Making the most of South Africa's natural capital

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1. The value of natural capital

Human actions have fundamentally changed the way the world's ecosystems look and function. Our efforts to produce more food, fibre, and fuel, control our water supplies and protect ourselves from the elements (e.g. storms or predators) have resulted in significant improvements in the global aggregate of human wellbeing (e.g. income, life expectancies, food supplied). On the flip side, these efforts to "domesticate" ecosystems have resulted in significant declines in the diversity of life on earth, otherwise known as biodiversity. In fact the last 50 years have witnessed the most rapid changes in biodiversity in human history (MA 2005a), including: large-scale conversion of natural habitat (e.g. forests) to other land uses (e.g. cropland), declines in species populations across the world, and species extinction rates 1000 times the typical rate over Earth's history.

While these declines were traditionally only the concern of the conservation community and the wealthy elite, it is now evident that biodiversity is not just a nicety to be admired in national parks and television documentaries. It underpins the wellbeing of all humans (rich, poor, urban or rural) by supporting what are called ecosystem services: the benefits that humans get from nature (Daily 1997). These benefits include products like food and water, as well as services like flood and disease control, climate regulation, and cultural, spiritual and recreational benefits (Figure 1). They are linked in a variety of ways to components of human wellbeing, ranging from basic material for a good life, through to freedoms and choices (MA 2003; Figure 1).

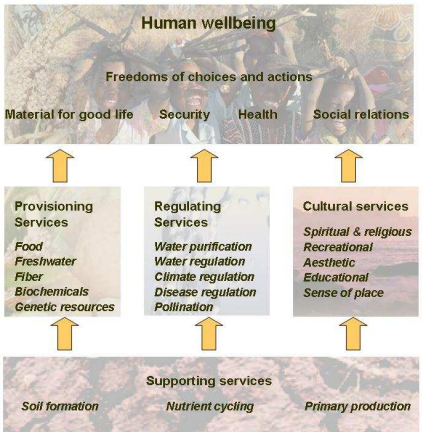

Figure 1: Links between ecosystem services and constituents of human wellbeing (from MA 2005b)

The Millennium Ecosystem Assessment (hereafter referred to as the MA) – a global assessment of the consequences of ecosystem change for human wellbeing – found that while changes in ecosystems have been good for many people, others are experiencing declines in wellbeing as a result of these changes (MA 2005b). These people are usually the rural poor, whose livelihoods depend immediately and directly on these ecosystem services and are therefore very vulnerable to changes in service provision. Looking to the future, these declines are likely to become more widespread with abrupt changes (e.g. crashes in fisheries) and surprise events (e.g. storms, disease outbreaks) occurring more frequently (MA 2005b).

As we have begun to appreciate the role that nature plays in promoting and maintaining human wellbeing, so it has become apparent that our existing indicators and frameworks for measuring and managing human wellbeing and development are inadequate (Hassan 2002). For example, a country might show positive growth in GDP as it mines its minerals, depletes its fisheries and cuts down its forests, without reflecting any of the changes in its renewable and non-renewable

natural resources. This incomplete accounting creates misperceptions of how the economy is doing and leaves a country vulnerable to a net loss of its capital assets which ultimately undermines the sustainability of any growth achieved.

Ecologists and economists have proposed a more inclusive way to measure a country's wealth, which includes recognizing four forms of capital: human, social, manufactured and natural (Costanza and Daly 1992; Costanza 2003) (Table 1).

Type of capital	Definition	Measured or quantified by
Natural	Natural resources or stocks	Levels of ecosystem services
Human	Capacity for physical labour, and knowledge and understanding	Levels of education Work force Research outputs
Social	Interconnected relationships, institutions, policies, rules and norms	Established institutions Legislation Standards
Manufactured	Machinery and infrastructure	Physical presence

Table 1: Definitions of natural, human, social and manufactured capital along with some measurements of these stocks and their flows (adapted from Costanza 2003)

Natural capital is made up of both non-renewable natural resources (e.g. uranium, oil, diamonds), and renewable resources (e.g. timber, food), which often maintain themselves at little or no cost to us (Milton et al. 2005). Natural capital is the stock that provides a flow of goods and services into the future. Examples of stocks include a population of fish providing a flow or annual yield of fish, or an entire ecosystem that provides a flow of services which include recycling waste, regulating water flow and quality, and preventing soil erosion (Costanza and Daly 1992). Figure 2 illustrates the links between natural capital and ecosystem services.

