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Voluntary Carbon Standard Project Description

Working for Woodlands Thicket Restoration Project

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Table of Contents

List of Annexes

List of Figures

List of Tables

List of Acronyms

AFOLU	Agriculture, Forestry and Other Land Uses
ARR	Afforestation, Reforestation and Revegetation
C	Carbon
CBSA	Combined Basal Stem Area
CDM	Carbon Development Mechanism
CER	Certified Emission Reduction
CDNGI	Chief Directorate National Geo-spatial Information
CO_2e	Carbon Dioxide Equivalent
CSIR	Council for Industrial and Scientific Research
CSS	Conservation Support Services
DBH	Diameter at Breast Height
DEDEA	Department of Economic Development & Environmental Affairs
DNA	Designated National Authority
dm	Dry matter
DWAF	Department of Water Affairs and Forestry
DWA	Department of Water
ECPB	Eastern Cape Parks Board
EIA	Environmental Impact Assessment
GHG	Greenhouse Gas
GIB	Gamtoos Irrigation Board
GIS	Geographic Information System
GMO	Genetically Modified Organism
GPS	Global Positioning System
GFRNR	Great Fish River Nature Reserve
ha	Hectare
HCV	High Conservation Values
IDP	Integrated Development Plan
km	Kilometres
LULUCF	Land Use, Land-Use Change and Forestry
MDG	Millennium Development Goal
NEMA	National Environmental Management Act
NMMU	Nelson Mandela Metropolitan University
PD	Project Document
PDM	Pebble Distribution Method
PGIS	Participatory Geographic Information System
PRA	Participatory Rural Appraisal
PRESENCE	Participatory Restoration of Ecosystem Services and Natural Capital in the Eastern Cape
QA	Quality Assurance
QC	Quality Control
RDB	Red Data Book
R3G	Restoration Research Group
RME	Reliable Minimum Estimate
RU	Rhodes University
SANParks	South African National Parks
SIA	Social Impact Assessment
SOC	Soil Organic Carbon
SOP	Standard Operating Procedure
SOM	Soil Organic Matter

STEP	Subtropical Thicket Ecosystem Project
STRP	Subtropical Thicket Restoration Programme
t	Tonnes
UNFCCC	United Nations Framework Convention on Climate Change
UP	University of Pretoria
US	United States
VCS	Voluntary Carbon Standard
VER	Verified Emission Reduction
WUR	Wageningen University
yr	Year

1 Project Description:

1.1 Project title:

Title: Working for Water Thicket Restoration Project
Version: 01
Date: October 2010
Authors: Dr Anthony Mills[1,2]*, James Reeler[2], Sarah-Jane Fox[2], Margaret Matthew[2], Mike Powell[3], Prof Richard Cowling[4]
* Contact author (mills@sun.ac.za)

1.2 Type/Category of the project:

The proposed project is a Voluntary Carbon Standard (VCS) project within the category Agriculture, Forestry and Other Land Uses (AFOLU) and sub-category Afforestation, Reforestation and Revegetation (ARR). It is a grouped project, hereafter referred to as "the proposed ARR project".

1.3 Estimated amount of emission reductions over the crediting period including project size:

The proposed ARR project will sequester approximately 19.2 million tonnes of carbon dioxide equivalent (CO_2e) over a period of 60 years at an average rate of 321,000 tonnes of CO_2e yr^{-1}. This assumes restoration of 70% of all degraded thicket within the three project areas.

1.4 A brief description of the project:

The proposed ARR project will restore degraded thicket in three project areas (two nature reserves and one national park) within the Eastern Cape Province, South Africa, namely: the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the Great Fish River Nature Reserve (GFRNR). Both moderately and severely degraded thicket vegetation will be restored, defined as (Lloyd et al., 2002):

- Moderately degraded thicket:
  - has reduced standing biomass for that particular thicket type;
  - alien plants are obviously present, but not dominant;
  - structural changes in the vegetation are evident, e.g. opening up by cattle, browse lines of goats; and
  - is still fully functional
- Severely degraded thicket:
  - has lost all its functionality;
  - has severely reduced woody biomass compared to fully functional thicket;
  - is generally associated with high levels of human activity (around towns, homesteads, near villages, stock watering points); and
  - is obviously degraded when comparing across fence-line contrasts between "good" condition and "poor" condition rangeland

Degradation of the thicket vegetation by over-browsing (by goats, in particular), prior to gazetting as conservation areas, has caused a significant reduction in biomass, and therefore ecosystem carbon stocks, in the project areas. The project areas are semi-arid, and natural recovery of degraded land is limited as a result of high soil temperatures and poor soil conditions, including

[1] Stellenbosch University
[2] C4 EcoSolutions
[3] Rhodes University
[4] Nelson Mandela Metropolitan University

slow infiltration. Restoration of these project areas will be achieved by planting cuttings of the indigenous thicket tree *Portulacaria afra Jacq.* (a common and frequently dominant species in this region) in specific planting sites (contracts) within the project areas. Restoration of the thicket using *P. afra* captures considerable amounts of carbon in biomass and soils (Mills & Cowling, 2006). The project will increase ecosystem carbon stocks and expand the restoration activities through funds generated by the sale of accrued carbon credits.

Planting area

The project aims to restore degraded thicket within the project areas by planting *P. afra* cuttings. The Baviaanskloof Nature Reserve, Addo Elephant National Park and GFRNR all contain planting sites classified as degraded lands through a comprehensive vegetation analysis (Lloyd et al., 2002). A restoration goal of at least 70% of the degraded thicket within these areas has been set. It is hoped that a higher proportion of the degraded land will be restored, but the conservative estimate of 70% is used due to fragmentation within the area – certain degraded fragments are too small for realistic management, and some are too distant from access routes to be reached by planting teams. Nevertheless, if some additional sites are identified as being feasible for restoration, they may be included over the project lifetime. In addition, it is hoped that in the future, successful implementation of the proposed ARR project will encourage private landowners to restore degraded land on their properties.

Once the project is validated, restoration will proceed at an estimated 5,000 ha yr^{-1}. Planting should be completed within ten years, and the project crediting period will be 60 years.

Baviaanskloof Nature Reserve

The Baviaanskloof Nature Reserve is a recently formed nature reserve, incorporating stretches of pristine vegetation amongst land used previously for farming and herding. Approximately 10,000 ha of thicket have been identified as degraded, of which approximately 7,000 ha will be restored through the activities of the proposed ARR project. Trial plantings have been carried out in approximately 174ha of this area in the period 2004 to 2009.

Addo Elephant National Park

The area used for planting in the Addo Elephant National Park was previously owned by farmers, and was incorporated into the reserve in 2003 after land purchases to expand the size of the national park. This planting area is limited to the northern part of the Park, which currently is not accessible to elephants. The estimated area of degraded thicket (Lloyd et al., 2002) within the designated long-term planting area is just over 33,000 ha. At least 23,000 hectares of this degraded thicket will be restored through project operations. Trial plantings covering an area of 729 ha have been carried out in the Park between 2004 and 2009.

Great Fish River Nature Reserve

GFRNR comprises three historical nature reserves that were combined into a single reserve in 1993. Over 25,500 hectares of this park comprise thicket degraded by previous land management practices, and the proposed ARR project hopes to restore over 17,800 hectares. 114 ha of *P. afra* have been planted in trial sites between 2004 and 2009.

Risks

No genetically modified organisms or invasive species[5] will be used in the proposed ARR project. *P. afra* will be the only species planted. Fire is not a high risk as it is an semi-arid area and contains

[5] A full list of invasive species can be obtained from http://www.sana.co.za/Alien-Invasive-Plants/. Te proposed project is planting *P. afra* exclusively, which is a local endemic species.

little grass cover. *P. afra* is naturally highly fire-resistant, because it is a succulent with a very high moisture content, and therefore the established *P. afra* plants will provide a natural firebreak.

