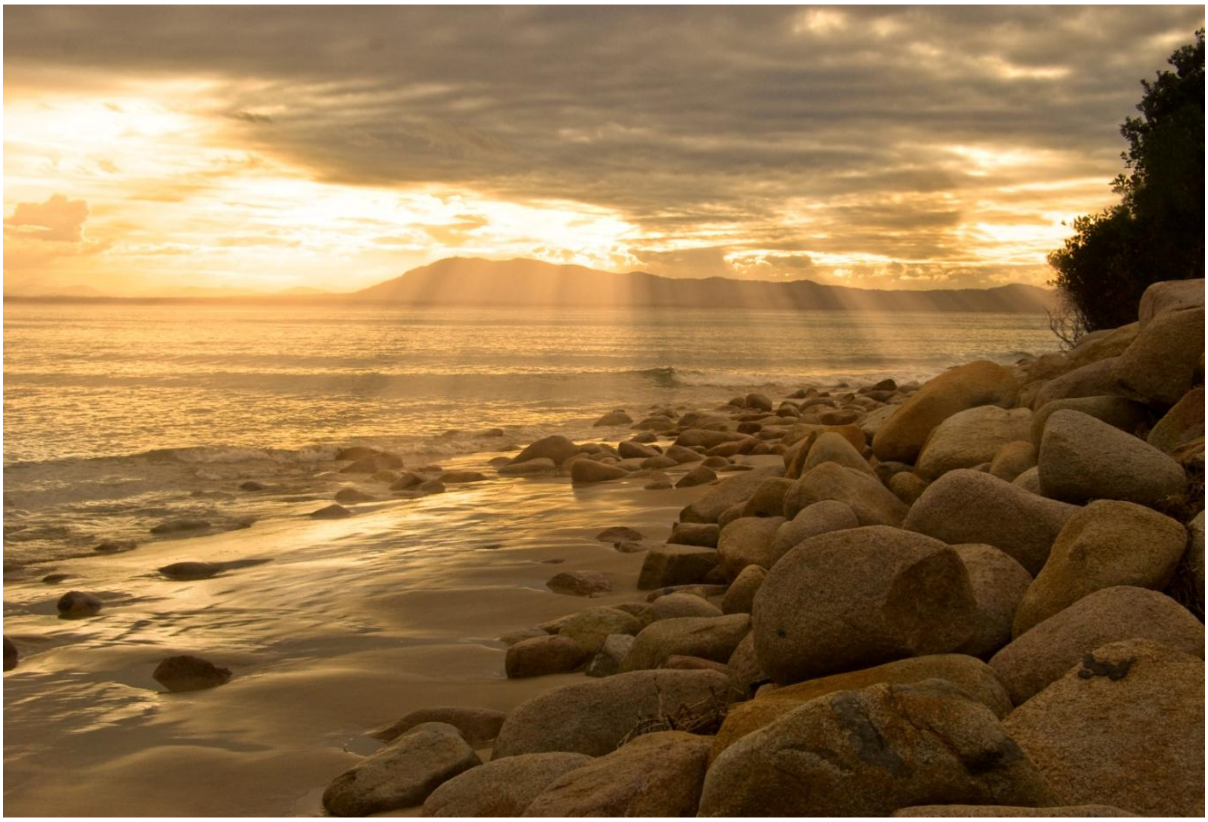
In practice, implementing an integrated, stakeholder driven regional plan with a view towards sustainability is at best, difficult. Cowling *et al.* (2004), state that a major factor of the 'implementation crisis' of conservation plans (see Prendergast 1999; Newburn *et al.* 2004; Knight *et al.* 2006) and the sustainability of natural systems is in society's failure to build institutions for the management of natural resources that are adaptable and have the capacity to respond to social, economic and ecological change. Discussing the 'implementation crisis' of conservation planning, Newburn *et al.* (2005) stated that only 13% of the 74 reviewed conservation plans were being implemented and only 12% of reviewed plans had stakeholder involvement. Six of the eight plans involving stakeholders and decision makers ultimately informed practical planning processes; whereas only 5% of plans that did not involve stakeholders were used.

Furthermore, rural communities are increasingly becoming less socially coherent with the diversification of agricultural land and reduction of related industries and, migrant retirees and 'lifestylers' with mixed socio-economic circumstances. Changing land values and housing prices create a more disparate societal mix both on a local scale and a larger regional scale (Barr 2007). It is therefore becoming increasingly challenging to meet the needs of all stakeholders in managing change in various social ecological system contexts (Sayer & Campbell 2004, Boxelaar *et al.* 2007).

The use of focus groups and community feedback is considered hard work, resource intensive and time consuming. When conducted well however, it has the potential to mobilise skills, incorporate local knowledge and collaboratively resolve social economic and environmental conflicts (Shannon 1998; Cheng *et al.* 2003; Boxelaar *et al.* 2007). The use of this social capital appears to be important to positive, community-civic engagement in planning towards a sustainable future (Knight *et al.* 2006). Further research would be valuable in testing efficient forms of stakeholder engagement and contributions to alternative landscape futures scenarios methods and applications.

Chapter 11

Conclusion: A Way Forward



Light breaking through, South West Rocks

Man cannot discover new oceans unless he has the courage
to lose sight of the shore
Andre Gide

CHAPTER 11 CONCLUSION: A WAY FORWARD

In Australia, current land use planning tends to be incremental and based on a short term view of the future that spans only a few years and builds on the past development. While increasing the predictive capacity of future planning outcomes based on knowingly or unknowingly following trends from past and current trajectories, there is little forethought given to the long term results. Other spatial influences of change or designed alternatives that might provide greater long term social-ecological benefits seem not to even make it onto the "agenda" for consideration.

It is apparent when considering any singular attribute of a region, such as the Northern Rivers of NSW, that a key ongoing problem is that of fragmented socio-ecological landscapes at a variety of scales. Fragmentation of ecological systems has long been a concern of landscape ecology and conservation biologists. It should also be a concern of urban and regional planners and considerations need to be expanded to encompass the social, economic and ecological matrix present in a landscape or region.

Analysis of ecological systems at any scale, including that of a whole region, shows fragmentation, degradation and a reduced capacity for ongoing persistence of not only, biodiversity and ecosystem services, but also physical and aesthetic features that attract human settlement. Our social structures are increasingly fragmented by in-migration, greater isolation from family and friends and the dissolution of the family unit and extended families. Rural communities are no longer a concordant assemblage; instead they are fragmented mix of backgrounds, incomes, ideals and visions. Economically, disproportionate land values create disparate areas of wealth and affluence. Finally, fragmentation and diversification of the agricultural landscape sees small scale farmers struggling and affects the viability of larger scale related and reliant industries.

The small scale, reductionist nature of our planning systems, institutions and management cannot address these concerns. Our local councils are bound in annual cycles of increasing development to raise revenue so as to be able provide infrastructure and services required by new development. Regional institutions are narrowly focused and have discrepancies over authority, jurisdiction and boundaries. Neither has the capacity to adequately plan for ongoing sustainability and persistence of any factor of socio-ecological systems.

Change is inevitable, as is new development. However, uncontrolled growth and development taking up too much space in the wrong place, has been and inevitably will continue to compromise social and ecological sustainability. Land use planning needs to move to more holistic, future oriented approaches that consider options at numerous scales and strive to balance the multiple needs of society. This shift to landscape and regional 'design' rather than ad-hoc pro-development in short cycles, was advocated over 40 years ago by McHarg (1967, reprinted 1992) in *Design with Nature*. Society's failure to take heed is apparent with rising environmental externalities and social issues. Otherwise our future living spaces, especially in our coastal areas, will be an ecologically denatured area of city suburbia and canal estates comprising concrete, roll out turf and plantation palm trees that surround prefabricated concrete "cookie-cutter" shopping centres filled with international franchises and an economy trying to entice tourists, but where residents are travelling elsewhere to 'escape' for holidays.

The methodological, computational and multi-scale spatial (GIS) capabilities of "design by landscape ecology" integrated into of alternative landscape futures design and evaluation techniques, such as those contributed to and demonstrated in this research reinforce and further empower McHarg's vision for the 21st century.

Appendix 1

Identifying land use/land cover trends for Future Scenarios in the Northern Rivers Region of New South Wales

Rainbow Lorikeet in Coastal Banksia, Yamba

Great things are not accomplished by those who yield to trends and fads and popular opinion.

Jack Kerouac

Identifying land use/land cover trends for Future Scenarios in the Northern Rivers Region of New South Wales

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Identifying Land use/Land Cover Trends for Future Scenarios in the Northern Rivers Region of New South Wales

1.0 Introduction

Population change worldwide has resulted in an ever changing mosaic of natural vegetation and human land uses (Pathan *et al*. 1993, Schmidt 1998, Seto *et al*. 2002, Weng 2002). Many of the changes reflect both direct and indirect interaction among human activities and the surrounding environment. Although changes occur, determining the linkage between human activities and environmental change can prove problematic (Engelen *et al*. 1995). Furthermore, our ability to determine the cause of change can influence policymakers and their ability to inform the general public (Shearer *et al*. 2006). Subsequently, there is a need to produce results where speculations over the cause of change may be done to allow for the projection of future environments.

A widely used method to assess environmental change is based on land use/land cover trend analyses to provide an indication of land cover change over time ranging from months to years (Fung 1990). Generally, a land use/land cover trend analysis attempts to portray what has happened in the past thereby allowing for a clearer trajectory into what might happen in the future. Alternatively, a land use/land cover trend analysis may also be used to search for potential cause and effect relationships. Such relationships are likely to be related to various past policies, planning instruments and socio-economic change.

