# Chapter 1

## Introduction

Rainbow Lorikeet and Coastal Banksia

*It is change continuing change, inevitable change,*

*that is the dominant factor in society today*

*Isaac Asimov*

# CHAPTER 1 INTRODUCTION

Throughout the world landscapes have been modified over time to meet the needs of humans. Although change is normal for all systems, this reshaping of landscapes and regions to meet our urban, agricultural and industrial needs has changed the structure and function of ecosystems at local and regional scales (Norton & Ulanowicz 1992; Power 1996; Essex and Brown 1997; Turner *et al.* 2001)

While the interaction of social and ecological systems produced new desirable properties for humanity, the modification of a landscape structure and composition affects key ecological processes that govern the movement and low of energy, nutrients, water and biota (Forman & Godron 1986; O'Neill & Ritters 1999). The type, extent and rate of changes caused by these interactions can subsequently over-stress interdependent systems leading to a loss in ecosystem function, services and amenity (Johnson *et al.* 1999; Herce *et al.* 2003; Gunderson & Holling 2002; Brunckhorst 2000, 2005)

Landscapes are often defined by the function of their interacting ecological processes and patterns (Forman & Godron 1986; Hansen & DiCastri 1992, Forman 1995; Turner *et al.* 2001). However, landscapes are also a human construct because they include people and communities, economies, resource production and political institutions interacting with other elements of biodiversity and ecological systems (Brunckhorst 2002). As an important influence on human perceptions landscapes provide a useful framework for guiding our expectations (and actions) towards shaping how we wish our environment to appear now and in the future (Cantrill & Senechah 2001; Lindley & McEvoy 2002; Field *et al.* 2003; Stewart *et al.* 2004; Dortmans 2005).

In Australia, the majority of the population lives along a narrow coastal fringe and in recent decades the rate of migration to beach-side areas had been increasing (Walmsley & Sorenson 1992; ASoEC 2001; Graymore *et al.* 2002). The term 'sea-change' refers to the intra and interstate migration from city and metropolitan locales to smaller coastal settlements in the hope of improved lifestyle benefits (Murphy 2002; Burnley & Murphy 2004; Gurran *et al.* 2005).

This movement of people creates demand pressuring local governments and policy makers for urban and peri-urban land releases, housing development and for the provision of quality infrastructure. Planners and government institutions are also under pressure to provide these services in both a social and ecologically sustainable manner (Westcott 2004).

The demands of sustainability require the preservation or improvement of local economies, lifestyle and culture as well as the conservation of ecological integrity at a local site scale through to broader, regional scale ecosystem health and function. Single issue or narrowly focused approaches, including incremental planning on an annual basis are unlikely to provide solutions or sustainability benefits. Furthermore these demands are expected to be applied not only to newly developed areas, but also to redesign already modified landscapes and regions (Johnson & Hill 2001; Terkenli 2005).

Remote imagery and spatial analysis technologies have started to provide relevant information on the distribution patterns of human communities, ecological systems and processes as well as the understanding of the products of social-ecological systems interactions (eg., Mouat *et al.* 1993; O'Neill *et al.* 1999; Jones *et al.* 2001; Kepner *et al.* 2002; Turner 2003). Such spatial data and analysis systems provide an improved policy and planning capacity for regional landscapes by increasing knowledge of progressively limited options and assessment of the spatial patterns of influencing variables or externalities so that more sustainable outcomes can be enabled (Brunckhorst *et al.* 2008; Field *et al.* 2003; Batabyal & Nijkamp 2004).

Hence with multi-scale spatial analysis tools a regional landscape approach provides for the study of spatial patterns and processes of complex interacting social and ecological elements (Slocombe 1983; Forman 1995; Brunkhorst 2000). It also allows for the influence of these elements on the sustainability of regional development and land use to be examined (Brand & de Bruijn 1999; Irwin & Geoghegan 2001; Von Malmborg 2004; Batabyal & Nijkamp 2004). Furthermore, analysis of the past trends of the changes of landscape elements and their interactions over time, allows for the modeling of future trends and for the future land use characteristics to be visualized with acceptable precision (Yang & Lo 2003; Cohen & Goward 2004; Syphard *et al.* 2005).

Alternative future landscape research is a spatially explicit approach to:

1. Understand and analyse cumulative sources of land use change over time;
2. Understand changes in the composition pattern, distribution and processes of regions;
3. Compare changing conditions within an explicit social-ecological spatio-temporal context; and
4. Consider and evaluate design of planned change or modifications to landscape elements to enhance the interaction of social-ecological systems towards more sustainable futures.

This thesis presents a framework and applied research application to a case-study region for the design or redesign of landscape elements towards future sustainability that is adaptive to pressures of change from population migration and urban growth. The Alternative Landscape Futures Assessment approach allows for explicit examination of the interactions of changing elements, specific to a spatial social-ecological context. This provides the capacity to visualize and analyse the future effect of present day decisions of modifications to landscape processes, and hence to adjust decisions and plan for the long-term. These methods seek, not to generate the 'panacea' as a single solution, but to provide through visualization (maps and quantifying affects tables of areas of landscape change to particular elements) a clearer understanding of:

1. where past/current trends are leading in the future;
2. options about what elements might be changes, redesigned or redistributed;
3. alternative future scenarios for a region;
4. visualization (maps) of what elements are changing where for each scenario; and
5. quantification of impacts and/or flow-on affects (tables of areas of landscape elements changed) for each scenario.

This approach should lead to more effective and well informed planning and decision making for planners, communities and governments at local to regional scales (eg Dunlop *et al.* 2002; Steinitz *et al.* 2003; Hulse *et al.* 2004; Brunckhorst *et al.* 2008).

## 1.1 RESEARCH AIMS AND QUESTIONS

The alternative landscape futures research presented here is the first application of an alternative landscape futures scenario design and analysis, based on Steinitz (1990, 1995) in Australia. The research was applied to the rapidly changing Northern Rivers region of New South Wales, Australia. This region exhibits considerable diversity and population change pressures on a number of scales. In particular the region contains a diverse mix of city, town and rural communities which, in terms of population growth and urban development range from one of the fastest growing locations in Australia to small towns and villages which have experienced a decline in population.

A number of agricultural land uses whose fluctuating extent compete spatially with new urban, commercial and industrial development as well as ecotourism operations, national parks and other environmental concerns. Regional landscapes contain a diversity of ecological systems from world heritage temperate rainforests to wetland (*melaleuca*) forests, coastal heath and mangroves. The region also has a large number of rare, threatened and endangered vegetation species including varieties of endemic flora. These form a number of unique interacting elements that each have a role in the future landscape of the region.

Internationally, the study area is the largest geographical area to which alternative landscape futures analysis has been applied. The size and diversity of the region has presented a number of research challenges which required novel approaches and modified methods. As a consequence, apart from new knowledge about the region, the study contributes valuable methodological enhancements as it developed and applied a multi-scalar and multi-zonal approach.

In relation to methodology, this project aims to combine the two primary methods of future landscape analysis and evaluates the capacity, usefulness and integrity of this process in its application to landscape and bioregional planning within Australia. This involves the combination of past and future trajectory population growth and density trends with the generation of constraints based scenarios to create possible futures. For application of alternative landscape futures scenario analysis to large heterogeneous regions, the research developed and applied a combined multi-scalar and multi-zonal approach to spatial modeling and analysis that more closely represents landscape contexts within the region. This method is transferable to other regions both within Australia and internationally.

The new knowledge contribution of this research can be broadly summarised as:

- development of a novel 'combined' methodology for alternative landscape futures scenario generation and analysis;
- first application of such methods within Australia;
- the largest spatial area in which these methods have been applied, resulting in a transferable, multi-scaled approach; and
- new understanding of current and future changes (and planned alternatives) for the north eastern New South Wales, Australia.

Due to its size the project applies a multi-scalar approach for representing socially, economically and ecologically diverse landscape elements and effected change. This required the modeling of three factors of population driven urban growth, and the interaction of numerous landscape elements. These contributions are presented diagrammatically in Figure 1.1

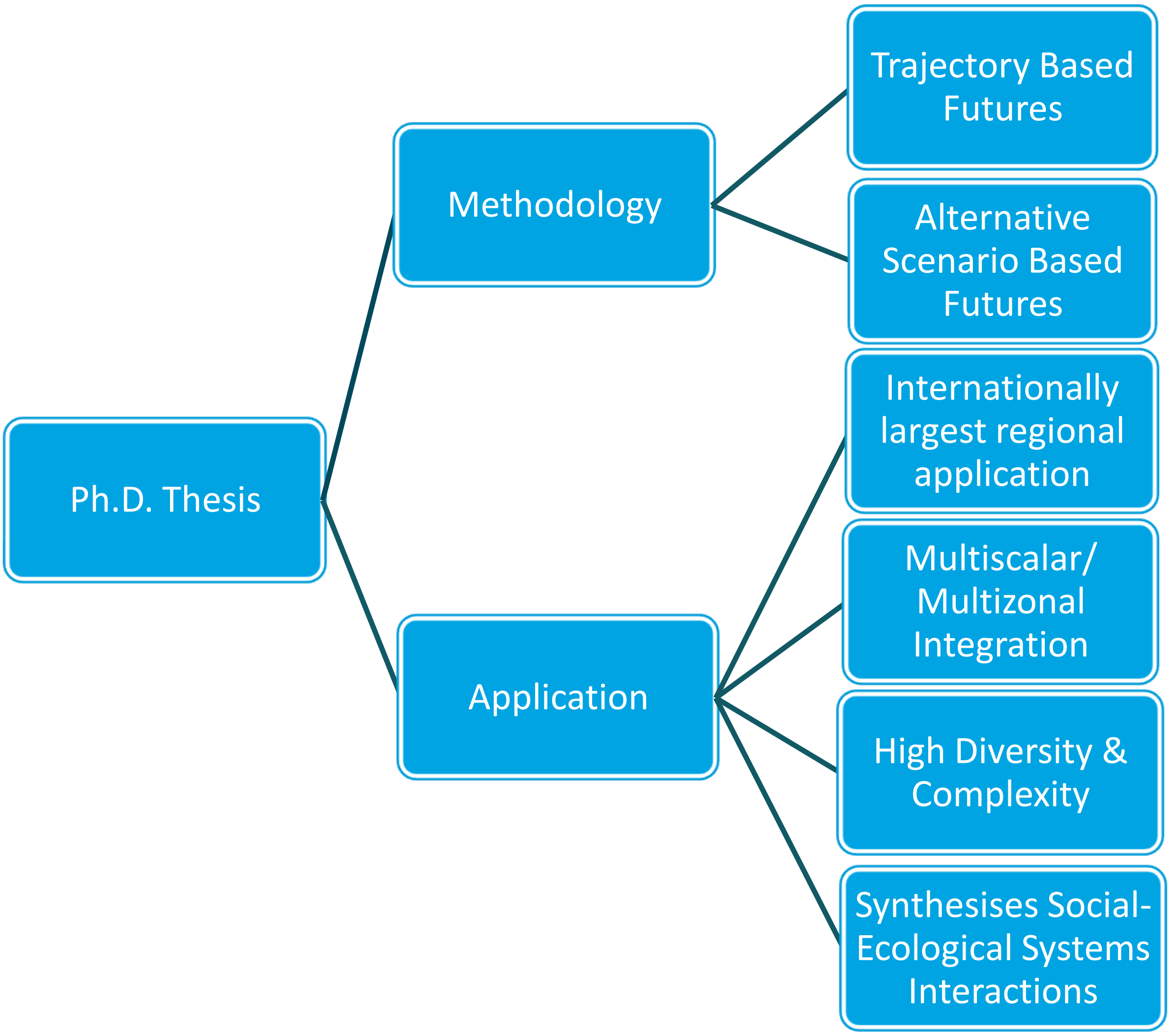



FIGURE 1.1 INTENDED CONTRIBUTIONS OF PH.D.

This research aimed to answer, not just one primary question, but four progressive questions; one specific to methodology and three focusing on the application of future landscape analysis:

1. How can trajectory based and scenario based landscape futures methods be combined for maximum benefit in bioregional planning?
2. How can the international alternative landscape futures research, methods and application be applied to Australian bioregions?
3. What are the factors, issues and considerations that are required for the application of alternative futures modeling within and across large scale bioregions?
4. What is the capacity to utilize alternative futures analysis in areas with considerable social-ecological diversity and variable change pressures?

## 1.2 THESIS STRUCTURE

The thesis is divided into a number of sections. Chapter 2 provides a review of related literature on the need, methods and application of alternative landscape futures approaches and modeling. A contextual introduction to the Northern Rivers region study area, together with a description of a number of concerns and issues specific to the area is identified by local communities, institutions and government bodies in provided in Chapter 3. Chapter 4 describes the main methodology that was used throughout the project. Due to the nature of the methods used, scenario specific methods are excluded from this chapter and presented in each chapter describing specific scenario development, modeling and analysis.  The 'past trends' to future trajectory 'minimal constraints' scenario is described and analysed in Chapter 4.

Each scenario is presented in separate chapters (Chapters 5 to 9). Chapters 6 to 9 present the designed and generated alternative future landscape scenarios.  These scenarios are 'environmental priority', 'agricultural priority', 'agricultural and environmental priority' and 'coastal protection'.  In each scenario chapter, the methodology of how constraints were developed and applied is described, followed by population changes, the visual and quantified landscape (landuse-landcover) changes, including the impact of that scenario on native vegetation within the region.

Chapter 10 is a discussion and analysis of the results of the alternative future scenario methods and of the research questions.  This is followed by a final conclusion.

# Chapter 2

## The Future of Changing places in Changing Spaces: An Overview of the Literature

Hobby Farming

*Change is not merely necessary to life - it is life.*

*Alvin Toffler*

# CHAPTER 2 THE FUTURE OF CHANGING PLACES IN CHANGING SPACES: AN OVERVIEW OF THE LITERATURE

Landscapes and regions represent both spaces and meaningful places. Over time they are changing. Human activity, especially since the industrial revolution, has become a major agent of large scale, rapid change to landscapes and their ecological patterns and processes. Highly visible from space are the enormous changes to the livable coastal fringes of all continents.

These elements of social-ecological systems interaction and interdependencies are influencing, directing or limiting thought of futures now. Changing places in changing spaces also influences how we might think about probable or possible future change. This chapter provides a brief overview of some literature relevant to the critical elements of rapid urbanisation of coastal areas and some landscape and regional ecology planning approaches towards understanding the future of such regions.

The inter-disciplinary nature of this research precluded an exhaustive disciplinary literature review, and therefore focuses more broadly across disciplines for contributions relevant to this particular study, rather than detailed analyses of contributions within specific disciplines (e.g. urban planning, economics, sociology, conservation biology)

## 2.1 SPATIAL PLANNING

The goal of spatial planning is to match land types with land uses in the most rational and sustainable manner and thereby achieve a balance between the needs of the individual, the needs of society as a whole and the environment (McLoughlin 1986, McHarg 1992, Lyle 1999). Allocation of the rights to use and develop land attempts to resolve both current and potential conflicts over the spatial arrangement of activities that inevitably arise (Hall 1982; Vigar *et al.* 2000). Complications and conflicts arise in deciding the allocation of priorities due to socially valued qualities and the variance in locational advantages of places (McLoughlin 1986; Campbell & Fainstein 1996). As places and society become more urbanised the greater the likelihood of complexity and conflict over access to space and development opportunities, environmental externalities affecting other users, and comprised ecosystem services (Campbell & Fainstein 1996; Vigar *et al.* 2000; Ruhl *et al.* 2007).

Spatial planning is concerned with the way in which land is allocated to specific land uses. It has the capacity to influence and achieve a level of social, economic development and environmental management (Fabos 1985; Guttenberg 1993). Ideally this allocation of land would serve to satisfy the diverse needs of society and provide for a balanced "triple-bottom-line" by creating the provision for multiple demands such as sustainable economic development and primary production along with the conservation of cultural and ecological heritage and ecosystem functional (Fabos 1985; Farthing 1997; Conacher & Conacher 2000). Figure 2.1 summarises a number of the participants and relationships that are typical in a planning system.

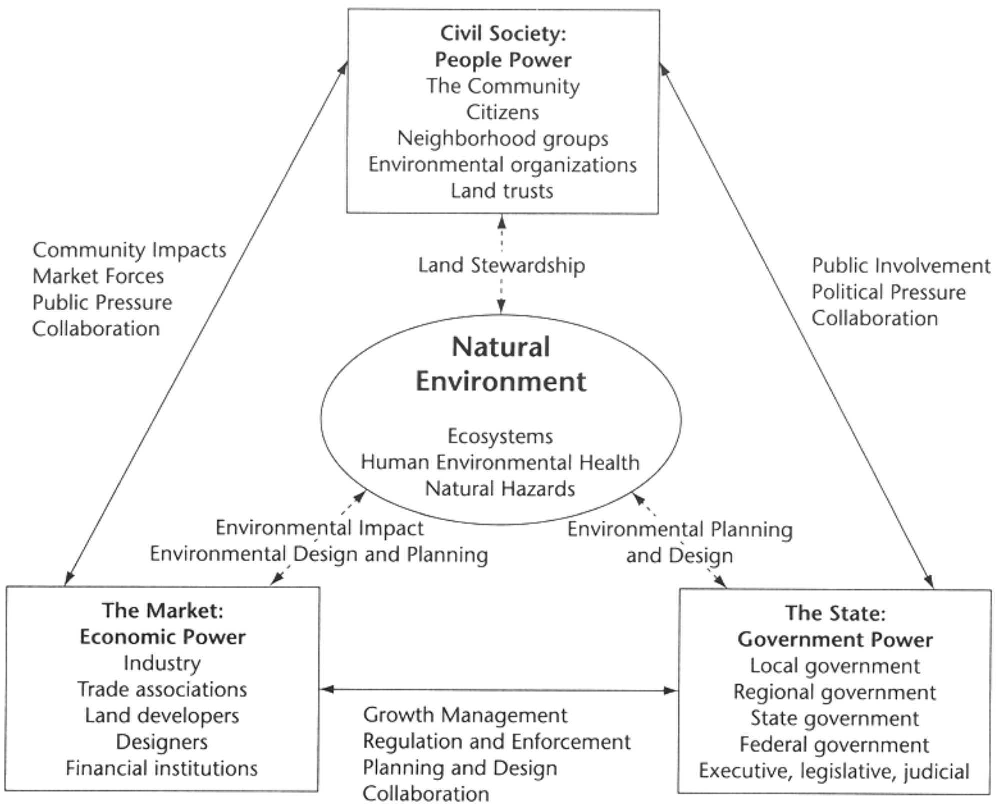



FIGURE 2.1 PARTICIPANTS AND RELATIONS IN A PLANNING SYSTEM (RANDOLPH 2004, P.6)

The considerable variance in scale that must be considered in planning of the use of any parcel of land or resource is also captured by Randolph (2004) in the figure. Stakeholders include local citizens, regional institutions, through to federal governments, all of whom may have differing perspectives regarding the best outcome for a given space. Even minor local developments may raise issues of concern or questions at regional, state, national or international levels (Dollery & Marshall 1997).

Ideally planning and policy systems need to have a strong local focus (Pearson 1994; Gleeson & Low 2000) yet be able to consider actions and the consequences of decisions on much broader scales. Local responsibility can be a feature of most planning systems with lines of responsibility crossing more than one level of government and other public and private agencies (Dollery & Marshall 1997). However as planning systems and the relationships between land and property are deeply entrenched in nationally specific historical, constitutional and legal arrangements planning methods vary throughout the world.

## 2.2 PLANNING IN AUSTRALIA

In Australia, urban and town planning has traditionally been a role of the local government. This is performed by each local council with the use of statutory planning instruments and aims to provide local services, infrastructure and orderly land use (Alexandra 1994; Dollery & Marshall 1997). These instruments provide a basis for both ‘forward planning’ and ‘development control’ in the form of strategic plans as well as zoning schemes and subdivision control (Ramsey & Rowe 1995; Dollery & Marshall 1997).

In recent decades local governments have also had to become more involved in social, economic and environmental concerns. Local governments have concern for access to services, developing better communities and the perceived quality of life of local residents. Councils have also needed to develop economic development policies and strategies to improve employment opportunities and boost local economies. Environmentally, local planning must now develop environmental plans and consider ecosystem services, catchment management. The RIO UNCED Declaration known as Agenda 21 had a component directed at local government. This declaration covers a wide range of issues, including sustainable development, land degradation, and the conservation of biological diversity (UNCED 1992).

Generally, however, local governments are often not funded to follow through in undertaking and applying environmental strategies. In order to achieve these aims and requirements some local governments are increasingly working with local interest groups, neighbouring councils, regional agencies and various government and non government organisations. A consequence of this larger scale collaboration involves a shift towards considering integrated planning and development inclusive of communities, but on a regional scale (Shannon 1992; Johnson *et al.* 1999; Brunckhorst 2000).

### 2.2.1 REGIONAL PLANNING IN AUSTRALIA

Over the last decade regional development has attracted renewed policy interest in Australia resulting in a proliferation of local and regional development programs and policies (Cooke *et al.* 1998; Beer 2000; Gleeson & Low 2000). A complex approach to regional planning has evolved, having a large number of institutions and agencies involved in various planning activities (Beer 1997). These organisations however, are generally narrowly focused and concerned with either a singular or small range of activities within a specified region. Although an issue or area of priority between these groups sometimes overlaps, the perceived best method of achieving goals may differ or have conflicting views and is subsequently approached individually, leading to further fragmented planning, development and management. Such institutions and agencies are often supported by local government, a community group, or may be mandated by state or federal government. For example, many regions now contain one or more business enterprise centres, regional development boards, and possibly multiple Catchment Management Groups.

The 'tyranny of small decisions ' (Odum 1982) seems to remain, perhaps occurring in this century at larger scales (Gurran *et al.* 2005). In the past decade in Australia, and particularly further since the publishing of *Blueprint For A Living Continent* in 2002 (Cullen *et al.* 2002), natural resources and biodiversity conservation, policies and management has increasingly focused on natural resource governance around catchment boundaries. However the scale of operation, activities and spatial boundaries of catchment management groups differs from local governments, community interest and other organisations within the region (Brunckhorst *et al.* 2008).

The mismatch of spatial and authoritative jurisdiction between agencies has inevitably led to a fragmented approach to regional planning with regional development policies being inadequate, partial and lacking integration (Lynn 2005, Reeve & Brunckhorst 2007). Consequently, regional planning has not necessarily resulted in better quality of life for communities (Beer 2000). Beer (2000) suggests that with the withdrawal and restructuring of public services, decline in many agricultural commodities, and persistently high levels of unemployment, non-metropolitan regions now face even greater pressure than in the past.

In coastal areas, many of these non-metropolitan regions have experienced high levels of population growth in the past few decades as people have migrated from inland areas, regional and capital cities (ABS 2004b). This increases pressures on coastal environments, ecosystem and community services and infrastructure as well as community cohesion (ABS 2004c).

## 2.3 MIGRATION WITHIN AUSTRALIA AND THE 'SEA CHANGE' PHENOMENON

The majority of Australians live in seven of the eight capital cities within 20 kilometres of the coast (ABS 2004b). Approximately four million people live in Australian coastal areas outside the capital cities (ABS 2004b). Demographer, Bernard Salt has estimated that the rate of population growth in some of these coastal areas is over 50 percent greater than the national average and that the coastal population will increase by a further million people over the next 15 years (Salt 2004).