Benefits
It is estimated that restoration of degraded land will sequester approximately 411 t CO_2e ha^{-1} in total (see Annex 7 for the different carbon pools, confidence intervals and uncertainties). The standing crop of carbon in intact thicket is estimated at between 320 t CO_2e ha^{-1} (Powell, 2009) and 920 t CO_2e ha^{-1} (van der Vuyfer, in press). The upper estimate is comparable to many true forest ecosystems (Mills et al., 2005a) and an extraordinarily high value for a semi-arid ecosystem. See Annex 13 for additional details regarding degradation within the project areas.

1.5 Project location including geographic and physical information allowing the unique identification and delineation of the specific extent of the project:

The project areas are located in the Eastern Cape Province of South Africa (Figure 1 – 3). The planting sites are located in degraded thicket landscapes within the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the GFRNR; the boundaries of which will form the proposed ARR project boundaries. Each planting site within these areas is delineated by a bounding box (maximum north, south, east and west coordinates). The following towns and villages are close to the project areas: i) villages within Baviaanskloof are Coleskyplaas, Zaaimanshoek and Sewefontein; ii) the northern section of the Addo Elephant National Park is close to the town of Jansenville; and iii) villages near GFRNR are Fort Brown and Peddie.

See Annex 12 for more detailed historical and biophysical information regarding the project areas. Additional sites within the project areas and on privately-owned land in the Eastern Cape that meet the VCS and methodology criteria (as specified in AR-AM0002 (V3)) will be included in the project areas in the future, in keeping with the VCS guidelines on project grouping. These additional planting sites will be validated and formally incorporated into the project during each verification period.

More specific boundary information is given below for each of the project areas, and in addition all information is saved in an appropriate digital Geographic Information System (GIS) format (KML 2.2 and ArcView/ArcGIS shapefiles) in the offices of CSS, the partner involved in preparation and management of all spatial information.

Baviaanskloof Nature Reserve
The Baviaanskloof Nature Reserve is state land managed by the Eastern Cape Parks Board (ECPB). It is the centre of the Baviaanskloof Mega-Reserve, a 500,000 ha planning domain for retaining strategic landscape-level conservation, incorporating the Baviaanskloof Nature Reserve, several other nature reserves, local landowners and local communities. The restoration work will focus on three main sites situated within the eastern, central and western sections of the Baviaanskloof Nature Reserve near Koleske farm, Rooihoek (campsite) and Goedehoep farm.

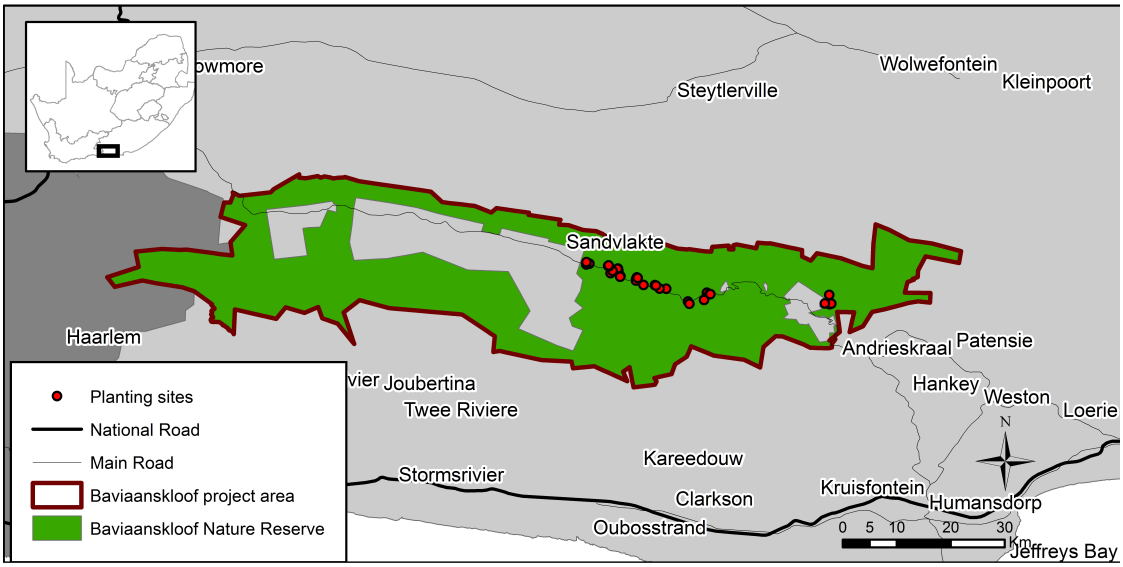

Figure 1: Geographic location of the ARR project within the Baviaanskloof Nature Reserve, Eastern Cape, South Africa.

Addo Elephant National Park

The Addo Elephant National Park is state land managed by the South African National Parks (SANParks). The park is approximately 164,000 ha in size with plans to expand into a 360,000 ha mega-park, in addition to the proposed proclamation of a 120,000 ha marine reserve. It is important to note that despite the park name, the project area within the national park (see Figure 2 below) is not currently stocked with elephants. The project area is presently too degraded to support elephants. The restoration work will focus on the delineated project area in the northern part of the park (Figure 2).

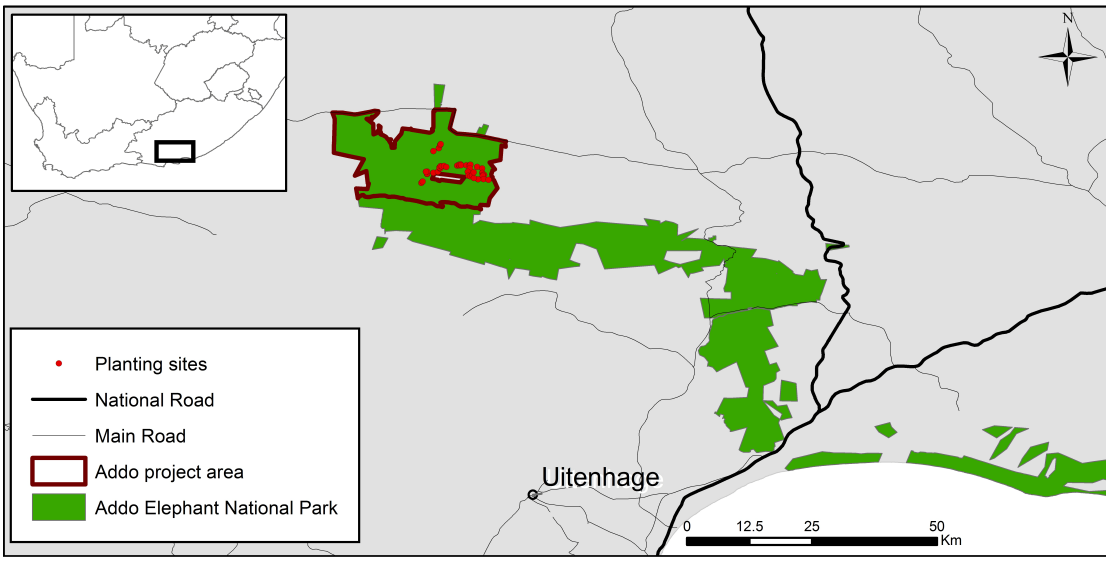

Figure 2: Location of the Addo Elephant National Park and ARR project area in the Eastern Cape, South Africa.

Great Fish River Nature Reserve

The GFRNR is state land managed by the ECPB and comprises three separate reserves: the Andries Vosloo Kudu Reserve, the Double Drift Nature Reserve and the Sam Knott Nature Reserve. The reserve is approximately 45,000 ha in size, and has large areas of historically degraded thicket vegetation. Phase 1 of the restoration work has focused on the southwest area of the reserve.

