Establishing the platform for a carbon sequestration market in South Africa: The Working for Woodlands Subtropical Thicket Restoration Programme

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The vegetation of the Albany Thicket Biome of South Africa's southern coastal belt comprises a closed shrubland that exhibits rainforest-like functioning, despite the region's semi-arid climate. Most of the arid (250-350 mm yr-1) thicket, where the succulent shrub Portulacaria afra (spekboom) is dominant, have been degraded by injudicious pastoralism. This process reduces the unusually high carbon stocks in thicket (which exceed 200 t ha-1 in some regions) by more than 50%. During 2004 the Working for Woodlands Project of the Department of Water Affairs and Forestry embarked on a pilot restoration programme in selected sites across the biome in order to restore the natural functioning of the degraded areas, create livelihood opportunities for the rural poor and establish baselines and best management practices for entering the carbon market. Initial results show that the establishment of P. afra (spekboom) has the potential to sequester carbon and restore the functioning of the ecosystem at a surprisingly fast rate (4.2 tons/ha/annum) for a semi-arid area. Results from the carbon stock baseline assessment within the Baviaanskloof Nature Reserve indicate that carbon sequestration is a viable opportunity with ~60 t C/ha (to a soil depth of 25 cm) having been lost as a result of degradation. Active restoration through the planting of P. afra truncheons has the potential to recoup these losses and generate carbon credits that could fund further restoration. . Restoration of degraded thicket has good potential for the creation of livelihood opportunities for the rural-poor and can contribute to the development of a natural capital economy in South Africa.

Keywords: Restoration, Natural Capital, Ecosystem Function, Stunted Forest Vegetation, Semi-arid vegetation, rural-poor economic development, Payment for Ecosystem Services, Desertification, Carbon sequestration

Introduction

Shortly after the first democratic elections in 1994 the South African government launched several innovative, large-scale environmental restoration and maintenance programmes. These include the now internationally acclaimed Working for Water programme focusing on the management of invasive alien plants (Turpie *et al*., 2008; van Wilgen *et al*., 2002; Macdonald, 2004), Working for Wetlands focusing on wetland restoration and sustainable use (Kotze & Ellery, 2008), Working on Fire programme, focussing on wildfire management, and Working for Woodlands focussing on ecological restoration as a vehicle for enabling the integration of rural and urban economies.

All five of the programmes have the aim of improving livelihoods of beneficiaries i.e. the sum of ways in which people make a living – both monetary and non-monetary inputs that individuals require to survive, and the social resources (e.g. networks) upon which people draw to support their livelihoods.

Soon after its initiation, Working for Water illustrated the potential for the development of a market for watershed services (Hosking & Du Preez, 1999), based on the significant impacts of aggressive invasive alien plants (both terrestrial and waterweeds) on water resources (Dye & Jarmain, 2004; Dye & Poulter, 1995; Everson *et al*., 2007). This has lead to invasive alien plant management being recognized in the water pricing strategy as a water resource management function (DWAF, 2007). Turpie *et al*., (2008)

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concluded that the restoration and protection of watersheds to improve water resources also lead to the conservation of biodiversity, a benefit which is very abstract and difficult to "sell". The same is true for the restoration of wetlands, woodlands and other ecosystems.

In a report to the South African deputy presidency, Blignaut *et al*., (2009) concluded that the estimated size of the market for ecosystem services in South Africa is worth around R17 billion (± $1.7 billion) with livelihood opportunities for as many as 350, 000 people. In a review of the "second economy programme" (an attempt to create opportunities in the formal economy for people that were historically excluded from it) for the presidency's fifteen-year overview, Philip & Hassen (2008) concluded that *"significant innovation is taking place in the development of environmental services and ecosystem services, delivering a range of public benefits."* They predict that with the right support, aspects of the environmental services programmes have potential to yield sustainable market-based returns for rural communities through the restoration and maintenance of natural capital. The rapid rise in carbon trading presents some exciting opportunities for labour-based restoration of natural capital.