In general, land use/land cover trend assessments fall into two broad categories determined by the methodology used to identify land use/land cover change. One method focuses on the identification of specific land use/land cover types while another uses analogous information portraying plant growth or lack thereof (Friedl *et al*. 2003, Homer *et al*. 1997). Studies with a cover type focus generally utilise a classification methodology or expert identification process resulting in categorical dataset (Hansen *et al*. 2000). Studies with an analogue approach generally use a classification process resulting in a continuous dataset representing the relative amount of plant growth. The technique utilised reflects the objective and goals of the study. Both methodologies often utilise a form of aerial or satellite image for use in measuring plant production or identification of land use/land cover types. Where ground surveys have been conducted, imagery is not required to perform a land use/land cover trend analysis.

Within Australia, population change is occurring and future projections show the majority of the change is expected to occur along the Eastern coast (Gaffin *et al.* 2006). The objective of the study is to perform a trend analysis along the Eastern coast of Australia focusing on changes in human uses. The study attempts to identify the trends in land use/land cover change, and goes a step further by linking the change in urban land cover with changes in population for the region. While an exhaustive procedure, the history of land cover and land use change provides a comprehensive grounding for understanding future probable scenarios and alternatives for the region.

2.0 Methods

2.1 Landsat satellite imagery

The study area comprised the far north coastal area or "northern rivers" of New South Wales (NSW) approximately from the Grafton-Clarence Shire, north to the Queensland border and bounded by the Shires at the bottom of the Great Dividing Range escarpment (Figure 2.1). The region encompasses the Local Government Areas (LGAs) of Tweed, Byron, Kyogle, Lismore, Ballina, Richmond and Clarence.

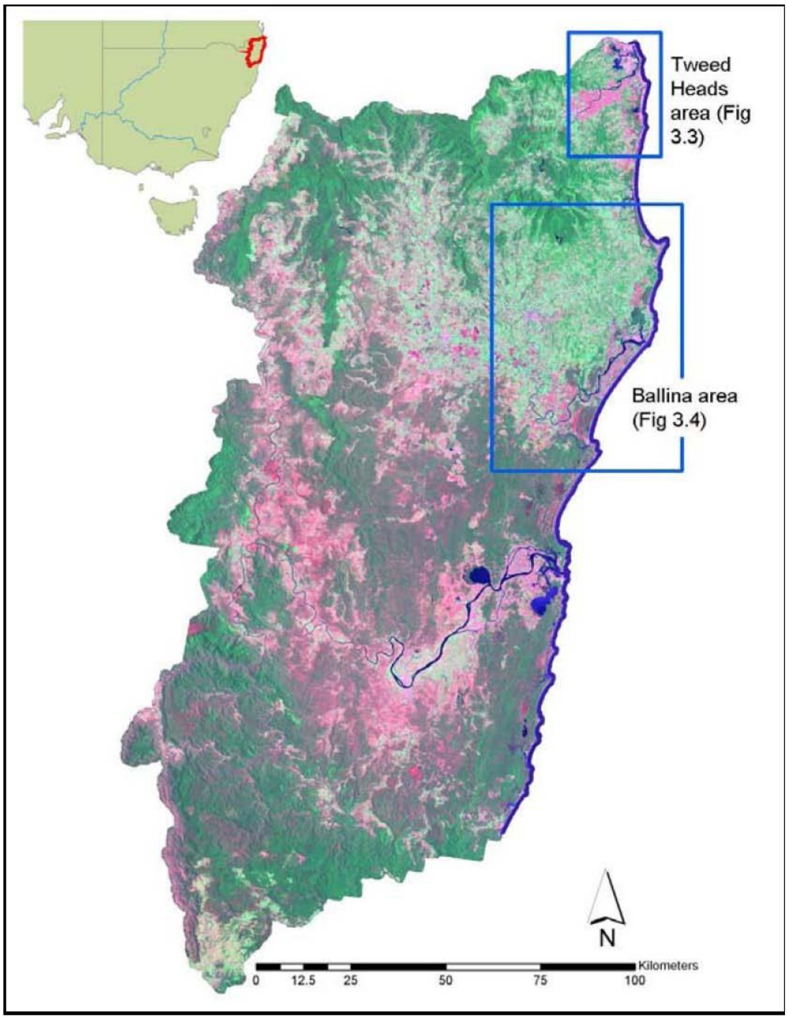


Figure 2.1. The "Northern Rivers" region of the study; the LGAs of Tweed, Byron, Kyogle, Lismore, Ballina, Richmond and Clarence.

The use of satellite imagery for regional land use/land cover identification can provide a relative indication of urbanisation and vegetation change. Although various forms of satellite imagery from a variety of sensors exist, a relatively small subset of the available satellite imagery/sensors provides the necessary information for assessments of land use/land cover change. Within the context of this study and over a 24 year time span the Landsat satellites in operation at the time of image acquisition highlighted land use/land cover characteristics of interest. Subsequently, image acquisition followed roughly a five year interval with Landsat satellite images acquired for the years 1980, 1985, 1990, 1995, 2000, and 2004. Whenever possible, images acquired reflected time periods where the possibility of vegetation discrimination was at its highest. Cloud cover and Landsat image corruption limited the availability of usable satellite images for specific areas within the Far North Coast study area. When images meeting cloud cover and corruption requirements could not be acquired for the desired time period, secondary image acquisition occurred during a less favourable time period.

The spatial extent of the Northern Rivers study region required multiple images for all sensors in any given time period. With multiple images comprising all time periods and to expedite the image classification process, images were mosaiced. The mosaic process used the overlap areas to standardise spectral values among the images (Homer *et al*. 1997). The earlier years, 1980 and 1985, required four Landsat satellite images from MSS sensors be acquired and mosaiced. The other four time periods —1990, 1995, 2000, and 2004 — required two images from TM sensors. Table 2.1 highlights the dates, sensor, path, and row for each time period.

Table 2.1. Date, sensor, path, and row of Landsat satellite images used to develop the New South Wales Far North Coast change analysis

Date	Sensor	Path	Row
Aug. 1980	MSS II	94-95	80-81
Feb. 1985	MSS V	94-95	80-81
Aug. 1990	TM V	89	80-81
Apr. 1995	TM V	89	80-81
June 2000	ETM VII	89	80-81
Nov. 2004	TM V	89	80-81

2.2 Landsat satellite image classification

When classifying mosaiced images a possible disadvantage occurs through an increase in the spectral variability which may result in an increase in misclassification rates. The advantage in the classification process is the need to only conduct the image classification process once per time period. Although the study area has a broad spatial extent, the overall land use/land cover heterogeneity remains fairly constant. Thus, the advantages override the potential disadvantages for classifying mosaiced images.

For all time periods the classification process generated unsupervised spectral clusters using the Imagine™ Isodata algorithm. Prior to clustering, urban areas throughout the region were masked from the image to reduced spectral variability. An iterative process provided an optimal number of spectral clusters to use in the land use/land cover classification process. With each iteration came an evaluation by examining average per band signature standard deviations. The total number of spectral clusters increased by 10 until the average per band standard deviation was 1. For each time period the number of spectral clusters approached 60.

Beyond the spectral clusters, a number of other ancillary datasets provided additional information prior to the land use/land cover classification. The ancillary datasets represent GIS layers describing the physical properties or context of many land use/land cover types of interest. The intent of incorporating ancillary datasets into the classification process is to reduce the potential for misclassification of specific cover types. When ancillary datasets are used in combination, the descriptive power and subsequent level of detail of the physical landscape can often increase. Table 2.2 highlights the ancillary datasets used in the classification process and their role or interval.

Table 2.2. Ancillary datasets used in the land use/land cover classification.

Elevation	Elevation divisions at roughly 90 meter intervals
Slope	Slope divisions smaller at lower slopes and greater at higher slope values
Aspect	Followed the eight dominant directions
Distance from Ocean	Used to identify beaches and the inland extent of coastal vegetation
Sugar cane locations	Used to identify and limit potential sugar cane field locations
Orchard locations	Used to identify and limit potential orchard locations

With the spectral clusters and ancillary datasets generated, cover type rule-sets had to be developed. General rule-sets developed for the 2004 time period were applied to the other time periods with small modifications. The 2004 time period comprised the most recently acquired satellite images and closest approximation to April 2006 training site acquisition. All training sites identified and visited during April 2006 provided the foundation for land use/land cover classification. Mobile GIS technology incorporating global positioning systems (GPSs), computer laptops, and PalmPCs allowed for correct location information to be derived and labelled according to the cover type present at each training site. Training site cover type overlaid on spectral cluster and ancillary datasets created a database where classification rule-sets could be generated for each cover type. Rule-set generation reflected the per-pixel distribution of spectral cluster values within each training site. Rule-set revision followed with further refinement by ancillary dataset. As an example, a spectral cluster value of 22 may be indicative of vegetation comprised of corn, sugar cane, and native rainforest. With the spectral cluster value limiting the possibilities to three types of vegetation further refinement may ensue. Rainforest occurs at higher elevations on steeper slopes. Sugar cane is located in flat areas within a sugar cane mask. Corn is in the mid range elevations away from sugar cane and in relative flat areas. Thus, by using the ancillary datasets the spectral clusters are refined through a discrete rule-set.

With a rule-set developed land use/land cover classification for each time period ensued. Eight dominant cover types could be readily identified with what was believed to be little misclassification error (Table 2.3). The eight cover types readily identified through the above described procedure are forest, coastal complex, beach, water, sugar cane, pasture/crops, orchard, and urban. Higher discrimination among cover types could not be obtained through all time periods even though attempts at doing so were made.

Table 2.3. Mapped cover type descriptions

Cover type	Description
Forest	Sclerophyll forests containing mostly species of *Eucalyptus* trees with various levels of density ranging from rainforests to dry and open forests.
Coastal complex	Vegetation communities found only within 15 km of the coast ranging from shrubs to mangroves.
Pasture/crop	Natural and exotic pasture land including mostly annual vegetation, primarily grassland communities. Isolated crops including corn, tea tree, or other plants which are cultivated mainly for human consumption.
Orchard	Orchards dominated by plantations of macadamia and avocado trees.
Sugar Cane	Fields where sugar cane production is the dominant activity. With a crop rotation system in place and sugar cane harvesting occurring every two years, the crops grown may be sugar cane or a legume.
Water	Locations dominated by either fresh or salt water.
Beach	Sandy beaches located within 150 meters of the Pacific Ocean.
Urban	Manmade features dominated by commercial or industrial buildings; the cover type includes urban residential, semi-urban residential or rural residential houses readily identified on satellite imagery.