Until recently, a common perception was that this coastal population growth was predominately people retiring to the coast. However the Australian Bureau of Statistics (ABS 2004b) states that four out of five 'sea-changers' are aged less than 50 years old. The Bureau's report shows that the greatest proportion of people moving to coastal areas were aged around 20-30 years of age with the age distribution is shown in Figure 2.2

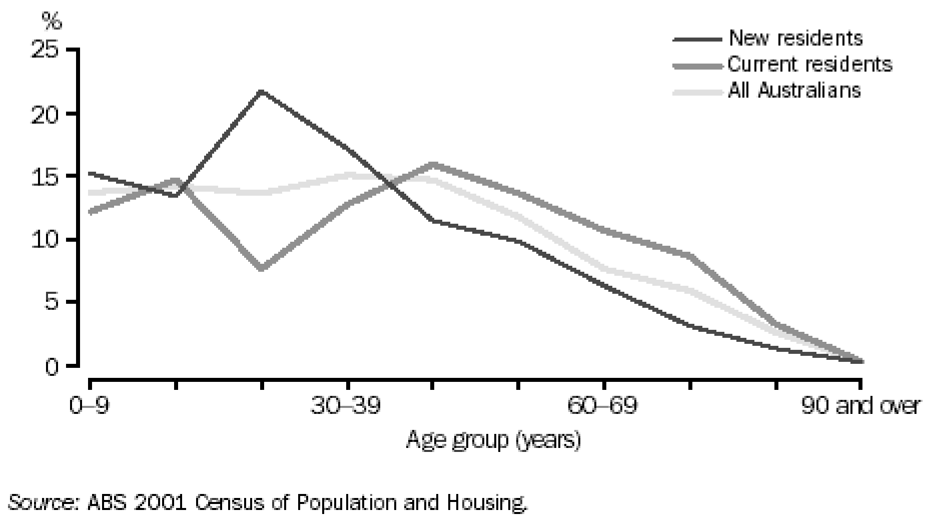



FIGURE 2.2 AGE DISTRIBUTION OF PEOPLE MOVING TO COASTAL AREAS (ABS 2004B, NP)

Another preconception is that 'sea-changers' are moving from capital cities (ABS 2004b), however this is only true in approximately one third of all cases. Some 42 percent of people moving to coastal areas had moved from other large population centres and the remaining 27 percent migrated from country areas (ABS 2004b).

Stimson and Minnery (1998) state that the motivation to move comes from a combination of reasons which can be categorised into those that 'push' people to leave a region, and those that 'pull' or attract people to a new region. In both cases these factors are primarily based on perceptions of environmental and lifestyle benefits (Hugo & Smailes 1985; Sant & Simons 1993; Burnley & Murphy 2002), with a lesser extent attributable to welfare-led migration (Burnley 1996; Hugo & Bell 1998). Marshall *et al.* (2005) considered the price of housing and accommodation to be a key factor for in-migration. The proportionally high cost of housing in metropolitan centres may allow for down-sizing or a capital gain to be made by moving. Similarly, the availability of low cost housing in smaller coastal towns is attractive to many 'sea-changers', particularly those of low income (Marshall *et al.* 2005). Other lifestyle factors include seeking a better climate, desire to leave the congestion of the city, proximity to family and friends, rising personal aspirations, and the aesthetics of surrounding landscapes (Stimson & Minnery 1998; Trewin 2004).

The decision to make a 'sea-change' may also be influenced by employment opportunities as jobs and business opportunities follow population growth. However, much of the residential demand in sea change localities leads primarily to growth in the service and tourism industries (Gurran *et al.* 2007). For people currently unemployed or already employed within these industries the availability of this type of work, coupled with more affordable housing may be attractive.

In the past decade above average rates of population growth have been experienced by a number of coastal locations, including Broome, Derby and Esperance in WA, most of the New South Wales coastline, selected cities in the mid north coastal areas of Queensland and the Sunshine and Gold Coasts (ABS 2004b). While the perception is that the growth is entirely in small towns and villages, Salt (2004) observed that the shift to the coast is occurring on such a scale that in 2004, the Gold Coast had become a larger population base than Canberra and the Sunshine Coast, and replaced Hobart as the tenth largest urban centre in Australia (Salt 2004).

Study of the past, current and future trends of in-migration is important because the redistribution of population to coastal areas has dramatic short and long term impacts on the social, environmental and economic processes of an area (Hugo 1996; Hugo 2002; Burnley & Murphy 2004; Gurran *et al.* 2005). Consequently, these issues raise many planning challenges for governments and agencies involved in the planning for large levels of rapid population growth.

### 2.3.1 EFFECTS OF POPULATION MIGRATION AND DEVELOPMENT IN COASTAL AREAS

The pressures associated with population growth in coastal areas result in many environmental, social and economic consequences. Unlike growth corridors in outer metropolitan areas, coastal areas have rarely been planned with a strategy of managing high growth rates. Planning authorities in coastal areas are faced with significant challenges when dealing with the social, environmental and economic issues related to rapid growth (Gurran *et al.* 2007). This growth is not only an Australian phenomenon. For example, in the United States large numbers of 'sea-changers' moved to small coastal townships in Oregon. Development and the effects of high population growth eventually destroyed the original community character that was attractive and many 'seachangers' consequently moved again to another town with a more appealing coastal ambience (Gurran *et al.* 2006).

Coastal population growth brings with it both social and economic changes. Population growth leads to increased demand for infrastructure, such as roads, mains water supply, sewerage, and power as well as essential services, including public transport, health care, emergency services and education facilities (NRMMC 2003). In the case of retirees, problems arise over their transition to specialised retirement accommodation where such facilities are not available locally. Many also find themselves separated from family and friends when they are heading into a stage in their life when they are most likely to need support from friends and relatives (Burnley & Murphy 2004; Gurren *et al.* 2005).

Although growth stimulates employment opportunities, the new jobs are generally in lower paid occupational sectors such as retail, restaurants, tourism, and care-giving. These types of jobs are often part time and in many cases subject to seasonal fluctuations (O'Connor 2004, Stimson *et al.* 2003). Many non metropolitan coastal communities therefore experience constant or seasonally high levels of unemployment, lower than average household incomes, and greater levels of socio-economic disadvantage along with higher numbers of seniors than other parts of Australia (Vinson 1999; NRMMC 2003). Consequently, there is a disparity between existing residents and newcomers, as well as between the more affluent sea changers and those of a lower income (Gurran *et al.* 2005).

Not only are the local governments of coastal communities attempting to cope with high population growth, they are also facing a dramatic increase in the level of international and domestic tourism (NRMMC 2003). Although tourism provides a number of economic benefits, tourism can have a number of social impacts on local communities, including antisocial behaviour, extra pressures on existing infrastructure and increased traffic congestion (NRMMC 2003). High levels of tourism and the development to cater for this influx also has the capacity to change the nature and identity of a location, which was often the attraction for relocation to that area. This also creates concern for the long term residents of the community.

The environmental implications of 'sea change' migration and increased tourism are also profound. As well as providing the base for extensive human settlement, the coastal zone is biologically mega-diverse, with beaches being the only ecosystem on earth containing representatives from every phyla. Coastal areas are also home to some of the world's most productive and diverse ecosystems such as mangroves, coral reefs and salt marshes (see Ray 1991, Wilson 1992). It is these features that provide the unique coastal environments that attract many people to coastal areas and are consequently under threat from coastal growth and tourism.

Development pressures associated with rapid population growth pose threats to sensitive coastal processes and environments, including coastal inlets, estuaries, dunes, wetlands, and distinctive landscapes. Furthermore, many coastal communities are surrounded by environments of national and international heritage importance, such as national parks, world heritage areas, and marine protected areas. These places are particularly vulnerable to inappropriate development which threatens biodiversity, cultural heritage sites, recreational and tourism values (Gurran *et al.* 2005). The expansion of urban growth also causes problems such as habitat loss and fragmentation, loss and degradation of coastal wetlands, soil acidification, introduction of exotic species and erosion and pollution (Hamilton & Cocks 1996).

### 2.3.2 LOCAL GOVERNMENT CONCERNS IN COASTAL AREAS

As local government areas (LGA) grow in population they have to accommodate major economic, industrial and social activities that increase greater pressure on resources and create significant challenges, some of which become emergent factors beyond the local scale due to interdependent synergies amongst multi-scaled elements (Johnson *et al.* 1999, Brunckhorst 2000). Councils are therefore forced to support a broad range of commercial and non-commercial activities that are dependent on healthy environments. Such activities include for example, tourism and recreation, urban development, aquaculture, shipping and transportation, agriculture, mining, manufacturing and trade (NRMMC 2003).

This greatly increases the issues involved with local planning and meeting the needs of residents and balancing the LGA budget. Local councils typically are left to provide support services with inadequate resources and struggle to meet the continuing demand for infrastructure, such as roads, mains water supply, sewerage, and power. In addition, high growth communities also experience a lack of essential services, such as public transport, health care, emergency services and education facilities (NRMMC 2003, Burnley & Murphy 2004, Gurran *et al.* 2005). There are few options for Australian local council income and the most effective are revenues from developers and more rate-paying residents. This inevitably leads to more land releases in "attractive" areas for residential development.

A 2004 survey of coastal councils across Australia (conducted by the Australian Local Governments Association (ALGA)) identified the five highest priority environmental issues as nominated by councils (ALGA 2004, p11). These issues include:

- *Planning:* Rapid growth and a shortage of planning staff, has placed significant pressure on council resources and severely limits their capacity to undertake and implement much needed strategic planning. Additionally, the strategic planning being undertaken lacks co-ordination between the three tiers of government.

- *Water supply:* The consistent supply of good quality water and providing infrastructure for water provision and treatment were identified as concerns. This in turn influences the ability for towns to expand industry and generate economic growth. [An apparent contradiction occurs in practice (Chapter 10, section xxx) in that water scarcity rarely seems to slow or limit development].
- *Biodiversity conservation:* It was recognised that biodiversity continues to be lost. Managing this issue requires councils to undertake work in this area and for regional NRM organisations to address biodiversity decline in regional strategies.
- *Climate change:* climate change is occurring and LGA's fear that the longer it takes governments to respond to climate change, the greater the cost of undertaking adaption and mitigation activities.
- *Infrastructure provision:* infrastructure provision in many areas is severely lacking and there is a need to undertake maintenance of much of the existing infrastructure.

Policy reviews (e.g. RAC 1993; Westcott 2004; Murphy and Burnley 2005; Gurran *et al.* 2005) have also called for the development of coordinated regional plans by State Governments that would provide an integrated balance with environmental protection along with greater certainty about the extent and limits of urban growth rates in coastal communities. These reviews also suggest that more effective integrated regional planning is considered by many coastal communities to be critical to the management of growth and change in coastal growth areas.

Many coastal communities report that existing regional plans are inconsistent, lack weight, or are out of date. In practice local plans of councils tend to be revised to allow for further urban land releases on a 1-2 year cycle (Lynn 2005). Gurran *et al.* (2005) demonstrates that there are no mechanisms within Australia to fund regional infrastructure and there is extremely limited funding to protect and enhance the natural environment. The authors point to a lack of effective coordination between the three levels of government, which is critical to addressing coastal urban growth. These issues in funding, policy and management exacerbate the enormous challenge already present in dealing with the interactions of these rapidly changing social-ecological systems.

## 2.4 SOCIAL-ECOLOGICAL SYSTEMS AND LANDSCAPE ECOLOGY

### 2.4.1 LANDSCAPE ECOLOGY AND BIOREGIONS

Urban planners are experts in small areas, parks, urban and commercial development. However, focusing at these small scales leads to a fragmented arrangement of patterns and processes across socio-ecological landscapes (Dramstad *et al.* 1996). Landscape ecology focuses the spatial patterns and processes inherent in social ecological systems at a range of scales. Consequently landscape ecology has become an important area of research and knowledge for land use planners and landscape architects during the last two decades (Dramstad *et al.* 1996; Turner *et al.* 2001).

Definitions of the term landscape vary considerably among planners, researchers and other professionals. Landscape ecologists consider a landscape to be a heterogeneous area of land where emergent patterns from ecosystem interactions are that is generally hierarchically structured. (e.g. Forman & Godron 1986; O'Neill *et al.* 1986, 1988, 1999; Slocombe 1993; Turner *et al.* 1989, 2001; Hansen & DiCastri 1992; Forman 1995; Liu and Taylor 2002). 'Bioregion' refers to a group of spatially contiguous and ecologically similar landscapes with a concurrent human attachment to 'place' and local social interactions (Platt 1996, Goble & Hirt 1999; Johnson *et al.* 1999; Brunckhorst 2000, 2001; Brunckhorst *et al.* 2004, 2005; Cheng *et al.* 2003).

Forman (1995, pp. 514-516) lists 12 key principles considered important in planning for future sustainability. These principles are summarised below (Forman 1995).

- *Landscapes and Regions* - A landscape is a spatially heterogeneous area of land with at least one consistently similar element. Multiple contiguous landscapes form a region – the next broader scale of a non-repetitive, coarse grained pattern of landscapes (see Bailey 2002).

- *Patches* - Large vegetation patches are often the only structures in a landscape that maintain and protect surface and ground water and interconnected streams and rivers (see also Dailey 1997).
- *Corridor, Matrix* - The pattern and arrangement of patches, corridor linkages and the collective matrix that constitutes a landscape is the major influence on biodiversity movement, functional flows and change across the landscape (see also Turner 1989; O'Neill *et al.* 1997; Turner *et al.* 2001).
- *Shape* - An ecologically optimum patch shape should maximise core area by minimising boundary length and hence edge effects.
- *Ecosystem interaction* - All ecosystems across a landscape and region are interrelated and interdependent to varying degrees.
- *Species metapopulation dynamics* - Local extinction rates of sub-populations decrease with greater habitat quality, patch size and connectivity across the matrix (see also Cody and Diamond 1975; Crooks and Sanjayan 2006).
- *Landscape resistance* - The arrangement of spatial elements (proximity, barriers, conduits or corridors) creates or influences functional flows and movement, including species, energy,

disturbance and material over a landscape (see also Crooks and Sanjayan 2006).

- *Grain size* - Fine grained patches making up a coarse grained landscape are usually best for large scale ecological, and resource benefits for maintaining biodiversity including humans, and environmental health (Sometimes discussed as fractals; eg. Brunckhorst 2000).
- *Landscape change* - Landscape transformation occurs through spatial processes such as aggregation, accretion, perforation, attrition, fragmentation and isolation which in turn have various effects on ecological processes and patterns (see also Turner *et al.* 2001).
- *Mosaic sequence* - Transformation of land to less suitable habitat for biodiversity occurs to a small number of repeated mosaics (sequences). The ecologically optimal form is considered to be progressive parallel strips from an edge (see also Dramstad *et al.* 1996, Bailey 2002).
- *Aggregate outliers* - An ecologically optimum spatial pattern in human dominated landscapes is best arranged by aggregating land uses, while maintaining small patches, corridors or other forms of linkage throughout developed areas (see also McHarg 1992; Van der Ryn and Cowan 1996).

- *Indispensible patterns* - Unrepeated, non-replaceable, patches of high ecological benefit. To sustain priority conservation patches of this category precedence must be given to the largest, most connected patches (see also Dramstad *et al.* 1996, Crooks and Sanjayan 2006).

Dramstad *et al.* (1996) provides a detailed, illustrated guide to the application of Forman's principles in landscape planning and design. McHarg's (1992), reprint of 1967 edition of *Design with Nature* and Lyle's *Design for Human Ecosystems* (1999) are amongst the most comprehensive guides for urban and regional planning and design which incorporate landscape ecology principles. With increasing use of GIS tools in regional analysis and planning applications, new approaches using combinations of the above principles together with McHarg's and Lyle's design approaches have emerged (for example, Steinitz 1993, 1997; Liverman *et al.* 1998; Kepner *et al.* 2002; Johnson & Hill 2002; Steinitz *et al.* 2003; Terkenli 2005). Other applications of landscape ecology in design for urban and regional planning are provided by Mackenzie (1996), Van der Ryn & Cowan (1996) and Bailey (2002).

### 2.4.2 SOCIO-ECOLOGICAL SYSTEMS

Mumford (1938) characterised the entwined processes of social-ecological systems as producing a distinctively patterned and functioning regional landscape. While landscapes can also be considered a social construct, they are inherently diverse, embodying a multitude of values for their inhabitants (Cheng *et al.* 2003). These values influence socially derived drivers of change. Though society and its economies arise from interactions with the environment, human activity is a major change force shaping landscapes (Figure 2.3). It is the interaction of the human communities, with the ecological systems of a landscape that shape a 'place' and give rise to its social identity (Cheng *et al.* 2003, Brunckhorst *et al.* 2004) and related policy communities interested in deliberating on the future of that place (Shannon 1992, 1998) or region (Johnson *et al.* 1999).

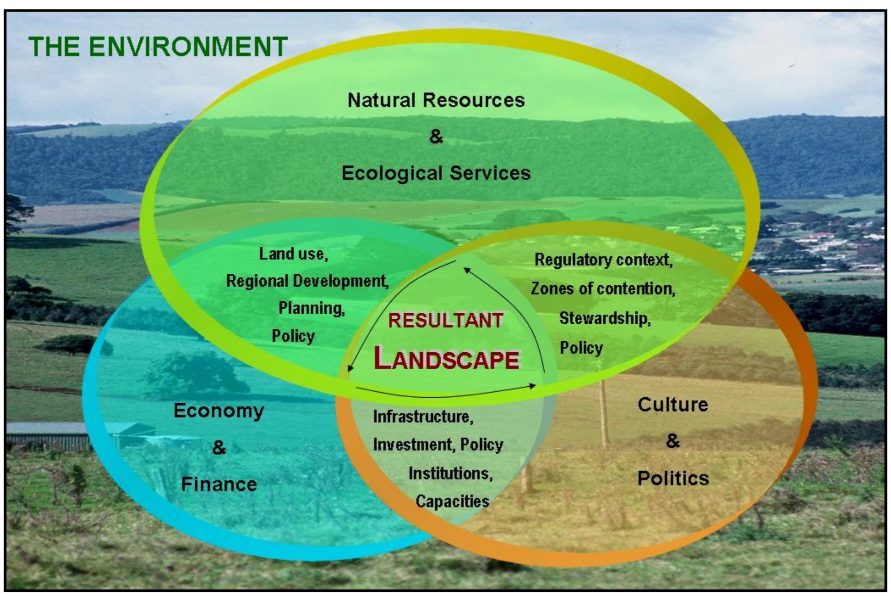



FIGURE 2.3 INTERACTIONS OF ELEMENTS IN SOCIO-ECOLOGICAL SYSTEMS TO FORM RESULTANT LANDSCAPES (BRUNCKHORST 2002, PAGE 109)

In Australia the interaction between landscape, people and place since the beginning of European settlement has dramatically and increasingly changed the natural landscapes and brought many economic and social benefits. The exploitation of natural resources however, often comes at an environmental cost. This generally includes the modification of landscape structure, composition and processes, which in some cases may be linked to continuation of ecosystem and other socio-economic functions.

For instance, agricultural development is essential for food production and has brought profit to many vibrant rural communities and contributed significantly to national economic growth. However, agricultural practices have also led to increased clearing of land and extraction of water for irrigation, resulting in negative impacts on land resources, river health, biodiversity and other sectors of the economy (Dunlop *et al.* 2002).

Similarly, land cover changes may result from various actions, such as clear-fell logging, drainage or other alterations to wetlands, soil degradation in cropping lands, changes in extent and productive capacity of pastoral lands, dryland degradation or changes related to urban infrastructure (Lepers 2005). While these all have benefits for a subset of society, each action produces externalities which tend to have detrimental consequences for other elements with the social-ecological matrix. As the space between social-ecological interactions diminishes such that the scale of externalities can not be described or assimilated less flexible changes emerge (Reeve & Brunckhorst 2007)

Enduring ecological, social and economic sustainability requires integrated planning and management of natural resources, ecological functions and primary production across landscapes (Kim & Weaver 1994; Forman 1995; Lyle 1999; Liu & Taylor 2002). Rural landscapes include people and communities, resource production and related industries, social networks, economies and political institutions, biodiversity and ecological systems. These components operate at various scales (Pattee 1973; O'Neill *et al.* 1986) and also interact at a variety of organisational levels (Goodin 1996; Shannon 1998).

### 2.4.3 SYSTEMS INTERACTIONS

The interaction of ecosystems, social systems and economic systems clearly exhibits characteristics of complex, networked, cross-scale systems that give rise to a diverse range of elements, interacting and influencing one another (Costanza 1993; Gunderson & Holling 2001). As such, research into novel or holistic integrative systems that consider the ecological and social processes that occur and interact at various scales across landscapes require, not only inter-disciplinary methods, but also a multi-theoretical basis (Gunderson & Holling 1995; Shannon 1998; Gunderson & Holling 2001; Brunckhorst 2001).

Non-linear interactions and continual feedbacks characterise complex systems and make the determination of specific cause-effect relationships extremely difficult (Pattee 1973; Gunderson & Holling 2001). Complex systems produce new properties or synergistic influences, referred to as emergent properties due to a myriad of interactions and interdependency. Systems are generally non-additive due to the existence of diverse hierarchies. Emergent properties therefore cannot be discerned from individual components (Pattee 1973; Brunckhorst 2002, Walker & Salt 2006). Higher level combinations can affect a variety of other states or products, in turn facilitating new interactions or dependencies (O'Neill *et al.* 1986, Brunckhorst 2001, 2003).

Local economies, cities, towns and communities are emergent properties of social-ecological systems interactions in a 'place' (Platt 1996, Brunckhorst 1998, 2000). Systems interactions also produce self-organising properties which are crucial for adjustment, repair and maintenance of system functions, and capacities to adjust to pressures of change (e.g. in response to disturbance) and adapt to new circumstances (Walker and Salt 2006). To minimise complexity, but retain the reality of interactions, systems researchers look for boundaries where there are reduced interactions between system elements or other systems (Bailey 2002). In this way hierarchies of interactions can be identified. This capacity can, to some extent, be provided through a place-based, "regional landscape" approach, grounded in landscape ecology theory (Shannon 1992; Kim & Weaver 1994; Brandenburg & Carroll 1995; Forman 1995; Odum 1998; Brunckhorst 2000, 2002).

Furthermore the incorporation of this approach into a long-term, holistic planning perspective that recognises the physical, environmental, ecological, economic, social and cultural decision processes that characterise and control landscape systems has the capacity to reduce the adverse impacts of selective land use change in a complex system (Bailey 2002, Steinitz *et al.* 2003).

### 2.4.4 REGIONAL LANDSCAPE ECOLOGY AND DESIGN IN PLANNING FOR THE FUTURE

Various forms of planning often fall short of considering the spatial configuration of ecological processes and land use intensities, resulting in configurations that can lead to undesirable effects on society and ecosystems (Conacher 1980; Tjallingii 2000; Hersperger 2005).