The key challenges for restoration of natural capital for carbon capture in South Africa are as follows:

- To simultaneously develop the ecological case for restoration interventions and capacity for conducting restoration ecology,
- To conduct research in collaboration with key stakeholders (implementing agencies etc.) ensuring – via effective learning organizations - that research is interdisciplinary (that the objectives of the programme in terms of both biophysical and social objectives define the research questions and actions) and that strategy is responsive to research feedbacks.
- To identify voluntary payments for ecosystem services,
- To identify ways to monitor changes in service delivery and linking payments to service delivery for a broad range of services.
- To develop an effective institutional framework for the development of the market for ecosystem goods and services.

This paper focuses on a programme aimed at evaluating carbon sequestration in terms of monitoring changes in service delivery and linking payments to service delivery. Rural poor, energy and food insecure communities have relied heavily on biomass for survival over many decades. Overstocking in free-hold title areas of commercial agriculture, and a lack of capacity to administer the Conservation of Agricultural Resources Act (CARA) has further lead to vast areas being severely degraded (Lloyd *et al*., 2002). A central aim of Working for Woodlands is to equip recipients with the necessary skills and support to implement carbon farming and provide sustainable livelihoods. The programme is aimed not only at restoring the natural resources/capital, but also giving rural communities affection and attachment to their land.

The programme also aims to provide access to markets for rural people in that the restored ecological services provide products demanded by urban communities. Rural people can supply these services through large scale natural resource restoration and maintenance programmes on both degraded commercial and communal land and so improves their livelihoods. The market comes to them! The activity is local, while the benefits and services are both local and global.

Unlike many other rural development programmes, the market for environmental goods and services is not confined to government-funded programmes. Woodland restoration has the ability to be funded through private funding in the form of carbon sequestration (for both a local and global beneficiaries), the provision of water regulation and purification services (for the local market), and the development of tourism opportunities. However, the initial programme development by government who has the capacity to fund the process until the market has the potential to reach a critical financial mass and broad-based support that could be turned into a sustainable and viable economic sector. This, however, is a long-term vision starting with restoration and needs to be informed by a scientifically based monitoring, evaluation and development programme.

Approach

The special nature of subtropical thicket

South African subtropical thicket, which is centered on coastal forelands of the Eastern Cape Province, is part of a global biome of semi-arid, rainforest-like vegetation whose origin dates to the mid-Cenozoic (Cowling *et al*., 2005) The vegetation comprises evergreen shrubs and low trees (0.5 - 3.0 m) often straddled by woody lianas and a sparse understorey of shade-tolerant herbs. Large succulent shrubs may dominate the canopy (e.g. *Portulacaria afra*, *Crassula ovata*) or emerge from it (*Aloe* spp., *Euphorbia* spp.) (Vlok *et al*., 2003). The woody canopy component includes for example *Azima tetracantha*, *Euclea undulata*, *Gymnosporia* spp., *Pappea capensis*, *Putterlickia pyracantha*, *Rhus* spp., *Schotia afra*, all of which are long-lived and reproduce mainly via ramets, or occasionally via seedlings that originate mostly from vertebrate-dispersed propagules (Midgley & Cowling, 1993; Cowling *et al*., 1997; Sigwela, 2005).

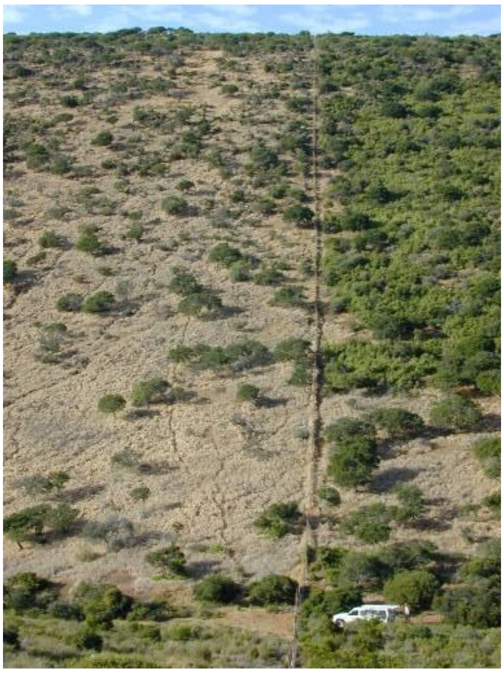
Biomass, litter fall and carbon storage in intact thicket are also exceptionally high for a semi-arid ecosystem, exceeding by orders of magnitude values recorded for other semi-arid ecosystems and approaching values recorded for some forest ecosystems (Mills *et al*., 2005a; Lechmere-Oertel *et al*., 2008). It has been suggested that the unusually high biomass maintained in thicket ecosystems is a consequence of the accumulation of soil organic carbon (133 t C ha^{-1} to a depth of 30 cm at a rainfall of *ca*. 300 mm yr^{-1}) (Mills *et al*., 2005a) beneath the densely shaded and relatively cool and dry canopy (Lechmere-Oertel *et al*., 2008).