2.3 Spatial classification generalisation

With the land use/land cover classification complete to a single pixel resolution of 25 meters, a generalisation algorithm was executed to create cover type GIS layers at a 2 hectare minimum mapping unit resolution (Edwards *et al*. 1995). The generalisation algorithm produced topologically simpler GIS layers by reducing the overall number of small polygons present. Furthermore, the process of eliminating very small polygons is intended to lesson misclassification results produced when single pixels contain a mix of cover types therein.

The generalisation process runs in an iterative fashion doubling the elimination area with each iteration. The entire process begins by subsuming polygons composed of a single pixel during the first iteration, two pixels during the second iteration, four pixels during the third iteration, and so on until a 2 hectare minimum mapping unit is reached. Throughout the iterative process determination of how polygons not meeting the minimum pixel area requirement are subsumed, is done through user defined weights assigned in a matrix and based on the cover type of the small polygon and other adjacent polygons. Where no priority weighting is given, small polygons are subsumed within the largest polygon sharing the longest edge boundary. The entire generalisation process when followed produces land use/land cover maps at a 2 hectare resolution for all time periods.

2.4 Population census collector district assessment

Census collector district information obtained from the Australian Bureau of Statistics provided a useful layer for comparison with the urban cover type identified in the land use/land cover classification process. Urban areas are also made up of a combination of dwellings (of various types), infrastructure, utilities, roads, schools, light industry and commercial areas. Increasing (or decreasing) population might therefore be reflected in a proportionately larger increase (or loss) of the urban land cover type. Detection of urban areas in this study excluded detection of small acreages or "hobby" farms.

Overlays between the 2 hectare land cover/land use and the collector district GIS layers allows for a change comparison among population and cover type to be conducted. Specifically, the change in area for the urban cover type for the time periods 1980, 1990, and 2000 when compared with the change in population for the 1981, 1991, and 2001 census collector districts may provide insight into the performance of the land use/land cover classification. For overlays among the two GIS layers to reflect similar information the urban land cover area was summarised by census collector district. The change in population between the time period 1981 and 1991 may then be compared with the change in urban area for the time period 1980 and 1990. The same process may then be conducted for the 1991 and 2001 population change and the 1990 and 2000 change in urban area.

3.0 Results

3.1 Land use/land cover type distribution and change

Cover type distribution for all time periods show an abundance of vegetation in the forest and coastal complex cover types (Figures 3.1 and 3.2). Forest communities dominate mountain and escarpment areas, and inland locations largely void of human habitation. Coastal complex vegetation communities appear relatively close to the coast where urban and agricultural development has not removed the flora. The water cover type is dominated by the ocean shoreline and a mixture of rivers, estuaries, and lakes. The beach cover type only occurs along ocean shoreline locations. Sugar cane fields are present along many of the major rivers in the region with a proliferation of fields located where the difference in elevation between river levels and the surrounding land area is less than 10 meters. Most of the sugar cane fields are located within a close proximity to the coast. The pasture/crop cover type dominates areas located in relative close proximity to residential urban areas in the lower elevations. In general pasture and crop locations are in low sloping areas, however, there are exceptions where pastures extend into foothill locales. Orchards are located in the north-western portion of the study area in areas of rolling hills with a rather limited spatial extent. Orchards are absent during the 1980 time period. A summary of cover type area by time period is presented in Table 3.1.

Table 3.1. Area in hectares for each cover type by time period.

	1980	1985	1990	1995	2000	2004
Coastal complex	80,741	74,122	75,136	64,378	83,015	67,844
Forest	1,299,363	1,279,883	1,277,190	1,212,614	1,287,359	1,248,753
Pasture /Crop	694,047	714,817	718,733	790,345	682,429	731,498
Orchard	0	418	3,332	4,376	7,194	8,730
Sugar cane	53,119	53,557	47,941	47,407	57,042	56,073
Water	46,770	48,193	45,510	45,478	45,291	47,989
Beach	2,249	2,192	753	1,387	991	1,089
Urban	6,762	9,240	13,828	16,437	19,101	21,075

Trends in cover types vary for each time period. In general, the urban and orchard cover types show a linear increasing trend with time. The urban cover type has more than trebled over the time period. Beach area appears to have halved, while orchard cover types (e.g., Macadamia) was initiated and grown considerably since just before 1985. The extent of sugar cane fields decreased in the 1990s rebounding in the 2000s.

A single anomaly in year 2000 shows an increase in the coastal complex cover type which can be explained by two factors, the timing of the image in June and the apparent lack of moisture in the image. These two factors would increase grazing and agricultural activities in locations where soils in wet years would be too moist for cattle and human access. Thus, with an increase in coastal complex a concomitant decrease in pasture and croplands occurs. In general, forest and pasture/crop cover types alter year-by-year and may reflect forest clearing and regrowth activities associated with both logging and grazing practices.

A comparison of the combination of the more natural cover types coastal complex, forest, and pasture with the combination of more human cover types orchard, sugar cane, and urban shows a decline in the more natural cover type combination and an increase in the predominately human cover types (Table 3.2). Although the pasture/crop cover type may be presumed to be human induced the majority of the cover type is composed of grasses some of which naturally occur in the region.

The largest change in the human cover types occurs between the years of 1995 and 2000 with more moderate increases occurring between the earlier 5 year time periods of change. In other words, land use change has accelerated in the last decade. Most of the 2 to 3 fold increase in urban area has occurred around Tweed Heeds in the north (Figure 3.3), and Ballina areas (Figure 3.4).

Table 3.2. Area in hectares for the lumped natural and human cover types.

	1980	1985	1990	1995	2000	2004
Natural	2,074,151	2,068,822	2,071,059	2,067,337	2,052,803	2,048,095
Human	59,881	63,215	65,101	68,220	83,337	85,878

Landscape change analysis (reported further below and as an attachment), in brief, include:

- Accelerating rates of large land cover change due to urbanisation related to population change – especially Tweed Heads and Ballina areas.

- Urban area change related to newcomers and new dwellings is in many areas only a fraction of total urbanisation change brought about by development of large commercial areas and light industry as well as roads, utilities and other infrastructure.

- The NSW Planning Department's North Coast Strategy is planning on an additional 150,000 in population over the next 20-25 years, however our land use, demographic and socio-economic change analyses provide some evidence of a scenario of 500K population increase for the region over this period.

Figure 3.1. Land use/land cover distribution for 1980, 1985, and 1990.

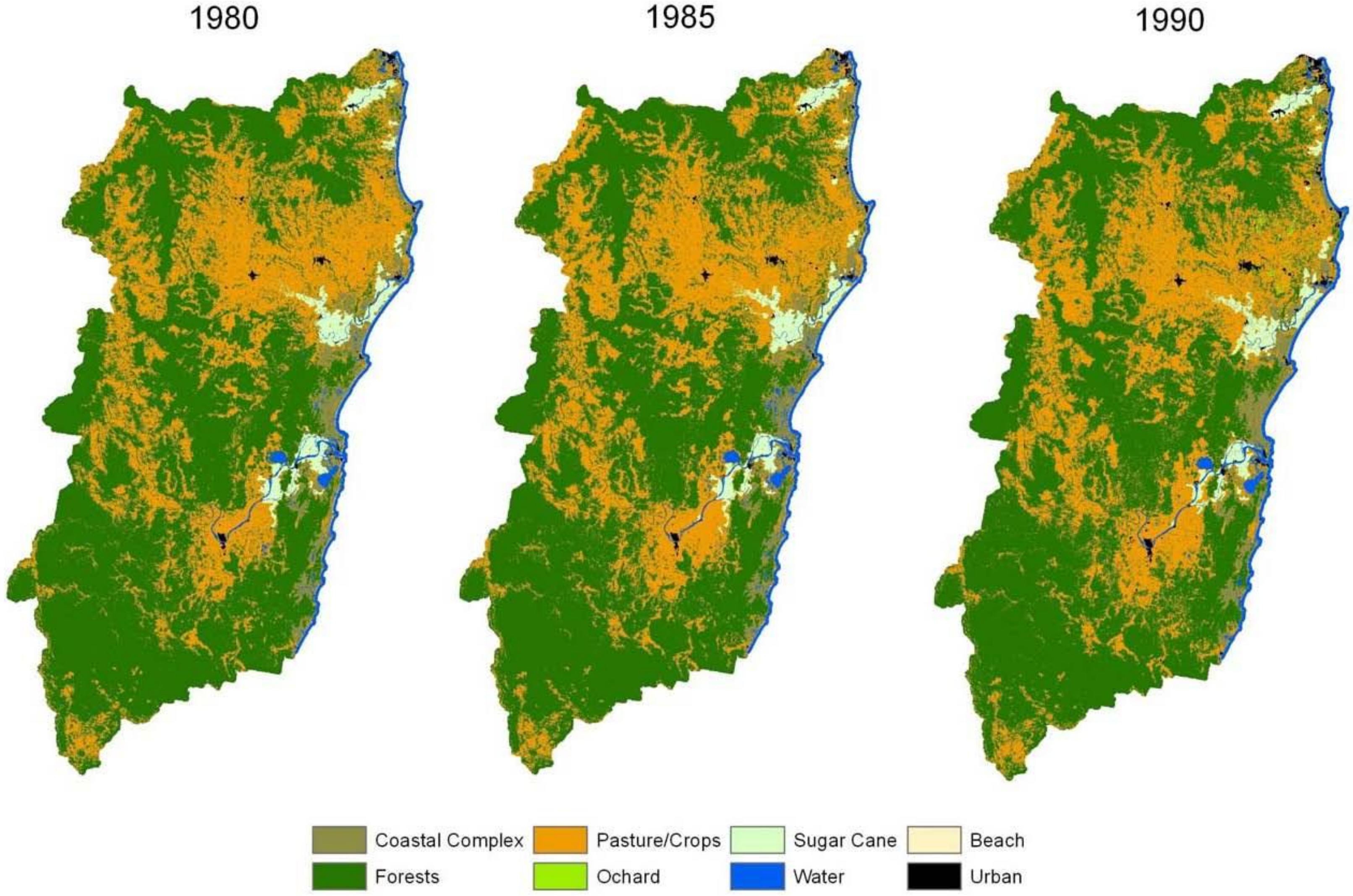


Figure 3.2. Land use/land cover distribution for 1995, 2000, and 2004.