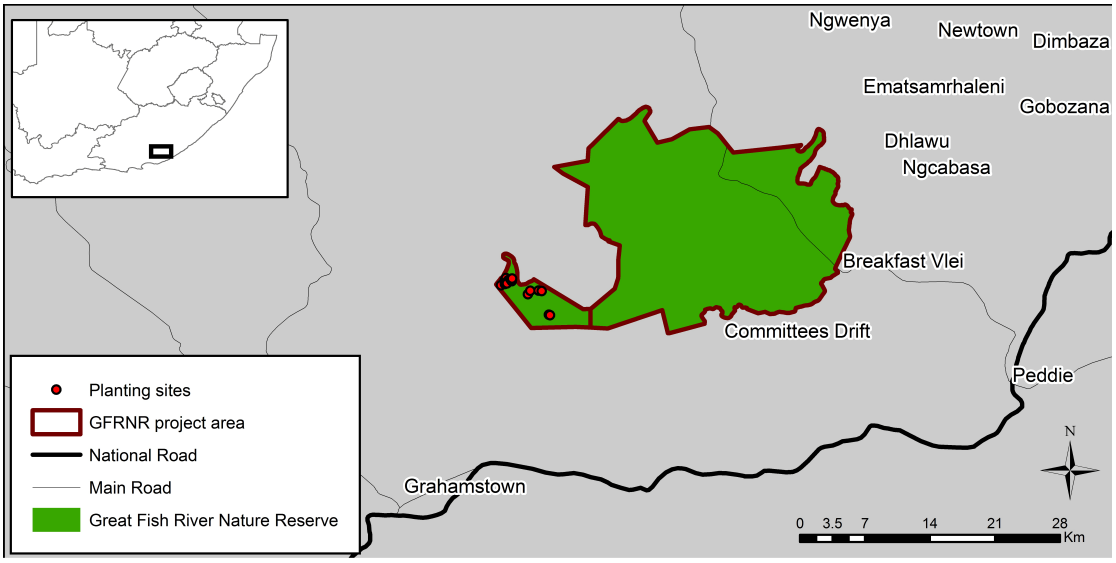

Figure 3: The location of the GFRNR and the associated ARR area in the Eastern Cape, South Africa.

1.6 Duration of the project activity/crediting period:

Project start date: 01/01/2004

The Department of Water Affairs (DWAF) provided funding for the early stages of the ARR VCS project activities. Over the period 2004-2010, DWAF contributed approximately US$ 750,000 per year (see Annex 2). This funding was provided specifically to catalyse additional funding for the ARR of degraded thicket through the generation of Verified Emission Reductions (VERs) (See the 2004 Pilot Project Business Plan, Annex 10)[6]. After a portfolio shuffle in government departments in 2009, DWAF became the Department of Water (DWA), which continues to provide funding for project activities. Securing funding from the sale of VERs will facilitate considerable expansion of the project areas planting sites to be restored.

Crediting Period start date: 01/01/2004

The first planting of *P. afra* cuttings in the Baviaanskloof Nature Reserve took place in January 2004 (Annex 9). Planting in the Addo Elephant National Park and GFRNR areas began in 2007.

Crediting period: 60 years.

It is anticipated that carbon stocks will increase for 50 years after planting (van der Vuyfer, in press). The duration of planting will depend on the planting rate, but it is estimated that it will continue for at least 10 years.

[6] The Business Plan for the "Eastern Cape Subtropical Thicket Rehabilitation Pilot Project" dated 5 August 2004 indicated that although the Kyoto Protocol had yet to be ratified, carbon trading was already occurring in various places in the world. The Business Plan states that the aims of the pilot project were to assess carbon storage through rehabilitation of spekboom, and to study the economic, social and ecological impacts of the project. It was funded by DWAF specifically to assess and develop methods of thicket rehabilitation for carbon trading.

1.7 Conditions prior to project initiation:

The planting sites fall within two nature reserves and one national park. Therefore, the condition prior to project initiation is conservation. Although, the land is under conservation, much of it is degraded due to the previous land use of farming. Natural regeneration of the arid and valley forms of thicket does not occur spontaneously after degradation (Sigwela, 2004; Vlok et al., 2003). A number of factors prevent natural regeneration, including an altered micro-climate resulting in extremely high soil temperature and reduced infiltration into soils due to soil hardening. This degradation can be observed as structural simplification (Hoffman & Cowling, 1990), loss of biomass (Lechmere-Oertel et al., 2005a; Mills et al., 2005a; Mills et al., 2005b), loss of soil organic matter (SOM) (Mills & Fey, 2004b; Mills & Fey, 2004a) and/or soil erosion (Lechmere-Oertel et al., 2005b; Mills & Cowling, 2010). Most importantly, with degradation there is a concomitant loss of carbon (Mills et al., 2005a; Mills et al., 2005b) throughout the ecosystem, which can only be recovered through a process of active restoration and regeneration.

Additional evidence of long-term degradation has been demonstrated in a study that showed high mortality with little regrowth in the only significant remaining tree species (*Pappea capensis*) in transformed areas (Lechmere-Oertel et al., 2005a). Aerial photographs of the project areas (Annex 15) show clearly that there has been no natural regeneration of thicket in the degraded landscapes for the past 40 years, and that the land was already degraded by at least 1972. All selected planting sites are classified as thicket vegetation as defined by the Subtropical Thicket Ecosystem Project (STEP; Vlok & Euston-Brown, 2002), and have been identified as degraded or severely degraded by the landscape-level transformation study undertaken by Lloyd *et al.* in 2002.

1.8 A description of how the project will achieve greenhouse gas (GHG) emission reductions and/or removal enhancements:

Degraded thicket vegetation in the project areas will be restored by planting *P. afra* cuttings, which will result in the return of ecosystem carbon. The restoration process has been clearly demonstrated at several sites across the thicket biome:

Site name	Location	Study
Krompoort	33°33'S; 25°11'E	(Mills & Cowling, 2006)
Fish River	33°7.5'S; 26°38'E	(Mills & Cowling, 2006)
Rhinosterhoek		(van der Vuyfer, in press)

Restoration trials have demonstrated a return of an average of 8.22 t CO_2e ha^{-1} yr^{-1} (corresponding to an accumulation rate of 2.23 t C yr^{-1}: see Annex 7 for the carbon stock meta-analysis). Restoring thicket by planting cuttings of *P. afra* results in the removal of carbon dioxide from the atmosphere and the return of ecosystem carbon (in above ground biomass, below ground biomass, deadwood, litter and SOC), thereby providing removal enhancements. It is important to note that restoration of the project areas would not occur without the project activities (see Section 1.7).

The proposed ARR project activities entail planting *P. afra* cuttings exclusively. *P. afra* is the dominant species in many thicket types in the project areas and is known locally as spekboom. No maintenance of the system is required once the *P. afra* cuttings have established. Game stocking in the project areas is carried out by the ECPB and SANParks, and is legally required to be at or below the optimal stocking level. Restoration of the area as a result of the project will improve ecosystem function in the project areas. The canopy of *P. afra* reduces soil temperatures, improves soil quality through the addition of leaf litter, reduces the incidence of frost at ground level and is likely to reduce runoff of rainwater by improving soil infiltration (Mills & Fey, 2004b). These effects improve

the micro-climate and soil conditions for natural recruitment of indigenous shrubs and trees (Lechmere-Oertel et al., 2005a).

