People, the Cape Floristic Region, and sustainability

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The remarkable biodiversity of the Cape Floristic Region (CFR) is examined in much of this book from an ecological and evolutionary perspective. Its management (conservation, fire) and the impact of invasive alien species and climate change are the focus of other chapters (Chapters 3, 12, 13, 14). Here we examine the CFR from the perspective of a system of interdependencies between people and the environment. Can the CFR's biodiversity continue to support people, and will this biodiversity itself be conserved under the pressures of expanding demands by society? By looking at the current impacts and how they arose we make suggestions as to how these impacts may be ameliorated. We regard a sustainable state of the CFR as one able to support human existence (in an equitable manner) through its wise management so that it continues to support physical and emotional well-being while maintaining its own intrinsic value. Assuring sustainability in the future requires not only scientific knowledge and appropriate technological innovations but also the adoption of ethical approaches to people and nature.

This chapter examines these questions and objectives from the perspective of the CFR as a floristically diverse ecological system, largely congruent with a political unit, the Western Cape Province of South Africa, centred around a large and growing metropolis, Cape Town, the oldest city established by settlers in South Africa. While it would be naïve to regard this as a closed system, there are high levels of interdependencies and interactions between its human population and its biodiversity. Cape Town, the biggest and most complex metropolis in the CFR, like other cities worldwide (Grimm et al. 2008; Grove 2009), relies on ecosystem services delivered

within its boundaries and from outside (O'Farrell et al. 2012), and impacts on the ecology of systems within, adjacent, and distant from its boundaries.

Shifts in use, management, and perceptions of terrestrial nature have been recorded since the fifteenth century. This serves as a point of departure for the more detailed contemporary consideration of land cover change as experienced through the expansion of housing, the interplay between landscape management and water provision, natural resource use and food production from within and beyond the city, and implications for the biodiversity of the CFR. Key challenges and opportunities in imagining a more sustainable relationship between the city and the biodiversity of the CFR are highlighted. Emerging are novel habitats with new assemblages of biota which may offer alternatives for some ecosystem services but generally reduce the uniqueness of the environment. People's relationship with, and perceptions of, nature form a narrative thread that runs through the chapter as a means of understanding change and exploring options for a more sustainable future.

15.1 A brief history of natural resource use in the CFR

Understanding and interpreting current landscapes and future development directions requires reading, reflecting on, and understanding past landscapes and social engagement with resource use (Ramalho and Hobbs 2011). Several turning points in the social, economic, and political realms have marked important changes in perceptions and use and consequently impacted the state of nature in the CFR.

The environment in and around Cape Town has been used for millennia, first by San hunter-gatherers (Chapter 8) and from about 2 000 years ago by Khoi pastoralists who moved through the region in search of seasonal grazing and water for their herds of sheep and cattle (Deacon 1992). While large scale and significant degradation probably only occurred with the arrival of the Dutch, the San and Khoi manipulated the landscape, especially through fire (Deacon 1992) but also grazing, foraging, and hunting in a manner that would have resulted in some environmental impact.

Human impact accelerated in the CFR with visiting seafarers (in the fifteenth century), attracted by prospects of fresh water and meat traded from the Khoi, and settlers (from 1652) who brought with them technologies that led to much wider alteration of this environment (Worden et al. 1998). Along with the settlers came the process of the suppression of nature, or 'taming' associated with city and state building (Anderson and O'Farrell 2012). Early on Cape Town's population took on a cosmopolitan character. The Dutch East India Company's administration employed people from many European countries, slaves, and political exiles were brought in from Indonesia, Madagascar, India, and other parts of Africa, and indigenous people were assimilated, resulting in a society divided along lines of class, race, and bondage (Worden et al. 1998).

Exploitation of the natural resource base in this period was high but generally localized, with resources being secured for a passing maritime trade supported by a small residential population established for this purpose by the Dutch along the shores of Table Bay (Fig 15.2). Nature became a commodity: new plant species were sent to Europe to enter the horticultural trade (Fraser and Fraser 2011), agricultural land was allocated for the exclusive use of individuals, wood was harvested for building and fuel, local food and water resources were traded with sailors (Worden et al. 1998), and bounties were placed on the heads of problem wildlife (Skead 1980). Growth of the residential population led to an expanding permanent settlement whose resource needs outstripped those of passing ships. This era saw the establishment of farms in fynbos and renosterveld, the canalization and frequent fouling of water sources, the promulgation of the first fire legislation, and systematic extermination of large and dangerous wildlife (Skead 1980; Worden et al. 1998).

Expansion by settlers into the hinterland was headed by livestock owners who got land grants in areas occupied by Khoi livestock keepers. Several types of

relationships and partnerships developed between local and settler livestock keepers (Penn 1989) but ultimately these were marked by the Khoi losing their cattle so that by 1800 no indigenous pastoralists existed in the region except in isolated pockets in Namaqualand and the Cederberg (Mitchell 2009). Displaced Khoi became indentured farm workers, working alongside slaves with few practical differences in working conditions (Mitchell 2009), or fugitives (Penn 1989). Initially socio-economic factors determined access to land and some mixed race¹ people were able to gain loan farm permits. With increasing value of introduced crops by the end of the 1700s, race was used to exclude black² people from receiving loan farms (Mitchell 2009).

By the 1800s extensive livestock grazing was a diminishing land use. There are suggestions that grazing was leading to environmental degradation because tickets of occupation to new lands were issued when land became too overgrazed (Penn 1989). In most of the fynbos and renosterveld areas agriculture took on its current characteristics driven by the suitability of the mild and wet winters of the western part of the CFR for the cultivation of certain crops imported from temperate and mediterranean climate areas. Grains with C₃ photosynthetic pathways (wheat, barley, oats, and rye), vines and deciduous fruit, citrus, and many vegetables were suited to the CFR. The climate had excluded the crops cultivated by African farmers in earlier times in the summer rainfall areas to the north and east of the CFR. Despite the low fertility of many of the soils, cultivation resulted in the transformation of most lowland vegetation. Certain types of renosterveld, on moderately fertile soils, were so completely obliterated by cultivation (McDowell and Moll 1992) that conception of their original composition are built from early traveller's tales of abundant grazing herds of wild and domestic animals, early botanists' collections, and surviving remnants of vegetation, in atypical habitats, on soils too rocky to cultivate or repeatedly burnt for grazing (Curtis and Bond 2013).

Colonization, under the British from 1795–1802, and then from 1806, placed Cape Town in the web of a much larger global colonial endeavour (Worden et al. 1998). This era saw ongoing environmental extraction but also a scaling up of the manipulation of the

¹ Race is used here as a sociopolitical construct and not a biological one.

² Black is used to refer to all groups, who because of their ethnicity, were regarded by the state as having lower status to people of European origin from the early days of the Cape settlement.

natural environment to meet human needs. There were 13 million vines in the CFR in 1819, 69.9 million vines in 1875, and by 1880 30% of the population was involved directly or indirectly with wine farming (Giliomee 1989). In this period an example of how valuation of an ecosystem service may have unintended consequences occurred which was to presage developments in twentieth century politics. Dutch-speaking wine and wheat farmers in the late 1800s were unhappy with government imposed excise fees, and market control by urban-dwelling English-speaking traders for these commodities. This dissatisfaction led to the formation of the first organizations which fostered the growth of Afrikaner nationalism and ultimately the apartheid state (Giliomee 1989).

The Cape colony saw a number of visits from botanists, plant collectors, and naturalists in the seventeenth to nineteenth century, fuelled by a growing fascination with the exotic in Europe (Fraser and Fraser 2011). Although these visitors found the flora of the colony remarkable, early local settlers were for the most part less enamoured with it and preferred horticultural plants from elsewhere (van Sittert 2003a). As the 1800s advanced increasing identification with the Cape colony and, subsequently, the Union of South Africa (established 1911), as 'home', was mirrored in a growing appreciation of the local flora. This saw the utilitarian value of nature being complemented by an aesthetic appreciation of the unique flora, and initiatives such as the establishment of the Kirstenbosch Botanical Gardens (1913) to promote local flora, and legislation to prevent its over-exploitation (e.g. Wild Flowers Protection Bill 1905, van Sittert 2003a). Public concern over the management of Table Mountain manifested itself throughout the 1900s spurring ecological studies and reviews of the mountain (e.g. Moll and Campbell 1976; Macdonald and Cowling 1996). These identified the underlying problem as the multiplicity of managers of the mountain (14 public bodies and numerous private owners in 1996) leading to uncoordinated management (van Wilgen 1996). Table Mountain National Park, coordinating management under one body, was only declared in 1998, seven decades after the Wildlife Society of Southern Africa had called for a national park to be proclaimed (Macdonald and Cowling 1996).

Industrialization was slow to take hold in South Africa, and only began in earnest with the advent of diamond, gold, and coal mining, north of the CFR, towards the end of the 1800s. The Cape became the passage for equipment moving to the interior mines, and their products to be extracted to Europe. Cape

Town became an environmentally exposed global port. Numerous plant species were brought in for afforestation, and environmental management purposes, with significant environmental consequences (Chapter 12). These included the introduction of invasive plant species which altered ecological processes and ecosystem functions (e.g. fire regimes and fire-return periods were shifted), and a change in the associated biodiversity (Chapter 9). This period also saw economic stagnation in the Cape, as investment shifted elsewhere (Mabin 1989) which slowed the growth of Cape Town until after the two world wars.