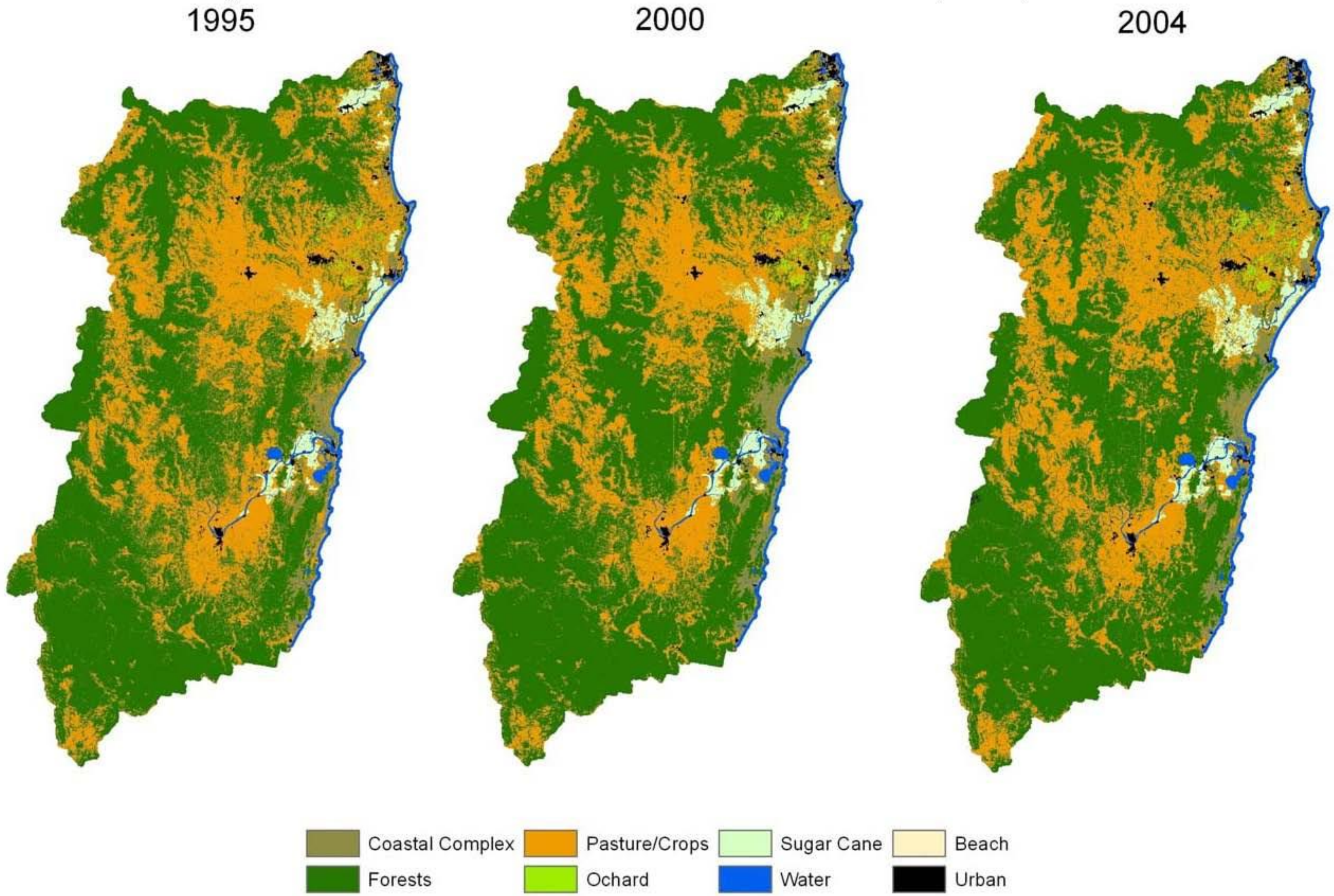


Figure 3.3. Detail of land use/ land cover change between 1980 and 2004 for Tweed heads area

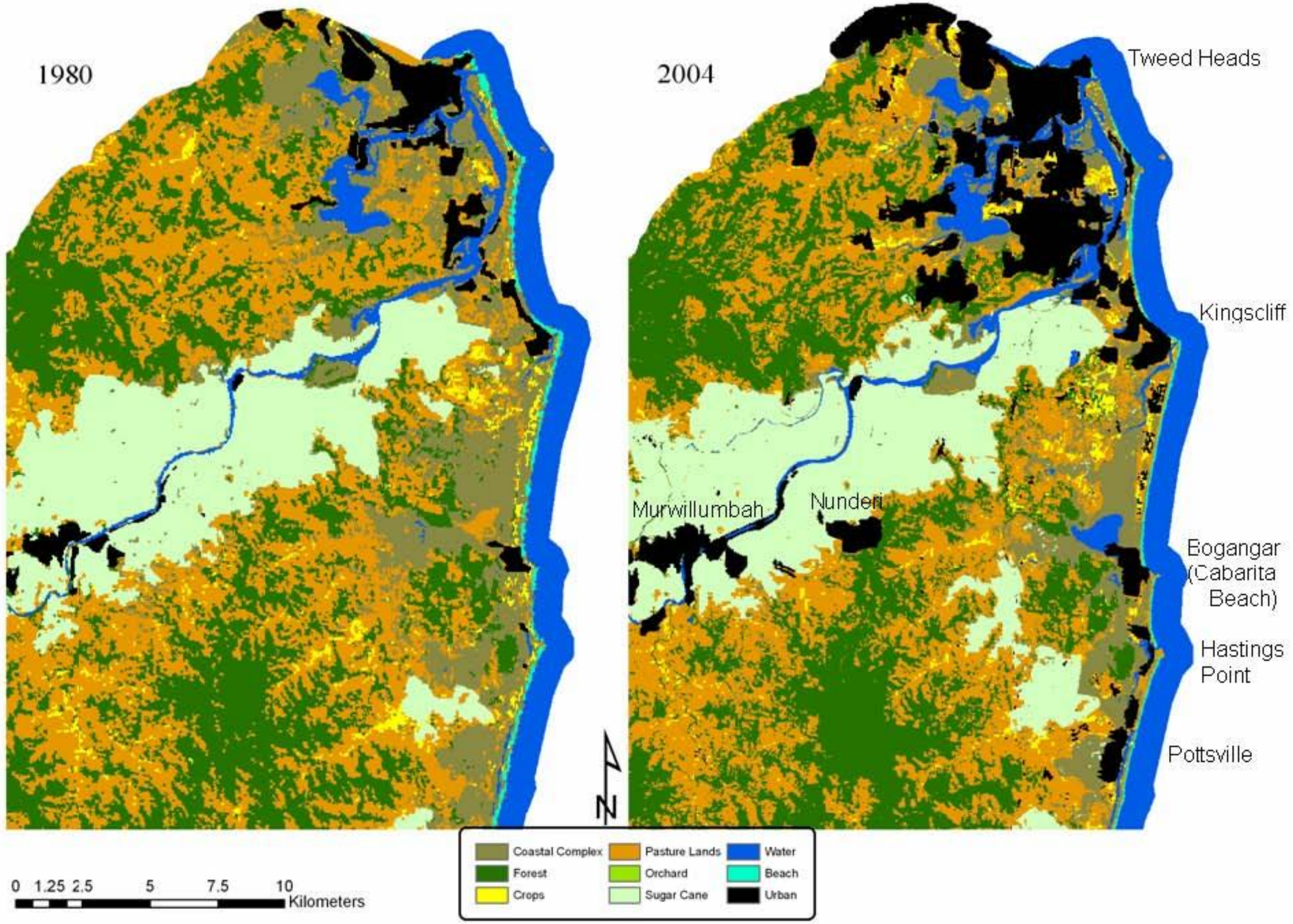
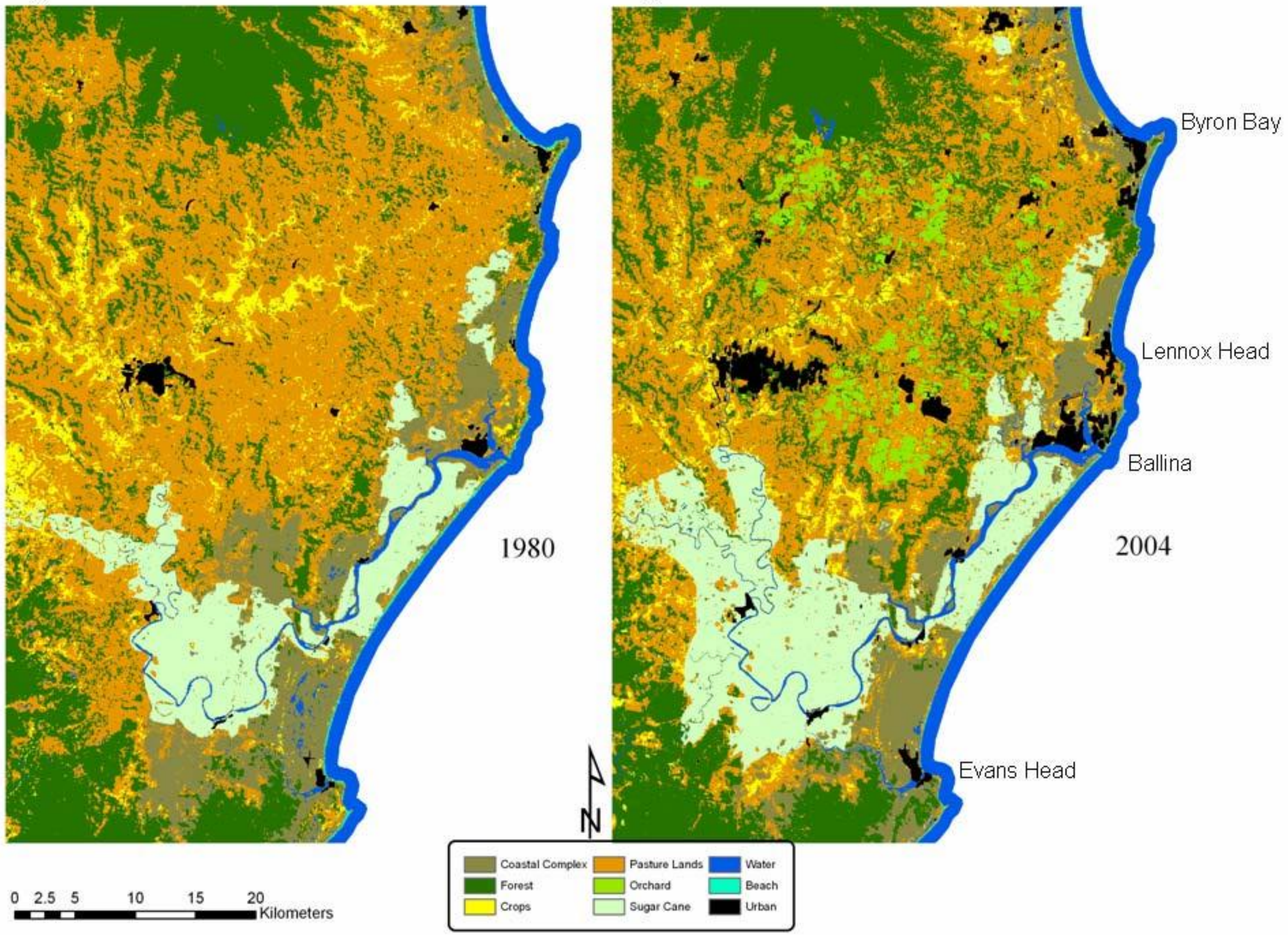