While relatively resilient to browsing by indigenous herbivores (Stuart-Hill, 1992), subtropical thicket is highly vulnerable to browsing by domestic goats (see Figure 1). Sustained, heavy goat browsing can transform the dense closed-canopy shrubland into an open community comprising scattered and degraded thicket clumps and isolated trees in a matrix of ephemeral herbs (Hoffman & Cowling, 1990; Stuart-Hill, 1992; Moolman & Cowling, 1994; Kerley *et al*., 1995; Lechmere-Oertel *et al*., 2005a; Lechmere-Oertel *et al*., 2008). Particularly vulnerable are drier forms of thicket (Arid and Valley forms) (Vlok *et al*., 2003) dominated by the tree-like leaf succulent, *Portulacaria afra* (spekboom) (Stuart-Hill, 1992; Lechmere-Oertel *et al*., 2005a; Lechmere-Oertel *et al*., 2008). Of the 16,942 km^2 of solid (unbroken canopy) thicket with a substantial *P. afra* component, 46 % has been heavily degraded and 36 % moderately degraded by domestic herbivores (Lloyd *et al*., 2002).

Excessive goat browsing of *P. afra*-dominated thicket reduces natural capital by reducing species diversity (Moolman & Cowling, 1994; Lechmere-Oertel *et al*., 2005a), above- and below-ground carbon stocks (Mills *et al*., 2005a; Mills *et al*., 2005b, Powell 2009, Powell *et al*. 2009), soil quality (Mills & Fey, 2004; Lechmere-Oertel *et al*., 2005a) and plant productivity (and hence livestock and game stocking capacity) (Stuart-Hill & Aucamp, 1993). Differences in plant productivity between degraded and intact thicket are especially apparent during drought years (Stuart-Hill & Aucamp, 1993). Degradation also reduces the availability of wood, fruit and medicines for local communities, with a potential financial loss of approximately $150 per annum per household (Cocks & Wiersum, 2003).

Spontaneous recovery of populations of canopy species does not appear to occur in browsing-degraded Arid and Valley forms of subtropical thicket (Stuart-Hill & Danckwerts, 1988; Sigwela *et al*. 2009, 2005; Lechmere-Oertel *et al*., 2005a). Browsing by goats initially destroys the canopy skirt on the edge of thicket clumps (Stuart-Hill, 1992), thereby altering the beneath-canopy microclimate and destroying the rich layer of organic mulch that accumulates there (Lechmere-Oertel *et al*., 2008). Deprived of an organically enriched soil medium, and subject to browsing higher up on the canopy, plants eventually die, and the thicket clumps steadily dwindle (Lechmere-Oertel *et al*., 2005a).

Figure 1: Fence-line contrast showing intact and goat-degraded Sundays Spekboomveld



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Building the ecological case

Unfortunately, rapid restoration (achieved within a human lifetime) is not as simple as just removing the goats. Regeneration in formerly heavily impacted thicket is slow or non-existent (Stuart-Hill & Danckwerts, 1988) being primarily hampered by a lack of shrub recruitment (Sigwela *et al*., 2009). Restoration, therefore, requires active intervention to establish shrubs. Sowing seeds is unlikely to be effective (Todkill, 2001), as the harsh microclimate of the exposed soil in transformed thicket appears to limit seed germination and also prevents seedling recruitment of thicket plant species that normally establish in protected microsites beneath the shrub canopy (Holmes & Cowling, 1993; Sigwela, *et al*., 2009).