In 1948 the Nationalist Party gained power in South Africa, establishing the policy of apartheid. Apartheid legislation cemented the alienation of the majority of people from agricultural land, with the removal of black³ farmers from land they owned or rented in the Cape. In support of their rural powerbase, government subsidies for agriculture were provided to move white (mainly Afrikaner) farmers, from a peasant agrarian economy to technology driven, commercial agriculture. This provided the means of transforming all but the most marginal land in the CFR lowlands to agriculture.

With democracy (1994) the political landscape of South Africa changed again. Specific provision in the constitution is made for access to a healthy environment, clean water, and sanitation (Steyn 2005). This has instituted an increased commitment to deliver services to all people. The establishment of the City of Cape Town Metropolitan Municipality saw the amalgamation of many smaller municipalities under one authority. The lifting of trade restrictions has seen an expansion of high value agricultural crops and tourism, including ecotourism. However, wealthier people have best been able to harness the benefits of these trends and the wealth gap has grown rather than diminished since apartheid (McDonald 2008).

15.2 Matching a political unit with a biodiversity hotspot?

Political boundaries define the peopled space while natural entities are defined by the presence of suites of species, and while both are human constructs, these

³ During the apartheid period, differences between the treatment and rights of different black groups were legislated but the dominant outcome was that black people were deprived of a meaningful plebiscite, the right to own agricultural land, and freedom of choice with respect to where they lived, studied, and spent their leisure time, as well as what work they could do.

seldom coincide. This presents challenges when examining the interface between human society and nature in defining what units to refer to. Statistics may be available for politically bounded entities which do not match the natural environment, or vice versa. In this chapter we focus on the Western Cape Province. The majority of the CFR falls within the Western Cape (small portions also occur in the Northern and Eastern Cape Provinces). Other vegetation types found in the Western Cape are the Nama karoo and the succulent karoo (the latter being part of the Greater CFR) but being areas of low rainfall and low population density (1.8 and 5.2 inhabitants km⁻² respectively (StatsSA 2011)) are less influential to the profile of the province.

The majority (64%) of the Western Cape's population lives in Cape Town with the balance in rural areas and small towns (Table 15.1). Cape Town forms a large municipality with its own local government

structures for planning, service delivery, and environmental management. It in turn falls within the Western Cape Province which exists as a partially federal state (conservation, agriculture, and economic development, for example, are provincial responsibilities). Bulk water supply is a joint undertaking between the national ministry and the city. Spatial planning is a municipal mandate although the province has its own spatial planning section and comments on municipal planning products.

15.3 Cape Town: trends in housing and impacts on biodiversity

Although Cape Town's footprint is only 1.9% of the area of the Western Cape, the impact of cities has regional and global consequences beyond their boundaries. Both the impacts in and beyond cities play out

Table 15.1 Census statistics for Cape Town and the Western Cape for 1996, 2001, and 2011 (StatsSA 2011; CCT 2012a).

	1996 census	2001 census	2011 census
Population			
Western Cape	3 956 876	4 524 334	5 822 734
% growth of province	—	14% (2.7% yr ⁻¹)	29% (2.5% yr ⁻¹)
Cape Town	2 563 095	2 893 249	3 740 026
% growth of city from date of previous census	—	13%	29%
Growth rate of city since previous census	—	2.5% yr ⁻¹	2.6% yr ⁻¹
City as % of total provincial population	65%	64%	64%
Housing			
Number of households	—	777 389	1 068 572
Formal housing	—	79%	78%
Informal housing	—	21%	22%
Increase in housing by category			
Formal	—	—	39%
Informal	—	—	44%
Population distribution			
Age 0–14	—	27%	25%
Age 15–24	—	20%	18%
Age 25–64 years	—	48%	51%
Age 65 +	—	5%	6%
Education level			
% finishing high school at highest level	—	25%	30%
% with post school education	—	12%	16%
Employment			
% employed 15–64 age group	—	47%	50%

with respect to cover change, biodiversity losses and gains, biogeochemical and hydrological cycling, and climate (Grimm et al. 2008), and in a myriad of social experiences and perceptions that in turn inform use and governance of nature.

The Cape Town metropolitan area encompasses 2 460 km² in the southwestern corner of CFR. The CFR is a recognized global biodiversity hotspot (Myers et al. 2000), and the city's footprint coincides with the most diverse portion of the CFR (Cowling et al. 1992) and harbours over one-third of the CFR's plant species (Rebello et al. 2011). Several national vegetation types are unique to the city and support many endemic species.

Against the backdrop of a unique and biodiversity-rich natural environment is the pressure of a rapidly growing human population. Cape Town currently has the highest per capita growth rate of all cities in South Africa (CCT 2012a). Population growth accelerated from the 1960s during the apartheid era and again intensified from the late 1980s following the demise of apartheid influx control (Fig 15.1). Currently this growth is due mostly to influx of rural people from other provinces in South Africa. Such growth is mirrored by other towns and villages in the Western Cape (Table 15.1). Human population growth, in turn, has driven urban development and the transformation of natural ecosystems. In this pattern, Cape Town is part of a global trend of rural-to-urban migration and ahead of the trend for developing countries which

predicts 66% of the population urbanized by 2050 (Montgomery 2008).

Cape Town's population increased from 2.56 million in 1996 to 3.74 million in 2011 (Table 15.1). Current demographic data indicate a young population, with a median age of 26 years. Thus the population is projected to continue growing, both from natural increase and ongoing in-migration, reaching 4 million by 2016 and 4.3 million by 2031 (Dorrington 2000). Because of in-migration and decreasing household size, the number of households in Cape Town has grown by 37% since 2001 (Table 15.1). All housing categories show increased numbers of dwellings over the period 2001–2011 with informal housing growing most (Table 15.1). The city is sprawling in nature and retains a separatist spatial form, and development inequalities characteristic of the apartheid city (McDonald 2008).

Increasing population growth has been mirrored by an increasing urban footprint, including both infill and greenfield (urban sprawl) developments: Cape Town is seven times larger than it was in 1945 and has doubled in size since 1977 (Fig 15.2, Sinclair-Smith 2009). The rate of urban growth is now 1 232 ha yr⁻¹ (CCT 2013). Cape Town population densities have progressively declined over a century (1904: 115 people ha⁻¹, 1946: 73 people ha⁻¹, 1970: 52 people ha⁻¹, 2000: 39 people ha⁻¹ (Gasson 2001)).

The 1930s saw the first phase of urban planning. The 'garden city' concept, then becoming popular in

Figure 15.1 Growth in Cape Town's human population and the urban developed area from the early 1900s until present (data prior to 2009 from Sinclair-Smith 2009; 2013 urban area estimate may include some transformed areas not considered in the former dataset (City of Cape Town Environmental Resource Management Department)).

Figure 15.2 Increasing urban footprint of the City of Cape Town (1904–2013). Proclaimed conservation areas dominate undeveloped areas in the south east (9 120 ha) and south west (32 232 ha) of the municipality while non-urban areas to the north are dominated by agriculture. TM = Table Mountain, RW = Rondevlei Wetlands, MD = Macassar Dunes

Europe, was taken on by the city planners, segregating business and residential areas, which would set the pattern for the subsequent expansive footprint of Cape Town (Pinnock 1989). Removals served to move the poorest, mostly black, people to the outermost reaches of the city, to areas where nature was often harsh with windswept sand dunes and winter flooding. This foreshadowed the overtly racist forced removals of the nationalist government from 1948 onwards (Pinnock 1989). The new black townships, segregated by race, isolated from places of work and other amenities, surrounded by greenbelts, and with single or few access roads, served to restrict movement and isolate communities so that in times of unrest they could be controlled (Pinnock 1989). Concomitantly the middle classes, afforded mobility with private car ownership, also moved to new suburbs. These planning policies undoubtedly were influenced by the cheap oil years which encouraged urban sprawl globally (Angel et al. 2010).

The 1970s saw the transition from a city within natural vegetation to natural vegetation remnants within a city (Figs 15.2, 15.3, Rebelo et al. 2011). Urbanization has also encroached on agricultural land since the late 1990s (Fig 15.3). Land transformation, in combination with the high number of local endemic and Red List species (Raimondo et al. 2009; Holmes, Rebelo, et al. 2012), means that most natural ecosystems in the city are classified as nationally threatened (GovtSA 2011). Threats resulting from land transformation are particularly acute in the lowlands (Holmes, Rebelo, et al. 2012). Thirteen plant species in the city are globally extinct and 319 are threatened with extinction: this represents 12% of South Africa's threatened Red List flora in 0.001% of the land area (Rebelo et al. 2011).

The fynbos and renosterveld ecosystems that dominate the CFR are fire-adapted ecosystems which need periodic fire to maintain biodiversity (Chapter 3, Rebelo et al. 2006). Fragmentation interrupts the natural fire regime, and maintaining this essential process can be challenging within an urban matrix. Remnants adjacent to settlements are subject to too-frequent fires, resulting from mostly accidental ignition during the dry, windy summer months. Too-frequent fires can eliminate species with longer juvenile periods and also promote graminoids which then start to dominate these ecosystems, altering their structure and functioning. One positive feedback that entrenches this transformation is nitrogen deposition from car exhausts (Wilson et al. 2009) which promotes the competitive ability of grasses (usually alien) over fynbos species (Yelenik et al. 2004). Another is the shorter fire cycle that is carried by grass fuels.