Figure 3.4. Detail of land use/ land cover change between 1980 and 2004 for Ballina area



3.2 Relationships of urban land cover change with population change

In the Coastal Northern Rivers region of NSW, the population has increased from 173,000 in 1981 to 266,000 in 2001 (273,000 in 2006). Analysis of past and current trends of accelerating migration and population growth suggest that the population of this region continues to follow linear growth overall, but with exponential growth occurring in particular areas, mostly along the coastal fringe.

The regional population will reach around 400,000 within the first two decades of this century, and quite probably 550-600,000 by 2030. Historical and probable future population growth trend for the whole study region is shown in Figure 3.5 (Note from Figures 3.3, 3.4, 3.7 & 3.8, that there is considerable spatial variability in the location of increasing, decreasing or neutral population change across the region). Overall the trend is for linear growth, however in reality some areas will not increase in population, some will decrease and some areas (mostly along the coastal strip of available freehold land) are likely to grow exponentially (Figure 3.5).

Most of the population growth and urbanization over the past two decades and in the next few decades will be along the coastal fringe – Tweed Heads to Byron Bay, around Ballina, Evans Head, and Yamba area – and some focused around a few hinterland towns – for example, Murwillimbah, Lismore, Grafton (Figures 3.3, 3.4).

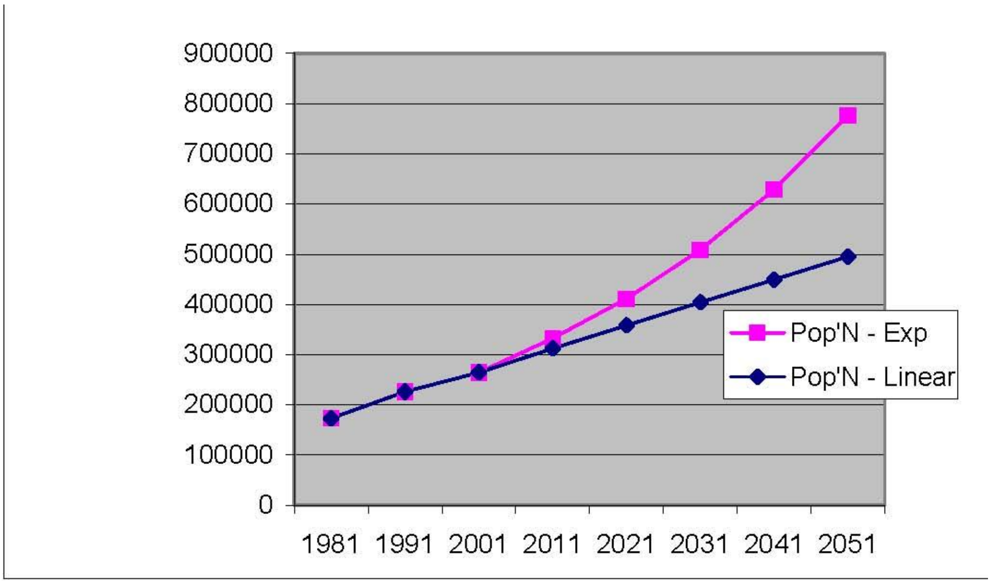


Figure 3.5. Historical and Probable population growth for entire study region

An analysis of the change in urban area compared with the change in population shows that, overall for the region, as population increases so does the urban land cover type (Table 3.3). While the population increase was more than 50% between 1980 and 2001, the urban area increased by over 180%. Although the population and urban area increases on a decadal scale the urban area appears to be increasing at a greater rate than population.

Table 3.3. Change in urban area and population by decade.

	Urban area (in hectares)	Population
1980 (1981)	6,762	173,140
1990 (1991)	13,828	226,010
2000 (2001)	19,101	266,459

An initial linear regression analysis of change in urban area and population change by census collector district (CCD) shows that a significant relationship (p-values < 0.00) exists such that as population increases the area of the urban cover type increases. Although all the regressions for each time period range are significant the R^2 values are quite variable.

While this might suggest a less predictive capacity for change in urban area with population change per census collector district, there are other relationships that explain the spatially disparate nature of population growth and urbanisation. Urban areas are also made up of a combination of dwellings (of various types), infrastructure, utilities, roads, schools, light industry and commercial areas. Increasing (or decreasing) population might therefore be reflected in a proportionately larger increase (or loss) of the urban land cover type. The recent urban area growth along the coast depicted in Figures 3.3 and 3.4 shows the enormous concurrent increase in "urbanised" areas that are known, from ground truthing, to include large areas of commercial and light industry premises. In addition, speculative housing development in fast growing areas may precede migration, which in turn incrementally fuels further development speculation and land releases.

Trends around highly urbanised areas show large increases in both population and urban area (Figures 3.7 and 3.8). The majority of the coastal increase in urbanisation occurs in the far Northern portion of the study area around, and just to the south of, Tweed Heads (Figure 3.4).

Regressions of population increase (numbers) with urban area return stronger R values (around 0.5-0.6), but are probably still confounded because, in terms of urban area, the population reflects more than the dwellings in which they live. This appears to be well supported by a regression analysis of the relationship between population change and change in the number of dwellings (Figure 3.6), which shows a very strong correlation ($R^2 = 0.96$). Local governments and State planners confirm that there are various "multipliers" for various infrastructure, roads and commercial premises that are applied to new urban land releases. It is therefore reasonable in the current study to use the observed change trends for population and urban area in spatially describing future growth and alternative scenarios.

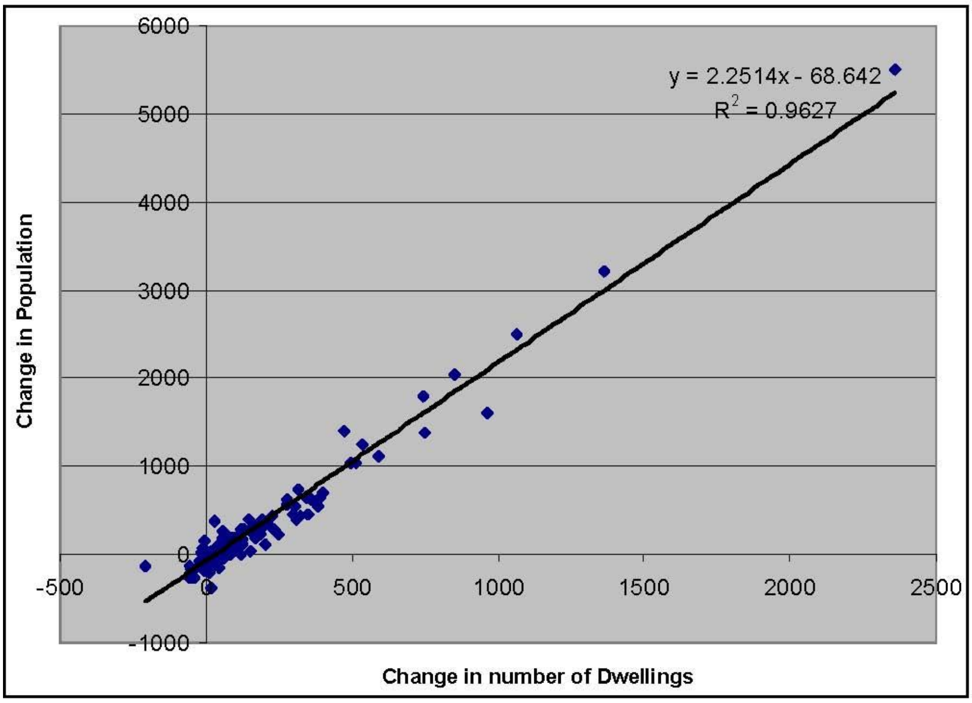


Figure 3.6. Relationship between change in population and change in number of dwellings

More detailed examination of these relationships is being undertaken to decipher the contributing influences and components of urbanisation. A better understanding of the differences reflected in spatial consequences of these factors along with differences associated with position – proximity to beach and coastal strip or hinterland towns close to popular coastal areas – will provide valuable input to scenarios.