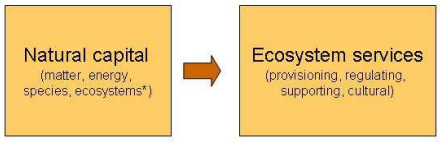

Figure 2: The links between natural capital and the ecosystem services it provides
*Ecosystems include human cultivated ones

Recent attempts to include measures of natural capital into national income accounting have shown that while measures like GNP have increased over time in countries like the USA, South Africa, Namibia and Botswana, measures that include natural capital (Green GDP, Adjusted Net Savings as a proxy for genuine savings, among others) reveal an economy with low or negative growth over the same period (Randall, 2008; World Bank, 2008; Lange et al. 2003).

These four forms of capital provide a framework for interpreting and evaluating sustainable development with regards to maintaining the capital base upon which human welfare depends (Arrow *et al.*, 2003; Pezzey and Toman, 2008). Opinions differ, however, on whether each of these forms of capital (e.g. natural capital) needs to be maintained in its own right or if it is sufficient simply to maintain the aggregate stock of capital.

Proponents of *weak* sustainability argue that different forms of capital are substitutable, such that it is sufficient to maintain the *total* stock of capital. By contrast, *strong* sustainability recognises that not all forms of capital are readily substitutable, and requires that the stock of each form of capital (including natural capital) is maintained in its own right (Dasgupta and Maler, 2001; Randall, 2008). A compromise may be to allow some substitution between different forms of capital, so long as some minimum, core stock of critical natural capital is maintained (Pearce et al., 1989). Quantifying this core level of natural capital is, however, controversial. In fact natural and human capital are often complementary rather than substitutable, and all of them are required to produce a particular flow (Costanza and Daly 1992). Likewise, all forms of capital have complementary roles in supporting and improving our quality of life, and ultimately contributing to sustainable development (Figure 3).

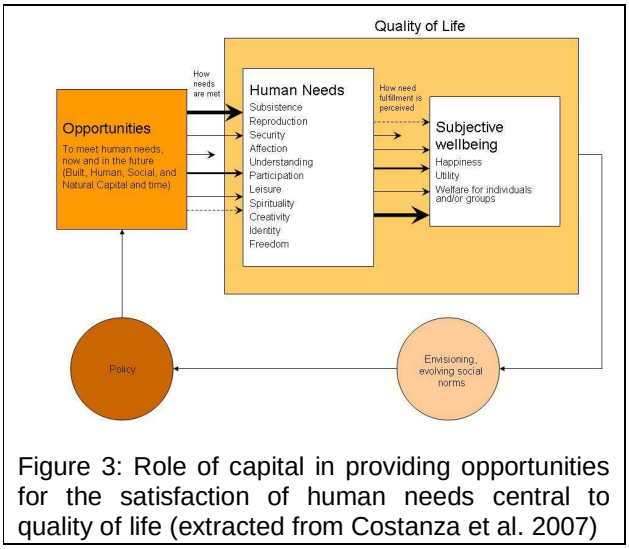

Figure 3: Role of capital in providing opportunities for the satisfaction of human needs central to quality of life (extracted from Costanza et al. 2007)

As we begin to recognize the role of natural capital in achieving national sustainable development goals, as well as the depleted current state of this capital, so research agendas are being formulated to provide the knowledge necessary to understand and manage natural capital and promote sustainable development (e.g. Kremen 2005; Daily & Matson 2008)

This paper highlights the importance of natural capital for ecosystem services and human wellbeing, the need for directed and transdisciplinary research to support the development of management and policy options, and the role of the CSIR in ensuring that the best science is used to improve management and policy for the benefit of all South Africans. The directed, transdisciplinary research that the retention and restoration of natural capital requires is central to the CSIR and its mandate of contributing to an improved quality of life for South Africans. Below we outline the research and development (R&D) agenda around natural capital and the current contributions by the CSIR and its partners to this agenda. We define R&D using the *Frascati Manual* definition: as creative work undertaken systematically to increase the stock of knowledge, including knowledge of humanity, culture and society, and the use of this knowledge to devise new applications. We use a research, development and innovation (RDI) chain to categorise this research.