Invasive alien species, especially the hard-seeded Australian acacias, are promoted by fire and quickly smother indigenous vegetation to form dense thickets that are detrimental to bird (Dures and Cumming 2010) and plant (Holmes and Cowling 1997) communities. In poorer suburbs, open spaces invaded by Australian acacias are associated with crime and are referred to colloquially as the 'bush of evil'. Thus vegetation management also may be seen as a social imperative, since controlling invasive species and maintaining the appropriate fire regime for the indigenous vegetation will maintain it in a state that is less attractive to criminals and less threatening to local communities. In other areas a lack of fire, owing to fire suppression along the mainly affluent urban–mountain interface, causes senescence in fynbos species and invasion by thicket and afrotemperate forest species. Once thicket or forest have established as the dominant cover, it is less fire prone and becomes self-sustaining (Chapter 9), to

Figure 15.3 Changes in the proclaimed conservation estate and broad land-use categories in Cape Town from the early 1990s until 2013. The total Cape Town metropolitan area is 246 141 ha.

the detriment of the more biodiversity-rich fynbos or renosterveld, of which several rare types are located on the lower slopes of mountains (Rebelo et al. 2006).

Fragmentation increases extinction risk throughout the CFR as the area of habitat declines and populations become smaller and separated in island remnants (Bond et al. 1988; Kemper et al. 2000; Sandberg 2013). Animals may no longer be able to migrate across the transformed matrix to recolonize remnants or enable gene flow. For plants, gene flow may still be possible if pollen or pollinators are able to move amongst remnants. However, in plant species with specialized pollinators, there is the additional risk that if the pollinator is eliminated from a remnant, then the population will be at high risk of local extinction. This has been documented on the Cape Flats where a specialized pollinator (the oil-collecting bee *Rediviva peringueyi*) is locally extinct on smaller reserves (<385 ha) and six specialist plant species dependent on its services failed to set seed (Pauw 2007). Many fynbos species are bird pollinated and have tubular flowers co-evolved with pollinator bill length. Pauw and Louw (2012) found that all but one of these bird pollinators were highly sensitive to urban development. The Cape sugarbird and orange-breasted sunbird, did not penetrate urban areas, and the malachite sunbird penetrated only 1 km into the urban matrix. Only the shorter-billed southern double-collared sunbird utilized urban green

spaces. The sensitivity of these birds to urban areas has implications for pollination function in the long-tubed, bird-pollinated guild in urban nature reserves.

15.4 Ecosystem services within the city

Access to natural open space for recreation and emotional and spiritual uplift are well-documented health benefits of conserving nature in urban areas (Chivian and Bernstein 2008). Natural England (2010) recommends a minimum of 1 ha of land under formal conservation for every 1 000 of the population. Since the City has 43 980 ha under conservation, approximately 12.5 ha per 1 000 people, this is fulfilled. However recommendations are for minimum areas that are much more accessible to people's homes (e.g. 500 ha within 2 km of home) which is particularly problematic for poor people in the city who tend to live further from nature reserves and natural remnants (O'Farrell et al. 2012).

Many people across the economic spectrum do access natural areas, however, and Petersen et al. (2012) have shown that people in the city use 250 and 198 locally occurring plant and animal species respectively (including marine organisms) for a variety of purposes. Most of these are harvested in small quantities although the cumulative impact can be great. Within the city, 261 tonnes of biological material are extracted by traditional healers every year (Petersen et al. 2014).

Recent studies have highlighted other ecosystem services which are delivered within the city boundaries (De Wit et al. 2009; O'Farrell et al. 2012). Many of these cannot be delivered offsite but are no longer functioning as they would if vegetation was intact (O'Farrell et al. 2012). These include soil infiltration and ground water recharge which govern the yield and quality of aquifers, including the Cape Flats Aquifer used for agricultural purposes and tagged as a future water source for Cape Town. Currently part of the Cape Flats Aquifer is polluted by agricultural chemicals, naturally occurring salts in the geological formation, and overflow from storm water drains and sewage treatment (Aza-Gnandji et al. 2013).

Flooding is a common feature of the Cape Flats in winter. Natural flood mitigation is estimated to have lost 32% of its potential capacity due to vegetation loss and canalization but can be ameliorated by buffer zones of vegetation around rivers and wetlands and the improved infiltration that vegetation offers (O'Farrell et al. 2012). With the prospect of climate change associated increases in storm surges and sea level rise and the generally low lying nature of the Cape Flats, coastal zone protection by intact dune systems is also critical. The coastal protection zone has lost 25% of its potential capacity due to unwise development (O'Farrell et al. 2012).

In one of the few examples of the city providing ecosystem services beyond its boundaries, urban gardens and vegetation fragments in the city offer the opportunity of maintaining some of commercial beekeepers' Cape honeybee hives, required for pollination by the adjacent deciduous fruit industry (Melin unpublished). Urban landscapes provide important year-round floral resources both from natural vegetation and novel ecosystems (e.g. gardens and stands of *Eucalyptus*; Chapter 12). While Cape Town can outsource many of its provisioning services, the city is dependent on regulatory and cultural services within its boundaries, which in turn are best delivered by natural systems (O'Farrell et al. 2012). Vegetation remnants serve multiple functions which are of societal benefit. By protecting these natural remnants for service delivery, the case for the preservation of threatened and endemic species can be developed.

15.5 Provisioning services from beyond the city borders

Many impacts of the city that affect the sustainability of the CFR's ecosystems occur beyond the boundaries of Cape Town. These are primarily associated

with provisioning services delivering water and food. Fresh water and food provisioning for the burgeoning European maritime trade with Asia, from the 1500s onwards, were the prime reason for the establishment of Cape Town. The Dutch engaged in engineering to control and channel the water supply and tried, somewhat unsuccessfully, to prevent pollution of water sources within the city through legislation (Brown and Magoba 2009). The first major ecosystem engineering project to harvest water was the construction of two dams on Table Mountain in 1887 and 1904 respectively, and redirection of the Disa River by tunnel to Cape Town in 1891 (van Sittert 2003b). These were followed by several other small dams on the peninsula mountains until demand outstripped local supply and water had to be brought in from outside the city boundaries, the first of these dams being developed in 1921 (Brown and Magoba 2009). Cape Town now relies on eight major water supply schemes capturing surface water flow from mountain catchments, including inter-basin transfers, outside the metropolitan area (Brown and Magoba 2009).

During the 1930s, awareness of the impact of environmental management on water resources grew. Farmers blamed reduced stream flow on the establishment of plantations, and a group of South African scientists led by John Phillips lobbied for action based on this concern at the Fourth Empire Forestry Conference in 1935 (Bennett and Kruger 2013). One upshot of this was the establishment of stream flow monitoring in small catchment experiments under fynbos and plantations in the late 1930s and maintained to the current day. This was a seminal moment in evidence-driven management of the CFR environment, setting up as it did an interdisciplinary research agenda for the rest of the twentieth century that still guides fynbos management (Chapter 3, Bennett and Kruger 2013).

Confirmation that plantations utilized more water than fynbos led to the proclamation of Mountain Catchment Areas Act no 63 of 1970 (GovtSA 1970) to secure water delivered by these ecosystems. The catchment research led to the establishment of Working for Water, an initiative of the post-1994 democratic state, to alleviate poverty through the creation of jobs to clear invasive alien plants while improving water delivery by catchments (Chapter 12). Despite clearing efforts, the Fynbos Biome is still the most impacted of all the major biomes, losing 7% of its water to invasive plants (Le Maitre et al. 2013; see Chapter 12 for further discussion of the consequences of this).

Water remains a prime natural resource for human well-being, and access to sufficient safe water and

sanitation is part of the nation's Vision 2030 (National Planning Commission 2011). Supply of potable water and sanitation has kept up with the city's growth since 1994 and currently 99.3% of the city has access to piped water while 87% have water piped to their dwelling or residential plots (Table 15.1). Cape Town uses by far the biggest proportion of the province's water resources: 63% is being used in the city, 5% in smaller towns, and 32% by agriculture (DWAF 2009).

Food provisioning in the Western Cape is important not only because it feeds the city and the nation but also because it contributes 23% of the value added by the agricultural sector in South Africa and over half the country's agricultural exports, mainly fruit and wine (Provincial Development Council 2005). While wheat production has remained steady (40% of the nation's production) since the 1980s (DAFF 2013), fruit production has grown in response to the opening of international markets post 1994 (Table 15.2). Wine production has increased by 20% since 1995 (DAFF 2013). Other important agricultural products of the Western Cape include milk, eggs and chicken, ostrich, vegetables, and recently canola. This diversity contributes to the stability of the agricultural sector, offering alternatives in the face of uncertain global markets and global change.

Agricultural ecosystem services come with biodiversity costs. In the GCFR natural biodiversity is substituted by foreign biodiversity to feed and generate income for people, a win-lose situation for ecosystem services and biodiversity, respectively (Reyers et al. 2012). Foreign biodiversity, including grapes and fruit trees, displace local biodiversity and disrupt ecosystem processes but also create new landscapes that contribute to the ambience of the Cape that is much appreciated by locals and tourists (Davey 2012). While 89% of the Western Cape's 129 386 km² of land is classified as agricultural land, only 19% of this is potentially arable (DAFF 2013, reflecting the situation in 1991).

Table 15.2 Growth of fruit production in the CFR from 1981 to 2010 (calculated from data in DAFF 2013).

Product	Production average 1981–5 (tonnes)	Production average 2006–2010 (tonnes)	Percentage increase since 1981–5
Apples	420 125	729 783	74%
Apricots	38 872	59 029	52%
Grapes	1 165 250	1 785 445	53%
Pears	148 521	347 512	134%
Peaches	160 832	173 589	8%

The expansion of international trade since the demise of apartheid, and technological advances have seen land conversion in the few remaining fairly intact low-land areas previously not contemplated for agriculture such as the Agulhas Plain and the West Coast sandveld (Heydenrych et al. 1999; Rouget et al. 2003).