Figure 3.7. Census collector district population change by decade.

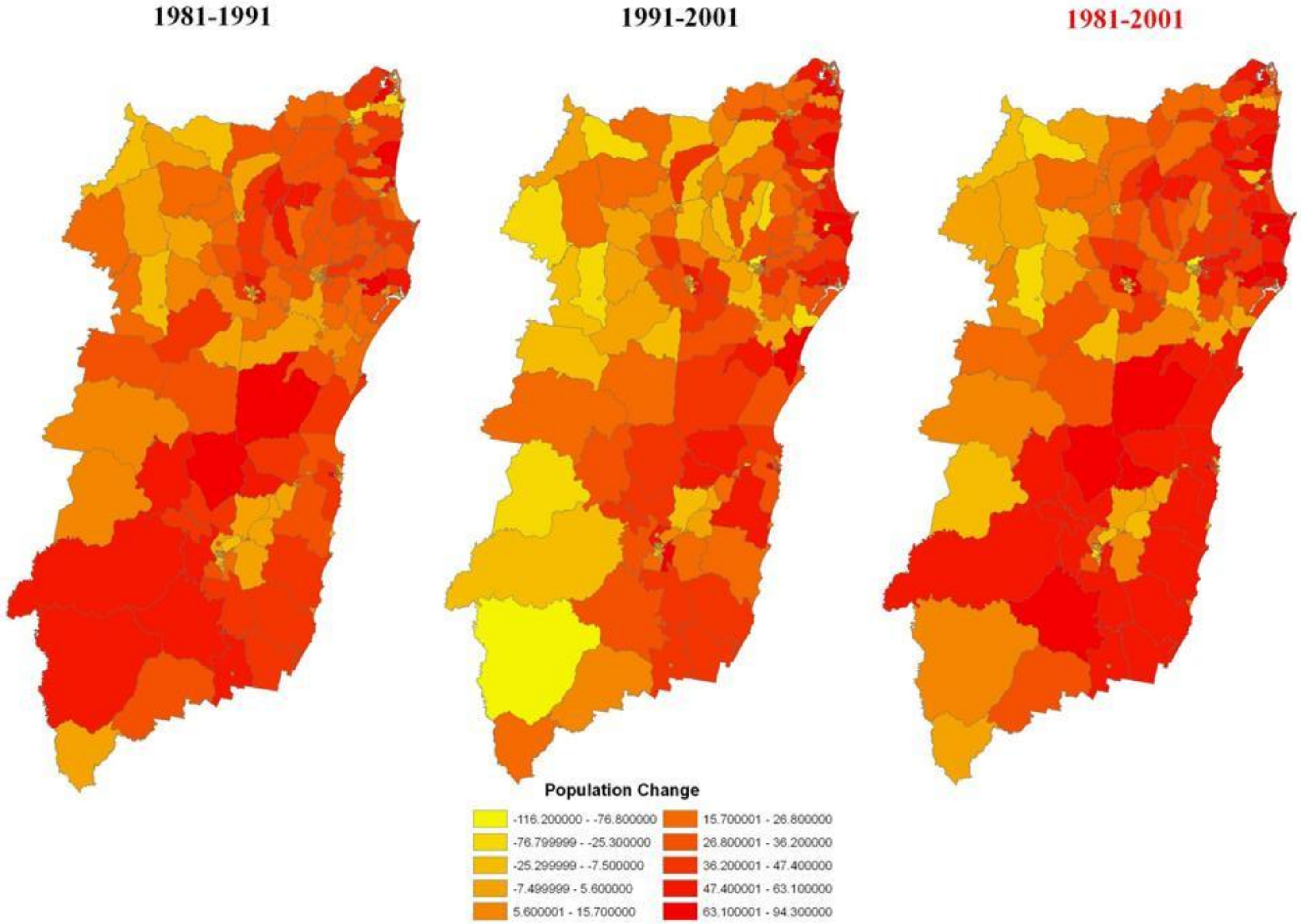
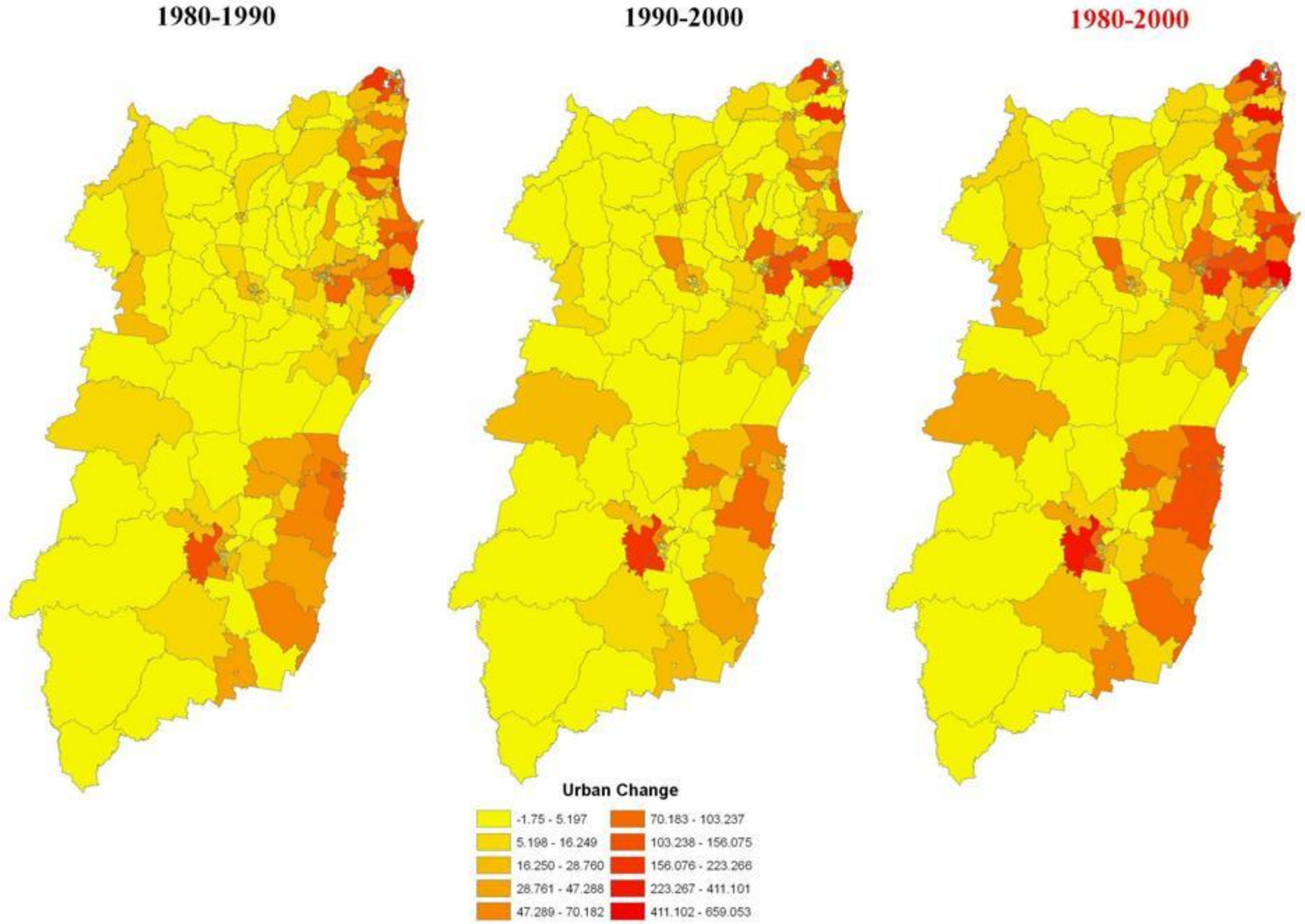


Figure 3.8. Census collector district urban area (in ha.) change by decade.



4.0 Discussion and Conclusions

The Northern River region's land use/land cover characteristics have changed considerably over the past twenty-four years. The area increase in human dominated cover types is resulting in a decrease in the aerial extent of vegetation communities throughout the region. This research quantitatively presents the change in land use/land cover types. Residents and policy makers in the region will have to determine whether the amount and type of change is acceptable given their individual desires.

The location of change also varies considerably. The greatest amount of urbanisation is occurring on the edges of existing coastal towns – in particular, around the cities and fringes of Tweed Heads and Ballina. New settlements have also appeared and grown in more recent times. The urban cover type shows the most dramatic increase in the cities along the coast showing the need for active planning in coastal towns. The lack of active planning within coastal towns may result in an ever decreasing presence of coastal vegetation which currently is the least represented natural vegetation cover type mapped in the region. Future demand for coastal housing in the region might result in loss of this rare vegetation community along with mangroves in estuarine areas . There is also likely to be a loss of agricultural land along the riverine areas between towns.

There is a strong relationship between population growth and the increasing number of dwellings. The 2-3 fold urban area growth may be indicative of an increase in low density housing, reduction in family size in urban areas, or errors in the land use/land cover type classification, or a combination of the three. Given the strong correlation between increasing population and number of dwellings, despite low density housing being hard to identify at 25m pixel resolution (see also Jenson and Troll 1982), these results would seem to be low in such errors. Nevertheless, further exploration of other social and demographic information contained within the census data would be useful in future studies examining change in population and urban cover type area.

Modern urbanisation is much more than residential addresses. The very strong relationship between increase in the number of dwellings with increasing population, coupled with the land cover change showing 50% population increase resulted in 180% urban area increase, suggests that urbanisation increasingly uses more land (perhaps up to 3 fold) for a wide range of services for the residents than reflected simply in population or dwelling numbers. The amount and specific location of urban area increase is most likely related to an increase in population and concurrent increases in roads, utilities, infrastructure and commercial areas.