Grazing and browsing by game (including elephants, in the case of Addo), provided it occurs at optimum stocking levels, promotes *P. afra* growth. This is largely because any such disturbance will result in portions of the *P. afra* plants breaking off and re-sprouting on the ground, thus facilitating additional *P. afra* growth and consequent carbon accrual (Aucamp et al., 1980). This response is typical of the stable ecosystem, to which state the restoration project hopes to return the project areas. In addition, natural ecosystem recovery is likely to be facilitated because of an improved micro-climate at the soil surface. This recovery would entail the dispersal of trees and shrubs into the proposed ARR project areas by animals. Indeed, an increase in biodiversity has been observed in several such restoration sites (van der Vuyfer, in press).

Activities to be undertaken in the proposed ARR project include the following:

- selection of contract (planting) sites;
- appointment of contractors;
- harvesting of *P. afra* cuttings from within the project area;
- planting of *P. afra* cuttings within the planting sites; and
- supplemental planting of *P. afra* cuttings where required.

The DWA F funding was provided for a programme called Working for Water (WfW), in order to provide employment for local communities, whilst restoring indigenous vegetation and seeding the operation potential for a long-term carbon sequestration project funding through international carbon offset finance. The Gamtoos Irrigation Board (GIB) is the implementing agent for WfW and is responsible for all of the above activities. GIB has appointed Conservation and Support Services (CSS) as their mapping service provider and all spatial development work will be conducted through CSS.

Selection of contract sites

Several constraints must be met before the contract site can be created and before the size of the contract can be considered:

- All areas must fall within the suitability layer[7].
- No new contracts will overlay old contracts.
- All supplemental planting contracts will be contained in a separate layer and will be entered into the spatial database to ensure data continuity and integrity.
- Historical sites and soil depth must be established (soil depth is determined by field visits by the Project Manager[8] after initial contract areas have been identified by CSS).

Two planting methods are employed, namely: mechanical and manual (see descriptions below). Manual planting is used rarely and only for sites that are too steep or too rocky for mechanical planting. The method of planting determines the size of the contract and is based on the area that can be planted in a 20 day contract. Contracts that make use of a mechanical auger are 26 ha and manually planted contracts are 7 ha in size. Once all the constraints have been satisfied, contract sites are digitized and allocated a unique identification number. These areas are then supplied to the Project Manager with draft contract maps, shapes and identification numbers for field verification of site selection in conjunction with land or reserve managers (logistical considerations are also investigated and considered). Once the sites have been deemed suitable, quotations for

[7]The suitability layer is used to determine viable sites for the project. It is a GIS layer representing the intersection of vegetation types identified as spekboom-rich thicket in the STEP vegetation analysis (Vlok & Euston-Brown, 2002) with those areas identified as degraded in the STEP-wide study by Lloyd et al., in 2002.

[8] Each project area is coordinated by a project manager, cooridinates site selection and directs the planting operations.

planting the contract are sourced and sent to the Regional Project Manager[9] for approval. CSS is then notified via e-mail to commence the block-marking of new contracts and GPS confirmation of old contracts. Contractors must be present at the block-marking stage to confirm the area that is to be planted.

The planting sites do not require any preparation prior to the planting of the *P. afra* cuttings. *P. afra* is a naturally occurring species in this area and is thus adapted to growing alongside the other species found in the project areas. Planting sites typically have small quantities of shrub and bush vegetation, but the area disturbed by planting is minimal.

Hiring of staff

- GIB uses contractors to undertake the restoration.
- Each contract is specific to a predefined area and must be completed within a given time period[10].
- Each contractor appoints their own staff and signs an employment contract with each staff member for that specific contract.
- Staff are sourced from towns and villages inside or surrounding the project areas:
  - Baviaanskloof Nature Reserve staff are sourced from Coleskyplaas, Zaaimanshoek and Sewefontein (48 staff currently employed);
  - staff to work in the Addo Elephant National Park are sourced mostly from Jansenville (38 staff currently employed); and
  - staff for the GFRNR are sourced from Fort Brown and Peddie (48 staff currently employed.
- The project is expected to be expanded significantly over the long term and it is estimated that employment will be increased to about 300 staff over the next two years.
- Contractors must select their workforce along the guidelines of Expanded Public Works Programme[11] where 60 % of employees should be women, 40 % should be men and 25 % should be under the age of 35.
- Most of the staff employed by the project were unemployed prior to the inception of the project.

Harvesting of *P. afra* cuttings

Cuttings, which are approximately 1,000 mm in length, are harvested from intact thicket within 50 km of each planting site. This reduces the risk of genetic 'pollution'. Additionally, sustainable harvesting (ensuring that no more than 30% of the branches are removed from a single source plant) prevents ecosystem damage, as the biomass harvested is replaced by regrowth. Such sustainable harvesting is possible as thicket (and *P. afra* in particular) has evolved with herbivory (i.e. harvesting) by mega-herbivores such as the African Elephant (*Loxodonta africana*), and the Black Rhinoceros (*Diceros bicornis*) (Kerley et al., 1999), and thus has a strong regeneration capacity. In fact, defoliation is essential if the production potential of *P. afra* is to be increased (Aucamp et al., 1980). A study of the influence of the rest period on the plant mass of defoliated *P. afra* showed that *P. afra* increased in biomass by 49 % over an 18 month rest period (Aucamp, 1979).

Cuttings are stored in the shade for two days to harden them off before planting. This process has been found to improve the survival rate of the cuttings.

[9] The Regional Project Manager is in overall charge of the project operations.
[10] Approximately 26 ha are planted in a 20 day contract.
[11] Available from: http://www.epwp.gov.za/

Figure 4: A mechanical auger used by an operator to drill a hole for planting *P. afra*. cuttings.

Planting of *P. afra* cuttings

Harvested cuttings of *P. afra* are planted either mechanically using an auger with an adapted drill bit or manually. Mechanical planting occurs according to the following system:

- The ground, where the hole is to be drilled, is moistened with water (approximately 200 ml).
- The auger operator drills a hole in the wet ground (10 - 20 cm in depth, and approximately 10cm wide).
- A member of staff plants the *P. afra* cutting, which is approximately 30 mm in diameter and approximately 1,000 mm in length, into the hole.
- Another member of staff uses a *koevoet* (heavy metal pipe) to compact the soil around the cutting.

The manual planting follows the following system:

- The ground, where the hole is to be dug, is moistened with water (approximately 200 ml).
- A hole is dug by a staff member using a pick or a spade (10 – 20 cm in depth).
- The *P. afra* cutting is planted into the hole.
- The hole is closed and a member of staff uses a *koevoet* to compact the soil around the cutting.

A space of 1.5 to 2 m will be left between the cuttings. As mentioned above, the size of a contract depends on whether the site will be planted mechanically or manually. The cuttings develop into trees/tall shrubs within 10-15 years (van der Vuyfer, in press; Mills & Cowling, 2006) and do not require inputs such as watering or fertilization (see Figure 5 below) (Mills & Cowling, 2006; Mills et al., 2007). The contracts are inspected by the Project Manager to ensure that the correct methods are being used, the results of the planting are satisfactory and the contractor is working in the correct place.

Figure 5: *P. afra* plants between the age of 10 and 15 years.

Supplemental planting of *P. afra* cuttings

Supplemental planting ("blanking") is performed to replace cuttings that have died. The survivorship in each block is monitored on an annual basis by GIB to assess the need for supplemental planting in order to maintain the effectiveness of the restoration process. Replanting of the cuttings that have died is the only post-planting maintenance that is required for the proposed ARR project. The established *P. afra* plants require neither pruning nor weeding to ensure continued healthy growth.