In the 1980s the greatest threat to vegetation in the West Coast sandveld appeared to be livestock grazing (McDowell 1995). Provision of electricity in this area in the late 1980s saw the installation of centre pivot irrigation, pumping water from local aquifers (de Lange and Mahumani 2012), for the cultivation of potatoes. Returns on potatoes are a 1 000-fold over that of livestock, and land has been converted at a rate of 1 000 ha per year (Ashwell et al. 2006). In 2007 the potato industry was valued at R400 million and provided 3 250 jobs in an otherwise economically depressed region (Knight et al. 2007). Apart from the impact of land conversion on several rare vegetation types, the long fallow periods for disease control in potatoes mean that about a fifth of all transformed land is cultivated to potatoes each year (Knight et al. 2007). From 1996 to 2006 there was an 8% increase in centre pivots (Knight et al. 2007). On average 20% of annual recharge is used but in three of the 14 catchments abstraction was 75% of recharge. The impact of this water use, and possible pollution of ground water with fertilizer, on wetlands such as the Verlorenvlei Ramsar site is unknown. Sustainable levels of water recharge have yet to be assessed.

In another example of recent agricultural expansion, fynbos in the more arid CFR, with extremely nutrient-poor soils, was considered safe from agriculture (Rouget et al. 2003). However, a burgeoning international market (sevenfold growth from 1993 to 2003) for rooibos tea, harvested from an indigenous shrub, *Aspalathus linearis*, drove conversion of flat, sandy areas for its cultivation (Hansen 2006), resulting in a large increase (now 149 species) of threatened Red List plant species endemic to this region (Raimondo et al. 2009). Again fallowing between crops leads to a higher footprint for rooibos than that under cultivation at any one time. Both the potato and rooibos example point to how distant factors, in this case electricity provisions and markets opened by political change, may impact biodiversity and ecosystem services in ways not readily predicted beforehand.

One example serves to illustrate the interconnectedness between provisioning ecosystem services, their impacts, and some of the unintended consequences of these. The Berg and Breede Rivers have shown increases in salinity over the last 3–4 decades, aggravated, especially in the low rainfall summer months, by

the extraction of water from the upper reaches of these rivers to supply Cape Town (van Rensburg et al. 2011). This salinity negatively impacts downstream ecology and water for irrigation and human use (de Clerq et al. 2010). Inorganic nitrogen and phosphates derived from anthropogenic sources contributes to the Berg River's eutrophic or hypertrophic state along much of its length (de Villiers 2007). However, the main source of this salinity originates from aerial borne marine salts deposited, in the past, in the underlying soils derived from Malmesbury shales (de Clerq et al. 2010). This salt layer may be as large as 200 tonnes ha⁻¹ and contributes 0.5 tonnes ha⁻¹ yr⁻¹ to the catchment (de Clerq et al. 2010). Under natural renosterveld, deep rooted shrubs kept the water table, and the salts dissolved in this, well below the surface. However, under agricultural crops, the water table rises to within a metre of the surface, in a process similar to that leading to widespread salinity of Australian cultivated fields, and salts are leached into waterways leading into the major rivers. Salinization of water is not the only impact of removal of renosterveld and replacement with crops. Soil characteristics (surface roughness, compaction, structure, and infiltration capacity) also change and result in faster runoff under wheat cultivation (de Clerq et al. 2010). Revegetating drainage lines or strips in fields with deep rooted indigenous shrubs has been proposed as a means of restoring deeper water tables (W. de Clerq pers. comm.).

15.6 Steps to a sustainable city

In global terms, Cape Town qualifies as a 'sanitary city' (Grove 2009) where the use of nature to absorb wastes is accompanied by various levels of management to ameliorate their immediate impact, although there are challenges as service delivery struggles to keep up with informal housing growth. Recognizing that overloading of global systems with waste threatens our existence as a species, through the generation of greenhouse gasses driving climate change, and pollution of water, soil, and air so that they can no longer support the ecosystem services that sustain people, the concept of 'sustainable cities' emerged (Grove 2009). In this section, we look at how Cape Town is developing in this direction through the lens of housing and the biodiversity and ecosystem services supporting the city.

During the apartheid era, isolation served to keep South Africans ignorant of growing international awareness of the impact people were having on the sustainability of the environment (Steyn 2005). This changed with a rise in politicized environmental

NGOs from the late 1980s. A consequence of this is that the environment featured as one of ten basic needs and a prerequisite for poverty alleviation in early post-apartheid documents. However, subsequent development of macroeconomic policy focussed on economic growth, which meant that both poor people and the environment were again sidelined (Steyn 2005; UNEP 2011). More positively, the inclusion of stakeholders in environmental planning and development rose in this period (Steyn 2005). Recent developments show a linking of environmental issues to poverty alleviation and tackling climate change (DEAT 2008; National Planning Commission 2011). Challenges still remain and much depends on the implementation of these concepts in locally relevant and sustainable ways.

In the CFR a major game changer in this respect is Cape Action for People and the Environment (C.A.P.E.). Initiated in 2000 to tackle threats to the CFR's biodiversity, it saw the need to bring government, the private sector, and civil society together to develop new approaches to conservation aimed at delivering benefits to people (Ashwell et al. 2006). C.A.P.E. has fostered partnerships aimed at improving environmental sustainability by mainstreaming this in government, business, and landscape initiatives that are reported on below.

Policy for local government ensures that municipalities and provinces develop integrated development plans (IDPs) and spatial development frameworks (SDFs) which direct the future development path of the city. The City of Cape Town has increasingly integrated environmental matters in their IDPs and SDFs (CCT 2013). In addition, state of the environment reporting is undertaken by local government (CCT 2012b).

In 2007 the environment was emphasized as a strategic area in the vision: 'Cape Town as a sustainable city that offers a future to our children and their children'. In the 2012 IDP the emphasis is on integrating the environment in all relevant sectors for achieving the city's five pillars for the future: the opportunity city; the safe city; the caring city; the inclusive city; and the well-run city (CCT 2013). Thus objectives under the opportunity city pillar such as '1.3 Promote a sustainable environment through the efficient utilization of resources' is listed with, for example, '1.5 Leverage the city's assets to drive economic growth and sustainable development'. The safe city pillar states that 'Safety is essential to the public enjoyment of open spaces, city beaches and nature reserves'.

Green procurement is entrenched through supply chain management policy and all proposed activities and projects must indicate their potential impact on

the environment (CCT 2009a, 2012c) The IDP speaks to managing natural resources more efficiently, reducing the city's carbon and waste footprint, and adapting to climate change. While this integration of environmental issues in the business of a city is a move away from the separation of city management into silos, care is needed to ensure that the environment is not overlooked.

In practice, the road to integration between different city management divisions is still a work in progress as seen by ongoing challenges between preserving 'last of a kind' biodiversity and urban expansion. The need to provide infrastructure and housing for the increasing, and mainly poor, population, coupled with the objective to promote growth and development, leads to a conflict of interests over greenfield land (often critical biodiversity areas), and consequentially biodiversity status continues to deteriorate in the city (CCT 2012b). Whereas the Provincial and the Cape Town SDFs espouse urban densification principles, human settlements for the poor are constrained by national housing grants, which are sufficient only for single storey houses (multistorey having higher building costs) (Holmes, Rebelo, et al. 2012).

Spatial planning is a powerful tool to minimize conflicts between biodiversity conservation and development and to proactively direct developments to the least ecologically important and sensitive areas (Chapter 14). The Biodiversity Network, a fine-scale systematic biodiversity plan for Cape Town, is a key informant in the city's SDF. Thus, with the exception of a few contentious areas, in which the environmental impact assessment process must run its course, most priority biodiversity areas are identified as such in the SDF. However, until these areas are proclaimed under the Protected Areas Act (GovtSA 2003), they have no legal protection and private land owners may apply for development rights. An additional level of protection may in future be provided by the zoning scheme which will incorporate a biodiversity overlay zone.

The Biodiversity Network identifies the land needed to support critical biodiversity and ecological support areas in the most efficient configuration that takes into account existing conservation areas. At city district level, the more detailed district spatial development plans and environmental management frameworks incorporate the Biodiversity Network and associated environmental management guidelines. Remnants of natural vegetation have been assessed for habitat condition, and higher quality areas were prioritized in the planning analysis (Holmes, Stipnovich, et al. 2012). The latest 2011 analysis incorporated climate

change adaptation criteria in order to optimize resilience to climate change. Nevertheless most lowland ecosystems and wetlands are under-represented and are subject to fragmentation effects and other negative impacts resulting from urbanization.

The spatial plans and zoning scheme are important tools but require proactive implementation that delivers on-the-ground management to be effective. The Local Biodiversity Strategy and Action Plan 2009–2014 (CCT 2009b) aims to conserve 60% of the Biodiversity Network by 2014. Various implementation tools are being applied, including proclamation of managed nature areas, conservation stewardship partnerships with other city line functions and private landowners, and pursuing extensions to existing nature reserves. By 2013, 51% of the Biodiversity Network had been secured. However, some areas are experiencing rapid urbanization and informal settlement, and it is recognized that some trade-offs will be required. To this end, the City Biodiversity Management Branch initiated a conservation implementation plan for the False Bay strandveld with key stakeholders, both to identify priority areas for conservation and biodiversity areas that could be supported for development. Using this proactive approach it is hoped to obtain commitment from City Council to fund the operational management of the diminished set of conservation areas in return for development opportunities in a subset of biodiversity areas.