The results are important and support the concept of population growth along Australia's Eastern coast presented by Gaffin *et al.* 2006. The increase in urbanisation is likely to result in a concomitant change in coastal community lifestyle. The perception of increased population movement due to in-migration is likely to continue if the current census and land use/land cover trends are followed. The results further point to the need for more thoughtful long term planning of the placement and area used by services to the resident population.

The trend of loss in natural vegetation and increase in human land use/land cover types is indicative of a growing region. Over the 24 years of the spatio-temporal study of landscape change, the Northern Rivers region has seen a nett loss in area of coastal complex vegetation (-16%), Sclerophyll forest (-5%), ocean beaches (- 51%). Over this period there have been small losses and gains in areas of pasture land and sugar cane. Of note, in the central area of the study region, there has been the appearance since about 1982, and increasing development of orchard like horticulture plantations (e.g., Macadamia) with many small blocks totalling almost 9,000 ha by 2004.

While a time consuming procedure, the history of land cover and land use change provides a comprehensive grounding for understanding future probable scenarios and alternative futures for the region. Regional planners, local institutions, and other stakeholders should consider exploring future scenarios of land use/land cover change. Baker *et al.* 2004 and Steinitz *et al.*

2003 have shown how future projections in land use/land cover can aid individuals interested in planning for a regions future.

The current study will now focus on understanding the spatial ramifications of these change trends in likely future and alternative scenarios for the NSW Northern Rivers region.

The Northern Rivers region, as would other rapidly changing regions, will benefit from the study providing visual geographic data of quantifiable change to allow local stakeholders insights to understand and plan for a future where uncertainties are present.

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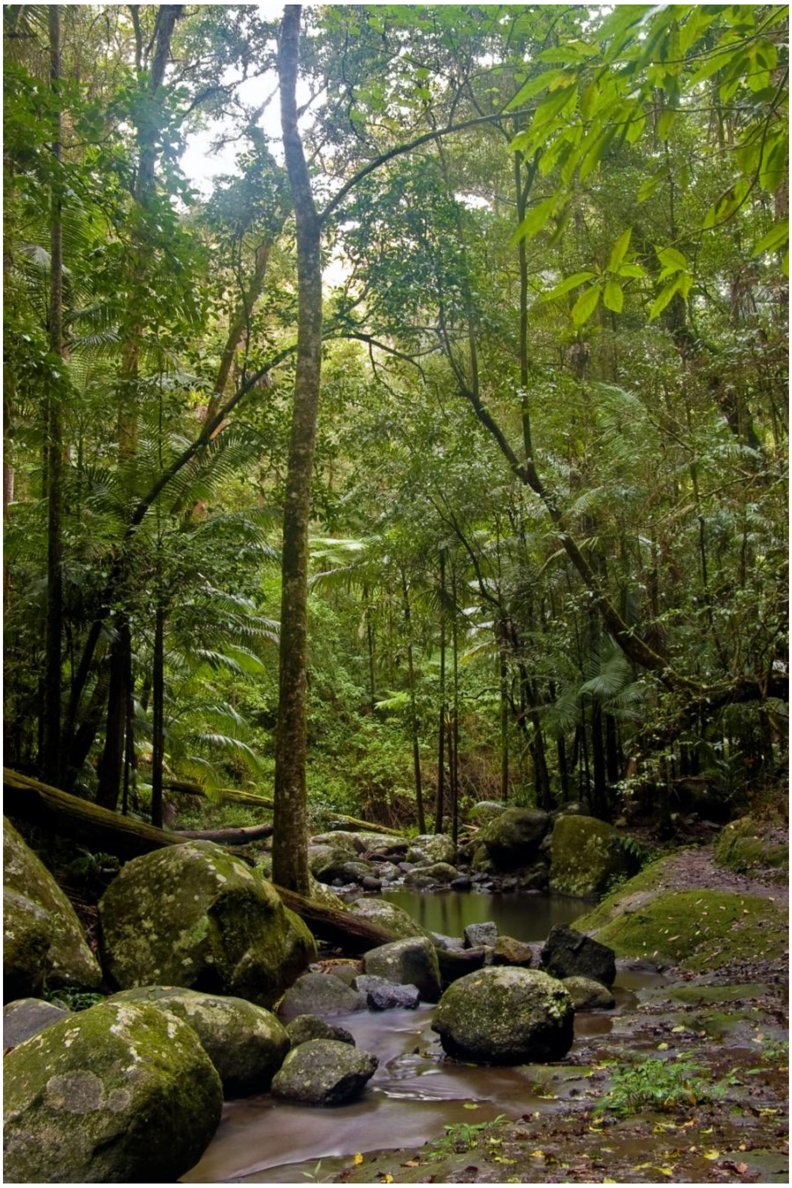
Appendix 2

Urban Lots Program



Border Ranges National Park

I am I plus my surroundings and if I do not preserve the latter,
I do not preserve myself.
Jose Ortega Y Gasset

APPENDIX 2 URBAN LOTS PROGRAM

The "urban lots placement" (URBLOTS) algorithm used to classify cells as 'urban' and predict the spatial location of future populations is based on a cellular automaton approach. It is written in the 'C' language and listed below

```
/*urblot.c
   Program to select urban lots
   Takes two input grids and output grid name:
     argv[1]:  Input buildable distance grid
     argv[2]:  Input buildable grid
     argv[3]:  Output grid
     argv[4]:  Number of lots to select
*/

#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#define numrows 10923
#define numcols 7762
#define strmax 100
#define cellsize 25

int builtd[numrows+1][numcols+1];/*Distance to built cell grid*/
short int  build[numrows+1][numcols+1], /*Buildable land grid*/
        zone[numrows+1][numcols+1]; /*Output zone grid*/
```

```
main(argc,argv)
 int argc;                  /*Input number of arguments*/
 char *argv[];              /*Input grids as described above*/
 {
  int countrow,             /*Counts number of rows*/
      countcol,             /*Counts number of columns*/
      numzones;             /*Number of zones to select*/
  FILE *fpout;              /*File output pointer*/

  int readindata();
  int zoneselect();
  int housealloc();
  int outputdata();

/*Reads in data and does global array initialization*/
  printf("Reading in data...\n");
  sscanf(argv[4],"%d",&numzones);
  readindata(argv[1],argv[2]);

/*Allocates houses*/
  printf("Allocating houses...\n");
  housealloc(numzones);

/*Prints out houses*/
  printf("Writing output housing file...\n");
  outputdata(argv[3]);

 }/*main*/
```

```
/******************************outputdata***********************************/
int outputdata(outfile)
/*Writes output house file*/
 char outfile[strmax];
  {
   int ctrows,             /*Row Counter*/
       ctcols;             /*Column Counter*/
   FILE *fpout;            /*Output file pointer*/

   fpout = fopen(outfile,"w");
   fprintf(fpout,"ncols        %d\n",numcols);
   fprintf(fpout,"nrows        %d\n",numrows);
   fprintf(fpout,"xllcorner     404280.459535\n");
   fprintf(fpout,"yllcorner     6629705.547908\n");
   fprintf(fpout,"cellsize      %d\n",cellsize);
   fprintf(fpout,"NODATA_value  0\n");
   for(ctrows = 1;ctrows <= numrows;ctrows++)
    {
     for(ctcols = 1;ctcols <= numcols-1;ctcols++)
      fprintf(fpout,"%d ",zone[ctrows][ctcols]);
     fprintf(fpout,"%d\n",zone[ctrows][numcols]);
    }/*for*/
   fclose(fpout);
 }/*outputdata*/
/*****************************************************************************/

/*****************************zoneselect*************************************/
```

```
int zoneselect(rowat,colat,percentin)
/*Allocates an entire zones buildable land as houses*/
 int rowat,                /*Current row number*/
     colat;                /*Current column number*/
 float percentin;          /*Percentage that rand number has to be at for lot*/
 {

  float randthresh;        /*Random Threshold number*/

  srand((unsigned int) (time(NULL) + rowat + colat));
  randthresh = rand() % 100;
  if (randthresh <= percentin)
   {
    zone[rowat][colat] = 1;
    return(1);
   }/*if*/
  return(0);
 }/*zoneselect*/
/*************************************************************************/

/*******************************housealloc*********************************/
int housealloc(maxlot)
/*Allocates houses*/
 int maxlot;               /*Number of lots to allocate*/
 {
  int ctrows,              /*Row Counter*/
      ctcols,              /*Column Counter*/
      mindist,             /*Minimum search distance*/
```

```
    lastmindist,        /*Last minimum built distance*/
    nummindist,         /*Number of cells at minimum distance*/
    zoneminalloc,       /*Number of zones to allocate at mindist*/
    lotcount;           /*Number of currently allocated lots*/
  float percentall;     /*Percentage of houses to alloc. at mindist*/

  lastmindist = lotcount = 0;
  while(lotcount < maxlot)
   {
    mindist = 100000;
    for(ctrows = 1;ctrows <= numrows;ctrows++)
     for(ctcols = 1;ctcols <= numcols;ctcols++)
      if(build[ctrows][ctcols] > 0)
       if((builtd[ctrows][ctcols] < mindist) && builtd[ctrows][ctcols] >
lastmindist)
        {
         mindist = builtd[ctrows][ctcols];
         nummindist = 1;
        }/*if*/
       else if(builtd[ctrows][ctcols] == mindist)
        nummindist++;
    lotcount = lotcount + nummindist;
    lastmindist = mindist;
   }/*while*/
  lotcount = nummindist = 0;
  for(ctrows = 1;ctrows <= numrows;ctrows++)
   for(ctcols = 1;ctcols <= numcols;ctcols++)
    if(build[ctrows][ctcols] > 0 && builtd[ctrows][ctcols] < mindist)
     {zone[ctrows][ctcols] = 1;lotcount++;}
```