A potentially cost-effective, practical restoration method is planting cuttings of the succulent shrub *Portulacaria afra* (spekboom) (Swart & Hobson, 1994). As is clear from the above discussions this shrub is dominant across large areas of the thicket biome (Vlok *et al*., 2003), especially in arid and valley thickets. It propagates vegetatively from branches that reach the ground at the canopy edge or those broken off by large browsing mammals (Stuart-Hill, 1992) and is able to switch between C3 and CAM[2] photosynthetic pathways (Guralnick *et al*., 1984a; Guralnick *et al*., 1984b); an unusual and useful adaptation to arid conditions. The use of C3 photosynthesis, when soils are wet, probably enables *P. afra* to be more productive than succulents that use only CAM. Several land managers have used *P. afra* cuttings to restore the shrub cover of transformed thicket. At an Arid Thicket site, a farmer planted cuttings in 1976 at 1-2 m intervals. By 2005, *P. afra* stood over 2 m high and covered 90% of the experimental site (Mills & Cowling, 2006). These plantings, despite the aridity and frequent drought years, exhibited excellent survivorship. This has not been mirrored in results of the experimental *P. afra* survivorship trials. Results from detailed multi-factorial trials that investigated a variety of factors (cut *P. afra* stem diameters, planting angle, clumping, planting density and planting angle) yielded conflicting results and sizeable variation is survivorship within treatments. Survivorship ranged from 13-72 % and considerable more work is needed on site specific restoration protocols (Powell, 2009).

[2] CAM photosynthesis refers to a photosynthetic pathway in some plants (some cacti and succulents) that open stomata at night, thereby reducing water loss. CO_2 is absorbed and stored in the form of an acid before being broken down and the CO_2 released for photosynthesis.

The role of herbivore management during the years of active restoration has not been fully explored. Both conservation agencies and landowners will have wild game entering the restoration sites. The carbon accrual rates under various stocking densities needs to be established. Similarly mechanisms (compliance monitoring) need to be designed and implemented to secure the carbon during sequestration as well as ensure the long term sustainable use of the natural capital post sequestration.

Can ecological integrity be restored?

Restoration implies the return of ecological integrity and the full pattern of biological complexity and diversity, together with the ecosystem processes that maintain this pattern (Hobbs & Norton, 1996). Planting cuttings of *P. afra* and other succulent plant species will not restore the ecosystem in the short-term. We hypothesize, however, that *P. afra* in particular will improve the microclimate of the planting sites for plant growth, and will provide cover for seed-dispersing animals and birds thereby facilitating natural ecosystem recovery over a period of decades.

At present, many transformed thicket landscapes appear to have abiotic barriers that restrict seedling establishment. These barriers include extreme soil surface temperatures (up to 50^{o} C), reduced soil water holding capacity (Lechmere-Oertel *et al*., 2005b) and soil crusts (Mills & Fey, 2004). Planting *P. afra* and other succulents would remove such barriers by shading soils and returning organic matter. Remnant shrubs are likely to benefit from the effects of *P. afra* establishment, though seedlings do not establish readily under *P. afra* canopies (Sigwela, *et al*., 2009), possibly due to root competition, excessive shading, rainfall interception, allelopathy, or a combination of these mechanisms. It is not known to what extent seedlings will establish via natural dispersal adjacent to *P. afra* canopies or below planted pioneer shrubs. An adaptive management approach is advocated whereby restoration methods will be fine-tuned as research for implementation yields knowledge on shrub establishment.

In some restored sites, *P. afra* may show a greater dominance than it does in pristine thicket (Mills & Cowling, 2006). We suggest, however, that although *P. afra*- dominated thicket may produce a new stable state (i.e., different to the pristine state), this community is preferable to the present transformed landscape because it provides a food source for livestock or indigenous herbivores during drought and its value is likely to increase through time as soil carbon reserves accumulate and additional plant and animal species colonise. Whereas the natural capital of a site restored with *P. afra* is likely to appreciate, that of a transformed and denuded landscape depreciates with time, due to ongoing death of remnant shrubs and trees (Lechmere-Oertel *et al*., 2005a), loss in soil quality and reduced ecosystem productivity. Milton (2003) discusses the concept of "emerging ecosystems" (ecosystems that emerge from land that has been cleared of natural vegetation for agricultural, industrial or commercial use) in a South African context, and notes that if society decides to manage these emergent states it is possible that their social, economic and ecological value may be enhanced. Transformed thicket restoration using *P. afra* cuttings may be an example of such management.