Many lowland Biodiversity Network remnants are degraded to a greater or lesser extent by invasive alien plants and other negative impacts resulting from fragmentation and lack of management (Wood et al. 1994). This implies that long-term conservation of biodiversity requires intensive management to maintain essential ecological processes. In some cases ecological restoration is required to restore community structure and threatened species. Fire is an especially contentious issue in managing natural vegetation fragments. Ecologically necessary burns in urban areas require careful planning and sufficient resources to ensure a successful outcome, both in terms of conserving biodiversity and protecting urban infrastructure (van Wilgen et al. 2012). Recently the City Biodiversity Management Branch has completed several ecological burns in collaboration with other line functions, including the City Fire Department. Educating the latter on the importance of fire in conserving biodiversity, via presentations, spring walks to view the striking post-fire flowering spectacle, and offering opportunities for training in wildfire management, were important in garnering their support (P. Glanville, pers. comm.). Other impacts of fragmentation, such as loss of connectivity

for specialist pollinators, may potentially be countered through the use of other green spaces as stepping stones (including parks and gardens) to cultivate pollinator host species, and some plant species currently being unsustainably harvested in nature reserves, but these aspects require further study.

As a sprawling city, Cape Town uses more energy on transport (50%) than the national average (28%; CCT 2012b), and while development is moving ahead with integrated rapid transport, its impact on private car usage (using half the transport energy budget) is not yet detectable. More direct benefits for people and the environment are seen in projects that install solar water heaters, energy-efficient lighting, and insulated or retro-fitted ceilings in low-cost housing (Cousins and Mahote 2003; Wlokas 2011; CCT 2012b). One notable exception to slight improvements in the environment appears to be steadily reducing water use per capita since 1999 (Pithey 2007; CCT 2012b). Another is a decrease in waste sent to landfill from a high of 2.5 million tonnes in 2007 to 1.7 million tonnes in 2011, representing a reduction of 39.5% per capita. While water saving has been encouraged by scaled water pricing, reducing leaks, and information campaigns, especially during droughts, the reason for reduced waste production is unknown since the city diverts only 10% of the waste it handles for recycling (CCT 2012b).

Notwithstanding the generally low impact of measures to mitigate environmental damage and conserve biodiversity, the setting of goals, ongoing monitoring of the progress and impact of implementation, and publication of results mark a commendable break with earlier municipal management. While the impact of these moves to reaching a more sustainable future may in themselves be small, such measures can facilitate sustainability since people respond more positively to messages that are inspiring, optimistic, and understandable (Cairns 2004). In an assessment of municipal IDPs, Western Cape municipalities identified 'environmental capacity and sustainable management' as one of the four main development challenges facing them, suggesting a recognition of the importance of sustainable environmental management, if not yet the capacity to act on this (Western Cape Government 2013).

15.7 Mitigating impacts on ecosystem services

Moves are afoot in the city to restore rivers and wetlands to a more natural morphology with riparian vegetation, which will also improve their capacity to self-cleanse, assimilate pollution, and avert flooding

(Pithey 2007). In the Rondevlei wetlands, hippos were reintroduced after an absence of 300 years in order to control an invasive grass (*Paspalum vaginatum*) which was reducing wetland viability (Rebello et al. 2011). Restoring natural vegetation by local communities around some city lakes adjacent to residential areas has promoted social cohesion (Ernstson 2013). Other rivers in Cape Town have been decanalized, replanted to natural vegetation and cleared of aliens to provide jobs, recreational opportunities, and improved habitat for animals. Working on Wetlands, a sister programme to Working for Water, has been active in wetland and river restoration (Ashwell et al. 2006).

Cape Town is reaching the limits of water that can be supplied by surrounding mountain catchments to support its growing population and it is estimated that current sources will be insufficient by 2020 (DWAF 2009). Alternative water resources such as desalinization are regarded as too energy expensive (UNEP 2011). Reuse of effluent water for irrigation and industry, at 7% in 2007, is growing and is targeted at 15% by 2015, with the aim to reuse 39% of all effluent. Tapping the Cape Flats and Table Mountain Group Aquifers (the latter is a deep, partially confined, fractured rock aquifer) are other alternatives. The Witsands and Silwerstroom aquifers, providing water for the satellite towns of Atlantis and Mamre, offer a service-oriented justification for protection from further development to the overlaying fynbos vegetation to secure natural recharge which is augmented by the return of treated sewerage water (Pithey 2007). Of concern for sand and fractured rock aquifers is ensuring water abstraction does not exceed recharge. Endemic species with narrow ranges and shallow root systems that are confined to permanently wet seeps may face extinction with slight drops in the permanent water table due to abstraction from these aquifers (February et al. 2004). To identify such threats the City of Cape Town Table Mountain Group Aquifer Feasibility Study and Pilot Project, initiated in 2002, currently monitors pilot wells to identify threats that abstraction may have on ecosystem function and biodiversity.

Rural land in the Western Cape is owned predominantly by individuals and companies. This puts the prerogative for conserving lowland biodiversity and managing land-based ecosystem services largely outside the custodianship of state conservation agencies. Conservation stewardship has been adopted by CapeNature, the provincial conservation agency, as a means of promoting biodiversity conservation on private land (Chapter 14).

The last decade has seen the links between sustainable agricultural practices, biodiversity conservation,

and ecosystem services being increasingly recognized and mainstreamed. C.A.P.E. and conservation NGOs have facilitated the Business and Biodiversity Initiative, with partners from commodity and retail businesses, government and farmers, which has encouraged farmers to adopt more biodiversity-friendly farming practices, and set aside natural habitat for conservation on their farms. Conservation agencies and NGOs, farmers and the agricultural sector have participated in the development of best practices for potatoes (Knight et al. 2007), rooibos (Hansen 2006), wine (Ashwell et al. 2006), and other agricultural commodities. The key to these efforts are that farmers often see the benefits of better practice or are incentivized by higher-value markets. Many of these initiatives are too young for assessment. It is disturbing, however, that of the 250 153 ha of natural habitat (61% of their land) Business and Biodiversity Initiative farmers had set aside from 2006 to 2010, 3 719 ha (1.5%) of this land had been transformed and degraded in this period (Pence 2012). While this is in the early stage of this initiative, much of the conversion has been in the critically endangered, endangered, and vulnerable ecosystems of the West Coast sandveld. In the more arid part of the CFR, private conservation areas have tripled the number of vegetation conservation targets reached by statutory conservation areas (Gallo et al. 2009). However, where no stewardship agreements exist, private conservation land can revert to other land uses and conservation may be rather broadly interpreted with the stocking of extra-limital mammals (Chapter 12).

The majority of best practice recommendations are expert based rather than evidence based. This provides opportunity for research (e.g. the provision of buffer zones or strip farming with indigenous vegetation left intact is aimed at improving landscape connectivity, pollination, preventing erosion and pollution, and offering opportunities for revegetation of abandoned fields). Some of the benefits for rooibos planted in strips with natural vegetation have been demonstrated, but the integrity of the natural vegetation remains equivocal (Herbst 2011). Arguments have been made that such measures may lead to fragmentation of natural vegetation and erosion of biodiversity as the impacts of disturbance spill over to the natural system. This leads to recommendations for consolidating agricultural areas while ensuring that large areas of conservation land are conserved. Both approaches need to be assessed in terms of ecosystem service functions, and biodiversity conservation. Research into the impacts of land sparing (sustainable intensification of agriculture with land set aside for restoration and

conservation) compared to land sharing (developing an agro-environment with certification schemes for lower impact agriculture) in India and Ghana suggest that biodiversity is better preserved by land sparing with higher intensity agriculture (Phalan et al. 2011).

While the state has not been absent from these initiatives to achieve sustainability, a barrier to wise land use is excessive bureaucracy, and departments that are under-resourced to execute their mandate. Conversion of natural land to agriculture may require permission from up to five different government departments. In the absence of sufficient capacity to censure farmers for contraventions, required procedure is often circumvented (Ashwell et al. 2006). C.A.P.E. has facilitated the bringing together of various regulatory parties to provide integrated advice on invasive species, water management, erosion control, and farm planning to ensure that land conversion only occurs under optimal conditions (Ashwell et al. 2006). Unfortunately this programme is under-resourced and has yet to be implemented beyond a pilot area.

Concerns about the sustainability of grain production, research into low or no tillage, and the benefits of crop rotations on disease control and yields (Lamprecht et al. 2006) have encouraged wheat farmers to adopt more sustainable agricultural practices although lack of capital to invest in equipment often constrains farmer adaptability. A study on sustainable agricultural practices for rooibos (Pretorius 2008) led to a decision by funders that true sustainability of the industry could only be achieved if ethical, social, and economic criteria were included with the environmental ones (Kruger 2009). In the socially inequitable rural landscape of the Western Cape, a legacy of colonization and apartheid has persisted in the main (Falletisch 2008), despite the 2001 Agri Wes-Cape code of conduct, 2002 Wine Industry Ethical Trade Association, a similar one for fruit growers in 2008, and various conditions imposed by importers of agricultural products promoting ethical employment practices (Human Rights Watch 2011). While biodiversity agriculture initiatives could be argued to have direct impact on sustaining biodiversity and ecosystem services, the ethical business initiatives could potentially have indirect, but profound, impacts on biodiversity. Greater prosperity, better working conditions, and shareholding amongst farmworkers may illustrate that biodiversity protection is not gained at the expense of poverty alleviation (Kepe et al. 2003).