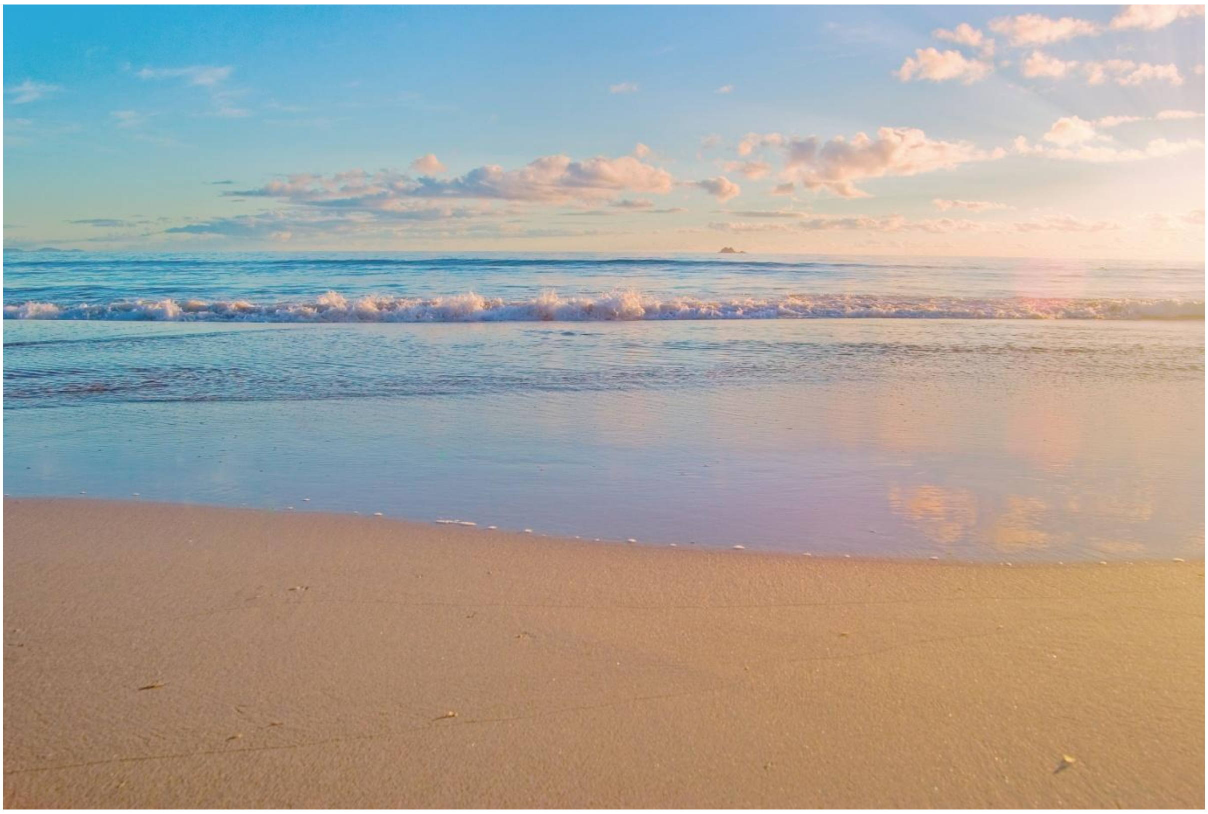
```
   else if(build[ctrows][ctcols] > 0 && builtd[ctrows][ctcols] == mindist &&
builtd[ctrows][ctcols] > 0)
    nummindist++;
  zoneminalloc = maxlot - lotcount;
  percentall = zoneminalloc * 1.0 / nummindist * 100;
  nummindist = 0;
  ctrows = ctcols = 1;
  while (nummindist < zoneminalloc)
   {
   if(build[ctrows][ctcols] > 0 && builtd[ctrows][ctcols] == mindist &&
zone[ctrows][ctcols] != 1)
     nummindist = nummindist + zoneselect(ctrows,ctcols,percentall);
   if(ctrows == numrows) ctrows = ctcols = 1;
   else if (ctcols == numcols){ctcols = 1; ctrows++;}
   else ctcols++;
   }/*while*/
 }/*housealloc*/
/***************************************************************************/

/******************************readindata************************************/
int readindata(zonenm,buildable)
 /*Reads in input*/
 char zonenm[strmax],         /*Name of zone grid file*/
     buildable[strmax];     /*Name of buildable grid file*/
 {
  int ctrows,               /*Counts through number of rows*/
     ctcols,               /*Counts through the number of columns*/
     valin,                /*Value being read in*/
     countreturns;         /*Counts through header lines*/
```

```
char inchar[strmax];       /*Dummy character string*/
FILE *fpzone,              /*File pointer zone file*/
     *fpbuild;             /*File pointer buildable file*/

fpzone = fopen(zonenm,"r");
fpbuild = fopen(buildable,"r");

/*Reads through the headers*/
for (countreturns = 1;countreturns <= 6;countreturns++)
 {
  fgets(inchar,strmax,fpzone);
  fgets(inchar,strmax,fpbuild);
 }/*for*/

/*Reads through number of lines*/
for(ctrows = 1;ctrows <= numrows;ctrows++)
 {
  for(ctcols = 1;ctcols < numcols;ctcols++)
   {
    fscanf(fpzone,"%d ",&valin);
    builtd[ctrows][ctcols] = valin;
    fscanf(fpbuild,"%d ",&valin);
    build[ctrows][ctcols] = valin;
   }/*for*/
  fscanf(fpzone,"%d\n",&valin);
  builtd[ctrows][numcols] = valin;
  fscanf(fpbuild,"%d\n",&valin);
  build[ctrows][numcols] = valin;
```

```
  }/*for*/

 /*Closes file*/
  fclose(fpzone);
  fclose(fpbuild);
 }/*readindata*/
/*****************************************************************************/
```

Appendix 3

AML Script Sample



Byron Bay Beach

Creativity can solve almost any problem. The creative act, the defeat of habit by originality, overcomes everything.

George Lois

APPENDIX 3 AML SCRIPT SAMPLE

This is a sample of the Arc Macro Language (AML) script used for the generation of each scenario. This script contains the locations of the relevant GIS raster maps and future population levels for each zone. Modified for each population level and scenario, it was used to iteratively call and provide the required data to the URBLOTS algorithm (Appendix 2). As the URBLOTS program was not originally designed to consider population density the sum of the population and urban density was calculated externally for each zone (termed 'shires' within this script). The resultant figure is then used as 'population' within this script and the value for each zone is listed as a percentage of the total regional population (passpop).

Start script

```
/*minimal constraints scenario population 403839
/* paths
&s .cpath c:\workspace\working08\ag\scen_400k\amls
&s .bound c:\workspace\core_gis\mask
&s test
&s .zones c:\workspace\working08\ag\scen_400k\zones
&s .buildable c:\workspace\working08\ag\scen_400k\buildable
&s .buildeuc c:\workspace\working08\ag\scen_400k\buildeuc

/* regional population
```

```
&s .passpop 474015
&s .cellsize 25
&s .elevbreak 400

/* number of zones and percentage of population (passpop) per zone
&s .maxshires 6
&s .shire1 .00964
&s .shire2 .03626
&s .shire3 .08242
&s .shire4 .61435
&s .shire5 .12966
&s .shire6 .12767

/* check data exists
&if ^ [exists %.buildable% -grid] &then &do
  &type no buildable grid...
  &type ending program...
  &return
&end
&if ^ [exists %.zones% -grid] &then &do
  &type no zones grid...
  &type ending program...
  &return
&end
&if ^ [exists %.buildeuc% -grid] &then &do
  &type no buildeuc grid...
  &type ending program...
  &return
```

```
&end

&s .urban 1.00
&s .urbdiv 25 /*1 cell (1 house)
&s .urbatt 1

&if [show program] <> GRID &then
  grid

setmask %.bound%
setcell %.bound%

/*Does urban stuff
&s .backfile urblots
&call urban

&return

/*****************************************************************
/*  urban
/*****************************************************************
&routine urban
&s urbtotpeople [calc %.passpop% * %.urban%]

zbuiltprox = con(isnull(%.buildeuc%) > 0,0,%.buildeuc%)
zbuiltprox.asc = gridascii(zbuiltprox)

/* Process a shire
```

```
&do count := 1 &to %.maxshires%
  zbuildable = con(isnull(selectmask(%.buildable%,con(%.zones% ==
%count%,1))) > 0,0,1)
  &s .urbpeople [calc %urbtotpeople% * [value .shire%count%]]
  &s .outfile zurb%count%
  &call urbanlots
  kill zbuildable all
&end

&s textstring zurb1
&do count := 2 &to %.maxshires%
  &s textstring %textstring%,zurb%count%
&end

%.backfile% = con(merge(%textstring%) > 0,%.urbatt%)
kill zurb1 all

&do count := 2 &to %.maxshires%
  kill zurb%count% all
&end
&sys del zbuiltprox.asc
kill zbuiltprox all
&return
/*****************************************************************

/*****************************************************************
/*  urbanlots
/*****************************************************************
&routine urbanlots
```

```
&type ***Urban lots to add is %.urbpeople%...***

/*&do count := 1 &to 4
&s count 1
  q
  &s passpeople [round %.urbpeople%]
  gridascii zbuildable zbuildable.asc value
  &type urblot zbuildable.asc zbuiltprox.asc zurbback.asc %passpeople%
  &sys %.cpath%/urblot zbuiltprox.asc zbuildable.asc zurbback.asc
%passpeople%
  &sys del zbuildable.asc
  asciigrid zurbback.asc zurban%count% int
  &sys del zurbback.asc
  grid
  setwindow zbuiltprox
  zbuildablea = selectmask(zbuildable,con(isnull(zurban%count%) > 0,1))
  kill zbuildable all
  copy zbuildablea zbuildable
  kill zbuildablea all
/*&end
copy zurban1 %.outfile%
kill zurban1 all
&return
/*****************************************************************
```

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Litoria Caerula (Green Tree Frog), Mt Warning

Look at every situation as if you were in the future
and you were looking back on it.
General Peter Schumaker

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