The landscape scale is the main scale of human interaction with the environment (Lyle 1985; Forman 1995; Platt 1996; Knight & Landres, 1998; Johnson *et al.* 1999). A regional landscape scale of analysis allows effective understanding of emergent and self-organising properties for 'holistic' integration and innovative redesign of human institutions and activities, and their influences across landscapes (Noss 1983; Lyle 1985; Urban *et al.* 1987; Takeuchi & Lee 1989; Johnson *et al.* 1999; Tjallingii 2000; Johnson & Hill, 2001; Brunckhorst 2000, 2002, Gunderson & Holling 2001; Steinitz *et al.* 2003).

A history of policy, decisions, and environmental history has resulted in the landscapes we have to work with and care for today. "Winding back the clock" is not an option. Past change has provided us with our present starting point; however the pressures of change on economies, ecological services and resources, as well as towns and communities appear to be increasing. Across many landscapes, all components are struggling for ecological and economic resilience. Forward looking responses are required to alter the course of unsustainable practices towards much longer term visions of future landscape patterns more likely to provide further adaptive capacity and resilience (see Walters & Holling 1990; Gunderson *et al.* 1995; Walker and Salt 2006).

Local government and regional development also needs to be compatible with the dynamics of the ecological services and resources, and with the social and institutional characteristics of the communities within the landscape. Furthermore these responses must incorporate the identity and 'sense of place' attachment by resident communities and their expectations for the future for that place, as this will frame the future of a region (Shannon 1998; Cantrill & Senechah 2001; Lindley & McEvoy 2002; Field *et al.* 2003; Stewart *et al.* 2004; Dortmans 2005).

Framing long term futures will require the integration of diverse and at times conflicting views, policy, agencies and organisations. Genuine attempts at integration will require changes to the way government and their organisations view regional administrative frameworks and governance, and adaptation or redesign of various organisational forms and institutional arrangements (Brunckhorst *et al.* 2007).

Within developed nations, the policies are turning towards regional and local governance to provide the capacity to integrate policy and practices of numerous social, economic and environmental agencies and institutions into strategic directions which can foster economic health, environmental quality and quality of life (Vigar *et al.* 2000; Wallis 2002). This shift is supported by Haughton who emphasises that regional planning is a 'process that is fundamental to future place-making activities, providing a forum for deciding what types of future settlement patterns society wishes to see' (Haughton 2004, p135).

## 2.5 REMOTE SENSING AND LAND COVER SPATIAL ANALYSIS

Increasingly Geographic Information Systems (GIS) are becoming useful syntheses and analysis tools in assessing the impacts human activities have on social-ecological systems. The combination of GIS with remotely sensed data and landscape ecology theory provides a basis to monitor and assess interactions of scale for social-ecological systems (Liverman *et al.* 1998; O'Neill *et al.* 1999; Alberti & Waddell 2000; Liu & Taylor 2002).

The surfaces of all things reflect, absorb, or transmit different amounts and wavelengths of light along the electromagnetic spectrum (EMS). The wavelengths that are reflected can be recorded by Satellite-based sensors to become the basis for identifying surface components. By collecting this information it is possible to determine characteristics and patterns of the landscape and ground surface. These characteristics can be turned into and mapped representations of land cover for example, information for visualisation, along with tables of spatial data (Bassett *et al.* 2008).

Satellite images, as maps, are digital raster images comprised of rows and columns of cells with each cell containing a number that represents the value at that point. The cells contain digital values that represent the intensity of the band-width of light reflected from surface materials. The reflective characteristics of each cell are compared and clumped together to form spectral signatures characterising the ground features (Bassett *et al.* 2008). In a perfect world, each spectral signature would represent a unique landscape component. This is rarely the case in practice. Many processes and applications have therefore been designed to extract information from digital imagery (Turner 1990; O'Neill *et al.* 1999; Wilson 2005; Corry & Nassauer 2005).

Computer software expedites spatial differentiation and analysis. Each satellite scene is individually classified. The classification process is generally coded to focus first on separating major categories (e.g. water, vegetation, grazing or farmland, urban development) using standard classification techniques (Legrande & Legrande 1998; Turner 1990, 2003; Liu & Taylor 2002). Fieldwork, often referred to as 'ground-truthing', then provides numerous individual areas for correct differentiation in the land cover classification. The mean and covariance statistics for these training areas are passed to an isodata classification algorithm which assigns every unknown pixel to the class in which, due to similarity, it has the highest probability of being a member (see for example, O'Neill *et al.* 1999; Turner 2003; Wilson 2005).

Iterative unsupervised classifications are then undertaken on each major category individually by masking out all other major categories. By masking out all data but a single major category, the spectral variance is greatly reduced, thus decreasing classification errors. After several classification iterations of the masked data, final classification labels are assigned to the spectral clusters. In small areas where land cover class confusion cannot be separated spectrally, human observation based, pattern recognition can be used to recode the data, however a range of other statistical techniques are constantly being developed (Hunsaker *et al.* 1994; Legrande & Legrande 1998; Turner 1990; Dale 1999; Liu & Taylor 2002; Lewis & Brabec 2005). Patterns of land use and land cover can be detected and classified at various scales and classes of identification for various spatial analytical and planning purposes.

### 2.5.1 LAND COVER AND LANDSCAPE CHANGE ANALYSIS

The generation of multiple land cover images allows for the comparison of human and natural landscape pattern changes on spatial and temporal scales. As each cell within an image contains a numerical value there is the capacity for small areas, land use classes or entire maps to be mathematically analysed and manipulated. Manipulation of the spatial extent of one or more land uses can be examined in terms of changes to other classes. Change detection between images is usually accomplished by subtracting the images to highlight differences (non zero values represent a change in classification) (e.g. Pan *et al.* 1999; Jones *et al.* 2001; Weng 2002; Alphan 2003; Vogt *et al.* 2005) or by performing correlation analysis to determine differences (Legrande & Legrande 1998; Verburg *et al.* 1999; O'Neill *et al.* 1999).

Usually, a land cover change analysis will proceed initially with a baseline interpretation or classification for the most recent time period. This baseline creates a mask where for other discrete time slices the pixels that did not change spectrally (i.e. land use did not change) are replaced by the mask values. Hence, only the pixels in images that have changed spectrally are necessary to reclassify and therefore an accurate change mask is critical for an accurate change detection analysis (Apan *et al.* N.D.; Baker 1989; Turner 1990, 2003; Corry & Nassauer 2005).

The change image produced using image differencing usually yields a brightness value distribution approximately Gaussian in nature, where pixels of no brightness value change are distributed around the mean and pixels of change are found in the tails of the distribution. A threshold value is carefully chosen to identify spectral "change" and "no-change" pixels in the change image. A "change/no-change" mask is derived by performing image differencing on TM band 4 (Near Infrared), Normalised Difference Vegetation Index (NDVI), a Principle Components Analysis (PCA), or a combination of the three on the two dates of imagery recoded into a binary mask file (Legrande & Legrande 1998; Dale 1999; O'Neill *et al.* 1999; Pan *et al.* 1999; Jones *et al.* 2001; Kepner & Edmonds 2002). The change/no-change mask is then overlaid onto the earlier date of imagery and only those pixels that are detected as having spectrally changed are viewed as candidate pixels for categorical class change. These candidate pixels are classified in the same manner as the baseline land cover analysis for consistency.

A change matrix is a table of all possible landscape changes and is useful for quantitative interpretation of tabulated results measuring change between classes. Change tables show the exact amount of change, where and what the pixel was, and what it became. Adding pixel area value provides how much an area (usually in Hectares) of land use or land cover class that was converted at that place. The change table matrix is valuable for examining the entire change analysis in one view and can be a powerful tool for evaluating landscape change (e.g., Jones *et al.* 2001; Jackson *et al.* 2004).

Remote imagery derived landscape metrics of regional land cover provide a useful comparative baseline on the state and condition of the region at a given time. This provides the initial step for scenario analysis by describing the landscape in terms of content, boundaries, space and time (Steinitz 1993, 1997; Steinitz *et al.* 2003; Brunckhorst & Mouat 2000; Kepner *et al.* 2002). The measurements of pattern across the landscape provide a predictive inference for measuring and assessing change and provides insights about how the land use of the landscape may be comprised in the future. The combination of landscape change metrics with spatial data of other social, economic, planning and ecological attributes contributes to a comparative evaluation of alternative courses of planning, design and policy action that lead to the decision model (Steinitz 1993,1997; Steinitz *et al.* 2003; Brunckhorst & Mouat 2000; Kepner & Edmonds 2002).

## 2.6 MODELLING FUTURE LANDSCAPES AND LAND USE

There are several methods and applications for the modelling and future prediction of land use change within academic literature (for example see Kok *et al.* 2001; Kok & Veldkamp 2001; Schoorl & Veldkamp 2001; Irwin & Geoghegan 2001; Veldkamp & Lambin 2001; Jackson *et al.* 2004; Syphard *et* *al.* 2005, Clarke 2007). This prediction group of models use past trends to extrapolate future trajectories of change and might be considered "business as usual" (i.e. same as recent past) models. Prediction models address two main questions: given historical land use trends, where are land use changes likely to occur? and at what rates will these changes occur? The first question is generally easier to deal with through models, as it mostly requires identification of the landscape attributes which are the spatial determinants of change. Veldkamp & Lambin (2001) claim however that this research often confuses spatial determinants for underlying causes and has led to an overemphasis of factors such as roads, soil types or topography as a cause of land use change. Similarly, the rate of change is driven by demands for land-based commodities and often modelled using various economic frameworks. However, the deeper underlying driving forces which control the rates of changes are often remote in space and time and generally involve macro-economic transformations and policy changes (Irwin & Geoghegan 2001). As such, modelling these driving forces often require the combination of system, actor-based and narrative approaches (Veldkamp & Lambin 2001).

Spatial land use change modelling, especially when conducted an integrated and multi-scale manner, is an important technique for the projection of future landscapes (Veldkamp & Lambin 2001). However, very few land use change models and methods integrate both location and quantity issues (Geoghegan *et al.* 2001; Verburg & Veldkamp, 2001; Schneider & Pontius, 2001). With decreasing resolution and increasing extent, it becomes increasingly difficult to identify key processes and as many of the drivers of land use change are scale dependant, models should be based on an analysis of the system at various spatial and temporal scales (Turner *et al.* 2001). Most existing regional-scale models do not address structural or functional complexity or the drivers of land use change on a fine scale. Furthermore with inherent complexity of the socio-ecological system, land-use modelers often confine themselves to either a single process such as deforestation or a single discipline such as economic modeling (Veldkamp & Lambin 2001).

For accuracy and credibility, land-use change models need to attempt to represent at least part of the complexity of land use systems and provide as a key characteristic the ability to analyse current and historic conditions and to forecast future conditions (O'Neill *et al.* 1986, 1997; Turner 1989, 1990, 2003; Hansen & DiCastri 1992; Legrande & Legrande 1998; Turner *et al.* 2001; Kepner & Edmonds 2002; Liu & Taylor 2002).

### 2.6.1 CELLULAR AUTOMATA

Many recent spatial land use modeling methods efforts incorporate the use of a cellular automaton (CA) algorithm. Cellular automata are a class of mathematical models in which the discrete state of cells in a matrix is generated by deterministic and probabilistic rules. The traditional CA framework is an iterative process that determines the discrete state of a cell based on the value of its surrounding cells in accordance with the predetermined rules for the model (Xu 2001; Jantz & Goetz 2005). After many iterations, these systems yield complex and highly structured patterns (Irwin & Geoghegan 2001).

CA methods are often used in modeling aspects of ecological systems (i.e. Tyre *et al.* 1999; Schneider 2001; Aitkenhead *et al.* 2004; Sole *et al.* 2004). However, the structures and patterns generated have also been shown to spatially resemble the growth in urban sprawl over time (White & Engelen 2000; Xu, 2001). As such CA systems are now also being utilised more often in urban dynamics to represent urban forms, development densities (Yeh & Li 2002) and urban growth over time (Clarke *et al.* 1997, Batty *et al.* 1999). However Irwin & Geoghegan (2001) warn that the underlying reasons for the transition of a land unit to urban area is inherently complex and that CA systems provide only a simulation of future transitions and cannot be considered a spatially definitive representation of future change.

In attempts to provide greater accuracy and more realistic modeling, CA models of urban systems often depart from the traditional CA framework. Constrained cellular models or stochastic models have been developed that change the transitions rules based on local land-use suitability, demographic and economic dynamics and other factors (White & Engelen 1997; Clarke *et al.* 1997; Yeh & Li  2001).  Additionally the CA framework in this modeling context supports the incorporation of real data through geographical information systems (GIS) and allows for the modification of basic assumptions in classic CA theory (Jantz & Goetz 2005).  With this linkage to GIS, CA serves as the analytical engine of a flexible framework for developing dynamic spatial models (Xu, 2001)

Stochastic CA models are attractive in applied settings as planning tools, because they are interactive and allow modification of rules and constraints,. Raster-based spatial data derived from remote-sensing is easily incorporated into the modeling framework and with the use of GIS results can be quantified and visualised (Jantz & Goetz 2005).  For these reasons CA based systems have become more widespread in planning future landscape planning.  One of the more widely used systems is SLEUTH (Slope, Land-use, Excluded land, Urban extent, Transportation) by Keith Clarke (Clarke *et al.* 1997) which has been used in over 100 applications throughout the world (Clarke 2007)(for examples see Jantz *et al.* 2003; Jackson *et al.* 2004; Jantz & Goetz, 2005; Syphard *et al.* 2005).

### 2.6.2 SLEUTH

Sleuth generates a future trajectory or future simulation of a designated land area.  Based on CA, it produces a raster land cover map and probability maps that represent the chance of becoming urbanised. Jackson *et al.* (2004 p235) describe the five 'growth' factors of SLEUTH:

- diffusion – overall dispersal of growth;
- breed – likelihood of the occurrence of new settlements being developed;
- spread – controls growth of neighbourhoods or sprawl;
- slope resistance – likelihood of urbanisation expanding up a slope; and
- road gravity –simulates the likely growth along transportation corridors.

The SLEUTH program then attempts to calibrate these factors on four past time slices of land use of the study area. To do this the system uses a brute force or 'Monte Carlo' method where multiple simulations with all possible variations of the growth factors are generated and then compared to the historic land use. Because of the computational requirements of this approach, calibration typically occurs in three iterative phases: coarse, medium, and fine with each phase using a smaller subset of variations (Jackson *et al.* 2004; Jantz & Goetz 2005) however, these computational requirements limit the extent and resolution of the study area.

After calibration, areas of exclusion or constraints to growth such as drainage channels can be added to the system. When predictions are produced, multiple simulations are run to create images showing the probability of any cell becoming urbanised over time and to create an averaged tabular output (Clarke *et al.* 1997). SLEUTH also changes the values of the growth coefficients as the model iterates, which is intended to more realistically simulate the different rates of growth that occur in an urban system.

This system output provides a spatial representation of a future trajectory of urban growth based on past trend analysis. As well as limitations of extent and resolution, the system does not consider population levels on a non-spatial basis and does not provide information on housing density. Jantz *et al.* (2003) and Jantz and Goetz (2005) also found that the calibration procedure may limit the kinds of growth processes that can be represented. In particular, as the SLUETH code gives precedence to edge growth, the system is limited in is capacity to simulate other urban development processes. This is most noticeable in areas of a spatially low density development which also become under-represented in final models due to the SLEUTH systems use of probability (Jantz & Goetz 2005). Additionally these authors found that some parameters exhibit stability only at certain scales, in particular the 'dispersion' and 'breed' are instrumental in maximising the clusters metric only at coarser cell sizes.

Jantz and Goetz (2005) also found irregularities with the use of the transportation or road gravity parameter but did not exhaustively test its use. Similarly, basic testing of the SLEUTH system for this study gave the impression that this parameter was largely redundant in areas where urban growth has historically been alongside road corridors and over emphasised growth in areas where it has not. However, as in the case of Jantz and Goetz (2005) additional testing would be required to draw definitive conclusions.

Finally, there are often multiple views of the past reflecting the different directions that influences on landscape pattern and land use have come from. These are not isolated states but interconnected and interacting elements, each affecting potential futures (List 2004; MacKay & McKiernan 2004; Dortmans 2005). The future is an iterative continuum of interdependent changes, which span the gap between the present, projected changes and alternative futures. SLEUTH and similar systems designed to predict the future are likely to fail to provide a spatially exact representation, whereas planners in the present day pressures of landscape change need to be able to pose "what if?" style questions and to address current concerns for future development.

## 2.7 REDESIGNING FUTURE CHANGE: PLANNING FOR ALTERNATIVE FUTURES

Community identity and "sense of place" plays a substantial role in determining visions of desired futures and for future landscape change (Stewart *et al.* 2004; Hulse *et al.* 2004; Dobers & Stannegard 2005). It is the desires and perceptions of people in a socio-ecological system that will shape the future landscape. Therefore an additional challenge for plausible, aspirational and sustainable future landscape scenarios is to provide an effective and efficient process for transition with present and future communities (van Notten *et al.* 2003; Nassauer & Corry 2004; Dortmans 2005; Dobers & Stannegard 2005).The second major group of modeling approaches is through evaluation of future scenarios based on changes to the present landscape.

### 2.7.1 SCENARIOS AND PLANNING

Scenario and alternate futures analysis uses integrated models to direct analysis on the best available range of spatial and temporal data. Integrated modeling uses a suite of models and associated data to represent different social, economic, and environmental processes such as transportation, land use allocation, hydrology, soil erosion, natural vegetation, wildlife viability, and so forth. Spatially explicit models can be connected in different combinations to address different social, economic and environmental uncertainties in land use / land cover (LULC) change and related interdependencies under different (trend or designed) scenarios for a specific regional context.

The development and analysis of scenarios can take various styles depending on the predictability of key variables, the role of controllable and uncontrollable drivers, and the purpose of the exercise (Dunlop *et al.* 2004).

Three typical uses of scenarios are: for choosing between alternative futures (i.e. which of these scenarios do we want for our own 'landscape'/place and is plausible to implement or plan for); strategies for testing new equipment or machines (Is our strategy robust to these different possible futures?); and, to help predictions (What factors might give early indication that one or other of these scenarios is going to unfold?).

The formulation and generation of scenarios that depict a possible future has many benefits. By describing processes, events and actions over time it becomes possible to visualise the consequences of decisions made in the present and capability to compare a variety of alternative future situations (Nassauer & Corry 2004). These futures scenarios are defined by Bell (1967, in Brewer 2007, p.167) as

> *"… the representations of alternative futures (by which) analysts sketch a paradigm (an explicitly structured set of assumptions, definitions, typologies, conjectures, analyses, and questions) and then construct a number of explicitly alternative futures which might come into being under the stated conditions."*

Scenarios are referred to by Brewer (2007, p.167) as "the crux of analysis". The use of scenarios in landscape ecology provides the parameters for modeling, allows the analysis of different possibilities, anticipates the future and hence aids decision making (Nassauer & Corry 2004).

Scenarios move away from ordinary predictions about the distant future by investigating what a desirable future would be and then tries to figure out how to make it feasible. As such, a set of scenarios can be used to help test the possible long-term consequences of a specific decision in each of the scenarios, or what policies might be required to achieve, or prevent a specific long-term outcome (Hulse *et al.* 2004; Dunlop *et al.* 2004).

The field of scenario planning has evolved to help planners and policy makers cope with uncertainty in the future and complexity of socio ecological systems. Scenario planning is based on the premise that the future is not something that cannot be changed by actions today and there are a rarity of hypothetical but possible futures that may or may not be realised. Hence, scenarios are not predictions or forecasts like trend trajectory, but futures 'by design" and empirical evaluation (Steinitz *et al.* 1996, 2003, Shearer *et al.* 2006, Brunckhorst & Morley 2008). Scenarios should be rich and multidimensional, and a set of scenarios should not be based simply on high, medium and low values of a single dimension, nor simply provide a pessimistic and an optimistic outlook (Idon 1996, O'Brien 2000).

The strengths of regional landscape design, scenario planning and evaluation derive from the process being a fundamentally integrative approach to thinking about the future. Participating in the development of scenarios that are an inclusive view of a possible version of the future integrates social, biophysical, economic, technological, cultural and demographic dimensions in a way that more reductionist planning processes cannot. Whilst fictional, scenarios represent the change of processes over time in a transparent and accessible manner (Brewer 2007) as well as provide the form to organise data and information within a defined framework which provides a basis for analysing and comparing the spatial consequences of several scenarios (Steinitz *et al.* 1996, 2003). The development of this framework can also often lead to additional factors being incorporated into the decision making matrix which might otherwise have been missed (Hulse *et al.* 2004, Shearer 2006).

Scenario planning requires knowledge of the region, the local and world forces or drivers shaping it, and how these drivers might possibly combine into scenarios. As described above, landscape futures scenario research tends to start with representation of the 'present' landscape. Past pressures of change are also considered important. The research reported herein confirmed trend- trajectory predictions and population-urban growth trends with examination and comparison of an alternative landscape futures, 'by design' scenarios approach. This requires an examination of past, present and possible future trends along with design of plausible, context specific scenarios congruent of local community and wider societal 'visions' or expectations. Some of this information can be provided by the community, policy makers and other stakeholders who can be involved in scenario building to envisage, define, design and negotiate relevant scenarios. The visioning process identifies challenges and issues facing the community and courses of action required to bring about a desired future (Hulse *et al.* 2004). Thus, it can increase public involvement in planning for the future, and it can build awareness of what can be done to enhance integration of communities' diversity of values and future sustainability (Boxelar *et al.* 2007).

The process of designing and developing scenarios is as important as the final scenarios themselves. The process helps deconstruct biases and preconceptions about the future, provides active learning and feedback about future opportunities and threats, and engenders a future-oriented, proactive strategy rather than reactive, incremental decision making (Idon 1996). The ultimate aim is to contribute to decision-makers being better prepared to make more appropriate long term policy and take strategic action (Dunlop *et al.* 2002). Furthermore, by allowing alternative futures to be evaluated and compared, scenarios allow decision-makers to anticipate their reactions to different future possibilities, to anticipate time-frames beyond the immediate future, and to make more clearly informed choices (Schwartz 1996; Steinitz 2002; Peterson *et al.* 2003).

### 2.7.2 ALTERNATIVE LANDSCAPE FUTURES SCENARIO DESIGN

Scenario approaches have been suggested as a means of integrating the science of landscape ecology with landscape planning, and a wide array of scenario approaches are being used by landscape ecologists (Johnson *et al.* 1999; Keitt 2000; Steinitz & MacDowell 2001; Ahern 2001; Tress & Tress 2003). More broadly, scenarios have been used to anticipate environmental and human effects of trade, agricultural, forestry, and land use policy – including climate change and biodiversity loss (Schwartz 1996; Cocks 1999; Peterson *et al.* 2003).

The interdisciplinary science of landscape ecology is particularly apt as a basis for developing scenarios because it allows scenario designers to experiment with inventing land cover patterns that are expected to have a diversity of environmental benefits and ecological functions that society values (Swetnam *et al.* 1998; Ahern 2001; Beilin 2005; Boxelar *et al.* 2007). For landscape ecology, map images or "pictures" of the future have an additional advantage: they depict landscape patterns that can be generated and tested by interdisciplinary thinking though in a slightly different way than landscape photography (eg. Beilin 2005), both integrating landscape values and potential futures. Maps encoded as appropriately scaled and classified coverages in geographical information systems (GIS) allow experts from different disciplines to make inferences from a single landscape pattern to a wide array of ecological, economic, social and cultural functions.