Harvesting of wild flora has long sustained a sector of the rural poor communities in the CFR (van Sittert 2003a). Efforts have been extended to improve

the sustainability of wild harvesting and to introduce alternative livelihoods based on the cultivation of some of these species, with the aim of conserving the species in the wild and generating larger incomes. The biodiversity economy is seen as a means of alleviating rural poverty and addressing unsustainable practices (Cadman et al. 2010).

Some success has been demonstrated by the benefits of the biodiversity economy in the CFR accruing to poor people who participate in the commercialization of biodiversity, while ensuring the sustainability of the ecosystems supporting these efforts. One example, the Heiveld Co-operative, now has 65 members after starting with 14 members in 2001. They have secured lucrative niche markets for their wild and cultivated organic-certified rooibos tea through Fair Trade. The factors contributing to this success have been documented (Oettle et al. 2009).

Another success is the Flower Valley Conservation Trust (FVCT) documented by Privett (2010). The FVCT was established in 1999 when Fauna and Flora International and the Arcadia group purchased a 578 ha portion of Agulhas Plain fynbos to conserve it and assess if harvesting of wildflowers could provide a viable social, ecological, and economic land use. The FVCT has benefitted from access to institutional development support (e.g. technical support, training, access to markets, branding and labelling of certified products, and access to infrastructure) in the form of partnerships with state institutions, the private sector, and NGOs. Additionally, essential to the success of both FVCT and the Heiveld Co-operative has been significant philanthropy (including grants from charities,) and long-term patronage (a minimum of a decade), which has been vital for developing decision-making skills and capacity to unlock resources.

In the absence of an enabling environment, other rural communities, such as the buchu (*Agathosma* spp.) harvesting community of Elandskloof, have struggled in their goal to extract long-term economic benefits from the sustainable use of biodiversity (Williams and Kepe 2008). They have experienced problems with establishing legitimate rights to harvest wild buchu, technical aspects of cultivation of buchu (a recently domesticated crop), and marketing due to weak business knowledge (Williams and Kepe 2008). As recent beneficiaries of land restitution, power relations between members of the common property association have compounded their problems (Barry 2011). These are common problems facing many beneficiaries of land reform and restitution who have been presented with options of entering the biodiversity economy

through use of indigenous plants or ecotourism without adequate long-term institutional support (Crane 2006; Barry 2011).

Despite the advantages that FVCT has had at its disposal, the development of a viable flower harvesting venture has been challenging and a gradual process of learning. FVCT has, however, established a niche market and currently supplies retailers Marks and Spencer in the UK and Pick 'n Pay in South Africa. Both reward sustainable harvest products and social responsibility. As part of the agreement with Marks and Spencer, FVCT had attained accreditation from the Wine and Agricultural Industry Ethical Trade Association for improved social and labour standards.

Securing steady demand with committed retailers has been paramount in enabling FVCT to provide permanent year-round employment. This has further enabled a steady increase in staff numbers (from disadvantaged backgrounds), with numbers having risen from 20 in 1999 to 57 in 2010. In total, 130 permanent jobs have been created through its supply network. Moreover, FVCT staff are paid 40% above the minimum wage for the Western Cape agricultural sector. This contrasts with other farms that pay their seasonal staff per flower picked⁴ rather than a fixed income (Heydenrych 1999). Overall, FVCT has made significant investment in their staff by providing them with training in sustainable flower harvesting, fynbos management courses, as well as establishing Early Learning Centres for FVCT staff's children and an Early Childhood Development programme across the Agulhas Plain.

The FVCT provides important lessons for other emerging biodiversity-based businesses (e.g. honeybush (*Cyclopia* spp.) tea, buchu, and ecotourism). Sustainable use of fynbos clearly requires consideration of not only the ecological aspects but also the social system with the beneficiaries at its core. Conserving biodiversity while sustaining human livelihoods requires approaches that reconcile often opposing management objectives (Milner-Gulland 2012), the complex interactions between decision making and the behaviour of stakeholders, the dynamics of natural ecosystems, and the associated uncertainty of managing such systems (Bunnefeld et al. 2011). Typically, research tends to focus on the direct impact human activities have on ecosystems (Milner-Gulland 2012), and assessments of the socio-economics of the resource

⁴ This approach raises some potential conflicts with sustainable harvesting and increases the incentive to harvest more than the recommended 50% of current year's flower heads.

users are undertaken in isolation (Crane 2006; Williams and Kepe 2008). One of the major challenges is bringing these disparate fields together.

15.8 Changing perceptions for a sustainable future

Moving towards a sustainable future requires that policy makers, implementers, and ordinary people recognize that this is built on healthy ecosystems. We have already noted that the city and province recognize the importance of managing natural resources wisely, as shown in IDPs, reports on meeting environmental goals, and climate change adaptation documents. At higher levels of government decision making in South Africa, the importance of a sustainable natural environment for human well-being seems reasonably well accepted (National Planning Commission 2011; SANBI 2011). In interviews conducted in the government sector, terms such as ecosystem goods and services, sustainable development, and rural resilience were preferred as means to promote sustainability of natural resource use (SANBI 2011). Respondents repeatedly warned that widely held perceptions prevailed that biodiversity conservation is an elite pursuit that competes with development objectives, and that the links between biodiversity and climate change, sustainable development, poverty alleviation, and ecosystem services have not yet been made (although implying that they conceived these links), and that emotional conservation arguments were seen as self-serving (SANBI 2011). Biodiversity conservation was perceived as socially unjust and antithetical to socio-economic development in a survey of decision makers in South African municipalities (Wilhem-Rechmann and Cowling 2011). Officials are also influenced by the perception that climate change and biodiversity are low priorities amongst residents (Wilhem-Rechmann and Cowling 2011; Pasquini et al. 2013).

One way of countering this is for conservationists to ensure that ethical approaches are taken with respect to people and their beliefs when potential conflict between people and biodiversity objectives arise (Cairns 2004; Turnhout et al. 2012). In developing adaptation for climate change, Ziervogel et al. (2010) have suggested that it is useful to bring developmental objectives to the fore. Similar approaches may enhance biodiversity conservation, as suggested by Wilhelm-Rechmann and Cowling (2011) who argued for using terms such as ecosystem service delivery instead of biodiversity when engaging politicians and officials at the municipal level.

The long history of alienation from nature experienced by the majority of people in the CFR suggests that attitudes to nature may be negative amongst the majority. Studies are scant but show that this view may not prevail. In two communities adjacent to Macassar Dunes (one of the last naturally vegetated dunes in the city), people reported positive attitudes to conservation of the dunes from the perspective of 'a sense of place' (Ferketic et al. 2010), and their capacity to prevent wind-blown sand entering residential areas (Graham and Ernstson 2012). A co-management initiative for conservation of the dunes, by residents and officials, has seen residents stopping residential encroachment on the dunes. However, unreliability in resource availability have challenged the project (Graham and Ernstson 2012), illustrating the need for long-term commitment to supporting society-biodiversity initiatives as demonstrated by the Heiveld and FVCT examples.

Recent initiatives by a relatively poor community to rehabilitate a fynbos area adjacent to their properties along a wetland lake in the city was important to the participants as a way of addressing the imbalances of apartheid, and reclaiming nature, of which they felt they had been dispossessed (Ernstson 2013). While city conservation staff helped them access plants and funding for a Working on Wetlands project, the dynamism for this project emerged from the community. Residents around other wetland areas were influenced by this project to oppose development and promote ecological restoration (Avlonitis 2011). While these sites do not fall into highly critical biodiversity areas they have created a way of bringing people, and especially people who felt alienated by the apartheid government, to feel a closer ownership of nature (Avlonitis 2011; Ernstson 2013). A recent study of teenagers from across socio-economic classes in Cape Town indicated that contrary to general perception, most have a deep affiliation for nature (Ashwell 2010).

Large numbers of local flora and fauna species are extensively utilized for food, medicine and horticulture by people in Cape Town. Official approaches have long been to legislate against the harvesting of plants and animals, especially by poor people, since this is seen as leading to the degradation of these resources (van Sittert 2003a). This merely reinforces the dispossession poor people have long been subject to, while richer people get access through asserting their power or capacity to pay. Petersen et al. (2012) have shown that the vast majority of harvesters of wild resources collect small amounts for personal use or limited sale. Since this gathering has been legislated as illegal for

decades, legislation has obviously had little impact on the actual practice (Williams and Kepe 2008). Instead of relegating criminal status to such harvesters, their use of local biodiversity could become a point of constructive engagement on conservation issues, rather than an unenforceable criminal activity, to develop societally and culturally acceptable, and economically beneficial programmes for biodiversity conservation (Petersen et al. 2012).

The custodians of large areas of natural and semi-natural vegetation, the land owning farmers of the CFR, can be expected to have major influence on the trajectory of biodiversity conservation and safeguarding of ecosystem services in rural areas. Again studies are scarce. Farmers with renosterveld on their farms show a wide range of conservation behaviour (McDowell and Sparks 1989; Winter et al. 2007). Farmers in the latter study regard fragments of natural vegetation as offering a combination of ecosystem services (grazing for livestock, erosion control, pretty bulbs) and dis-services (habitat for predators, lower prices for wool tangled with vegetation, source of weeds for crop fields) (Winter et al. 2007). While few of the farmers interviewed displayed in-depth knowledge of the ecology of renosterveld, farmers were open to both monetary and other influences to change to conservation friendly practices (McDowell and Sparks 1989; Winter et al. 2007). Incentives such as support for fencing and alien clearance, tax relief or rates rebates were welcome. In addition, access to scientific advice was a motivator. Intrinsic value seemed to rise with prolonged family ownership of farms. The importance of personal interactions with conservation agents in motivating farmers' conservation behaviour is emphasized in several CFR studies (McDowell et al. 1989; Winter et al. 2007; Pasquini et al. 2010; von Hase et al. 2010).