2. CSIR natural capital research themes

The research agenda can be organised under three themes: what are the current states and trends in natural capital, what are the main drivers of change in natural capital and their effects, and what are the most effective responses (including policies, guidelines, plans, and behaviour changes) required to maintain this natural capital. We discuss these research themes and the role of the CSIR in addressing them below.

2.1 Current state and trends

Research on this topic includes questions like:

- Where is our natural capital and the services it provides?
- How can natural capital be measured and valued to make commensurate with other forms of capital?
- How is our natural capital doing?
- Where should we focus our management efforts?

Research within the CSIR has spanned the entire RDI chain from the development of new tools and techniques for measuring natural capital and ecosystem services, the collation of data on natural capital, through to policy input into the management of South Africa's natural capital. A few examples of these research projects are listed below.

2.1.1 Ecosystem service assessments

The CSIR participated in the Millennium Ecosystem Assessment, as well as the Sub-global Southern African Millennium Ecosystem Assessment conducting the first ever assessment of ecosystem services in the southern African subregion at multiple scales (Biggs et al. 2004), from the regional to the local (Figure 4). These assessments made explicit the links between ecosystem services, biodiversity and human wellbeing. They provided baseline information on the current state of ecosystem services (globally as well as in southern Africa). They highlighted the large scale degradation in ecosystem services and the consequences for human wellbeing. They also explored future scenarios for ecosystem services and human wellbeing and highlighted the need for new thinking and management of ecosystem services.

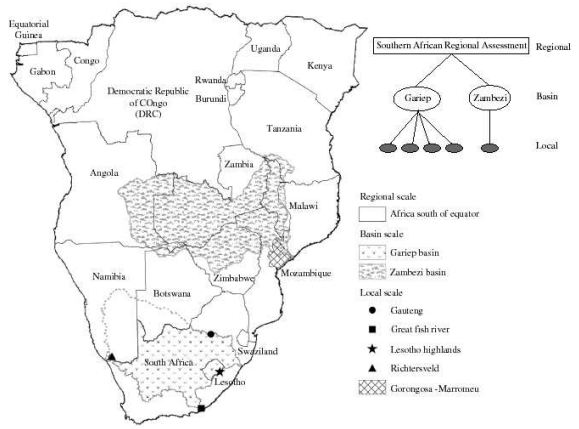

Figure 4: The Southern African Millennium Ecosystem Assessment (SAfMA) illustrating location of assessment sites (Biggs et al. 2004).

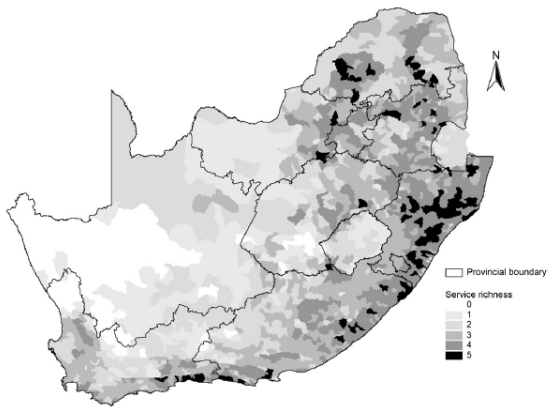

Figure 5: Map of number of ecosystem services per quaternary catchment for South Africa (extracted from Egoh et al. 2008)

Following on from the Millennium Ecosystem Assessment we have seen the development of research projects on understanding the ecology of ecosystem services, mapping and valuing natural capital and its condition and developing capacity in ecosystem service assessment. This work has involved the CSIR, as well as partners in Universities, PhD students and the South African National Biodiversity Institute. It has resulted in a number of publications (Egoh et al. 2007; 2008; Le Maitre et al. 2007; O'Farrell et al. 2007), maps of ecosystem services for the country (Figure 5), the first ever attempt to include ecosystem services into a National Spatial Biodiversity Assessment as part of the National Biodiversity Strategy and Action Plan (Reyers et al. 2007), and the development of frameworks for sustainable economics and valuation approaches. Work in the domain of sustainability science has also provided new ways of conducting these ecosystem service assessments, focussing on the concepts of resilience (O Farrell et al. 2008; Le Maitre et al. 2008; Cowling et al. 2008).