A number of alternative future scenario projects have been conducted in different parts of the world.  High profile examples of various scales of uses of scenarios include the following.

- Alternative landscape futures in the Netherlands, where the Dutch Government has generated spatial scenarios describing possible future urban and rural environments in the Netherlands as a means of initiating a conversation with the community about the preferred spatial arrangement of a landscape future (Schoonenboom 1995).
- Alternative future scenarios for two watersheds in Iowa, USA, where scenarios generated were used to assess the impacts of land use change in relation to farmland management on water quality, social and economic goals, and native flora and fauna (Santelmann *et al.* 2004).
- Alternative landscape futures for the Upper San Pedro river basin in Arizona and Sonora, where the scenarios generated in the research assessed the potential future impacts in terms of land use development, hydrology, vegetation, landscape ecology, species and habitats, and visual preferences (Steinitz *et al.* 2003).
- Alternative future scenarios were used in the Willamette River Basin to provide plausible development and conservation options for the regions future.  Impacts included terrestrial wildlife, water availability as well as river and stream conditions (Hulse *et al.* 2004).

- In Australia, CSIRO researchers used landscape future scenarios to assess policy, climatic and economic options for dryland agriculture in the Lower Murray Region (Bryan, Crossman & King 2007).

### 2.7.3 OUTLINE OF APPROACH TO ALTERNATIVE LANDSCAPE FUTURES TECHNIQUES

Alternative Landscape Futures (ALF) scenario approaches can be adopted as a regional planning and community-based approach to the design and evaluation of future sustainable landscapes. These integrated regional development approaches can incorporate biophysical, social and economic constraints, as well as potential emerging new industries. The cycle of observation, analysis, development of future scenarios, reflection, could be a continuous adaptive cycle as illustrated in Figure 2.4 (Brunckhorst 2002). ALF scenarios will often challenge governments, community leaders and the local people to decide for themselves if they want to implement action towards a desired future (time + ). If they do, over the course of time that landscape will become a present landscape, and eventually a past landscape (time –).

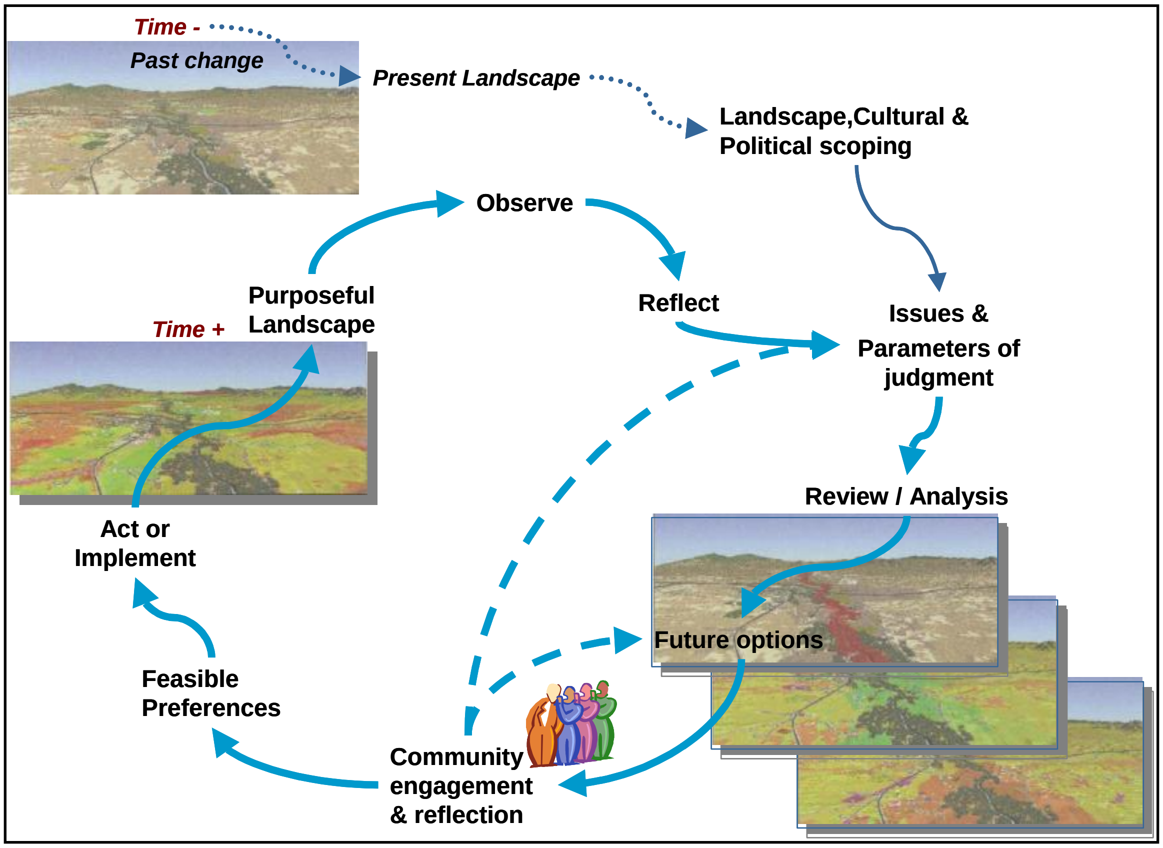



FIGURE 2.4 CYCLES OF ADAPTIVE IMPLEMENTATION OF ALF SCENARIOS BY LOCAL TO REGIONAL COMMUNITIES AND POLICY MAKERS (AFTER BRUNCKHORST 2002, 2005).

Professor Carl Steinitz (Harvard University) has developed and used in many regions around the world an alternative landscape futures scenario analysis and design approach. The Steinitz research framework (Figure 2.5) is the primary methodological driver of the ALF process (including community and stakeholder engagement) providing a clear direction (path), while allowing flexibility to deal with case-study specific context and issues (sometimes referred to as 'critical uncertainties') that will inevitably arise. The framework for design analysis identifies several different questions; each is related to a theory-driven modeling type (Figure 2.5 boxes).

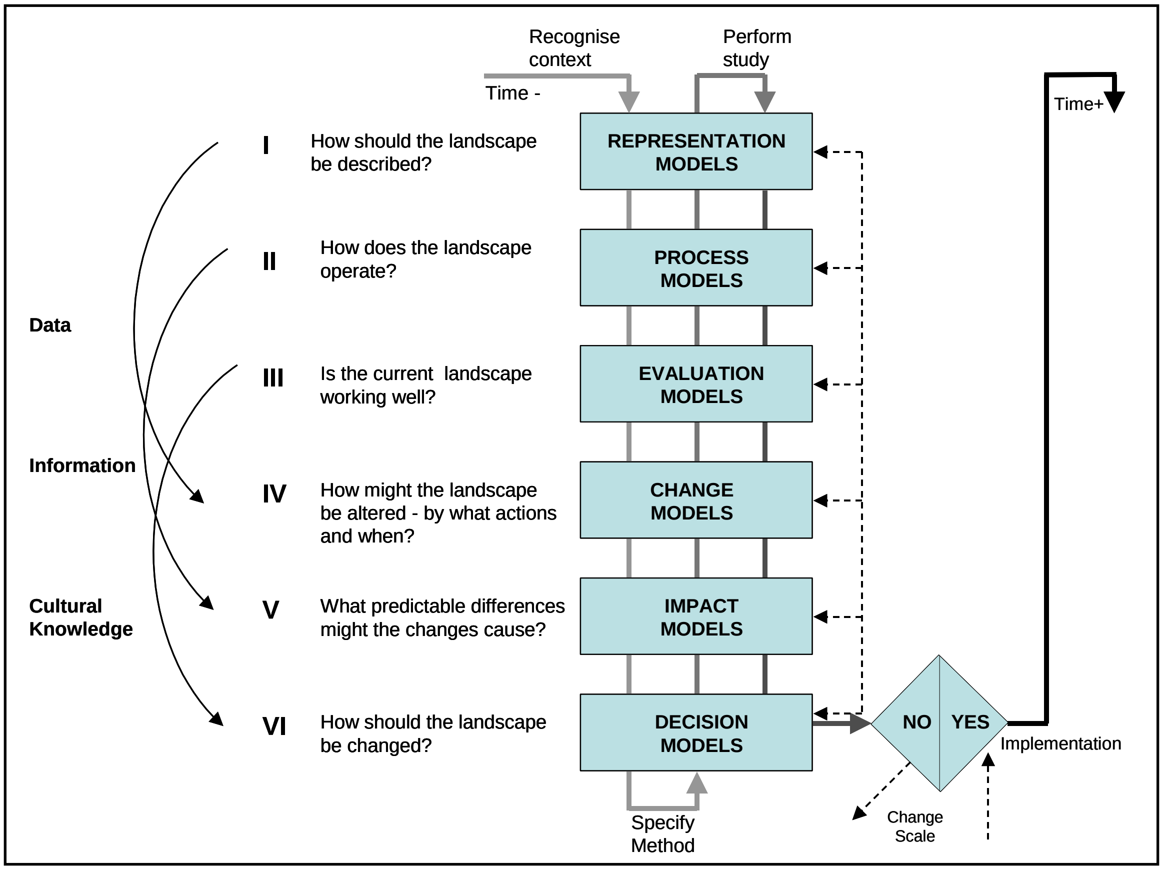



FIGURE 2.5 THE STEINTZ ALTERNATIVE LANDSCAPE FUTURES ANALYTICAL FRAMEWORK (STEINITZ *ET AL.* 2003 P.14)

The procedural path initially starts from the top passing down through each series of questions required of each model. This 'first pass' specifies the context, content and scope and defines specific questions (within each of six major questions) specific to the context of the study area:

1. How should the state of the landscape be described in terms of components, boundaries, space and time?
2. How does the landscape generally operate? What are the main structural and functional relationships amongst components?
3. Is the current landscape functioning well? And what are the parameters of judgment (eg. ecosystem health, community health, aesthetics, water supply, production)
4. How might the landscape be altered? And by what actions, where and when? i.e. are these changes by modification of trends or change by feasible design elements (such as regulations, industry placement, land use and infrastructure development).
5. What predictable differences might the changes cause? What impacts or other change is effected? What will be changed? Where and by how much? and
6. Should the landscape be changed (comparative evaluation)? How should evaluation and comparison of the impacts of alternative changes (future landscape scenarios) be made?

After recognising and describing the context and scope of purposeful landscape change, decision makers and stakeholders need a means of deciding on whether or what to change and a way to compare alternatives. Deciding how to answer the questions, what data is needed, and how it might be examined or synthesised is the next part of the process. Therefore the path reverses to travel upwards to define data needs and specific methodologies of assessment. These strategic elements (type of data, methods for analysis, mapping and design) required to undertake the design analysis are specified and organised by proceeding upward through the levels of inquiry. Each level defines its necessary contributing products from the models next above in the framework as follows (Steinitz 1990, 1993; Steinitz *et al.* 1996, 2003).

1. Decision: To be able to decide to change or protect, a process for comparing alternatives is required. What do decision makers need to know and how (data, visualisation, description)?
2. Impact: To be able to compare alternatives one needs to predict their impacts from having simulated the changes. What, where and how much changed?
3. Change: To be able to simulate change, one needs to specify or design the changes to be simulated. What is the parameter of change (i.e. time; horizon; population level; climate; major development)?
4. Evaluation: To be able to specify potential changes, one needs to evaluate the current conditions. What measure/s can be used to understand and compare changes?

5. Process: To be able to evaluate the landscape, one needs to understand how it works. What are major drivers? What models? How complex?
6. Representation: To understand how it works, one needs representational schema to describe it. What classes of landuse/landcover or other geographical attributes can be used? How complex? At what scale?

Then, in order to be effective and efficient, a landscape futures design and planning project should progress downward at least once through each level of inquiry, applying the appropriate modeling types (Steinitz 1990, 1993; Steinitz *et al.* 1996, 2003)

1. representation;
2. process;
3. evaluation;
4. change;
5. impact; and
6. decision.

While implementation might be considered a further level, the iterative cyclic nature of this framework considers implementation as feedback to the first level. The time-scale relationships assume that the design and implementation actions were preceded by similar considerations, and that they will in the future, be reconsidered in a continual adaptive management context (Walters & Holling 1990).

Visualisation, analysis and evaluation is accomplished using GIS techniques and performed iteratively, with alternatives and stakeholder's increasing understanding of multiple issues as they are identified. Alternative landscape futures scenarios are assessed and either discarded or identified for further design alternatives and assessment. At each stage of the iterative cycle two decisions present themselves: "no" and "yes." A "no" implies a backward feedback loop and the need to alter a prior level (Steinitz *et al.* 2003). All six levels can be the focus of feedback; hence, "redesign" is a frequently applied feedback response. Through prior and/or on-going consultation of communities/stakeholders "preferred" futures, it is expected that several alternative future patterns of land uses and development might be identified. The resultant impacts that "preferred" scenarios might have on patterns of ecological resource issues, regional development and socio-economic factors can be assessed and options reconfigured to elaborate the 'best' alternative scenarios – ones that might be acceptable for implementation.

## 2.8 SCENARIO DEVELOPMENT FRAMEWORK

The Steinitz procedure (1990, 1993, 1997, 2001, Steinitz *et al.* 1996; 2003; Shearer *et al.* 2006) provides a method of reducing complexity in analysis and decision making by creating a contextual framework for the issues that arise (Figure 2.5). By identifying key questions, a procedural process is created that iteratively follows a top down path through the model and goes back through the steps to model and empirically evaluate changes on the regional landscape. This framework uses scenario analysis and design to reduce the uncertainties inherent in decision making and has been used in numerous landscape and regional evaluations throughout North America, Europe and the Middle East.

The research reported in this thesis contributes advances to this procedure by combining the CA based past trend, future trajectory model with scenario development and the evaluation of possible alternative futures. The approach therefore includes baseline or reference scenarios from trajectories of past change projected on a temporal scale based on future trends. These trajectories provide the specific capability for retrospective or prospective modeling, in other words, an ability to cast backwards to an historical state or forwards to possible future states. This is expected to be a valuable part of the planning process and provide improved information for the scenario design phases. While the trajectory modeling is valuable for generating one suite of scenarios, the focus of the methodology is to provide plausible and practical alternative scenarios for sustainable futures, therefore aiming to produce normative landscape scenarios (see Nassauer & Corry 2004; Hulse *et al.* 2004). This conceptual model is represented graphically in Figure 2.6

where the mesh grids represent all possible futures along a central continuum extending from the past into the near and distant future. The blue and green dashed lines represent deviations from the current future trajectory to defined alternative future scenarios for which land use/ land cover representation are produced and can be compared to the expected future situation.

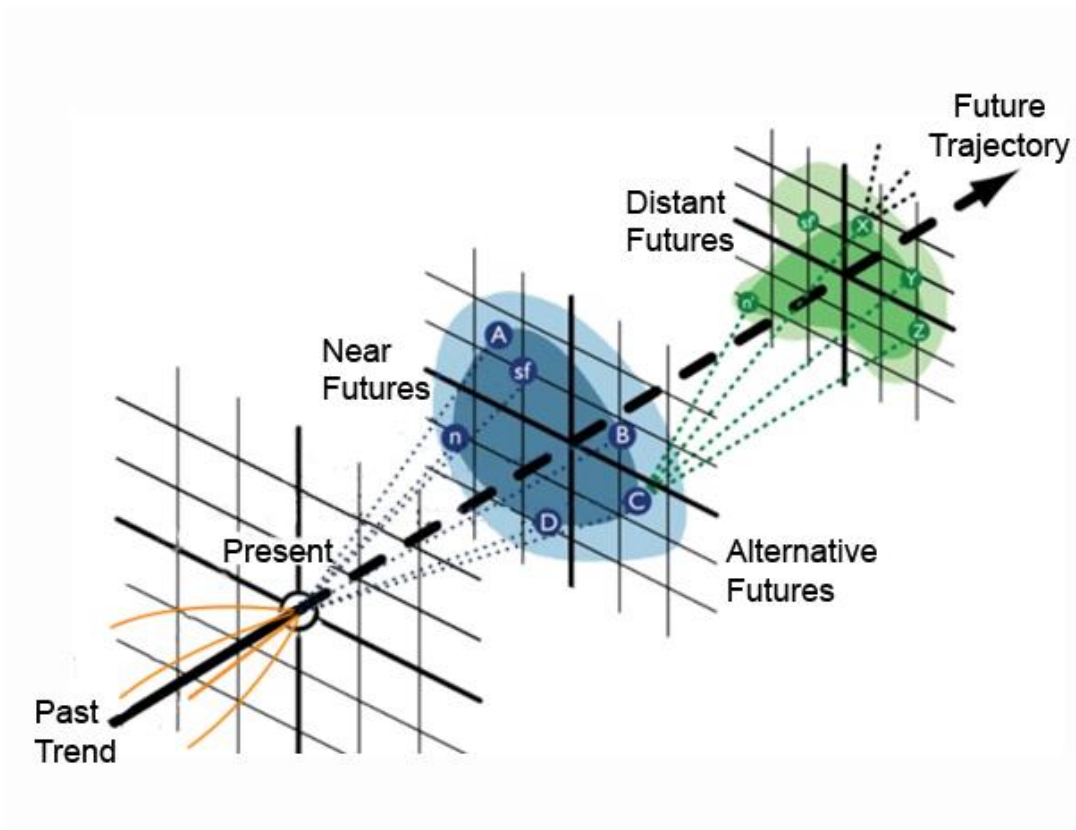



FIGURE 2.6 LANDSCAPE FUTURES CONCEPTUAL MODEL OF TRENDS, SCENARIOS AND FUTURE TRAJECTORY (ADAPTED AFTER SHEARER 2005)

Finally the model developed was applied to the northern New South Wales coast, generating new knowledge for understanding possible futures for that rapidly changing region. With the size of this region the method reported herein also developed a multi-scaled approach to multi-population growth scenarios. A generalised representation of the methodology is shown in Figure 2.7

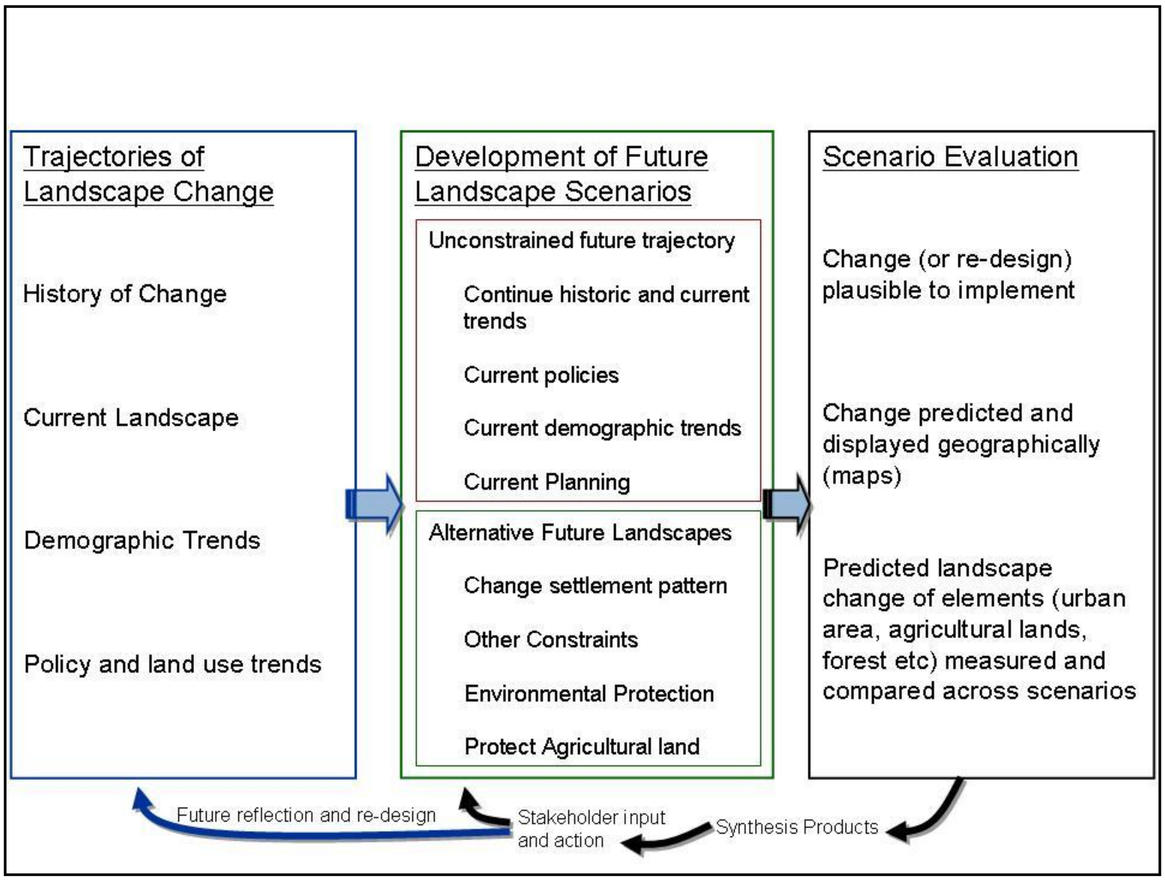



FIGURE 2.7 GENERALISED PROCEDURE OF TRAJECTORIES OF CHANGE AND ALTERNATIVE LANDSCAPE FUTURES MODELLING

The outcomes of this method will therefore include a number of maps, scenario comparison and analyses incorporating and providing knowledge through:

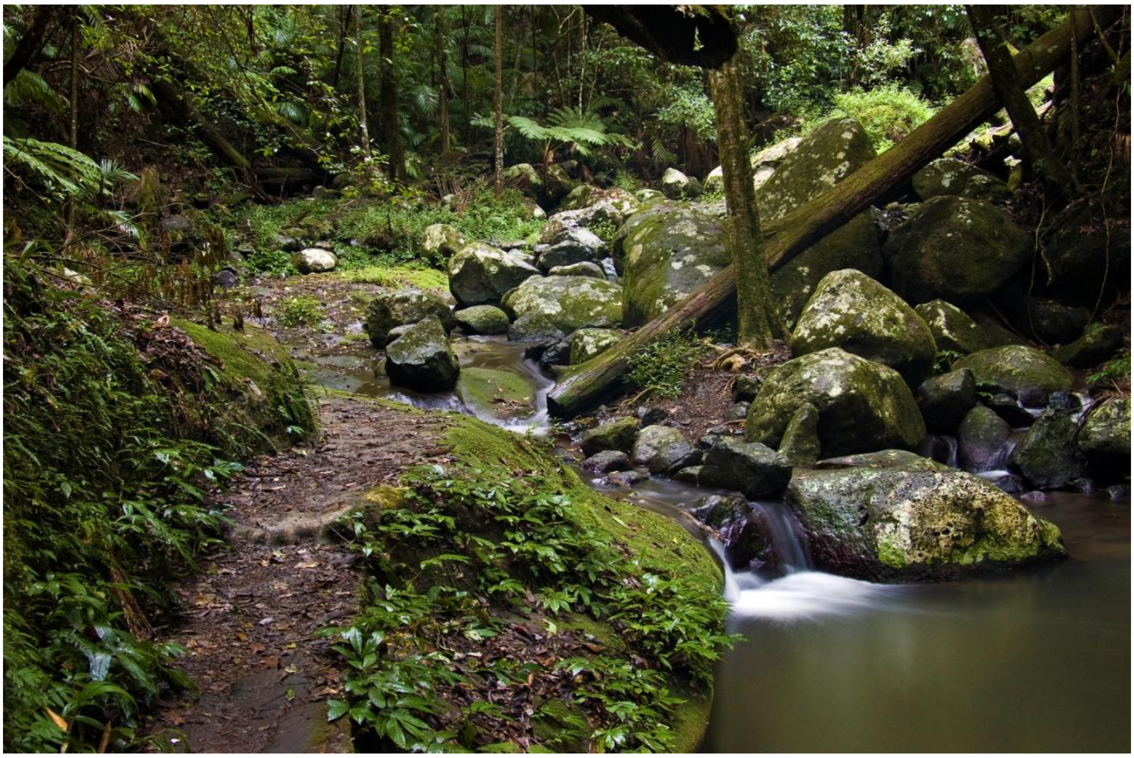
- visualisation and quantification of trajectories and rate of future landscape change;
- models of population growth and density;
- limits imposed by key resources or ecological attributes and their spatial arrangements (e.g., habitat, water, agriculturally productive land);
- possible future scenario option that incorporate and represent these other values; and
- community aspirations, visions and values through stakeholder input and action.