The contentious nature of the public debate on invasive alien plants is highlighted by van Wilgen (2012). He argues that attitudes to invasive plants can be influenced by practical realization of the impacts of fire on biodiversity and water resources but that the value of information becomes more problematic when value systems clash with scientifically rational conservation messages. Many people hold values that resonate with the protection of invasive species: trees for shaded recreation and dog walking, or the protection of extra-limital and foreign animals (including the Himalayan tahr, a wild goat under severe threat in its native habitat). Rational and evidence-driven arguments for the many disservices of invasive species seldom dent people's belief systems in these instances (van Wilgen 2012).

Turnhout et al. (2012) argue that by promulgating only the scientific consensus on biodiversity, the many ways of engaging with and understanding nature by people (as demonstrated in these studies) is ignored and yet may hold possibilities for innovation and locally appropriate solutions. In the cases examined here involving officials, urban dwellers of various classes and ages, and farmers, it is clear that engagement on conservation and sustainability has to resonate with the values that they hold (Wilhelm-Rechmann and Cowling 2008).

15.9 Building a sustainable future

Some of the impacts that a city can have on a biodiversity hotspot through the close dependence of people in the CFR on its biodiversity and ecosystem services have been illustrated. Reflections on past environmental engagements and system shifts, and contemporary use and management, highlight key challenges to the sustainable management and conservation of the CFR, to ensure the continued delivery of services, within and around Cape Town. In recent times, progress has been made in management of natural resources to ameliorate impacts of their utilization on the environment. Changes in attitude amongst officials reflect a realization of the dependence of humanity on well-managed natural environments, and amongst ordinary people an assertion of their right to access nature and the services this delivers. A key social-ecological challenge is resolving the apparent dichotomy between economic development needs and the need to curb land cover transformation so as to retain biodiversity and ecosystem services. The 'green economy'⁵ is proposed as a means to reaching these goals (National Planning Commission 2011). While the green or biodiversity economy has the potential to create jobs which might alleviate poverty, the investment in developing these should not be underestimated (Ashwell et al. 2006; Crane 2006).

The green economy needs to move beyond the payments for ecosystems services approaches still prevalent in some sectors as a panacea for sustainable management. The CFR's terrestrial and marine biodiversity is estimated to be worth 10% of regional gross geographic product in one study (Turpie et al. 2003). This represents a commoditized approach to biodiversity that contrasts with UNEP's valuation of

⁵ UNEP defines the green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities; see <<http://www.unep.org/greeneconomy>>.

biodiversity at 100% of global GDP on the basis that it underpins life on earth (Nellemann and Corcoran 2010). Limiting the value of biodiversity to what can be quantified by economists exposes ecosystem services, essential to long-term human well-being, to commodity price volatility, possibly unwise substitutions, privatization and dispossession, speculation and over-exploitation (McAfee 2012; Sullivan 2012; Turnhout et al. 2012). Valuation of ecosystem services can be used as an advocacy tool to promote an understanding of the importance of nature but is unlikely to lead to profound levels of biodiversity conservation and may even detract from biodiversity (Reyers et al. 2012). Valuation of natural resource use needs to explore the debts that resource use may incur in the longer term when degrading resources reach tipping points (Cairns 2004). A decoupling of economic growth from rates of resource use, including those provided by biodiversity, is suggested since natural resources are finite and cannot be expanded to meet a growing population's aspirations to a better standard of living (Blignaut and van der Elst 2009; UNEP 2011).

In the CFR urgent development and conservation agendas, bound up in spatially and fiscally constrained and socio-economically unfair circumstances, must compete. Urban sprawl, energy and resource use inefficiency, access to nature, capitalist system, expenditure patterns of the rich, governance, financial constraints, political time frames, institutional and social issues must in turn be addressed or accommodated. Trade-offs are inevitable. A model that highlights these trade-offs and ensures informed decision making is needed. Trade-offs need to be made in a way that takes full cognizance of social-ecological systems as complex, non-linear systems with feedback loops and unpredicted emergent properties (Cilliers 2000).

An approach that allows for the consideration of the full gamut of ecological and social issues would inform debate and direct the consideration of consequences and future trade-offs. Fig 15.4 highlights the development of ecosystem trade-offs that can be made and the potential for win-win outcomes. A proposed development, for example, could create a scenario that would put one in quadrant C, with low human well-being and low ecological integrity outcomes. Opportunities could then be sought to shift the development towards quadrant B. The actual outcome might be closer to quadrant A or D, but in the process a multitude of social and ecological outcomes, and associated trade-offs, would have been highlighted and considered concurrently. Multiple operational issues would need to be considered for moving along this trajectory.

In this regard Cowling et al. (2008), highlight a number of key issues, in particular, the need for stakeholder collaboration that empowers individuals; the appropriate analysis of biophysical and social issues to highlight possible opportunities and constraints; and the management of such initiatives to be adaptive and iterative. This requires informed capacitated groups who work together in a way that would be termed a learning organization. An inclusive approach is preferable to the current approach characterized by niche level responses and uncoordinated sector-specific efforts towards sustainability. The role of scale, where local decisions could have variably scaled trade-offs, also warrants attention. Any plan at city level needs to consider the greater regional and national context, and must include demographic, economic and ecological considerations. This would help develop a coherent, readily understood argument for the ability of wise environmental management to support development goals rather than detract from them. It is timeous to be considering joint agendas and a broadly informed approach to city and regional planning and resource management to ensure the sustainability of the CFR.

Policy and institutions that ensure socially and ecologically informed planning are critical. The emergence of ecosystem services and ecological functioning and their incorporation into the urban agenda, coupled with other critical anthropogenic considerations in post-apartheid South Africa, has highlighted conflicting or inappropriate planning tools, and variably or weakly enforced legislation. In this regard urban densification and infrastructure development are useful to consider.

A reduction in land cover change is one of the central rationales for densification and efficient infrastructure development, and the challenges faced are both tied to and parallel to those faced in safeguarding natural remnants in the city. Densification lines up with global trends towards low carbon economies. The expressed intention to promote a more dense form in the City in Cape Town has failed to take purchase. The concept is unappealing to rate payers and private developers, significant fiscal contributors, and resisted by authorities where the enormity of the challenge means it is easier to 'respond to development applications rather than put in the extra energy to design positive futures' (Swilling 2010, p. 235). The draft Densification Strategy produced by the City's Spatial Planning and Urban Design Department provides clear technical guidance but rather skirts the issue of trade-offs with reference to the fact that densification should not 'negatively impact on built and natural resources' (CCT 2009c).

Figure 15.4 Human well-being and ecological integrity continuums should be used in considering development outcomes and in ensuring the full exposure of trade-offs.

Here, rather than a robust engagement with likely development trade-offs, considered at multiple scales, a 'go lightly' approach has been adopted with an outcome that is environmentally vague and subsequently potentially porous. The complexities of densification are presented by Turok (2011) who goes on to note that a single densification target is inappropriate, and that local needs, and national imperatives, all need careful consideration.

Just as a clarification of the purpose of densification makes for more informed action, so would the purpose of the conservation, management, and active restoration of natural vegetation undoubtedly make for better buy-in and a diversity of approaches with improved outcomes (Egoh et al. 2010). Going beyond enhancing what is or could be working is a need for a creative vision on new, cross-cutting approaches to improving ecological functioning in the city. Urban design directly influences transformation rates of, and ecological processes in surviving natural remnants. The outcome within the city includes vegetation types becoming highly threatened, species going extinct and a variety of ecosystem services reduced in extent and quality, particularly in areas on the Cape Flats. These developments epitomize our current urban experience: typically to simplify and transform landscapes, and reduce and restrict the multifunctional character of landscapes and ecosystems. Here multiple possible services have

been traded in favour of single landscape function. Similar outcomes are manifest in rural areas in reaction to expanding agriculture and invasive alien plants.

While a variety of factors including history, culture, aesthetics, affluence, need, socio-economics, policy, and legislation have created the current conditions, they also provide points of leverage for steering urban development towards a more sustainable footing which retains varied bundles of ecosystem services within the boundaries of the city. Research into ecosystem services has flagged the multiple resource issues that need to be considered in decision making in relation to ecological assets. The social need for open green space to meet cultural, aesthetic, and recreational needs is now well recognized and central to human thriving in urban centres, and what is evidently needed are multiple, high quality, open spaces. This need, which does not come for free in an urban setting where access, security, and maintenance all raise the cost, must be pitted against the multitude of other urban demands.

While the capacity of the CFR to deliver future ecosystem services is further challenged by growing urban populations, the city, its people, infrastructures, institutions, and spaces, present opportunities for a more sustainable relationship between the city and the CFR to be imagined. Cities present spaces of significant social engagement and demand that social and environmental imperatives are met. The diversity of

people and practice, and higher rate of socio-economic activity suggest that answers are more likely to emerge in cities, and they can be readily tested in the rapidly transforming spaces that cities present. Cities have provided the industry and creativity that have led to solutions through history (Grimm et al. 2008; Grove 2009; Evans 2011). This capacity to change is particularly important when considering climate change and ecosystem-based adaptation approaches to reduce the risks that are posed by it.