Potential benefits of the restoration of natural capital

Thicket vegetation provides a variety of ecosystem goods and services that contribute to the economy, such as livestock forage, nature-based tourism and goods, including plant products used for domestic consumption and sale. Other benefits such as pollination and water flow have yet to be quantified. Restoration will, in addition, promote the sequestration of carbon which, in time, could be sold or traded on international markets. The sequestration rate will vary according to climate, planting density, herbivory intensity and soil type. Mills and Cowling (2006) quantified sequestration rates at two sites, one with 250-350 mm annual rainfall, and another with 400-450 mm, where restoration using *P. afra* cuttings began in 1976 and 1982, respectively. The difference in the estimated sequestration rates at Krompoort (4.2 t C ha^{-1} yr^{-1}) and the reserve (1.2 t C ha^{-1} yr^{-1}) has been ascribed to extreme herbivory pressure in the latter but still needs to be tested.

The feasibility of restoring subtropical thicket using carbon markets is largely a function of its carbon sequestration potential relative to other reforestation initiatives. Mills & Cowling (2009) measured below-ground carbon stocks in intact, degraded and old agricultural landscapes in Baviaans Spekboom Thicket - a highly degraded thicket type earmarked for restoration.

Table 1: Soil and root carbon stocks to a depth of 110 cm in old lands and degraded and intact thicket in Baviaans Spekboom Thicket (Mills & Cowling, 2009).

	Soil Carbon [(SE) t ha^{-1}]	Root Carbon [(SE) t ha^{-1}]	% of Intact Thicket
Intact thicket	92.5 ± 7.2	10.9 ± 1.6	
Degraded thicket	30.9 ± 1.8	2.7 ± 0.3	33%
Old agricultural lands	42.0 ± 4.4	2.6 ± 0.3	45%

Soil carbon stocks in topsoil were constrained at low concentrations of extractable K (<0.5 mmol$_c$ kg^{-1}), Mg (<1 mmol$_c$ kg^{-1}), Ca (<12 mmol$_c$ kg^{-1}) and extractable P (<40 mg kg^{-1}), suggesting that carbon sequestration will be strongly influenced by soil nutrient content.

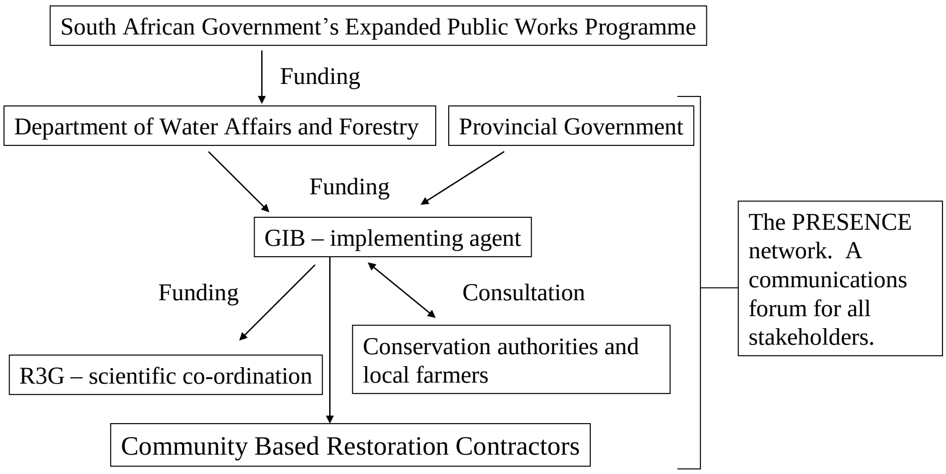
Table 1 indicates that restoration of Baviaans Spekboom Thicket stands to sequester 70 ± 7.6 t ha^{-1} of below-ground carbon – an amount rivalling sequestration potentials in degraded mesic forests. This figure is similar to that found by Mills and Cowling (2006) in Sundays Spekboomveld. In terms of above-ground biomass (including litter), Mills *et al*. (2005a) reported that carbon stocks in Sundays Spekboomveld were approximately 40 t ha^{-1} greater in intact than degraded thicket. By contrast, Powell, (2009) and Powell *et al*., (2009) report a difference of approximately 28 t C ha^{-1} in Baviaans Spekboom Thicket. The research to date thus indicates that the amount of carbon that could be sequestered in soils and plants by restoring degraded thicket is in the order of 100 t C ha^{-1}.