This model was tested in a regional planning context for a single study area, that of the Northern Rivers Region of New South Wales. Stakeholder input and evaluation of scenarios could not be incorporated into this study due to time constraints, however documents that include desired community values and future expectations for the region are presented in Chapter 3.

This large region has a diverse mix of urban and rural areas, that in terms of population growth range from declining to some of the highest levels of growth in Australia (ABS 2004b). As well as unique ecosystems and endemic fauna, the region also contains a number of important agricultural land uses such as recently developed macadamia and avocado orchards. This provides the modeling framework with a second growth factor (in addition to urban growth), which is unusual in alternative landscape future analysis. Finally it is the largest area in spatial extent in which scenario based methodologies that incorporate future urban growth has been used and it is the first case study performed in Australia.

# Chapter 3

## Northern Rivers Study Area



Border Ranges National Park

*You drown not by falling into a river, but by staying submerged in it.*

*Paulo Coelho*

# CHAPTER 3 NORTHERN RIVERS STUDY AREA

Chapter 3 provides a brief contextual description of the regional study area that is the focus of this research.

## 3.1 DESCRIPTION OF THE NORTHERN RIVERS REGION

The Northern Rivers region of New South Wales (Figure 3.1) is a distinct social-ecological spatial context defined by sub-tropical ecosystems, agricultural systems, coastal flood plains, communities of interest and sea-side lifestyles (NRRS 2003, Brunckhorst *et al.* 2008). Located in the north east of NSW, the region is characterised by three major river valleys and covers an area of approximately 20,896 sq km ranging from south of Grafton to the Queensland border in the north (Figure 3.1). With a population of approximately 280,000 in 2004 it is renowned for its surf beaches, scenic coastline, fertile and lush farm land, as well its natural environment.

Geography, latitudinal location and climatic conditions also define the region as an ecotone, having the southern-most limit for a range of tropical flora and fauna as well as the northern-most limit for a variety of temperate organisms (RACAC 1996). Accordingly the region has the second highest level of biodiversity in Australia and supports a number of locally, regionally and internationally significance species and includes a number of World Heritage listed areas (RACAC 1996).


FIGURE 3.1: STUDY AREA (WHITE) WITHIN NORTHERN RIVERS REGION OF NSW

Settlement patterns within the region are historically linked to early transport routes and land use practices for economic development. The economic base of the region developed through agricultural and forestry industries. The regional landscape is dominated by agriculture land uses (20%), forestry (50%) and environmental conservation purposes (30%) (NRRS 2005). Dairy farming was a predominant agricultural land use within the region but this has declined over the last 30 years (Department of Transport & Regional Services 2003) and although previously renowned for its sugar cane industry this is also now giving way to growth in macadamia nuts, banana, avocados and beef (DPI 2004). This historical background and the reliance on agriculture throughout much of the region has given most areas a predominantly rural outlook.

Aside from agricultural holdings the region contains approximately 300 cities, towns, villages and smaller communities (NRRS 2004) incorporated into the seven local government areas of Byron, Ballina, Clarence Valley, Kyogle, Lismore, Richmond Valley and Tweed. Many of these communities have a strong sense of identity based around their historical, environmental and lifestyle attributes. A number, such as Nimbin and Byron Bay have international reputations for the lifestyle that many residents enjoy, while others such as Tweed Heads, Ballina and Yamba are well known as coastal holiday destinations for different groups.

From the end of World War II to 1976, the Northern Rivers population rose from 75,000 to 92,000 persons (NRACC 2004). However intrastate migration, predominately of retirees, saw a dramatic rise in population growth along the north coast (Walmsley & Sorensen 1988). This shift in population mostly originated from Sydney and inland Northern and Western NSW as shown in Figure 3.2. The main reasons for this change, surmised by Walmsley and Sorenson (1992) were improved lifestyle such as better climate, less pollution, access to beaches and other leisure time pursuits. In more recent years, whilst the reasons for moving have remained the same; it is recognised by the Australian Bureau of Statistics that four out of five people moving to high growth coastal areas are aged under 50 (ABS 2004b). With this strong growth the region nearly tripled its population from 1976 to 2004. The Northern Rivers region is one of the ten fastest growing areas in Australia (NIEIR 1998) and is considered one of the major 'sea change' regions of Australia (Burnley & Murphy 2004).

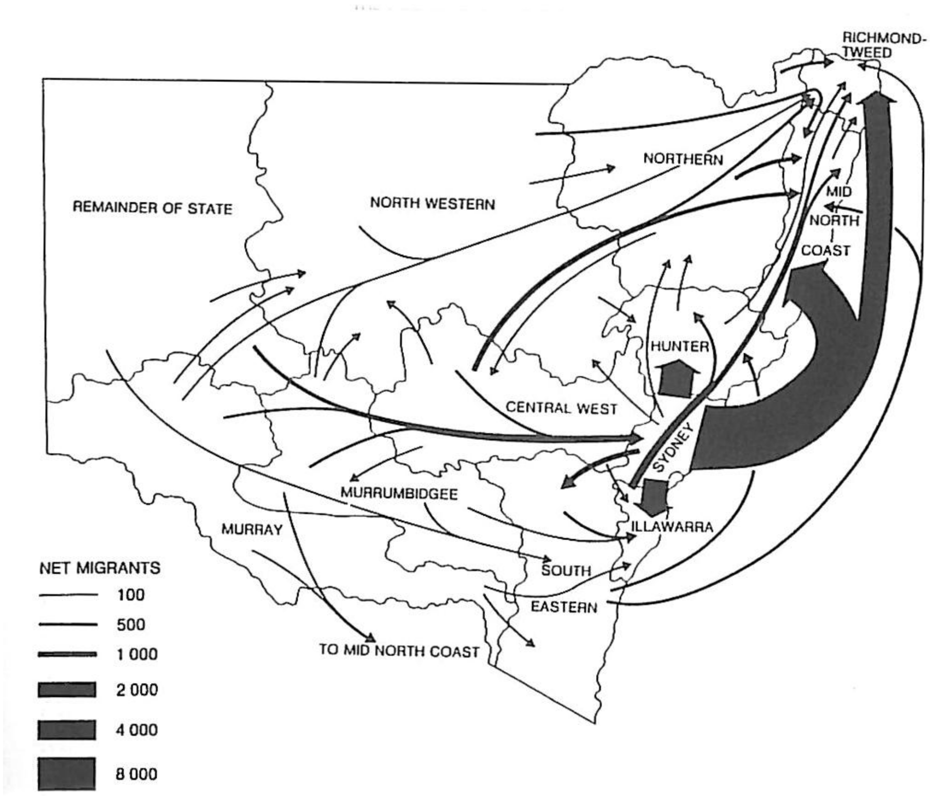



FIGURE 3.2: MIGRATION WITHIN NSW (WALMSLEY AND SORENSON 1992, P57)

### 3.1.1 VISION OF THE NORTHERN RIVERS REGION

With the growth in popularity of the region, particularly along the sea-board portion, the Northern Rivers Regional Strategy (NRRS) was formed to attempt to reconcile the range of both long standing and arising issues within the region. These issues included (NRRS 2000):

- Loss of farming land and the loss or degradation of natural resources;
- High rate of population growth, resulting in a high unemployment rate;

- Lower average incomes in comparison to the rest of the state;
- Impacts from pollution and sedimentation of waterways, land degradation and the loss of native species and plants, resulting in a declining quality of the natural environment;
- Dispersed settlement patterns, combined with limited public transport choices contributing to social isolation and
- Conflict over land use in the region

Comprehensive future visioning was then undertaken between 1996 and 2003 and included participants from State, Regional and Local Governments as well as interest groups and the general community who endorsed the regional vision:

> *A healthy, prosperous and sustainable future for the communities of the Northern Rivers region. (NRRS 2003,vol2, p2)*

This regional vision represents the future that the people of the region are aiming to achieve and provides an aspirational goal for the long term. The NRRS expanded on the regional vision in 2003 to develop a *Desired Future Character Statement* for the Northern Rivers which provides greater meaning and details outcomes for the region's natural, social and economic capital.

The Northern Rivers region *Desired Future Character Statement*:

*'Vibrant, inter-connected villages; expansion through innovative learning, lifestyle and the three sectors of agriculture, tourism and knowledge-based industries; a mosaic of farms, forests, pristine wilderness and human settlements.' (NRRS 2003, vol2,p6)*

Underpinned by the concept of ecologically sustainable development the NRRS aimed to manage the development of the region so that it can maintain the lifestyle aspirations of its residents for which the region is recognised as well provide some protection of the natural environment. It developed the following principles (NRRS 2003, vol2, p5):

- integration of planning within the region to promote co-operation and regional identity;
- development of human settlements and activities to ensure sustainability within communities;
- sustainable economic development and employment growth;
- improvement of the region's distinctive quality of life for all people;
- protection, maintenance and strengthening of regional biodiversity and ecosystems;
- protection of the region's natural resource base and ensuring the efficiency of its use;
- improvement of communications, accessibility and transport
- accommodation of the diversity of views and values within the region and reduction of the conflict between them

The NRRS aimed to increase the prosperity, employment, quality of life, cultural diversity and the environmental quality of the region. The strategy recognised fragmented planning as one of the biggest problems of the region and aimed to reduce the sprawl of new development, reduce the conflict between existing people and communities and minimise the loss of farming potential. It also recognised the growing problems of air and water pollution and the need to manage and protect the natural environment.

### 3.1.2 ECOLOGICAL FEATURES OF THE NORTHERN RIVERS REGION

Due to its location across climatic zones the region has an extremely diverse ecological profile that includes a number of rare species and ecosystems. Some, including sub-tropical and warm temperate rainforests, have been World Heritage Listed. The region has approximately 18% of its total area protected within the national park estate (Figure 3.3). However these conservation areas are not representative of all ecosystem types, but focus on the protection of large areas that are predominately comprised of high slopes and very steep escarpments (Pressey *et al.* 2002).

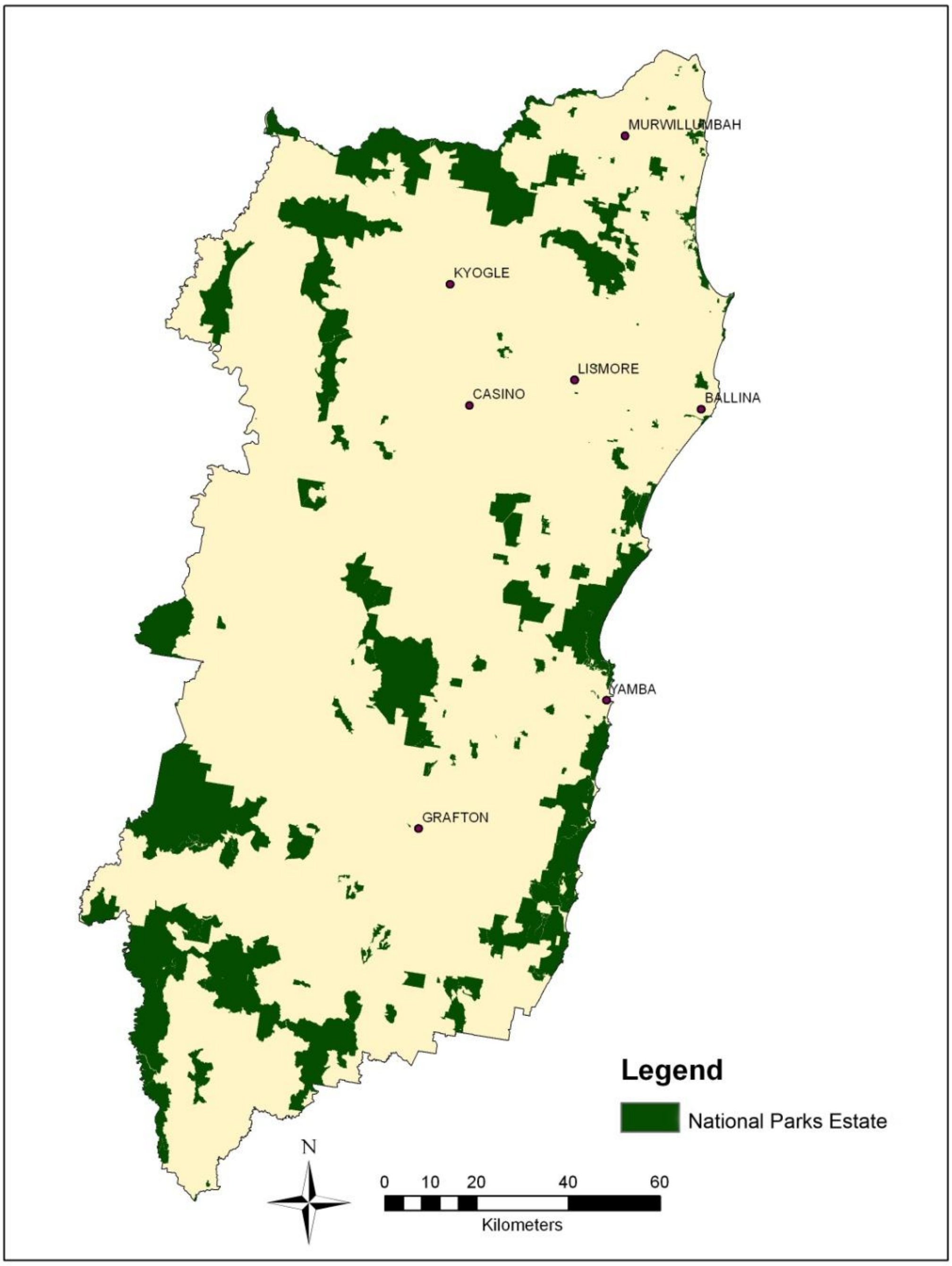



FIGURE: 3.3: NATIONAL PARKS ESTATE WITHIN THE STUDY AREA

Examination of the forested ecosystem database supplied by the Department of Environment and Climate change shows that according to the guidelines represented in the Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia (JANIS, 1997) approximately 10% of the vegetation classes within the region are considered rare, threatened, endangered or vulnerable. This includes stands of alpine gum, Casuarina woodland and swamp mahogany and overall covers in excess of 320,000 hectares as shown in Figure 3.4.

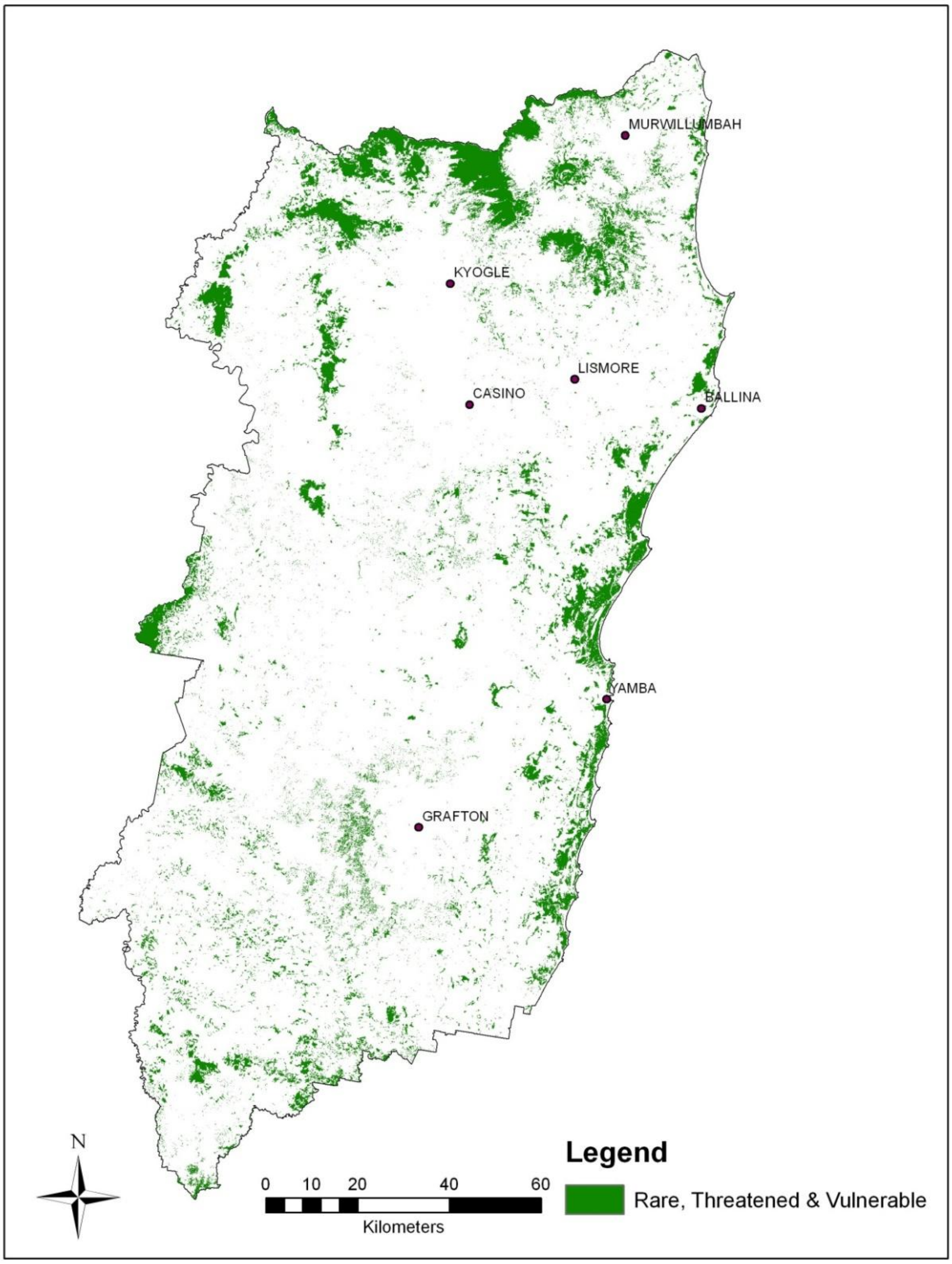



FIGURE 3.4: RARE, THREATENED, VULNERABLE OR ENDANGERED VEGETATION CLASSES. (DATA: JANIS 1997)

## 3.2 DEMOGRAPHIC CHANGE IN THE NORTHERN RIVERS REGION

By utilising population figures from the census collection data, the changes that have occurred throughout the 289 census collection districts (ccds) between 1981 and 2001 were compared. Figure 3.5 shows the change in population in each district between 1981 and 2001. It is apparent that the population growth for the region has been variable across scales of both space and time. The entire region experienced significant growth during the 1980s however has been increasing along coastal areas during the 1990's.

The escalating growth and settlement along the seaboard became more apparent when the number of people with a different address 5 years prior to the 2001 census was examined. Figure 3.6 provides a spatial summary of the number of people that have moved to each census collection district within the region between 1996 and 2001. While more people moved to the predominately large housing blocks and small acreage allotments to the south west of Grafton the greatest amount of new settlement was along the coastal fringe, notably the towns and coastal cities in the north east corner. The trend in the census data of fewer people per household, where home sites are on larger land allotments has resulted in lower density settlement patterns and spatially larger facilities such as shopping centres. In other words, in many new settlement areas, fewer people are taking up more space.