1.9 Project technologies, products, services and the expected level of activity:

A comprehensive Arcview-based GIS system is used to map and keep record of all large-scale plantings. The GIS database is housed at the CSS offices at 61 New Street in Grahamstown. Way point navigation is undertaken by means of handheld Trimble differential GPS units. The database is spatially explicit and attribute-driven, and is updated on a monthly basis. The database can differentiate monthly planting updates, cumulative planting updates and blanking information (see "Supplemental planting of *P.* afra cuttings" above) to replace cuttings that have died.

1.10 Compliance with relevant local laws and regulations related to the project:

The proposed ARR project and its activities comply with relevant laws and legislations applicable to a conservation area in South Africa, as well as overarching international and national obligations, including:

Environmental legislation for sustainable development:

- National Environmental Management Act 107 (NEMA) of 1998.
- Environment Conservation Act 73 of 1989.
- National Environmental Management: Biodiversity Act 10 of 2004.
- National Water Act 36 of 1998.
- National Forest Act 84 of 1998.
- National Environmental Management: Protected Areas Act 57 of 2003.
- National Environmental Management: Air Quality Act 39 of 2004.
- National Heritage Resources Act 25 of 1999.

Overarching international and national obligations:

- Convention on Biological Diversity.
- Local Agenda 21.
- The Ramsar Convention.
- The United Nations Framework Convention on Climate Change (UNFCCC).
- Constitution of the Republic of South Africa, 1996.
- The National Biodiversity Framework, 2007.
- South Africa's National Framework for Sustainable Development, 2008.
- The National Spatial Development Perspective, 2003.

The project activities are implemented by local government under the Expanded Public Works Programme, and will comply with labour guidelines and legislation.
The proposed ARR activities will contribute to sustainable development and are expected to have positive social, economic and environmental impacts. Sustainable development is defined in South Africa's NEMA (Act 107 of 1998) as "the integration of social, economic and environmental factors into planning, implementation and decision making so as to ensure that development serves present and future generations" (Government of South Africa, 1998). This is consistent with the United Nation's definition that reads "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[12]. In particular, sustainable development will be achieved through:

- Increasing biodiversity - particularly shrub and tree diversity – as a result of the planting of *P. afra* cuttings (van der Vuyfer, in press) (see Section 1.8).
- Reducing soil erosion and improving stabilization of slopes through the planting of *P. afra* cuttings.
- Improving the functioning of the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the GFRNR as water catchments that supply high quality water to downstream dams.
- Creating skilled and unskilled employment opportunities. The unemployment rate for the Eastern Cape is 39.5% (Statistics South Africa, 2007), therefore this is an important contribution to local economic development. Poverty alleviation is a major provincial and national objective.
- Building institutional capacity within GIB, DWA, and other involved organisations, related to:
    - ecological training;
    - exposure to the carbon market; and
    - training in the scientific method through interaction with scientists.

[12] Available from: http://www.un.org/esa/sustdev/index.html

- Contributing to local capacity building, environmental education, awareness and knowledge transfer.
- Showcasing South African innovation in environmental sustainability since the proposed ARR project is likely to be the first ARR in South Africa.
-

1.11 Identification of risks that may substantially affect the project's GHG emission reductions or removal enhancements:

Potential risks to the proposed ARR project's success are considered low, and under conservation conditions, it is anticipated that *P. afra* cutting survival rates will be high (Mills & Cowling, 2006). An overview of potential risks (including non-permanence) is detailed in Table 1 and Table 2 below.

Table 1: Risk factor table indicating a broad range of potential future risks.

Project risk	Risk rating
Risk of unclear land tenure and potential for disputes	Low – project activities take place on specified government-run nature reserves and a national.
Risk of financial failure	Low – running costs for the operation are low13, and carbon finance will assist in the expansion of operations. Carbon credit returns over the project lifetime are anticipated to exceed the restoration costs.
Risk of technical failure	Low – the technical requirements for the project are simple, and have been proved in the field. Field managers have been trained in monitoring operations, and collected data is housed in a custom-built spatial database and is regularly backed up.
Risk of management failure	Low – subsequent to planting, the management requirements of the project are exceedingly low due to the resilience of the *P. afra* plantings. Project management arrangements are carried out by a well-established organisation (GIB)[14] that is based in the area, and a management structure has been finalised.
Risk of rising land opportunity costs that endanger the future viability of the project	Low – planting sites are located on nature reserves and a national park that are statutorily protected, thus alternative land use is not possible. Restoration of degraded land will have only positive economic effects and it will enable an increase in the game stocking levels of the project areas as the carrying capacity will increase due to increased biomass.
Regulatory and social risk	Low – planting sites are protected by national legislation in the case of nature reserves and national parks, and should private landowners be included at a later date, legally-binding contracts will be entered into to ensure long-term viability .
Risk of political instability	Low – South Africa is a politically stable nation.
Risk of social instability	Low – South Africa is socially stable, and the location of sites within statutory reserves and private land ensures some insulation from local community activities.
Natural disturbance risk	Low – game stocking rates within the nature reserves have been shown to have minimal effects on the growth of *P. afra*, which is adapted to mild herbivory, and can even enhance

[13] An analysis of the current running costs (supplied through public finance with the goal of generating a viable carbon-financed restoration project) for the project are appended in Annex 2. Carbon finance will allow a significant increase in the scale of operations.
[14] In 2007 GIB was awarded the Water Conservation and Demand Management Trophy (the only award in the agricultural sector on a national basis), and the GIB-run Sand/Bulk Alien Vegetation Clearing Project was awarded winner of the National Project Flagship Competition. In 2006 the Working for Water Project in Port Elizabeth won the Airport Managers Award for Excellence.

	growth rates as a response to browsing (Aucamp et al., 1980; Mills & Cowling, 2006). Livestock stocking rates in potentially included private properties will be maintained at the Department of Agriculture recommended levels. Consequently, browsing is not expected to have a significantly negative effect on *P. afra* growth rates. No other forms of natural disturbance are anticipated in the project areas.
Devastating fire risk	Low – *P. afra* is a fire-tolerant species due to its succulent (water-bearing) and dense foliage (Kerley et al., 1995; Vlok et al., 2003).
Risk of incidence of pest and disease attacks	Low – *P. afra* is a major component of the natural thicket vegetation and is naturally resistant to pests and diseases in the area.
Risk of extreme climatic events (e.g. floods, drought, winds)	Medium – droughts are frequent in this area, although it is expected that such drought will have limited impact on plant growth due to *P. afra's* drought-resistant succulent nature. Floods tend to occur more readily where large areas of land are degraded, but the flooding is not likely since the project areas are all semi-arid and have very low annual rainfall (see Annex 12 for project climate details).
Geological risk (e.g. volcanoes, earthquakes, landslides)	Low – the Eastern Cape of South Africa is a geologically stable area.

Table 2: Risk factor table, indicating the specific potential future risks related to the proposed ARR project(VCS, 2008b).

Risk factor	Risk Rating
Project longevity/Commitment period	
Long-term commitment (i.e. many decades or unlimited) with no harvesting.	Low
Ownership type	
Established NGO or conservation agency; owner-operated private land.	Low
Technical capability	
Proven technologies and ready access to relevant expertise.	Low
Financial capacity	
Demonstrable backing from established financial institutions, NGOs and governments[15]. GIB has a long history of successful project implementation and project financial management, and is regularly audited.	Low
Management capacity	
Substantial previous project experience (≥ five projects) with on-site management team.	Low
Future income	
Appropriate management plan and financial analysis include future income to finance future management activities (e.g. carbon finance to be used for project management, planting and monitoring operations, etc.).	Low
Future/current opportunity costs	
Alternative land uses are unlikely to occur in the future.	Low
Endorsement of project or land use activities by local or national political establishment	
Endorsement given and not likely to change in the future.	Low

Based on the above risk ratings the buffer range should be between 5-20 % (VCS, 2008c).