Social engagement & building the social case

There has been an impressive growth in research on restoration in recent years. However, disturbingly few studies are embedded in a social process designed to ensure effective on-the-ground management of areas that deliver ecosystem services. It is unlikely that the outcomes of technically sophisticated assessments published in scientific journals will lead to implementation via a "trickle down" effect (Salafsky *et al*., 2002; Starbuck, 2006; van Kerkhof & Lebel, 2006). As a mission-oriented, pragmatic discipline (Max-Neef, 2005), restoration research should be geared for implementation and scientists should assist this process by responding to stakeholder needs from the outset, and by becoming involved in the messy process of collaborating with and empowering stakeholders in strategy development and implementation (Salafsky *et al*., 2002; Sayer & Campbell, 2004; Knight *et al*., 2006; McNie, 2007).

The Eastern Cape Restoration Programme is underpinned by scientific experiments and research, but is perhaps unique in that it is also socially well engaged through active involvement of a wide range of stakeholders including an implementing agency, government ministries, nature conservation authorities and private farmers. Figure 2 illustrates the various relationships between the Restoration Research Group (R3G, which provides scientific guidance and publishes findings in peer-reviewed journals), the Gamtoos Irrigation Board (GIB, which through a contracting system with community groups from a historically disadvantaged background creates employment opportunities for more than 100 workers to implement the planting of *P. afra* cuttings), and the Department of Water Affairs and Forestry (which funds the project through the Expanded Public Works Programme (EPWP)).

Figure 2: Institutional relationships between stakeholders in the Working for Woodlands Eastern Cape Restoration Programme.



Implementation and learning

Adaptive management needs to respond effectively to the complex feedbacks, opportunities and shocks that characterize social-ecological systems, and provide insights that can be incorporated into the iterative processes of assessment and planning. This process consequently needs to be institutionalized in a suite of learning organizations (Harwell, 1998; Kiker *et al.*, 2001; Carpenter & Folke, 2006; Knight *et al.*, 2006), each focusing on a different ecosystem service. Such organizations must be representative of the sectors that are concerned with land use decision making and planning, and should foster a spirit of co-learning, co-governance and accountability (Senge, 1990; Garvin, 1993; Folke *et al.*, 2005). This is not always easy to achieve (Roux *et al.*, 2006), with key individuals and good leadership being of paramount importance for effective learning organizations (Westley & Vredenburg, 1997; Folke *et al.*, 2005).

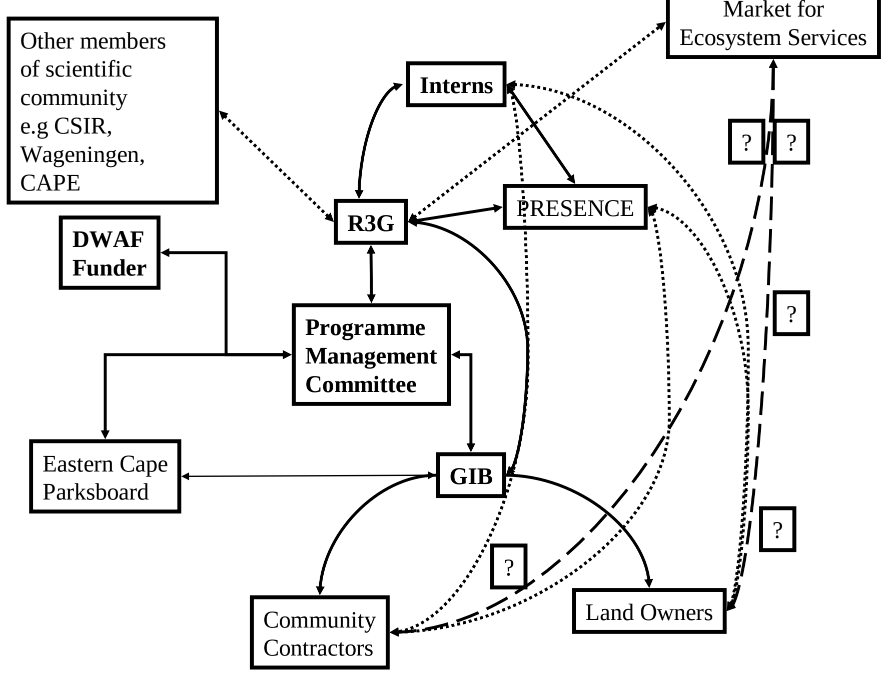
Because of the developmental nature of *Working for Woodlands*, the programme presents excellent learning opportunities to test government's ability to develop a platform for the market for ecosystem services and the mainstreaming of natural resource management into rural economies. Implementation needs to take cognisance of local socio-economic situation and livelihood profiles of the community. The programme is pro-poor and aimed at maximizing employment and capacity building. The programme is implemented through community based contractors. The appropriate business models for these community based contractors are still unclear. At the moment the vast majority of these contractors are sole proprietors who employ 10 – 15 persons from his/her own community. The socio-economic aim of developing the market is to enhance livelihood security in rural areas. It is still uncertain whether the sole proprietor approach that is generally being followed at the moment is the best model to achieve this, with the economic empowerment being centralised with the contractor. This is further complicated by the fact that currently (2009) an individual beneficiary (the workers) may only benefit from the EPWP for the equivalent of two years over a five year cycle. They then have to leave the programme, the premise being that they will be adequately empowered to enter the formal economy. The market for ecosystem services is, however, not yet well enough established to supply in the demand for livelihood opportunities based on private sector investment.