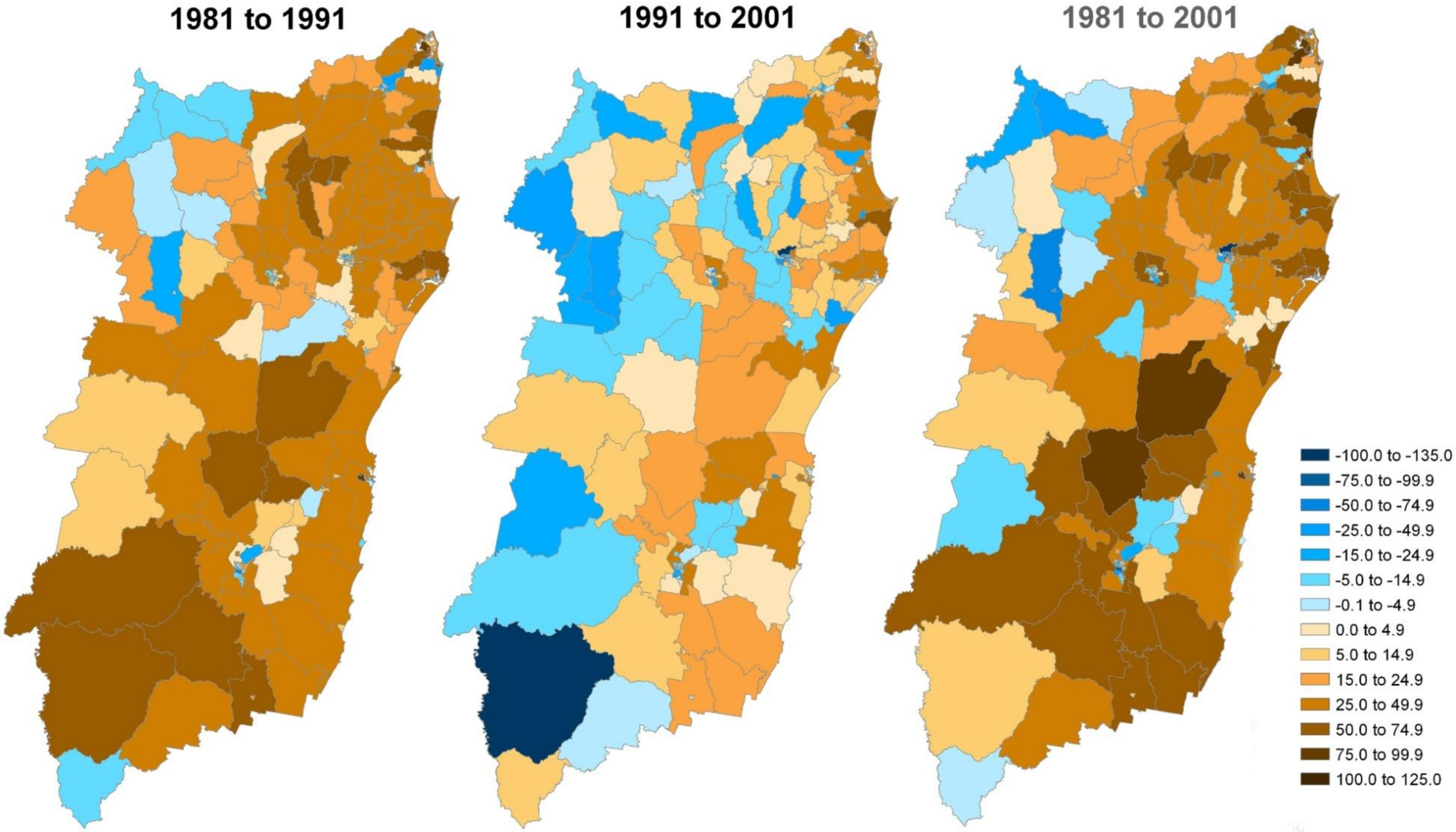



FIGURE 3.5: CHANGE IN TOTAL NUMBER OF PERSONS BY CENSUS COLLECTION DISTRICT

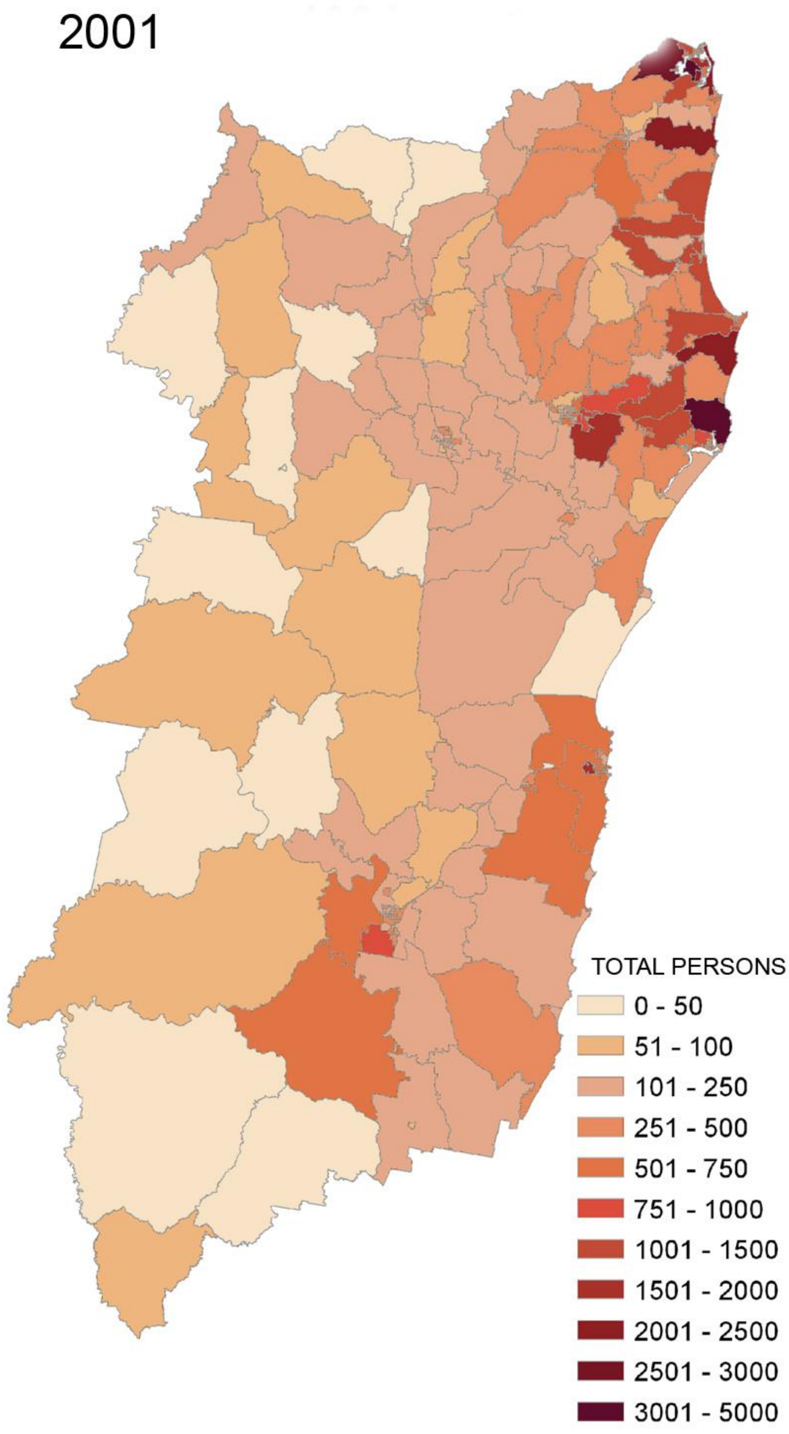



FIGURE 3.6: NUMBER OF PEOPLE WITH A DIFFERENT ADDRESS, 5 YEARS PRIOR TO CENSUS

## 3.3 HISTORICAL LAND USE AND LAND COVER

This research formed a major component of the Land and Water Australia funded, Alternative Landscape Futures research program of the Institute for Rural Futures at the University of New England Australia. Preliminary, scene-setting research documenting prior landcover was undertaken in collaboration with the Desert Research Institute (Scott Bassett and Jamie Trammell). The assessment of prior landcover change formed a basis and starting point for examining trends and alternative futures, and analysing scenarios, which is the subject of the research reported in this thesis. A history of past policies, planning and change on landscapes influences

options and likely trends or trajectories that those landscapes are likely to follow in the future as well as providing or limiting future landscape options in the future (Baker *et al.* 2004; Brunckhorst 2005; Shearer *et al.* 2006). Land Use and Land Cover (LULC) classification and comparison of historical satellite imagery of the study region was undertaken (Bassett *et al.* 2008; enclosed at Appendix 1) to provide a starting point for researching the future change scenarios reported herein.

In summary, land cover as shown in the satellite images is categorised into various classes for each discrete time increment. These images can then be used to spatially portray past changes and trends for each class and thereby allow insight into what might happen in the future for that class. In addition land use trend analysis may also show potential cause and effect relationships such as those related to previous planning, policies or socio-economic changes.

For this study region images were created for 1980, 1985, 1990, 1995, 2000 and 2004 and are shown in Figures 3.7 and 3.8. Eight general classes of land use or land cover were generated, those being forest, coastal complex, beach, water, sugar cane, pasture/crops, orchard, and urban (Bassett *et al.* 2008). These categories and their descriptions are outlined in Table 3.1 below.

TABLE 3.1 MAPPED COVER TYPE DESCRIPTIONS

| Cover type | Description |
|---|---|
| Forest | Sclerophyll forests, predominately *Eucalyptus* with 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. |

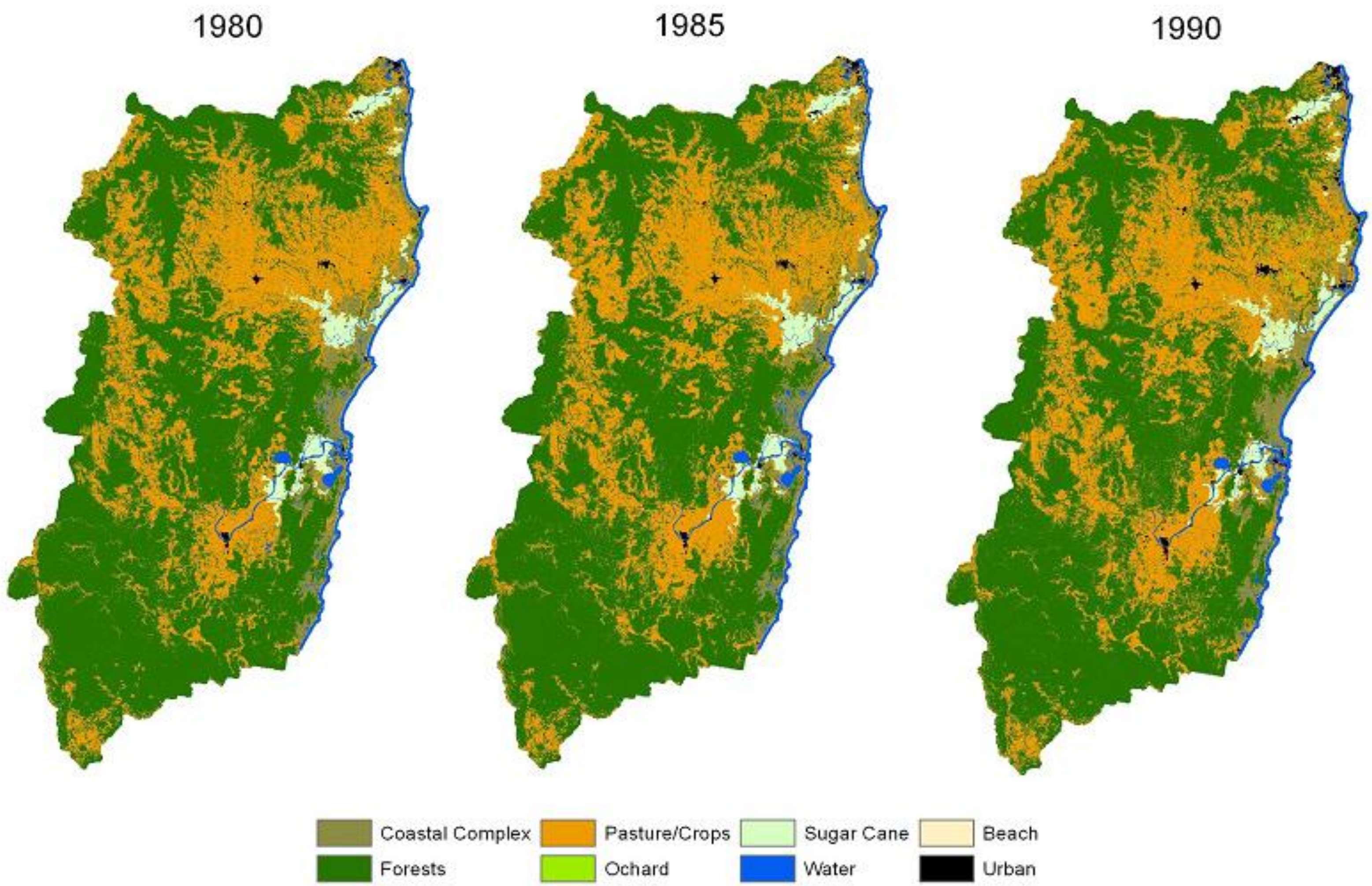



FIGURE 3.7: LULC FOR 1980,1985,1990

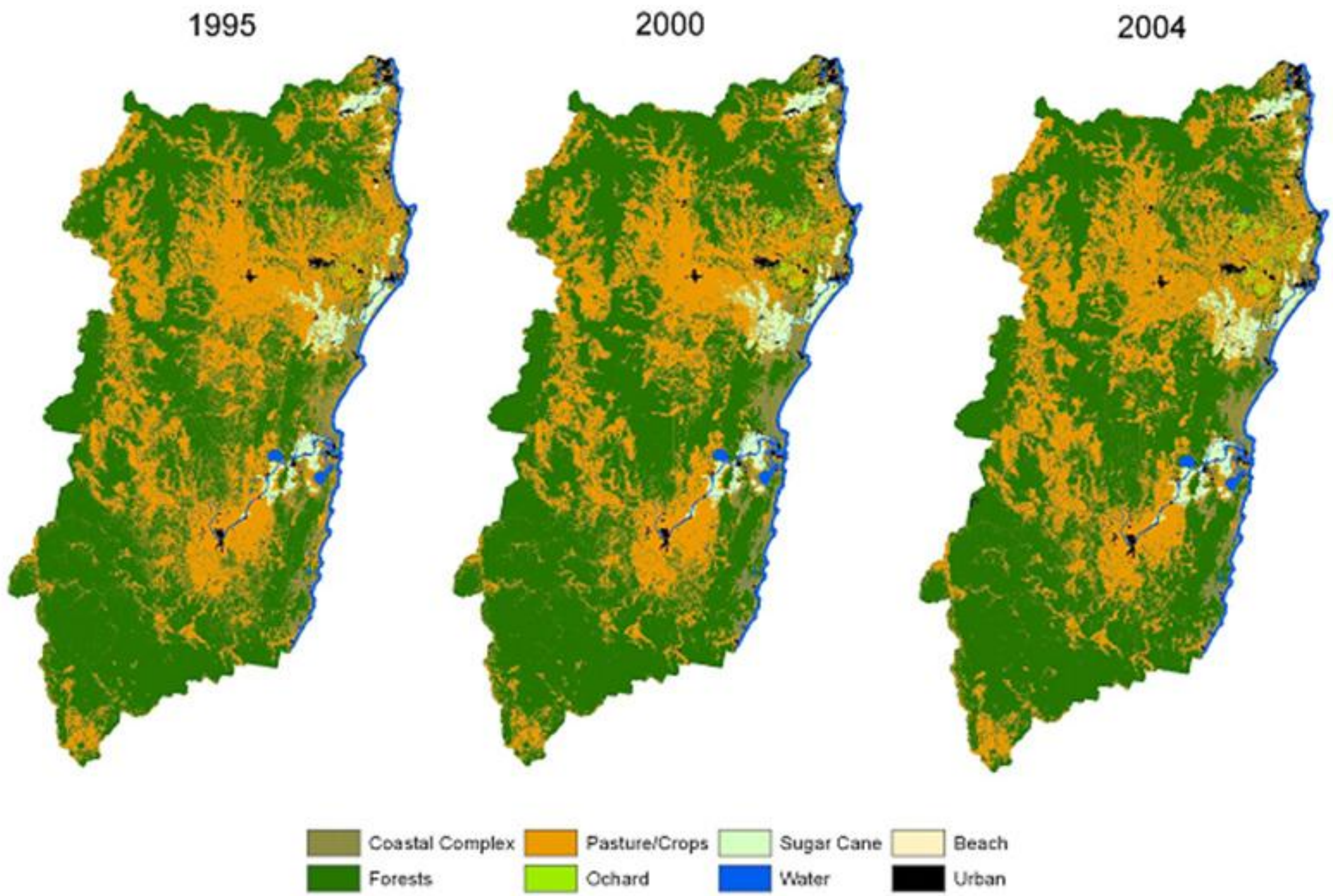



FIGURE 3.8: LULC FOR 1995, 2000, 2004

### 3.3.1 HISTORICAL LAND USE / LAND COVER CHANGE

The historical satellite imagery of the region showed that through to 2004, large areas of vegetation classed as forest dominated the mountain and escarpment areas. Similarly, to 2004, large areas of coastal complex and other remnant vegetation were intact and varying throughout the region. Areas cleared between 1980 and 2004 for agricultural and other human induced purposes were also discernable (Table 3.2)

The pasture/crop landcover type predominately occurred in areas close to human settlement in the lower elevations. These areas were primarily comprised of various natural and introduced grasses (pasture). The floodplains of the major rivers in the region were dominated by sugar cane fields, notably where the difference in elevation between river levels and the surrounding land area is less than 10 metres. Orchards, which are absent before 1985, were developed in the north-western portion of the study area in areas of rolling hills and have a limited spatial extent. The spatial area used by each class of cover by time period of satellite imagery is presented in Table 3.2 (Bassett *et al.* 2008).

TABLE 3.2: AREA (HECTARES) FOR EACH COVER TYPE BY TIME PERIOD

| Cover Type | 1980 | 1985 | 1990 | 1995 | 2000 | 2004 |
|---|---|---|---|---|---|---|
| Coastal complex | 8070 | 7400 | 7500 | 64300 | 8300 | 6780 |
| Forest | 129,900 | 127,900 | 127,700 | 1,21200 | 128700 | 124800 |
| Pasture/crop | 69,400 | 71,400 | 71800 | 79000 | 68200 | 73100 |
| Orchard | 0 | 42 | 330 | 440 | 720 | 870 |
| Sugar cane | 5300 | 5300 | 4800 | 4740 | 5700 | 5600 |
| Water | 4670 | 4810 | 4550 | 4550 | 4500 | 4700 |
| Beach | 220 | 220 | 1750 | 140 | 100 | 100 |
| Urban | 6.7 | 920 | 1380 | 1640 | 1910 | 2100 |

An anomaly in the year 2000 showed an increase in the coastal complex cover type which may have been caused by the timing of the image in June and the apparent lack of moisture in the image. These factors increased grazing and agriculture in locations where soils in wet years were too moist for cattle and human access. Thus, with an increase in coastal complex a concomitant decrease in pasture and croplands occurs and may reflect forest clearing and regrowth activities associated with both logging and grazing practices.

As well as residential housing, urban area also included human settlement related to commercial and industrial use, as well as roads, utilities and other infrastructure. In general, the spatial extant of the area described as urban, more than trebled in the 24 years from 1980 to 2004, and showed an accelerating trend. Most of this increase has occurred since 1995. The most affected areas are located on the coastal fringe, particularly around the city of Ballina and in the towns and cities on the far north coast such as Tweed Heads.

The area of orchards was non-existent to negligible prior to 1985 and highlights the growth of the macadamia and avocado industries within the region since this time (Table 3.2). The extent of sugar cane fields decreased in the early 1990s following the global markets trends for sugar, however grew again by 2000. The area classified as beach reduced to less than half of its 1980 extent by 2004. Overall from 1980 to 2004 the natural vegetation types of coastal complex and forest showed a decline in total area, whereas the human built cover types of orchard, sugar cane, and urban areas showed an increase in spatial extent.

### 3.3.2 POPULATION GROWTH AND URBAN AREA

Within the region, the population increased from 173,000 in 1981 to 273,000 in 2006 (ABS 2006). By examining the trends of accelerating migration and population growth within the area, the regional population follows a linear growth trend. However this was calculated across a very large area with a spatially heterogeneous profile. Some locales followed this linear growth trend, whereas some rural areas in the western portion of the region experienced slight population declines. Conversely, particular areas along the coastal fringe were following exponential curves for growth and development (these are described in more detail in Chapter 4).

The spatial trend for the area of landcover classified as urban showed that for the region, as population increases so does the urban land cover type. While the population increase was more than 50% between 1980 and 2001, the urban area increased by over 180% (Table 3.3). Within the urban classification is a combination of various houses, infrastructure, and roads as well as schools and both industrial and commercial areas. Ground truthing suggested that in many growth areas along the coast there has also been an enormous concurrent increase in speculative housing developments, large shopping centres as well as of large commercial entities and light industrial premises.

TABLE 3.3: CHANGE IN URBAN AREA AND POPULATION BY DECADE.

| | Urban area (ha) | Population |
|---|---|---|
| 1981 | 6,762 | 173,140 |
| 1991 | 13,828 | 226,010 |
| 2001 | 19,101 | 266,459 |

While linear regression analysis of the change in urban area and population by census collector district (CCD) showed that a significant relationship (p-values < 0.00) exists, the $R^2$ values are quite variable. Regression of population increase with urban area returns stronger R values (0.5-0.6), but are still reduced by the classification of urban area.  This was demonstrated by performing a regression analysis on the relationship between population change and change in the number of dwellings (Figure 3.9), which showed a very strong correlation ($R^2 = 0.96$).

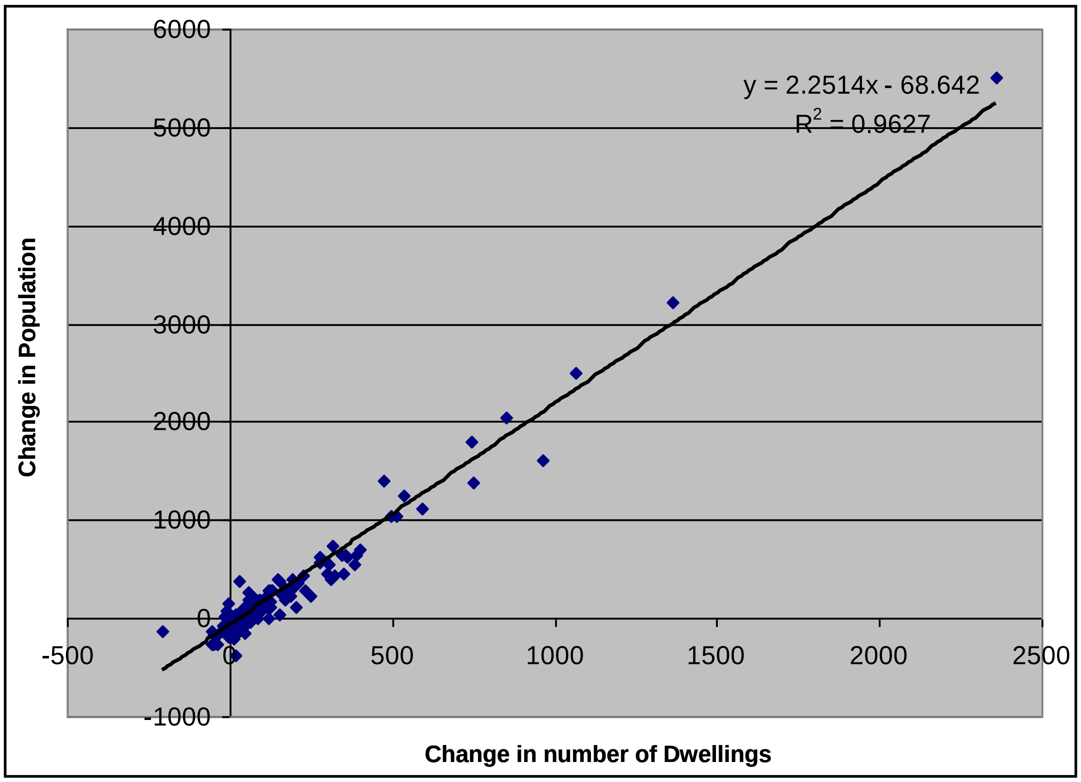



FIGURE 3.9: RELATIONSHIP BETWEEN CHANGE IN POPULATION AND CHANGE IN NUMBER OF DWELLINGS

Despite low density housing being hard to identify at 25m pixel resolution, there is a strong correlation between increasing population and number of dwellings, such that these results would seem to be low in such erroneous attribution of this cause-effect relationship as also found by Jenson and Troll (1982).  While Local government and State planning agencies use various "multipliers" to account for infrastructure, roads and commercial premises

(Dept of Planning 2007) such multipliers apparently do not match with the actual, "on-ground" spatial areas consumed.  For this study, it therefore seemed appropriate to use the actual spatial change trend relationship for population and urban area.