[15] There is some public financing available at present from DWA to ensure that the pilot operations are successful. This money will continue into the future, but additional finance is necessary for the potential restoration area to be expanded.

1.12 Demonstration to confirm that the project was not implemented to create GHG emissions primarily for the purpose of its subsequent removal or destruction:

No significant GHG emissions as a result of degradation of thicket vegetation have been created by the project proponents; all degradation is historically stable. Therefore, the project was not implemented to create GHG emissions for the purpose of their subsequent removal or destruction. Evidence to support this statement is contained within the aerial photographs displayed in Annex 15, which indicate the duration of time over which the ecosystem has been degraded. Furthermore, the mandate of the ECPB and SANParks is to conserve indigenous vegetation and thus restored sites will be protected in perpetuity. Future inclusions for grouping within the proposed ARR project will include only those areas that have a similar demonstrable history of long-term degradation.

1.13 Demonstration that the project has not created another form of environmental credit (for example renewable energy certificates):

Other environmental credits have not been generated by the proposed ARR project. Additionally, no such credit application has been made (see Annex 5, Figure A .6.2).

1.14 Project rejected under other GHG programs (if applicable):

Not applicable. This is the first application for carbon sequestration accreditation for the proposed ARR project.

1.15 Project proponents' roles and responsibilities, including contact information of the project proponent, other project participants:

The project proponents' roles and responsibilities are detailed in Table 3 below. See Annex 1 for the list of contact details of the project participants.

Table 3: Project proponents' roles and responsibilities.

Name of Party involved [(host) indicates a host Party]	Private and/or public entity(ies)/project participants, roles and responsibilities
Republic of South Africa (host)- Department of Water (DWA)	Public Entity and landowner of Baviaanskloof Nature Reserve, Addo Elephant National Park and GFRNR. (DWA is representing the Republic of South Africa as project developer and project financier)
Eastern Cape Parks Board (ECPB)	Public Entity (Manager of the Baviaanskloof Nature Reserve and the GFRNR).
South African National Parks (SANParks)	Public Entity (Manager of the Addo Elephant National Park).
Gamtoos Irrigation Board (GIB)	Public Entity (Project implementer).
Restoration Research Group (R3G)	Formal network of scientists and managers of the baseline measurements and monitoring activities.
Conservation Support Services (CSS)	Private Company (Mapping service provider for all spatial development work).

1.15.1 Management of VERs within the Spekboom Thicket Restoration Project

After validation, a financial entity (e.g. a trust or Section 21 company) will be formed with the main stakeholders (namely ECPB, GIB, DWA, SANParks) being trustees or board members. This financial entity will own and trade the VERs generated by the project and will be managed by a management company assigned by the trustees or board members at a market-related rate. The distribution of income to stakeholders will be decided by the trustees or company board. This income will be used to reinvest in thicket restoration and planting of spekboom within the project. The financial entity will serve several additional purposes. Firstly, it will provide potential investors with an opportunity to invest in the financial entity and thereby expedite the planned planting of *P. afra*. Secondly, it will provide transparency and accountability regarding income from the sale of VERs, as well as expenditures. And thirdly, it will provide sustainability over the 60 years of the project, in that it does not rely on the existence of any particular institution.

The management company will have in-depth knowledge and experience in: i) thicket ecology; ii) carbon stock accounting in thicket; iii) restoration protocols in thicket; iv) establishment of restoration projects in thicket; and v) VCS project document development. The knowledge within this company is to include at least ten peer-reviewed scientific publications on thicket ecology and/or thicket carbon stocks, and at least three decades of experience in Eastern Cape thicket.

GIB, as the implementing agency, will be assigned to undertake the implementation of planting of *P. afra*, which includes the administration of all planting contracts and monitoring of contractual commitments.

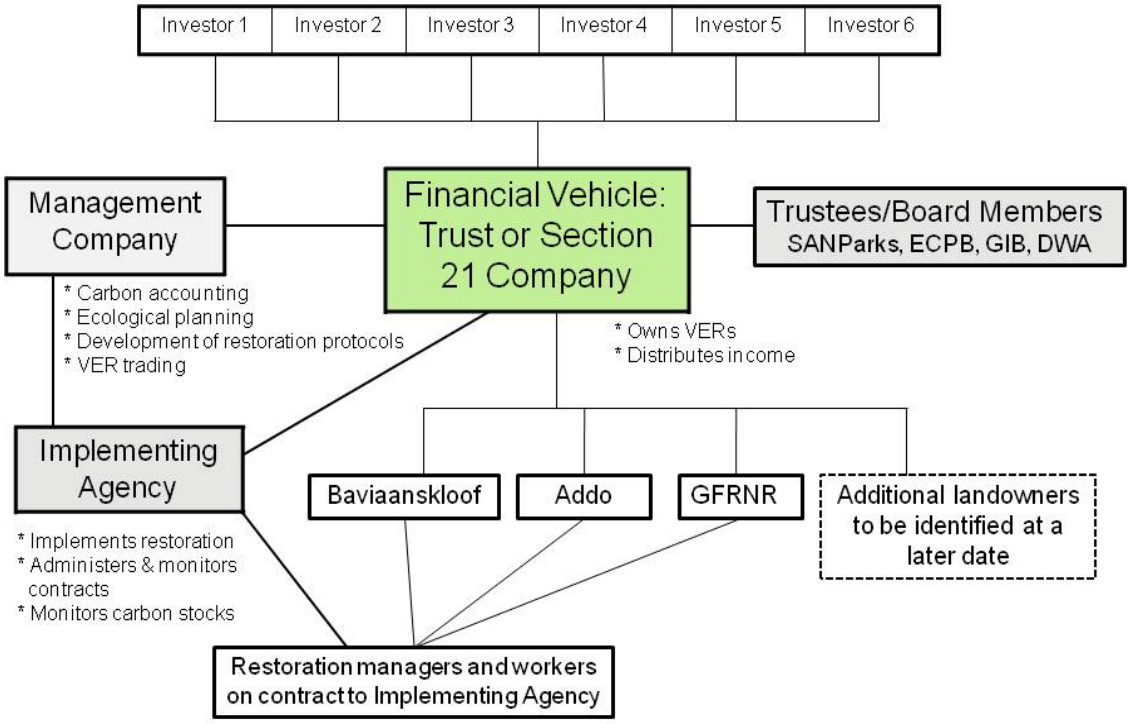

Figure 6: Management of VERs within the proposed project.

1.16 Any information relevant for the eligibility of the project and quantification of emission reductions or removal enhancements, including legislative, technical, economic, sectoral, social, environmental, geographic, site-specific and temporal information:

1.16.1 Demonstration of eligibility

Eligibility of land is demonstrated using the tool: "Procedures to demonstrate the eligibility of lands for afforestation and reforestation Carbon Development Mechanism (CDM) project activities (Version 01)" (UNFCCC, 2007). This tool will be referred to hereafter as EB35 Annex 18.

EB35 Annex 18 states the following:
"1. Project participants shall provide evidence that the land within the planned project boundary is eligible for an A/R CDM project activity by following the steps outlined below.
(a) Demonstrate that the land at the moment the project starts does not contain forest by providing transparent information that:

- *i. vegetation on the land is below the forest thresholds (tree crown cover or equivalent stocking level, tree height at maturity in situ, minimum land area) adopted for the definition of forest by the host country under decisions 16/CMP.1 and 5/CMP.1 as communicated by the respective DNA;*
- *ii. all young natural stands and all plantations on the land are not expected to reach the minimum crown cover and minimum height chosen by the host country to define forest; and*
- *iii. the land is not temporarily unstocked, as a result of human intervention such as harvesting or natural causes.*

(b) Demonstrate that the activity is a reforestation or afforestation project activity:

- *i. for reforestation project activities, demonstrate that the land was not forest by demonstrating that the conditions outlined under (a) above also applied to the land on 31 December 1989; and*
- *ii. for afforestation project activities, demonstrate that for at least 50 years vegetation on the land has been below the thresholds adopted by the host country for definition of forest.*

2. In order to demonstrate steps 1 (a) and 1 (b), project participants shall provide information that reliably discriminates between forest and non-forest land according to the particular thresholds adopted by the host country, inter alia:
(a) aerial photographs or satellite imagery complemented by ground reference data; or
(b) land use or land cover information from maps or digital spatial datasets; or
(c) ground based surveys (land use or land cover information from permits, plans, or information from local registers such as cadastre, owners registers, or other land registers)."