Such creativity is manifest in initiatives that have been developed in the CFR to protect the unique and diverse floral biodiversity against the depredations of human activities. These include the Working for Water programme and the C.A.P.E. initiative. Both have worked towards multiple benefits in safeguarding biodiversity and ecosystem services while tackling poverty.

Green infrastructure and ecosystems require restoration and rehabilitation to maintain and reverse damage to ecosystem service delivery. This is a clear example where public works programmes could be expanded. Financing biodiversity maintenance and restoration of provisioning and regulatory ecosystem services are proposed as means of investing in natural capital in the present to ensure a more secure and resilient future (Blignaut and Aronson 2008; De Wit et al. 2009; Reyers et al. 2009). These authors argue that although the cost may be high in the current era, the future impact of the degradation of natural capital that supports ecosystems service is much higher. The value of green and ecological infrastructure and its role in providing ecological services is particularly important when considering climate change, and ecosystem-based adaptation approaches to reduce the risks that are posed by this.

Often inappropriate engineered solutions result in municipalities having to constantly maintain and repair expensive infrastructure to protect against flooding and storm surges. Work in the Western Cape's Eden district has demonstrated that changes in land use and land cover are likely to have as great an effect on the potential impacts associated with flooding, storm surge, fire, and ground water availability as climate change will have (Nel et al. 2011). A critical starting point is the understanding of regulating services, their limitations and thresholds, the role of natural and semi-natural ecosystems in complementing built infrastructure, and when they can be a viable substitute for built infrastructure thereby reducing the risks of failure, collapse and costly maintenance. The sooner we engage with these concepts the greater the economic and environmental returns.

Will we reach a sustainable future through the accumulation of small positive actions (Cairns 2004) as are currently manifest, through an economic regime shift (Bignaut and van de Elst 2009; UNEP 2011) or a sustainability revolution akin to the agricultural and industrial revolutions (Meadows et al. 2005)? While it is clear that no recipe exists, concerted, innovative, and complementary change in society and the state, the economy, science, and technology is needed to move in a sustainable direction. The gulf between presenting challenging messages about complex and unpredictable social-ecological systems, and the need for coherent, readily understood arguments to foster wise environmental management, needs to be addressed. While science and technology can bring us water, energy, food, and waste disposal that have a much lighter footprint on the environment, people's perceptions and practices need to become more focussed on attaining sustainable lifestyles in order that these innovations can be realized. Government institutions need to provide an enabling environment, including cross-sectoral collaboration, to promote sustainable practices through policy that minimize the destruction of our natural life-support systems.

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Geography, climate, and biodiversity: the history and future of mediterranean-type ecosystems

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16.1 Introduction

Schimper, in his 1903 classic, coined the term ‘sclerophyllous’ to describe the tough, leathery leaves that characterize evergreen vegetation of the world’s mediterranean-type (MT¹) climate regions (Schimper 1903). In that passage, he recognized the five regions with MT climates: the Mediterranean basin (MED), the Cape Floristic Region (CFR), Western Australia (WAS), the California Floristic Province (CA-FP), and central Chile (CHI). Since then numerous researchers, especially in plant ecology, have highlighted the ecological similarities amongst the MT regions as some of the most powerful examples of ecological and evolutionary convergence: the similarities in organismal form and function of disparate biota living under similar climates (Cody and Mooney 1978). This work reached its apogee during the International Biosphere Program (IBP) of the 1960s and 1970s, particularly in the detailed comparisons between California and Chile (Parsons 1976; Mooney 1977). Early work focussed on the timing and seasonality of rainfall, and the role of leaf form as an adaptation to the hot summer dry season. On the other hand, researchers in the CFR and WAS always placed greater emphasis on the adaptive significance of long-lived leaves for growth in very low nutrient soils (Specht 1969), and the potential for adaptation to drought to provide adaptive function for low nutrients and vice versa (Chapter 11, Cramer et al.

2009; Yates, Verboom, et al. 2010). Wildfire has also gained more attention over time as a factor shaping similar ecosystem dynamics (Noble and Slatyer 1977; Rundel 1983; Keeley 1992; Lloret et al. 1999; Pausas 1999; Keeley 2012; Keeley et al. 2012).

Yet, researchers who have worked across the various MT ecosystems often comment on the striking differences between them. Certainly, they are more similar to each other than they are to a desert or a rainforest. But many differences also stand out: the dominant role of the monocot Restionaceae in the CFR and WAS, with no analogous growth form in the other systems; the frequency of serotiny amongst angiosperms in the CFR and WAS, and its absence in the other three systems; the reduced role for fire in CHI; the abundance of annuals in the CA-FP; and, perhaps most striking of all, the greater geological and climatic stability and low nutrient soils of the CFR and WAS.

In the past 30 years, ecology has increasingly considered the role of historical factors in the development of regional biota and the importance of ‘top-down’ regional effects on ecology of local communities, reflecting the diversity and composition of regional biota. While the current climates of the MT regions present striking similarities, the deeper histories of the regions are distinct and disparate. In this chapter, we consider the historical and regional influences that have shaped the floras of MT regions, focussing on the CFR, the CA-FP, and WAS, and present several analyses of the contrasting physical geography and climatic patterns amongst the regions. We draw on analyses of the composition and origin of regional floras (e.g. Chapter 5, Raven and Axelrod 1978), and highlight insights emerging from molecular phylogenetics and comparative studies of adaptive evolution.

¹ In this chapter, we use ‘MT’ for ‘mediterranean-type’ and then specify whether we are referring to MT climates, ecosystems, floras, etc. We follow the convention of lower case ‘mediterranean’ when used as an adjective to describe the climate or biome type, and upper case ‘Mediterranean’ for the geographic region.

We then examine the implications of these historical factors for the future of conservation in MT regions in the face of rapidly changing climate in the twenty-first century.

16.2 Continental drift, geography, and climate history

16.2.1 Setting the context: the distribution of MT climates

MT ecosystems have been identified based on similarities in climate and in the physiognomy and functional ecology of the flora, especially the dominance of evergreen, sclerophyll shrubs. MT climates occur on the western side of the world's five major land masses (excluding Antarctica), between 30° and 45° latitude (S or N). At these latitudes, high-pressure systems tend to form in summer over the adjacent oceans, blocking storm systems from hitting land, and leading to the characteristic dry summers. The same ocean basins are the source of winter rainstorms, when anticyclonic storm systems deliver heavy rains, usually arriving from the south west in the Northern Hemisphere and the north west in the Southern Hemisphere. Cold currents flowing from high latitudes run along the coasts (except in Europe and Western Australia), and offshore winds lead to significant upwelling in some regions, resulting in very cold sea surface temperatures immediately offshore (especially California). Proximity to this cool ocean water creates strongly maritime climates, with mild winters and cool summers. Coastal-inland temperature gradients can be very steep, especially in summer. In the San Francisco Bay Area, maximum summer temperatures increase by almost 20°C as one moves about 100 km in from the coast, equivalent to descending a 3 000 m mountain!

While all MT regions occur along the coasts, their positions relative to surrounding continental and oceanic areas are quite different. This is most strikingly illustrated by inverting the Northern Hemisphere continents and aligning them with their Southern Hemisphere counterparts (Plate 16). The CFR and WAS both occupy the southern extremes of their respective continents, with the vast Southern Ocean separating them from Antarctica. When North America is inverted, the contrast is remarkable, with the extensive continental areas of temperate and boreal North America occupying the high latitudes between the CA-FP and the pole. These geographic contrasts have important consequences for understanding the assembly of the MT

floras and their modern ecology (Dallman 1998), and we return to these points below.

The distribution and geographic context of the MT climates also exhibit important differences amongst the five regions. The MT climate is defined as semi-arid, with cool winters but little to no freezing temperatures, and a majority of rain falling in winter. Aschmann (1973) provided a formal definition that captures these features based on the intersection of five criteria: (a) >65% of rain falling in winter (November–April in the Northern Hemisphere and May–October in the Southern Hemisphere); (b) total annual precipitation ≥ 275 mm and (c) ≤ 900 mm; (d) mean temperature of the coldest month of the year $< 15^{\circ}\text{C}$; and (e) $< 3\%$ of annual hours below freezing. Using the WorldClim dataset (Hijmans et al. 2005); Klausmeyer and Shaw (2009) recently mapped the distribution of the five MT climate regions based on these criteria (approximating the freezing criterion based on the mean and range of monthly temperature; see Supplemental Information with their article). We have reproduced their analysis here, illustrating the extent of the five MT climate regions (blue areas in Plate 18).

As is apparent, these five criteria do uniquely identify the world's MT climates, though the criteria are somewhat restrictive and do not capture areas (such as the south of France, parts of northern California, and the eastern Cape region) that are often included within the MT biomes (Klausmeyer and Shaw 2009). To place the respective climates in a regional context, it is interesting to examine the neighbouring areas that fall outside this definition of MT climate, and which criteria lead to their exclusion. This analysis indicates further differences between the five regions, which set the stage for discussions that follow regarding geographic and climatic history, and the assembly of regional floras.

In California, the MT climate region is bounded by areas that are too dry (to the south, red in Plate 18), too wet (to the north, green), too cold (to the east, not shown), or some combination. The winter rainfall region, which is often invoked as the key criterion of MT climate, covers a larger area encompassing cis-montane California and north as far as British Columbia. The setting in Chile is broadly similar, with the MT climate bounded by areas that are too dry (to the north), too wet (to the south), or too cold (to the east), while the region is set in a broad zone of winter rainfall extending far down Chile's coast to the areas of temperate rainforest. The Mediterranean is by far the most complex region, geographically and climatically, as the MT climate zone occurs in