## 3.4 SUMMARY

Comparing the history of the LULC through a temporal set of satellite imagery provides valuable insights into the changes that have occurred across the study region over time.  Land use has changed considerably within the Northern Rivers region over a few decades from 1980-2004.  From 1995, the region appears to be undergoing accelerating social and economic change due to in-migration, globalisation and industry restructuring. Fragmented planning of land releases every 2-3 years for new development creates social and economic pressures of change, which over a couple of years seem small in spatial extent but which over decades take up very extensive areas.  The historical LULC change adds weight to concerns that rapid change in population and the subsequent changing land use mosaic in the long term is likely to threaten the unique features of the region.

The strong relationship between the increased number of dwellings with increasing population coupled with the land cover change showing 50% population increase resulted in a 180% urban area increase, suggested that urbanisation is increasingly using more land than is reflected by population or dwelling numbers. Housing density is increasing along with an expanding area being used by roads, services, commercial and industrial holdings. This increase in human settlement is converting other land uses such as agriculture and reducing areas of native vegetation and hence reducing biodiversity throughout the region, particularly adjacent to the coastline.

What does the future hold? The following chapter describes the methodology for generating future scenarios for the region.

# Chapter 4

## Methodology

Litoria Fallax (Dwarf Green Tree Frog), Casino

*You never change something by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.*
*Buckminster Fuller*

# CHAPTER 4 METHODOLOGY

The conceptual model and approach was modified from models of future scenario planning and trend analysis and is described in the introductory chapters. This chapter provides details of the method and procedure employed in the current study. Details of the cellular automaton program code and algorithm scripts are provided in Appendices 2 and 3.

## 4.1 PARAMETERS IN TREND ANALYSIS AND SCENARIO DEVELOPMENT

The Northern Rivers region is undergoing considerable change. Future development is under pressure to balance the numerous competing issues described in Chapter 3. These factors are summarised as;

- population growth, location of urban development and provision of infrastructure and services;
- agriculture, particularly the ongoing capacity of key activities such as grazing, crops, sugar cane and growth of orchards; and
- environment, ongoing provision of environmental services and protection of native flora and fauna.

In addition, the region has a number of large areas that are susceptible to being comprised of acid sulphate soils. Generally considered an environmental concern, these areas also pose numerous issues for human development and agriculture.

These factors are all interactive elements in a complex system of landscape dynamics. A generalised diagram of the main interactions is shown in Figure 4.1

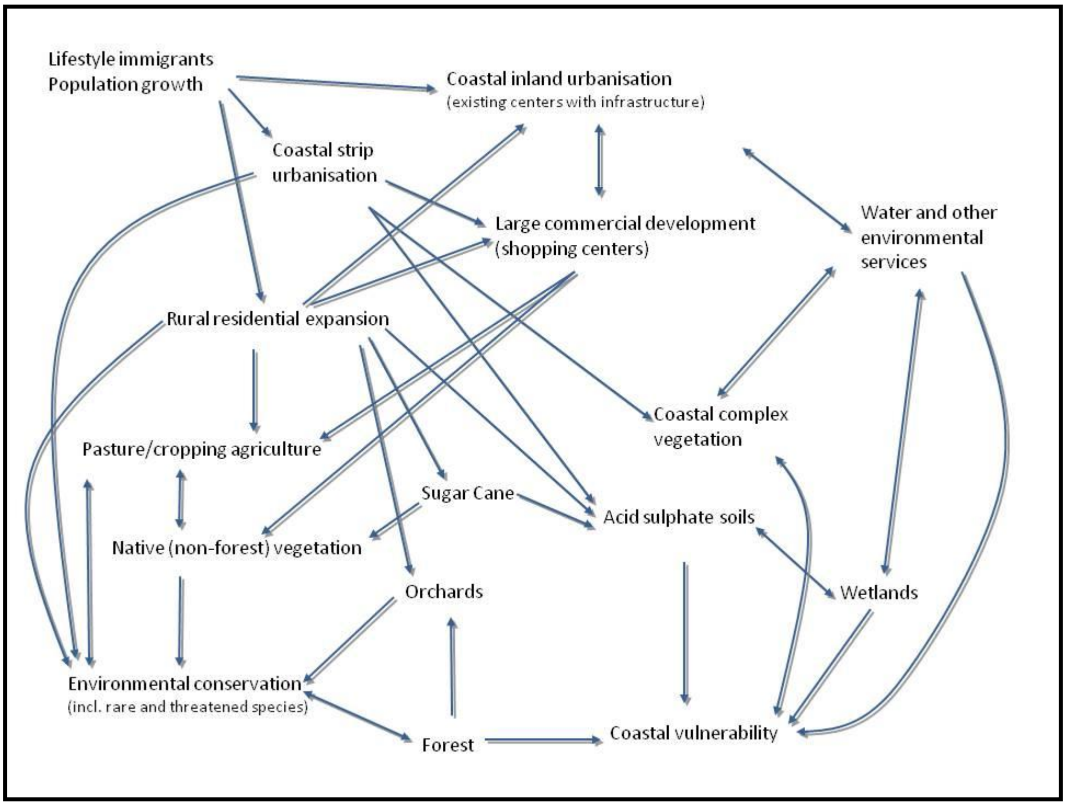



FIGURE 4.1 GENERALISED INTERACTIONS OF LANDSCAPE ELEMENTS (BRUNCKHORST AND MORLEY 2008)

A geographic information system (GIS) was used to incorporate the spatial aspects of each of these factors. Processing of these data layers (described later in this and subsequent chapters) provided the capacity for the interactions of Figure 4.1 to be represented and analysed in future trend and alternative futures scenarios. Table 4.1 lists these data layers and their source as well provides a reference to where within the thesis a description of the processing is located.

TABLE 4.1 LIST OF DATA USED, SOURCES, PROCESSING AND USE IN SCENARIOS

| **Data** | **Source** | **Scenario or Chapter** | **Section** |
|---|---|---|---|
| Forested Ecosystem Database | NSW NPWS | All | 4.3 |
| Census collection districts (CCDs) | Aust Bureau Statistics | - | 4.2.1.1 |
| Major Roads | NSW Dept. Lands | All | 5.1 |
| Acid Sulphate Soils | NSW DECC | 6,8,9 | 6.1.1 |
| Key Habitats & Corridors | NSW NPWS | 6,8,9 | 6.1.3 |
| Protected Agricultural Land | NSW Dept. Planning | 7,8,9 | 7.2 |
| Drainage | NSW Dept. Lands | 6,8,9 | 6.1.2 |
| NPWS Managed Lands | NSW NPWS | All | 5.1 |
| Important wetlands | NSW NPWS | 6,8,9 | 6.1.2 |
| World Heritage Areas | NSW NPWS | All | 5.1 |
| State Forests | NSW NPWS | All | 5.1 |
| Urban Area Class | LULC 2004 | All | 3.3 |
| Agricultural Land Use Class | LULC 2004 | All | 3.3 |
| Forest Land Use Class | LULC 2004 | All | 3.3 |
| Coastal Complex Class | LULC 2004 | All | 3.3 |
| Sugar Cane Land Use Class | LULC 2004 | All | 3.3 |
| Water Class | LULC 2004 | All | 3.3 /5.1 |
| Beach Class | LULC 2004 | All | 3.3 /5.1 |
| Orchards Class | LULC 2004 | All | 3.3 / 7.2 |
| Slope | LULC 2004 | All | 5.1 |
| Population | CCDs | All | 4.2.1.1 |
| Population Density | CCDs, LULC 2004 | All | 4.2.1.2 |
| Zones | CCDs, Urban Area | All | 4.2.1.1 |
| Riparian Vegetation | Forested Ecosystem, Drainage | 6,8,9 | 6.1.2 |

The incorporation of these factors into the scenario development methodology created the procedure represented in Figure 4.2 for the design of scenarios to depict the future trend regional landscape and alternate future scenarios.

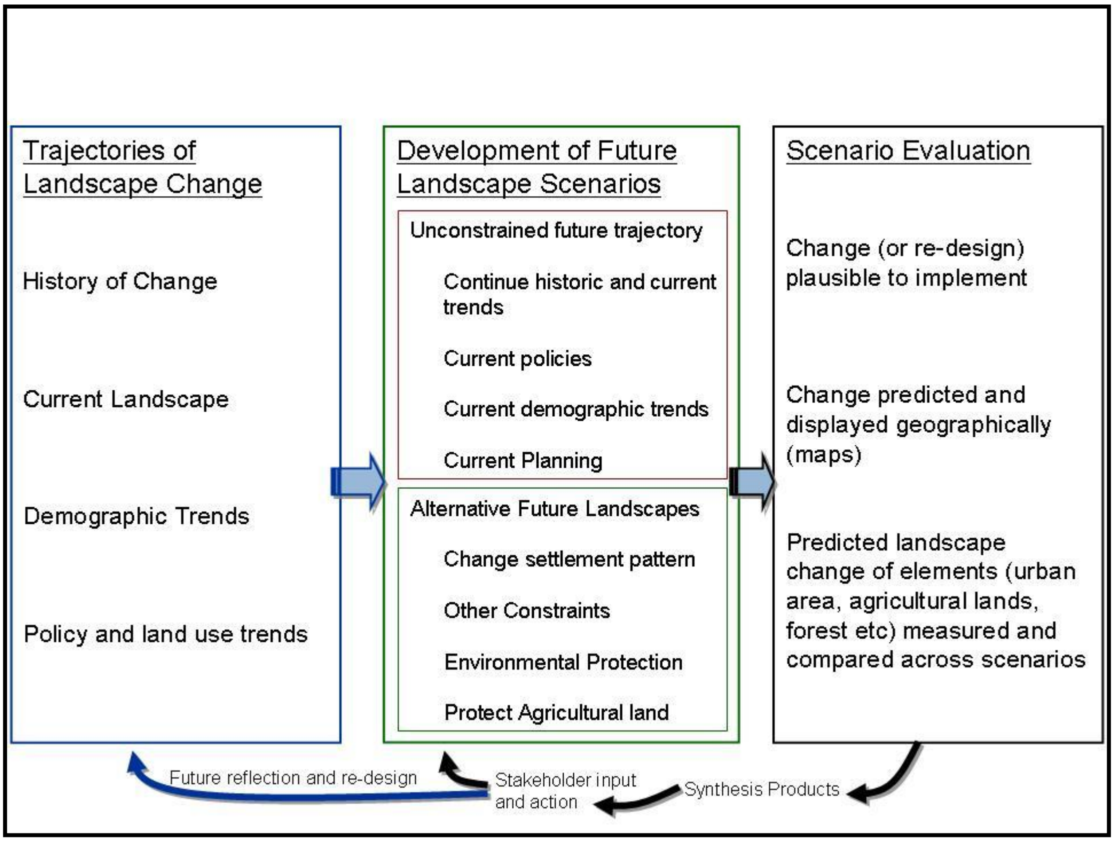



FIGURE 4.2 METHODOLOGY FOR SCENARIO DEVELOPMENT (BRUNCKHORST AND MORLEY 2008)

Detailed information relating to the past and current landscape within the "Trajectories of Landscape Change" box (Figure 4.2) was described in Chapter 3 and in the development of the land use land cover (LULC) model (Appendix 1).

## 4.2 DEVELOPMENT OF FUTURE LANDSCAPE SCENARIOS

A key driver of LULC change across the region is the expansion of urban areas due to the growing population, therefore the past and future trends of this growth must be determined in order to create and evaluate future landscape changes.

### 4.2.1 POPULATION GROWTH

There are various methods to estimating population growth. The Australian Bureau of Statistics utilises a number of methods that incorporate birth and death rates, in-migration and emigration, life expectancy as well as other factors (ABS 2009). This study is interested in LULC change which is driven by total population growth (births and in-migration), that in turn dictate how much space is converted to human community residential requirements (including related shopping centres, infrastructure and services).

In 2001, the NSW Department of Planning estimated the population of the Northern Rivers region to increase to approximately 400000 people by 2031 (Dept Planning 2001). In their 2005 release, the population projections estimated that Richmond – Tweed area would grow to 290500 people and the mid-north region to 373700 people (Dept Planning, 2005).

However, it would be inaccurate to calculate future population levels for a large region as a singular whole area because considerable diversity and heterogeneity of settlement patterns are historically evident across the region. Inherent differences in growth rates between specific interregional areas would create a high level of inaccuracy which is propagated when the new growth is placed uniformly throughout the region, regardless of the settlement pattern of any specific area. Therefore the region had to be scaled down to six smaller zones with higher levels of homogeneity of population growth and settlement. The zones allowed calculations to be made which provide an acceptable level of numerical and spatial accuracy.  Subsequent scaling up again to the whole region or multiple zone levels allows for the modeling of externality effects, or 'spillovers' effecting change on LULC elsewhere.

#### 4.2.1.1 ZONING

The region has seven Local Government Areas (LGA's).  However LGAs also tend to lack homogeneity within their boundaries in relation to population change, with most LGA's having areas of decline and areas of growth.  This is even more prevalent in non-urban regional LGAs that have a large spatial area in relation to population as is seen within the study area.

Census collection districts (CCD's) provide a finer scale of population data on which to assemble zones of similar population change characteristics. Census information contains population levels for the 289 CCD's within the region for each time period (ABS 2003).  Calculating estimates of population change characteristics for each of the CCD's resulted in statistical errors as some spatially small areas have experienced an extremely high population growth trend.  The past growth trend quickly extrapolated to a point in the near future in which some collection districts gained population levels well beyond the available space to accommodate them.  For example, in some cases this is in the order of hundreds of thousands of people, even though spatially, the entire CCD may only be a few square kilometres.

Reducing the size of the area for which calculations could be made creates an edge or boundary effect due to varying population levels between areas when represented spatially. The allocation of new housing or urbanised area within a specific location that is on the boundary of its zone is abruptly cut off along the boundary line, whereas flow on effects into adjacent areas are more plausible. This problem is exacerbated when the difference between population levels is large and / or the spatial area of zones is small.

To overcome these issues, CCDs were amalgamated into larger spatially homogenous zones to achieve a balance between sample size and resolution. Allocation of CCDs to zones was conducted by examining the change over time for each CCD's population according to the census data (Figure 4.3) and examining the change in each CCDs urban area from the LULC model (Figure 4.4). This formed a trial and error process through spatial inspection and then subsequent testing. In excess of fifty variations of zoning were created and tested.

These test cases divided the region into various configurations that incorporated from two to over twenty areas. After testing and refinement it was found that dividing the region into six specific zones provided the best balance between having a large enough extent matching realistic estimations of growth, and being small enough to allow for the large levels of variation across the region. Furthermore, this spatial sampling also created relatively few edge or boundary errors. The final zoning used in scenario modeling is shown Figure 4.5.

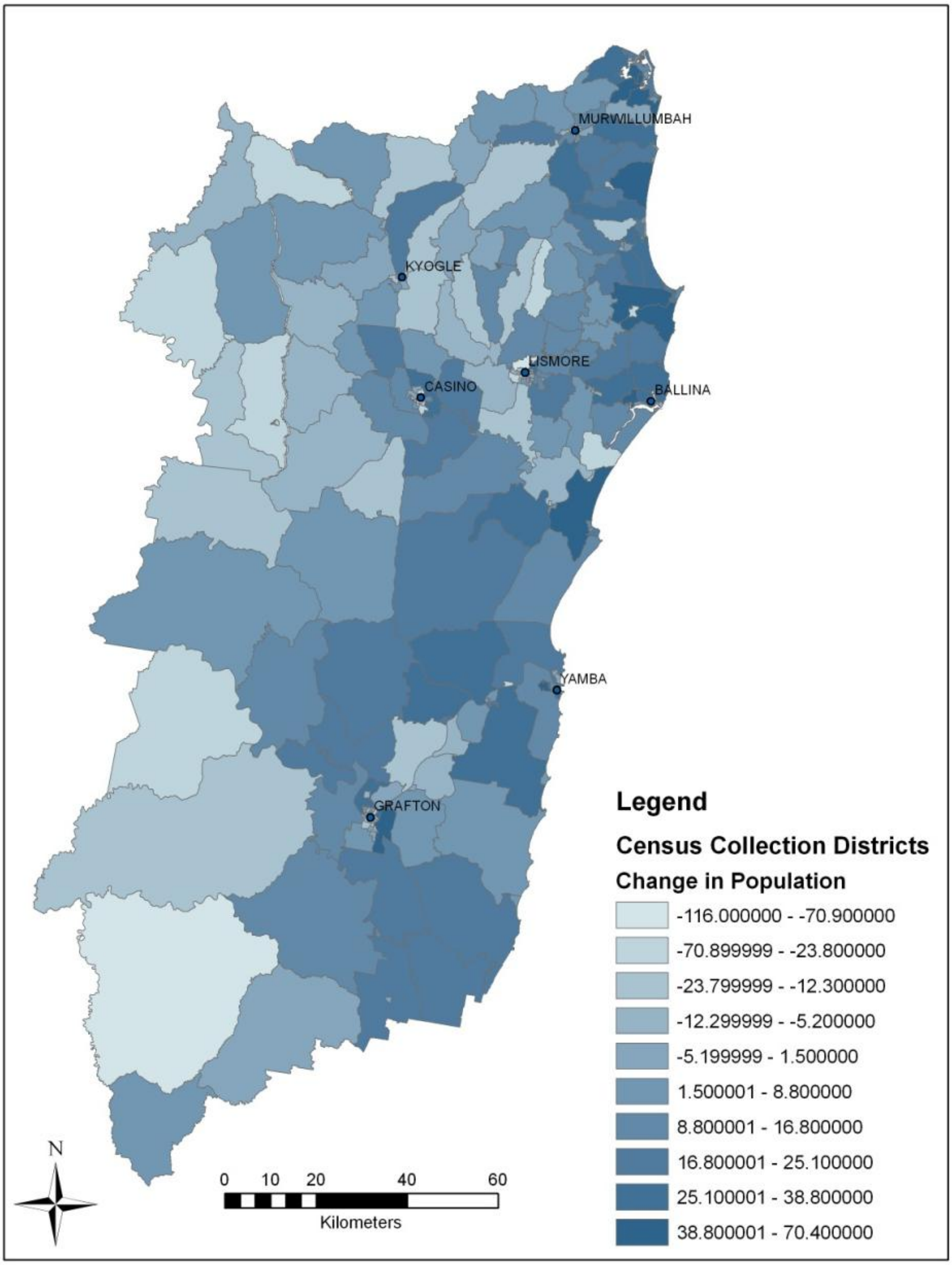



FIGURE 4.3 CHANGE IN POPULATION BY CENSUS COLLECTION DISTRICT

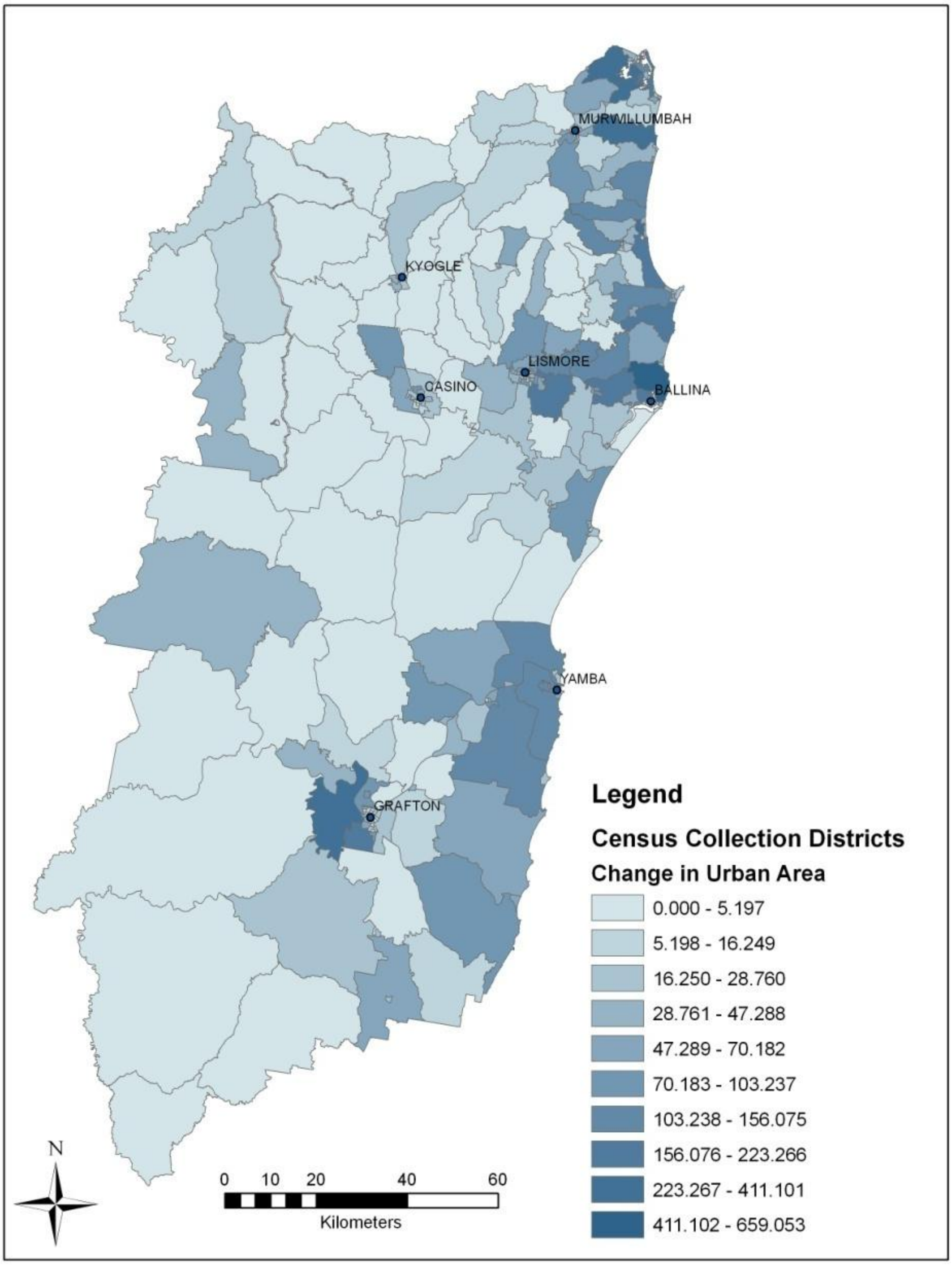



FIGURE 4.4 CHANGE IN URBAN AREA BY CENSUS COLLECTION DISTRICT

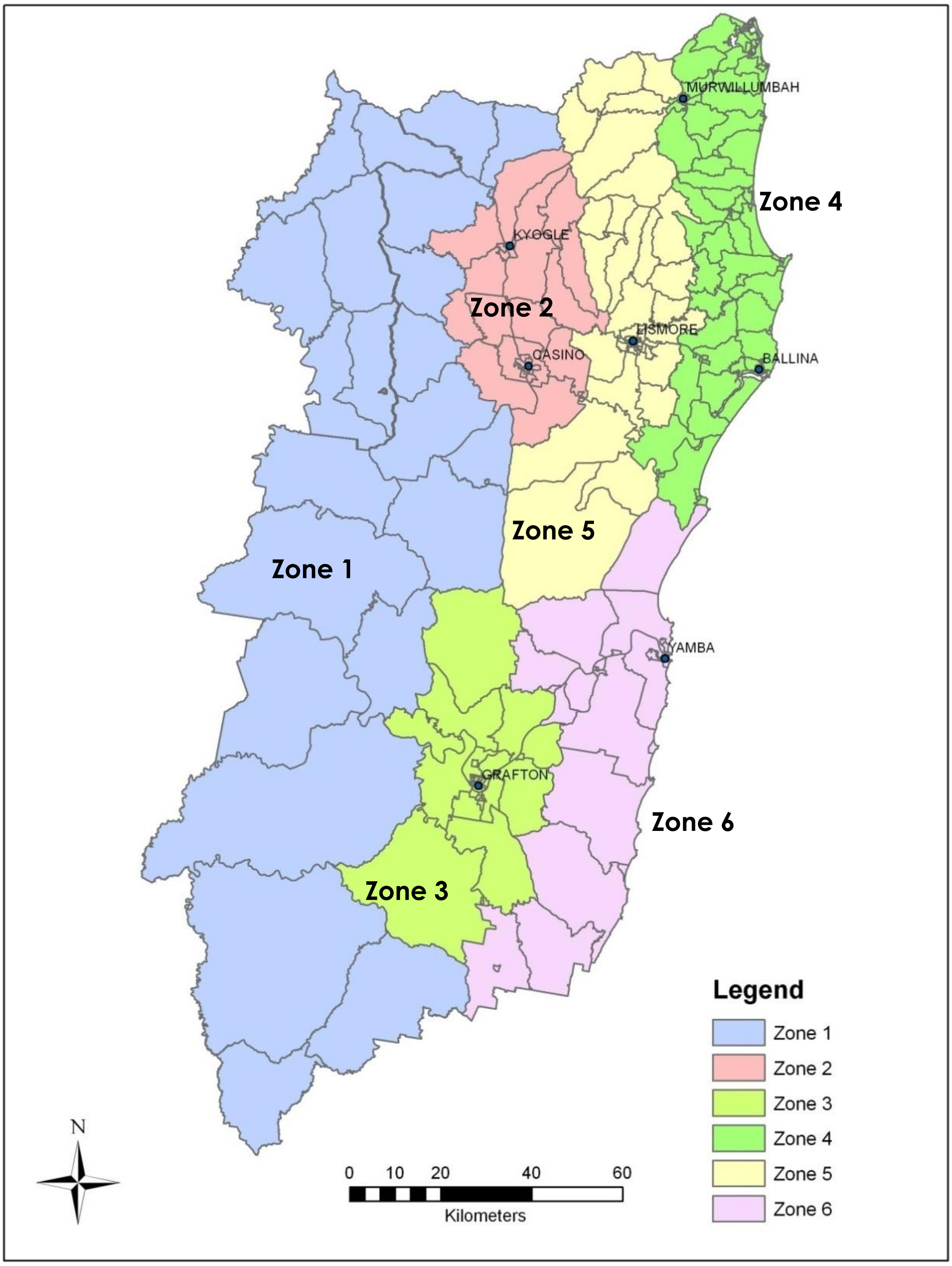



FIGURE 4.5 ZONING OF NORTHERN RIVERS REGION USED IN SCENARIO MODELLING

As can be seen in Figures 4.4 – 4.6 the total area, population change and the extent of urbanised area vary enormously between zones and highlights the diversity of population characteristics and settlement patterns across the region.