2.1.2 Spatial prioritisation

One of the difficulties in protecting and managing natural capital is that it is unevenly distributed. For example, about 20% of the surface area of the land generates over 80% of the surface water runoff; some areas provide better grazing resources; and biodiversity is extremely patchy, with large areas having relatively similar and low species concentrations, while others have amazing diversity in small areas, leading to their recognition as so-called "biodiversity hotspots" (Mittermeier et al. 2005). Managers and policy-makers require spatial information at appropriate scales to provide guidance on how to balance development, natural capital management and conservation in a manner that will optimise the use of the limited resources available to managers. This information must be based on the best available science.

The CSIR has been at the forefront in the development of data, indicators, techniques and tools, and strategy processes for addressing these needs. Together with partners from Universities, Department of Environmental Affairs' and Tourism (the South African National Biodiversity Institute, the South African National Parks, Marine and Coastal Management), the Department of Water Affairs and Forestry and several conservation NGOs, South Africa is now recognised as a leader in the field of conservation planning and implementation (Balmford et al. 2003). This work has resulted in many peer reviewed publications (Egoh et al. 2007; Nel et al. 2007; Reyers et al. 2007; Nel et al. In Press; Roux et al. In press), the first ever National Spatial Biodiversity Assessment (Driver et al., 2005), the initiation of a national

policy process for conserving freshwater biodiversity (Roux et al. 2006a), the development of freshwater conservation plans for several Water Management Areas (Nel et al. 2006) and the design of the world's largest Marine Protected Area (Lombard et al. 2007; Figure 6). A recent collaboration has produced the first ever national Protected Areas Expansion Strategy, which includes freshwater biodiversity.

Work at provincial and local levels has been significant in regional programmes like the Cape Action Plan for People and the Environment, the Wildcoast Conservation and Development Programme, the Greater Addo Elephant Expansion Plan and the Spatial Development Framework (SDF) processes. This work has spanned the entire RDI chain from primary research into data and tools, through to strategy and policy development and implementation (see Lochner et al. 2003; Roux et al., 2006b; Roux et al., In press).

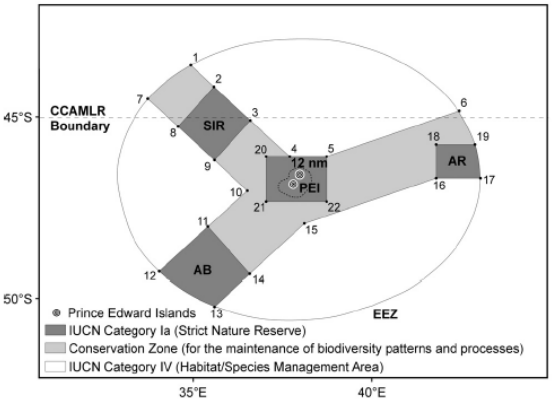

Figure 6: Proposed design of the Prince Edward Island Marine Protected Area (extracted from Lombard et al. 2007).

When determining spatial priorities, it is often useful to pull together parallel initiatives that address different issues and may have had different purposes. One example involves combining the prioritisation and management of invasive alien plant species, the prioritisation of rivers for the conservation of biodiversity, and broad-scale planning for water resource management. These datasets were used to develop a composite index for prioritising quaternary catchments for alien plant control. This approach identified new priority areas and should provide decision-makers with an objective and transparent method with which to prioritise areas for the control of invasive alien plants.

2.1.3 Assessing threat

Assessing the risk of extinction at the ecosystem level (as well as the traditional species level) is of critical importance to achieving sustainable development objectives (Rodriguez et al. 2007). Together with the South African National Biodiversity Institute and its partners, the CSIR has contributed to the development of criteria and thresholds for ecosystem risk assessment, tested these criteria in the freshwater domain and contributed to the listing process nationally. Figure 7 shows large rivers containing ecosystems that are threatened in South Africa. This study highlighted the dire state of river ecosystems in South Africa, and the strategic need to elevate freshwater biodiversity concerns on national, provincial and local agendas of both the conservation sector and the water resources management sector. As a consequence, priority areas for protection of freshwater ecosystems have been identified at a catchment scale for several of South Africa's Water Management Areas for the purpose of informing the development of integrated catchment management strategies and water allocations.