Initial selection of degraded thicket areas makes use of the fine-scale vegetation survey carried out by Lloyd *et al.* in 2002. Aerial photographs (2b) complemented by ground reference data (2a) have been selected to demonstrate eligibility for the proposed ARR project. This tool will be used for each discrete area of land to be included in the project boundary in order to prove its eligibility for ARR project activities.

Initial assessments on early sites included ground referencing and field assessments of vegetation cover in each site (see Annex 15, Figures A.15.1 – A.15.11). According to the Designated National

Authority (DNA) for South Africa (i.e. the Department of Minerals and Energy), the minimum definition of forest for reforestation and afforestation under the CDM[16] are as follows:

- a minimum tree canopy cover of 30%;
- a minimum area of 0.05 ha (500 m^2); and
- a minimum tree height of 2 m.

The sizes of reforestation contract planting sites within the project areas are 26 ha (mechanical) or 7 ha (manual), which exceeds the minimum area defined by the DNA of 0.05 ha.*P. afra* grows to heights exceeding 2m when mature, and the rate of planting will ensure that the minimum canopy cover criterion is exceeded. The steps required by the tool are detailed below (the step number within the tool is appended at the end of each heading):

1a (i) Vegetation is below forest thresholds

Areas were initially selected on the basis of the map of degraded thicket vegetation compiled by Lloyd et al. (2002) supplemented by field surveys by park rangers, botanists, or local experts. For each area, recent rectified aerial imagery was procured from the Chief Directorate of National Geo-spatial Information (CDNGI), within the Ministry of Rural Development and Land Reform. These areas were then examined to confirm that the current total woody cover (2m or more in height) is below the 30% canopy cover threshold specified by the DNA. The specified satellite imagery has been appended in Annex 15.

1a (ii) All young natural stands are not expected to reach the forest threshold

There have been no pre-project reforestation operations in these areas. Natural woody vegetation on the sites is exceedingly low, and is not expected to improve. Soils from degraded sites show a significant increase of crusting and decreased infiltration (Mills & Fey, 2004b) and soil temperatures are much higher in degraded thicket.

Thicket conditions	Mean maximum soil temperature (˚C)
Intact thicket (canopy)	24
Transformed thicket (under canopy)	31
Transformed (open areas)	40-50

Figure 7: Average maximum soil temperature for intact and transfformed thicket (Lechmere-Oertel et al., 2008).

These factors mean that the establishment of additional plants, without intervention, will not occur. Furthermore, historical aerial imagery (from 1972 onwards) obtained from the CDNGI confirms that the vegetation cover for the degraded land has either remained stable or decreased for long periods of time (Annex 15). Consequently, it is reasonable to assume that the current vegetation is unlikely to reach forest thresholds without active restoration.

The land is not temporarily unstocked (1a (iii))

Ground-truthing and aerial imagery confirm that for all sites, the extent of woody cover is below the national definition of forest. No prior afforestation or restoration has taken place in any of the project areas, and none of the sites are temporarily unstocked, as demonstrated by the historical aerial photography (1972 onwards) (see Annex 15).These photographs also indicate that there has been no natural regeneration of thicket in the selected sites for at least 37 years, demonstrating that without the human intervention of the proposed ARR project activities such regeneration will not occur.

[16]Available from: http://cdm.unfccc.int/DNA/ARDNA.html?CID=197

1.16.2 Socio-economic impacts of the proposed ARR project activities

The proposed ARR project activities are expected to have net positive socio-economic impacts in that they will: i) increase employment opportunities; ii) improve technical capacity and enable skills transfer; iii) increase economic prospects through improved tourism products; and iv) improve ecosystem services.

Poverty alleviation: The project activities will create employment opportunities for local communities, who are currently faced with high unemployment and limited economic prospects. The unemployment rate for the Eastern Cape is 39.5 %, the second highest for any province in South Africa (StatsSA, 2007). The high unemployment rate is in part due to habitat degradation, which has resulted in a decline of the agricultural sector in this region (Kerley et al., 1999).

Poverty alleviation is one of the key goals of the national and provincial governments and job creation is the main way that this is to be achieved. The project implementer, GIB, currently employs 124 staff. These staff are unskilled and are often unable to find permanent employment. If the project is implemented, carbon revenues will enable planting to be undertaken over 25,000 ha. The scale of operations and number of employees will be increased (5,000 ha of planting per year , with a staff component of approximately 300), boosting local economic development in an impoverished rural area.

It is also important to note that the project promotes gender considerations and opportunities for unemployed youth[17]. The teams closely follow the National Government guidelines of the poverty relief principles (i.e. those taken up by the Department of Public Enterprises' "Expanded Public Works Programme") under which at least 60 % of employees are required to be women and at least 25% of employees are required to be youths (under 35).

Capacity building and skills transfer: The proposed ARR project activities will provide specific training opportunities, which will increase skills and thus improve opportunities for employment for those trained. Team training includes relevant skills such as Health and Safety, First Aid, basic bookkeeping and productivity planning. The work that is provided by the project is on a contract basis and entails physical labour (planting of *P. afra* cuttings) for the majority of employees. In each team of 10-13 staff there is a team leader who is trained to manage the contract, and earmarked to become a business person (carbon entrepreneur). Ten employees have already been trained to be field technicians i.e. they are able to sample soils and plants, and enter data. A further 15 people have been employed in a nursery operated by DWA, where trials on *P. afra* are undertaken and other species are propagated.

Such skills provide opportunities for the labourers to potentially become employed as project managers; field technicians and horticulture technicians. The employment model of such "Expanded Public Works Programme" specifically promotes the transfer of skills so that those who show promise can move on to start their own private contracting teams and build up their own business. In addition to these skills, some employees may also be enabled to move into the conservation field to become conservation rangers or field guides.

[17] According to the Youth Act, the South African Definition of youth is between 14 and 35 years of age, but in terms of the Expanded Public Works Programme only those youths of a legal working age are recruited. The legal working age in South Africa is 15, according to the Basic Conditions of Employment Act 75 of 1997.

Enhanced tourism: The restoration of degraded thicket in the project areas will enhance the aesthetics of the landscape as a whole, and enable an increase in the game stocking levels (as the carrying capacity will increase due to increased biomass). This will increase the tourism potential of the three conservation areas, consequently improving local economic development in communities surrounding the project areas. In addition, an increase or enhancement of the tourism products offered by the conservation areas will likely result in an increase in tourism revenue. Due to the fact that the project areas are on government owned conservation land, tourism revenues are used to further conservation management practices.