The total area, levels of population and the spatial extent of urban area for each zone is quantified in Table 4.2.

TABLE 4.2 POPULATION AND URBAN AREA BY ZONE

| Zone | Population | | | Area (ha) | Urban Area (ha) | | |
|---|---|---|---|---|---|---|---|
| | 1981 | 1991 | 2001 | | 1981 | 1991 | 2001 |
| 1 | 5545 | 6349 | 5705 | 10071348 | 758 | 1889 | 2386 |
| 2 | 17604 | 20324 | 19677 | 1525966 | 7291 | 10148 | 12989 |
| 3 | 22255 | 25281 | 25742 | 2148478 | 10263 | 16026 | 22703 |
| 4 | 76343 | 110656 | 144387 | 1859398 | 27064 | 65908 | 93399 |
| 5 | 38216 | 45436 | 46833 | 2784705 | 10256 | 19111 | 28169 |
| 6 | 13177 | 17964 | 22114 | 2501159 | 7802 | 17104 | 22353 |
| | | | | | | | |
| Total | 173140 | 226010 | 264458 | 20891054 | 63433 | 130186 | 182000 |

While zone 1 is the largest in area it has the lowest population and lowest urbanised area as it is comprised of small villages and farming communities. Zones 2 and 3, which represent the cities and surrounding areas of Casino and Grafton have a fluctuating population and historically low levels of population growth. Zone 5 experienced greater than 20% growth in population level and some 270% expansion in urban area within the 20 year time frame.

The coastal areas of zone 4 which encompasses Ballina to Tweed Heads and zone 6 which includes Yamba and Maclean have seen considerably large increases in both population and urban area.

The amount of urban area in each zone has increased more than the population growth. In several cases (e.g. Zones 4,5,6) the extent of urbanised land has almost trebled, despite only having a modest growth in population.

#### 4.2.1.2 POPULATION DENSITY

The increasing urban area can be partly attributed to the urban classification including industrial and commercial property. Such development includes large shopping centres which were not as prevalent or as large during the early 1980s (Basset et al 2008). Another factor attributing to the increased urban area per population is the reducing size of households throughout Australia (ABS 2009). As the average size of a household is reducing and more people are living as a single person household, the amount of urban area is increasing without a corresponding increase in population. The Australian Bureau of Statistics report that they expect this trend to continue for the foreseeable future (ABS 2009).

Examining the trend more closely, using the values from Table 4.1 and dividing the urban area of the zone by its population for each time period, an average spatial area per person was derived. This trend and the overall change for each zone is provided in Table 4.3 and shown graphically in Figure 4.6.

TABLE 4.3 SPATIAL AREA (HA) PER PERSON

| | People / Urbanised Hectares (ha) | | | |
|---|---|---|---|---|
| | 1981 | 1991 | 2001 | % change |
| Zone 1 | 0.14 | 0.30 | 0.42 | 305.93% |
| Zone 2 | 0.41 | 0.50 | 0.66 | 159.40% |
| Zone 3 | 0.46 | 0.63 | 0.88 | 191.26% |
| Zone 4 | 0.35 | 0.60 | 0.65 | 182.47% |
| Zone 5 | 0.27 | 0.42 | 0.60 | 224.13% |
| Zone 6 | 0.59 | 0.95 | 1.01 | 170.72% |

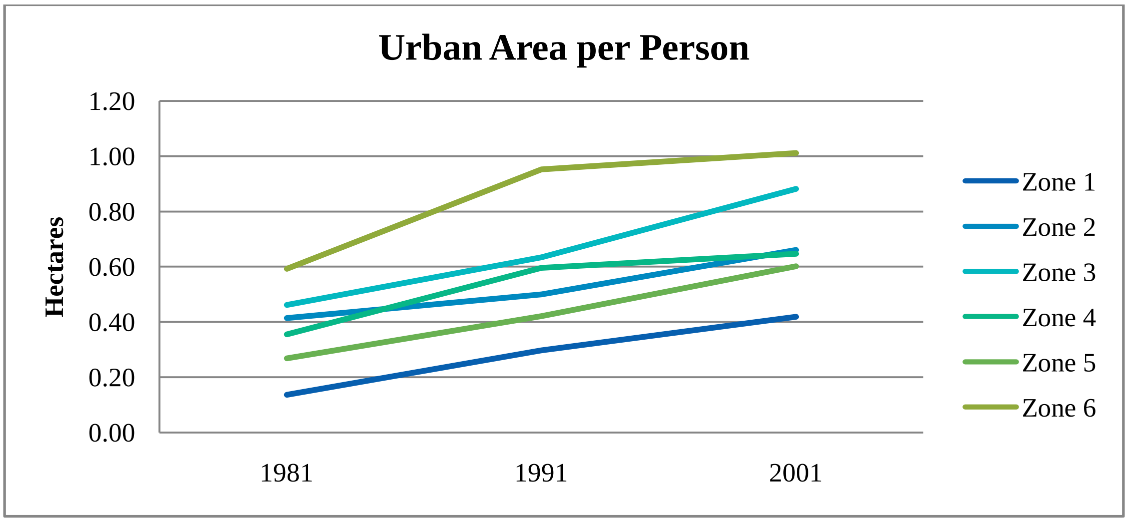



FIGURE 4.6 SPATIAL AREA (HA) PER PERSON

Although the number of samples is small, all the zones show a relatively linear growth. The greatest change was experienced by the two zones with the lowest population per urban hectare in 1981. Zone 6 shows a peak in 1991 and then considerably less growth, although overall it is generally linear trend.

### 4.2.1.3 FUTURE POPULATION DENSITY

By utilising this past trend information it is possible to determine an approximate population density for designated future periods. The sum of squares method was used in Microsoft Excel to fit a linear trend and projection from the known data. By designating future control points (in this case discrete time periods), the function extrapolated from the known data and calculated the rate of growth or decline to predict a value for that control point. Table 4.4 shows the results of using this function for the spatial urban area per person and Figure 4.7 represents the same information graphically.

TABLE 4.4 ESTIMATED FUTURE URBAN AREA PER PERSON (HA)

| Zone | 1981 | 1991 | 2001 | 2011 | 2021 | 2031 |
|---|---|---|---|---|---|---|
| 1 | 0.14 | 0.30 | 0.42 | 0.57 | 0.71 | 0.85 |
| 2 | 0.41 | 0.50 | 0.66 | 0.77 | 0.89 | 1.02 |
| 3 | 0.46 | 0.63 | 0.88 | 1.08 | 1.29 | 1.50 |
| 4 | 0.35 | 0.60 | 0.65 | 0.82 | 0.97 | 1.12 |
| 5 | 0.27 | 0.42 | 0.60 | 0.76 | 0.93 | 1.10 |
| 6 | 0.59 | 0.95 | 1.01 | 1.27 | 1.48 | 1.69 |

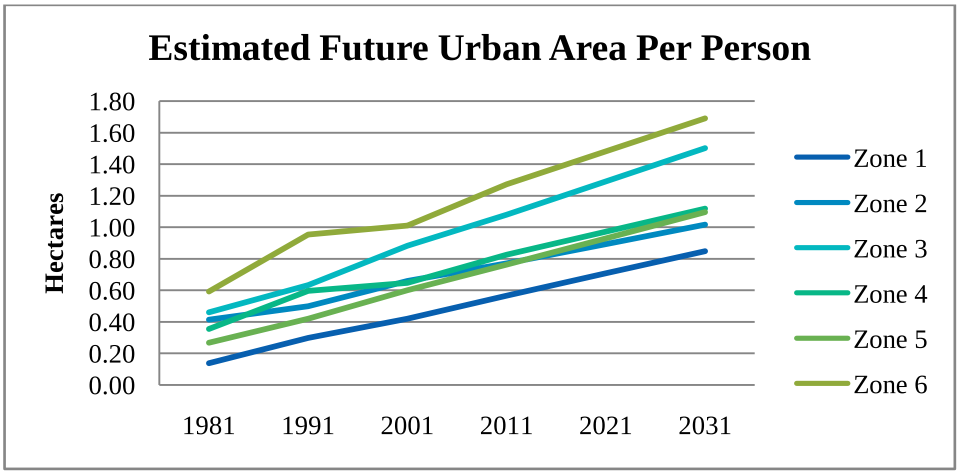



FIGURE 4.7 ESTIMATED FUTURE URBAN AREA PER PERSON (HA)

Table 4.4 shows that the extent of urban area in some zones will more than double in size between 2001 and 2031 and in the case of zone 1 that will be over six times the urban area measured in 1981. This area per person is irrespective of the level of population in the future.

### 4.2.1.4 FUTURE POPULATION LEVELS

Calculating linear and exponential trajectories for future populations from past trends provided a range of figures. A linear trend simply continues the growth of population based on the predetermined constant rate and was calculated using the TREND function of Microsoft Excel. The 2031 population was specified as the end date to provide a minimum total regional figure for population levels in scenario development. The results of these calculations for each zone are given in Table 4.5

TABLE 4.5 LINEAR GROWTH OF POPULATION BY ZONE

| Linear Growth | | | | | | |
|---|---|---|---|---|---|---|
| Zone | 1981 | 1991 | 2001 | 2011 | 2021 | 2031 |
| 1 | 5545 | 6349 | 5705 | 6026 | 6106 | 6186 |
| 2 | 17604 | 20324 | 19677 | 21275 | 22311 | 23348 |
| 3 | 22255 | 25281 | 25742 | 27913 | 29657 | 31400 |
| 4 | 76343 | 110656 | 144387 | 178506 | 212528 | 246550 |
| 5 | 38216 | 45436 | 46833 | 52112 | 56421 | 60729 |
| 6 | 13177 | 17964 | 22114 | 26689 | 31157 | 35626 |
| SUM | 173140 | 226010 | 264458 | 312521 | 358180 | 403839 |

An exponential trend uses a constant rate of "growth upon growth " or compound interest and is expressed by the formula

$P(t) = P_o e^{rt}$

Where Po is the initial population, t is time and r is the rate of growth.

This is the Malthusian growth model or exponential law and is referred to as a first principle of population dynamics (Turchin 2001, 2003). However the calculation method has some limitations. It assumes that the rate of compounding interest remains constant which becomes increasingly unlikely as the length of time continues. Furthermore, depending upon the rate of interest applied after a period of time the population level will reach a point where the basic needs of life could not be met by that space (Lucas 1994). However, as the extent of each zone is relatively large and the time frame relatively short, these limitations were not reached.

Exponential growth was calculated in Microsoft Excel by using the GROWTH function with date ranges up to 2051 to provide a maximum population level and range of population figures for scenario development. Results of this calculation are given in Table 4.6.

TABLE 4.6 EXPONENTIAL POPULATION GROWTH BY ZONE

| Exponential Growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | 1981 | 1991 | 2001 | 2011 | 2021 | 2031 | 2041 | 2051 |
| 1 | 5545 | 6349 | 5705 | 6025 | 6112 | 6199 | 6288 | 6378 |
| 2 | 17604 | 20324 | 19677 | 21423 | 22649 | 23945 | 25316 | 26765 |
| 3 | 22255 | 25281 | 25742 | 28195 | 30323 | 32612 | 35074 | 37722 |
| 4 | 76343 | 110656 | 144387 | 202077 | 277905 | 382186 | 525599 | 722826 |
| 5 | 38216 | 45436 | 46833 | 53093 | 58775 | 65065 | 72028 | 79736 |
| 6 | 13177 | 17964 | 22114 | 29139 | 37749 | 48902 | 63351 | 82069 |
| | | | | | | | | |
| SUM | 173140 | 226010 | 264458 | 339952 | 433512 | 558910 | 727656 | 955497 |
| | | | | | | | | |

It is apparent that areas such as the Far North Coast (zone 4) are likely to experience exponential levels of growth whereas the inland lightly populated areas (such as zone 1) are likely to remain sparsely populated with minimal growth.

The regional population of 403839 people by 2031 (Table 4.5) calculated by linear growth correlates well to early figures produced by the NSW planning department (Dept Planning 2001). However the growth trend for some areas, notably zone 4 are experiencing exponential growth and the therefore Table 4.6 correlates better to the expectations of the later revised government estimates (Dept Planning 2005). Given the strength of growth and new development in coastal areas however, it is likely that both the linear and exponential 2031 figures were conservative and it would not be implausible to develop spatial models based on the 2041 and 2051 exponential growth figures.

The population trend calculations provided four levels of regional population to be projected onto the regions current land use that will effect land use land cover change on landscapes and allow for design and evaluation of scenarios. The regional population levels used, based on linear and exponential growth models (Table 4.5 and 4.6) were

- 403839
- 558910
- 727656
- 955497

### 4.2.2 SCENARIO DEVELOPMENT

With the trajectories of the historic and current trends and a knowledge of past-present policies and planning in particular, incremental land release and the relationship of urban growth area to residential settlement, an "unconstrained future trajectory scenario" (Figure 4.2) can be modeled and evaluated (described in Chapter 5). To undertake the creation and generation of a map based scenario, a Geographical Information System (GIS) was used to process the spatial information that forms the underlying database for a specifically written computer algorithm which conducts the placement of new urban areas.

#### 4.2.2.1 PLACEMENT ALGORITHM

The "urban lots placement" (URBLOTS) algorithm and associated code (Appendix 2) used to classify cells as 'urban' and predict the spatial location of future populations is based on a cellular automaton (CA) approach. In this method cells are arranged in a regular grid and change state according to designated transition rules, often in the manner of a self organising system (Alberti & Waddell 2000). As urban development can often replicate the basic features of these systems the use of CA in urban modeling to simulate land-use changes is now an active area of research (Xu 2001, Veldkamp & Lambin 2001, Jantz & Goetz, 2005).

After specifying a predetermined number of cells to be allocated within a zone, the algorithm will progress iteratively through the area, selecting additional urban cells until the number of cells corresponding to the end point population level is reached. The selection of new urban cells is dependent upon the proximity and relationship of cells to existing urban areas. This creates a predisposition to select new areas adjacent to existing development and hence build or enlarge neighbourhoods. Furthermore, as areas become popular and experience strong growth they will tend to continue to "attract" further growth in adjacent areas.

As the program functions on a singular zone at a time an ESRI AML script (Appendix 3) was used to iteratively call and provide the required data to the URBLOTS algorithm. This script contains the locations of the relevant GIS raster maps and future population levels for each zone. Both the AML script and URBLOTS program were modified and adapted for the current research and regional context from code provided by Dr. Scott Bassett (Desert Research Institute, University of Nevada).

The population of each zone is calculated by multiplying the future population for that zone by its future population density to determine the zone's overall future urban area. The 2004 urban area is then subtracted from this figure to provide the net amount of urban area to be placed by the algorithm. These figures are provided in the following chapters as part of the specific description and procedure applied to each scenario. As the URBLOTS program was not originally designed to consider population density the sum of this figure for all zones is called population within the

AML script and the value for each zone is listed as a percentage of the total regional population (Appendix 3).

#### 4.2.2.2 SCENARIO GENERATION

The URBLOTS program uses a separately produced raster grid (as a spatial layer) that defines grid cells as being potentially buildable based on designated constraints on urban development applied to each scenario. This method allows for the creation of a variety of scenarios using any combination of restrictions to urban development. An explicit "buildable area" map was produced specifically for each scenario in ESRI ARCGIS.

To create this map, a mask of the area was created as a raster grid where all of the cells within the region's boundaries were set to the value of 1. Constraints to new development within the region are represented on similar grid maps but have a value other than 1. The mask and constraints are then merged to produce an intermediary data layer where a value of 1 has the potential for new urban development and any other value is not available within that scenario. The values of this intermediary step are then reclassified or changed to produce the buildable area map that contains the value '1' for buildable cells and the 'nodata' value for not buildable cells.

This buildable area layer together with a mask of the region, the zone map (such as in Figure 4.5 without CCDs) and the amount of new urban area for each zone provides the input for the URBLOTS program to generate a future scenario. Constraints to development, buildable area maps and the results of the URBLOTS program are presented within each scenario description in Chapters 5-9.

## 4.3 SCENARIO EVALUATION

The output of the URBLOTS program is a raster grid of value for new urban cells and nodata for other areas for each zone. At the completion of the placement algorithm for all the zones the AML script merges the new urban areas produced for each into one raster grid for the whole region.

This grid is then combined with a copy of the 2004 land use land cover map in ARCGIS using the merge command to overwrite the 2004 value of the cells that have converted to urban use. This produces a map that depicts the regional land use patterns at a specified population size and can then be used to evaluate change in comparison to the 2004 landscape. As well as producing a visual reference, ARCGIS provides the total number of cells and hence the area, used by each land use class. These totals are then compared to the equivalent information for 2004 LULC and the difference between the maps represents a numerical loss or gain in area per land use class.

The Forested Ecosystem Database, provided by NSW National Parks and Wildlife is a raster grid map of approximately 250 vegetation classes with a 100 x 100 metre grid resolution. This data also contains information regarding the vegetation status in regards to classification as rare, threatened, endangered, vulnerable (JANIS 1997)(Figure 3.4).

To provide a more comprehensive evaluation of the effects of new urban development, the areas of the ecosystem database that spatially matched the 2004 LULC classes of forests, coastal complex and pasture were selected and placed into a new spatial data layer. This provides a higher level of information for the vegetation type of these land cover classes and a greater spatial accuracy as to the existence of vegetation, particularly along patch boundaries, than the ecosystem database. However, the spatial the accuracy of the underlying data (ie the vegetation type) of the new derived spatial layer remains based on a 100 x 100 metre grid and as such can only be considered an approximation at a 25 x 25 metre scale. In addition, boundary areas of vegetation from the LULC classes may be considered not vegetated within the ecosystem database due to the latter's lower resolution. In these cases the vegetation type is termed 'unclassified'.

Even with these caveats, this process and information together with the comparison of the overall land use changes provides a valuable tool for the assessment of the impact of future changes and supports the design of alternative scenarios.

## 4.4 FUTURE LANDSCAPE SCENARIOS

The "development of future landscape" box in the methodology for future scenario development (Figure 4.2) shows the initial unconstrained future trajectory as a primary scenario. This is a 'business as usual' approach with few constraints to development and is based on extending the past trends into the future. Described in detail in Chapter 5, this scenario forms the basis of the comparison for alternative future landscapes. By analysing the results of this future trend, other socio-ecological factors and interactions can be encompassed into the scenario framework to produce alternative future landscape scenarios (Chapter 6-9).

## 4.5 ALTERNATIVE FUTURE LANDSCAPES

The capacity to generate multiple future scenarios provides the flexibility to introduce changes to constraints or population and then create "what if" scenarios. This allows for the concerns and issues raised in Chapter 3 and the beginning of this Chapter 4 be incorporated into the scenario creation and evaluation methodology.

These factors were grouped into environmental concerns, agricultural protection and changing settlement patterns. With the addition of the unconstrained future trajectory the following scenarios were designed.

- Unconstrained future trajectory or 'minimal constraints' scenario;
- Environmental Priority Scenarios;

- Agricultural Priority Scenarios;
- Agricultural and Environmental Priority Scenarios; and
- Changed Settlement Pattern or 'Coastal Protection' Scenarios

Each of these landscape futures was generated at the four overall population levels of 403839, 558910, 727656 and 955497 people. As scenario methodology is designed to be cyclic and generate feedback the Agricultural and Environmental Priority scenarios and the Changed Settlement Pattern scenarios each have two variations. Overall with seven sets of scenarios at four population levels, in total, 28 scenarios were designed, created and evaluated.

The details of the creation of constraints to development, population levels and population density that distinguishes each set of scenario is provided within chapters 5 to 9 as outlined below in Table 4.7.

TABLE 4.7 SCENARIOS CONTAINED IN EACH CHAPTER

| Chapter | Scenario | Variations |
|---|---|---|
| 5 | Unconstrained future trajectory or 'minimal constraints' | - |
| 6 | Environmental Priority | - |
| 7 | Agricultural Priority | - |
| 8 | Agricultural and Environmental Priority | Increased Density |
| | | Urban Shift |
| 9 | Changed Settlement Pattern or 'Coastal Protection' | Minimal Constraints |
| | | Agricultural and Environmental Protection |