The science reported on above, generated by the investments made through Working for Woodlands in the Eastern Cape, is aimed at unlocking private sector funding for the restoration of natural resources and carbon sequestration. It takes place not only in the form of investment in research to inform decision making but also in the form of incentives for private investors and land users to invest in the restoration of natural resources. In turn it creates the demand for restoration services which leads to increased employment and therefore livelihood opportunities to the rural poor.

Learning through implementation takes place at a number of levels. The capacity of the community contracting teams is being built through functional training in restoration methodologies. Project managers (GIB) are exposed to science through their exposure to scientists of R3G. A substantial percentage of the responsibilities of R3G are capacity building of students in the fields of restoration ecology and socio-economic development (20% of budget is aimed at student support). This is further enhanced through the PRESENCE partnership with Wageningen University that recruits international postgraduates who contribute to the research and mentoring programme. The feedback loops for implementation and learning in the programme function as shown in Figure 3. Solid lines represent the current formal contractual relationships between parties; dotted lines represent temporary and informal relationships; and the broken lines represent formal relationships that still need to be developed. Blignaut *et al*. (2009) suggest that the biggest challenges in the development of the market for ecosystem services is not to prove its value, nor convincing communities to participate but the institutional arrangements to govern the market. They propose the development of an ecosystems facilitation agent as a private sector entity but in close collaboration with government.

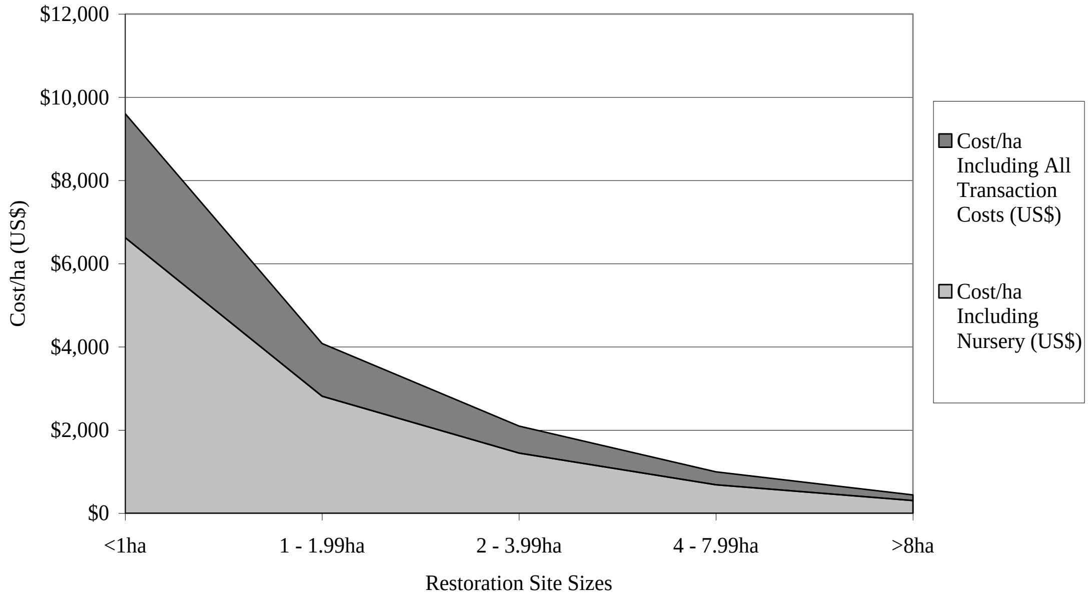
Furthermore it is clear that none of the current demands (water, carbon and biodiversity) will be able to financially sustain the supply of the services (restoration and maintenance of natural landscapes). The water sector in South Africa has developed in such a way that trading could relatively easily be incorporated in the national water pricing strategy. The carbon sector though is highly capital intensive and transaction costs are extremely high. The biodiversity sector is still very poorly developed.