2.1.4 Measurement, modelling and economic valuation for inclusion in capital accounting at all geographic scales

Currently, South Africa's development decision making is predominantly based on narrow, conventional macroeconomic measures (e.g. interest rates; GDP/GNP; household income), and the sustainability of this development is assessed based on various supplementary social and environmental indicators and reports (e.g., State of the Environment Reports, Environmental Impact Assessments, and StatsSA's satellite accounts). There is therefore a lack of integrative thinking in the assessment and management of development in SA to ensure it is sustainable. Attempts to overcome the limitations of these *ad hoc* approaches to assessing the sustainability of social-ecological systems include the Human Development Index (HDI), Green GDP/GNP and Genuine Investment/Savings (Hamilton and Clemens, 1999; Dasgupta and Maler, 2001). These are essentially flow measures (i.e., they measure changes in capital stocks), and are based

on the 'weak sustainability' criterion (see above). As such, they do not adequately account for critical ecological thresholds (irreversibilities), risk, uncertainty, or resilience (Harris *et al.*, 2004). An indicator is therefore required that combines the desirable elements of the weak sustainability criterion with restrictive conditions on the maintenance of essential natural assets (i.e., a 'strong sustainability' criterion); and which is sufficiently aggregated to allow analysis of trade offs between natural, human and manufactured capital. The Inclusive Wealth (IW) measure enables these conditions to be met (Arrow et al., 2003). Inclusive wealth is a measure of the value of an economy's capital stocks (including human, manufactured, and natural capital) and is a proxy for intergenerational social welfare, since capital refers to productive assets that generate social welfare over time. Importantly the IW concept broadens the definition of 'well-being' to include the environmental (future) aspects of sustainability. The CSIR is currently undertaking R&D to investigate the feasibility of estimating IW for SA and the potential of the IW concept to facilitate South Africa's developmental efforts towards sustainability. These efforts are currently focused on understanding and modelling the changes in Natural Capital stocks and their values over time.

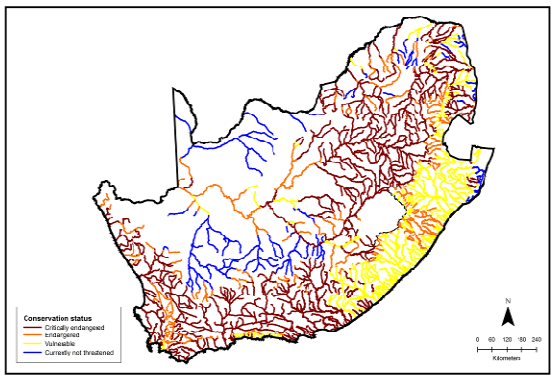

Figure 7: Threatened river ecosystems of South Africa (extracted from Nel et al. 2007)

2.2 Drivers of change

Drivers are natural or human-induced factors that cause a change in an ecosystem. They can be direct or operate more indirectly or diffusely. Changes in human populations, economic, socio-political, cultural and religious factors, and science and technology, are the key indirect drivers of change. They act on and change the direct drivers affecting ecosystem services and human wellbeing. The most important direct drivers of ecosystem change are: habitat change (including land use change and physical modification of water bodies), overexploitation, invasive alien species, pollution and climate change (MA 2005b). The CSIR has a long history in the study of some of these drivers relevant to the management of South Africa's natural capital.

2.2.1 Habitat change

The CSIR's remote sensing capacity has contributed significantly in the development of products for monitoring changes in land use and cover. The National Land Cover products are used in many assessments of natural capital (Reyers et al. 2007, Nel et al. 2007) and are an essential component of South Africa's National Biodiversity Monitoring and Reporting Framework. The CSIR has also become involved at a global level in this field in the development of the 10 year implementation plan for GEOSS (the Global Earth Observation System of System), the development of a Global Earth Observation Biodiversity Observation Network and work in the EU-funded GEOBENE project on benefit assessment of Earth Observation data (Fritz et al. 2008). The River Health Programme, coordinated at a national level by CSIR in its formative years, is another example of a biological assessment and monitoring programme aimed to detect impacts in freshwater ecosystems.