Figure 3: Learning through implementation



Restoration costs are high but substantial work is still needed to better understand the value chain. Figure 4 shows restoration costs for selected areas recorded during the 2008/09 financial year.

Figure 4: Preliminary Restoration Costs for Thicket Restoration in the Eastern Cape Province of South Africa



Restoration at the experimental scale is very expensive, ~ \$9, 500 ha^{-1} which is not realistically applicable to commercial scale restoration. Costs achieved in the larger plot sizes are more realistic at ± \$440 - \$1000 ha^{-1}. This is in line with earlier estimates by Mills *et al.* (2007) who estimated restoration costs at \$722 - \$862 ha^{-1}. There is still much development needed and learning to be done when it comes to restoration options. The cheaper the restoration costs the more viable the market will become to land users and community contractors.

To enhance the sustainability of the market Blignaut *et al.* (2009) suggest that it will be necessary to bundle services to make it feasible for rural communities and their clients. From the preliminary cost figures it is clear that bundling of services might well be needed to ensure long term sustainability.

Discussion and Conclusions

Establishing the platform for a carbon sequestration market in South Africa is by no means an easy task. In comparison with other countries active in the carbon sequestration market South Africa has a very dry climate which makes it less competitive. However the science reported on in this paper shows that Eastern Cape Subtropical Thicket might in fact hold the key to the development of a carbon sequestration market despite the limited water resources available.

Work done in Working for Woodlands through the Eastern Cape restoration programme has laid the scientific baseline for the establishment of a platform for the development of a carbon sequestration market in South Africa. Both from a scientific and implementation/operational perspective our understanding of the value chain is improving constantly through interactions between senior scientists, managers, students, community contractors and land users. The biggest challenge though is not in getting the science right but rather the institutional model for the trading in ecosystem services. While the market cannot operate without the science and the related baseline values the market will never develop without a proper institutional platform. Individual land users and community contractors will simply not be able to enter the carbon market due to the substantial transactions costs involved. The relationship between the sellers and the buyers as shown in Figure 3 is the key to the successful development of the market. Blignaut *et al.* (2009) have identified this as the key to the successful development of the market in order to mainstream natural resource management in rural areas into the economy of the country.

In summary, the development of the market is dependent on the availability of appropriate human capital, research and development with regards to restoration ecology and maintenance of restored areas and the establishment of appropriate institutional arrangements to govern the market. Research has shown that there is the potential to sequester carbon in the order of 100 t C ha^{-1} and at rates of between 1.2 and 4.2 t C ha^{-1} yr^{-}

[1]. At the lower rates of sequestration, restoration may not be viable based on income from the carbon market alone. Other investment will have to be secured. The bundling of services therefore becomes critical, even if it means through corporate social investment by government and the private sector. From research done to date though, it is clear that markets for ecosystem services might well have major potential for enhancing livelihood opportunities in rural areas.

Acknowledgements

We are thankful to Department of Water Affairs and Forestry for funding the development and implementation of the restoration programme. Gamtoos Irrigation Board and its management team for the implementation of not only the restoration projects but also for their effort to accommodate the development work done by the team of scientists in the programme.

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