Veldfires are a natural event in many South African ecosystems. As an ecological force, fire has few parallels, and it consumes over 200 million tonnes of plant biomass in South Africa every year. Our ecosystems are fire-adapted, and also fire-dependant - many species actually require fire to survive and reproduce. Changes in fire regimes may affect the conservation of fire-adapted vegetation types. Such changes could be caused by a variety of factors. Landscapes are fragmented by agriculture, roads and urbanization, preventing natural fire patterns from developing. Fire suppression and prescribed burning try to influence or change fire regimes, while accidental or arson fires further complicate the picture. Effective management of fires requires managers to understand the effects of these changes, as well as the degree to which they can be managed. CSIR

has played a significant role in the development of practical approaches to fire management in many conservation areas, including the Cape fynbos, Drakensberg grasslands, and important savanna areas.

2.2.2 Alien invasive species

Invasive alien species are a product of the ongoing and increasing human re-distribution of species to support agriculture, forestry, mariculture, horticulture and recreation, as well as a result of accidental introductions. At least 161 alien plant species are regarded as invasive in South Africa, and they have invaded about 10 million hectares (8%) of the country.

Water use increases where short vegetation is replaced by alien trees, which use an estimated 7% of the country's runoff. Fuel loads at invaded sites increase tenfold, increasing fire intensities and causing soil damage, increased erosion and killing the seed banks of indigenous species. South Africa has unusually high levels of biodiversity, and alien plants could eliminate several thousand indigenous species if spread is not controlled, seriously affecting the delivery of ecosystem services such as grazing (Figure 8).

The CSIR has played a leading role in the quantification of the ecological and economic impacts of alien plant species (Van Wilgen et al. 1998). These studies have been pivotal in motivating for the establishment of the government's Working for Water programme, a multi-billion rand initiative that combines job creation and ecological benefits. The programme has received wide acclaim both nationally and internationally, and provides a clear example of the impacts of combining rigorous science and the need to address pressing social needs in the development of innovative solutions.

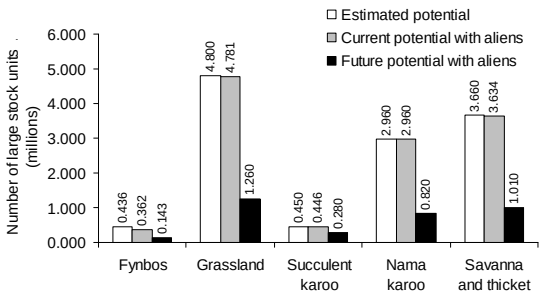

Figure 8: Alien invasive impacts on grazing services across the biomes of South Africa (from van Wilgen et al. 2008)

2.2.3 Climate change

Climate change will be the most important driver of change in ecosystems and natural capital in the future. Currently, research capacity in the field is limited and fragmented in South Africa. Here the CSIR has made a significant contribution to understanding the drivers of change. Examples include an international programme aimed at establishing the role of vegetation fires in the chemical dynamics of the atmosphere, which continues to monitor carbon and nitrogen fluxes in the atmosphere at a number of sites. This role is set to grow in terrestrial as well as marine environments. CSIR is currently co-managing the development of the South African government's report on responses to climate change (required in terms of the UN Framework Convention on Climate Change), plays a pivotal role in the Africa Centre for Climate and Earth Systems Science (ACCESS) and is co-leading the development of a 10-year science plan for global change on behalf of the Department of Science and Technology. Climate change research will remain an area of focus and growth within the CSIR and nationally.

2.3 How should we manage our natural capital

This research question brings together all the research and knowledge we have developed on the topic of natural capital and interprets it for decision makers. This question is not dealt with in isolation and is in fact always part of the research agenda on natural capital, ensuring that the knowledge we are generating under the other themes is shaped by the users and their requirements.

South Africa is a world leader in the management of natural capital with some of the most advanced and innovative policies, institutions and practices dealing with sustainable development and natural capital. Our constitution with its emphasis on equity (both social and natural) provides a sound basis for the development of policies that enhance this equity. Our National Environmental Management Act, Biodiversity Act and Protected Areas Acts are enlightened and supportive, and we are world renowned for our progressive National Water Act, and its recognition of a human and ecological reserve.

Another key strength is the ability of South African policies, institutions and practices to integrate across disciplines, sectors, and science and society. Examples include the existence of SANBI, an institution which, together with its networks, integrates sectors, scientists and decision makers spanning the entire RDI chain. The development of cross-sector policies for the management of natural capital is another good example of this ability to integrate (Roux et al. 2006a). One of the strengths of South African scientific capacity has been the existence of a relatively small but vibrant research community in universities, conservation departments, and science councils. In many other parts of the world (particularly the developing world), this level of experience and local knowledge is simply not there.

We also have examples of programmes which integrate natural capital with other forms of capital in an effort to improve the quality of life of South Africans. The poverty relief programmes of Working for Water, Working for Wetlands and Working for Woodlands are examples of innovative integrative ways to manage natural capital while building social capital through job creation, network formation and skills development. Other such integrated responses include community-based natural resource management, wildlife-based land uses and biodiversity friendly agricultural practices (biodiversity-business initiatives). These responses address conservation and development needs and appear to have demonstrated success in achieving these aims.

The CSIR has played a key role in informing and shaping many of these policies and practices, especially the National Biodiversity Strategy and Action Plan, the Working for Water programme, water resource management practices, and aspects of the National Biodiversity and Water Acts. At sub-national scales the role includes the development of fire management guidelines and fire danger rating systems, and prioritisation of alien invasive clearing programmes.

3. The future

It will be a major challenge to stem and reverse the degradation of natural capital while meeting the ever increasing demands for economic development. The MA showed that changes in policies, institutions, and practices can mitigate some of the negative consequences of the growing pressures on ecosystems. It also highlighted that the changes required are large, often radical and not currently in existence. The challenge extends across all the spheres of government and society, from the treasury to the rural village.

Effective management of natural capital is currently constrained both by a lack of knowledge and information concerning natural capital, and by the failure to interpret and use the existing information in management decisions.

The CSIR and its partners can play a significant role in informing and designing the necessary policy, institutional and behavioural changes. As Biggs et al. (2004) conclude in the Southern African Millennium Ecosystem Assessment: “Nothing may be more crucial to the sustainable management of ecosystem services than the free flow of information, and the enabling of individual as well as institutional flexibility, creativity, and innovation”.. The CSIR has the multi-disciplinary skills and the scientific networks to take the emerging understanding of sustainability science (Burns et al. 2006) and implement it in practice (Reyers et al. 2008).

Figure 9 provides an operational model to guide this RDI chain, and the CSIR’s research, towards the achievement of social and ecological resilient systems in an uncertain world. At its core are three elements: socially relevant, user-inspired research; stakeholder empowerment; and adaptive management embedded in learning organizations.

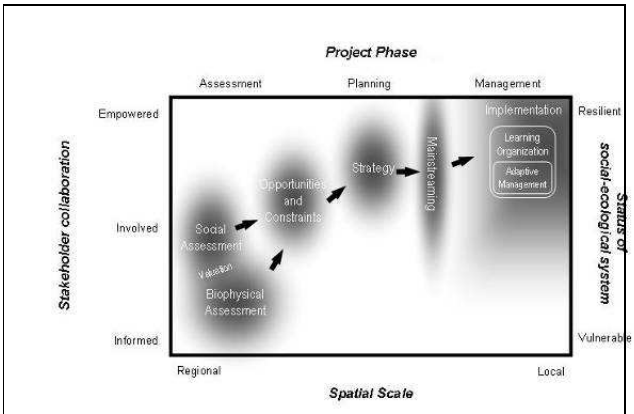

Figure 9: An operational model for safeguarding our natural capital (Extracted from Cowling et al. 2008)

This RDI chain for natural capital and its management is central to the management of South Africa's natural capital, integrating the disciplines, knowledge and needs of a variety of researchers, decision makers and other stakeholders in the generation of useful information on effective ways to manage our natural capital for future generations.

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