Improved ecosystem services: The restoration of degraded thicket will improve the ecosystem services currently provided by the project areas (see Section 1.8). The consequential knock on effect of such improved ecosystem services will have both social and economic benefits. Improved ecosystem services and their associated socio-economic benefits include:

i. Improved soil quality and SOM will result in improved infiltration rates and water retention capacity of the soils (Mills & Fey, 2004a; Mills & Fey, 2004b).
ii. The improved water retention will result in increased water flow and water supply to the project areas and the surrounding water catchments. This will result in improved water security for the local communities as well as the farms surrounding the project areas. The economic benefit from improved water supplies is considerable in this drought-prone region, and may reduce the number of expensive engineering solutions required for increasing water supply.
iii. The restoration of degraded thicket will encourage the proliferation of bees and other pollinators in and around the project area (de la Flor Tejero, 2008). This may improve wild plant reproduction within the project areas as well as the reproduction of crops grown in areas surrounding the project areas, leading to improved food production and resulting in an economic boost for farmers.

The proposed ARR project areas are designated for conservation and thus the following are not negatively impacted by this proposed project:

- Land tenure. The land is not owned by local communities thus the proposed ARR project activities do not interfere with any community ownership rights.
- Religious or culturally significant sites. There are no religious or culturally important sites within the specific planting sites. Sites of constraining historical significance are excluded during site selection.
- Food production (within the project boundary). No food production activities are permitted in the project areas.
- Access to fuelwood and other forest resources. The project areas are under environmental protection and no access to fuelwood or forest resources is permitted.

The Baviaanskloof Nature Reserve has a small community within its borders. A meeting with the community was arranged by GIB on 11 June 2007 to inform them of the project aims and objectives and to gain their support for the project. The meeting was attended by 42 community members as well as Mike Powell (Technical Advisor) and Yolande Vermaak (Project Manager). Please refer to the minutes of the meeting in Annex 5 for more information. All of the community members at the meeting indicated their understanding of the aims and objectives of the proposed ARR project and supported the project.

Similar meetings were not arranged for the Addo Elephant National Park and GRFNR because these areas do not have communities living within their boundaries. Nonetheless, the

management of these project areas have confirmed their willingness to engage in the proposed ARR project, as demonstrated by the letters in Annex 5.

Annex 3 details the how the proposed ARR project fulfils South Africa's sustainable development criteria, and Annex 11 contains further information regarding the socio-economic benefits of the proposed ARR project activities.

1.17 List of commercially sensitive information (if applicable):

No commercially sensitive information has been excluded from the proposed ARR project.

2 VCS Methodology:

2.1 Title and reference of the VCS methodology applied to the project activities and explanation of methodology choices:

The proposed ARR project uses the VCS approved afforestation and reforestation baseline methodology AR-AM0002 "Restoration of degraded lands through afforestation/reforestation" (Version 3).

This choice of methodology is appropriate as the proposed ARR project will establish woody biomass on severely degraded land in a semi-arid area with low agricultural potential by planting cuttings of the indigenous thicket tree *P. afra*. The degradation of the project areas dates back to at least 50 years prior to publication of this document, therefore the proposed ARR project satisfies the requirements that *"no ARR or [Agricultural Land Management] ALM project areas were cleared of native ecosystems within the ten year period prior to the proposed Project Start Date"* (see Annex 15). Current environmental conditions do not permit natural recovery of thicket within these areas, in all likelihood due to the high temperatures, reduced soil quality and reduced soil moisture content of degraded landscapes (see Section 2.2.2).

The project activities fall under the definition of afforestation as defined in the methodology guidelines (VCS, 2008a) "*increasing carbon stocks in woody biomass by establishing, increasing and restoring vegetative cover through the planting, sowing or human-assisted natural regeneration of woody cover*".

2.2 Justification of the choice of the methodology and why it is applicable to the project activity:

Methodology AR-AM0002 (V3) is applicable to the proposed VCS project because the project activities are implemented on areas having low inherent potential to support living biomass without human intervention.

2.2.1 Applicability

The applicability conditions of AR-AM0002 (V3) are addressed as follows:

a) The project activity does not lead to a shift of pre-project activities.

The land use before, during and after project activities is conservation, since the project areas are all conservation areas mandated and run by provincial or national conservation agencies. The increase in vegetation within the areas as a result of project activities will improve the land's carrying capacity, and result in a consequent increase in the conservation potential of the areas. Therefore, there is no shift in pre-project activities, and the current land use will be enhanced as a result of the project activities. See more details in the baseline identification procedure in Section 2.4 below.

b) The planting sites to be restored are degraded.

All proposed ARR project planting sites are defined as degraded by a peer-reviewed landscape study (Lloyd et al., 2002), and are confirmed as degraded by pre-project area visits. This classification of degradation meets the criteria laid out by the "*Tool for the identification of degraded or degrading lands for consideration in implementing CDM ARR project activities*" (UNFCCC, 2008). See Section 2.2.2 for additional details.

c) Current environmental/anthropogenic pressures do not permit significant encroachment of natural vegetation.

The project areas are typified by low rainfall (less than 500 mm per annum; see Annex 12). The land being restored is moderately or severely degraded (see Section 1.4) (Lloyd et al., 2002) and has exceedingly low agricultural potential. Furthermore, the land will remain degraded in the absence of the proposed ARR project activities because the environmental conditions do not permit natural recovery of thicket i.e. the degradation state is stable (Lechmere-Oertel et al., 2005b). This is further confirmed in Section 2.2.2 below.

d) The specified procedure for identifying the baseline confirms that the selected baseline is appropriate.

The application of the procedure for determining the baseline scenario in Section II.4 of the AR-AM0002 (V3) leads to the conclusion that the baseline (identified in Section 2.4 below) is the most appropriate choice for determination of the baseline scenario and that the land would remain degraded in the absence of the proposed ARR project activities. In order to assess land eligibility for the ARR project methodology, the proposed ARR project utilises the procedures to define the eligibility of lands for afforestation and reforestation CDM project activities (UNFCCC, 2007) (see Section 2.2.2).

2.2.2 Demonstration that the land is degraded

The steps outlined in the "Tool for the identification of degraded or degrading lands for consideration in implementing CDM ARR project activities (version 01)" (UNFCCC, 2008) were carried out in order to confirm eligibility. The tool specifies that:

"The procedure to implement the two-stage approach is described below. The presence of one of the following is enough for demonstrating that land is degraded" and/or "degrading":

> *Provide documented evidence that the area had been classified as "degraded" under verifiable local, regional, national or international land classification system or peer-review study. Participatory rural appraisal, satellite imagery and/or photographic evidence in the last 10 years..."*

There have been a number of studies undertaken regarding the degradation processes which occur in the Subtropical Thicket Biome, and a summary of this is presented by Lloyd et al. (2002), which also includes a comprehensive analysis of the extent of thicket degradation throughout the region. This analysis utilised a combination of field surveys and satellite imagery to provide fine-scale degradation maps of the entire Subtropical Thicket Biome. These maps were made available to the public[18], and form the basis for the selection of suitable areas for planting within the proposed ARR project areas. The publication is accepted as being definitive for the Subtropical Thicket Biome. Nonetheless, each site nominated for planting is individually assessed in the field by an assessment team to ensure that it is currently degraded, and if sites are found to be misclassified, they will not be planted under the project activities.

This study and publication meet the qualification criterion III (a) of the selected tool, and consequently planting sites can be defined as degraded within the conditions of the selected tool.

2.3 Identifying GHG sources, sinks and reservoirs for the baseline scenario and for the project:

GHG sources:

Based on the baseline and monitoring methodology applied by the proposed ARR project activities (AR-AM0002 (V3)), GHG emissions generated by the proposed ARR project (i.e. GHG sources) are negligible and can be excluded from calculations. The sources of emissions listed for

[18] See http://bgis.sanbi.org/STEP/STEPreports.asp

consideration under this methodology are: i) emissions from the decline in the carbon stock of non-tree vegetation; and ii) GHG emissions from biomass burning. The former source is discounted for the proposed ARR project because there is no site clearance for land preparation at the start of the programme, and it has been observed that woody shrub vegetation increases as a result of *P. afra* planting (van der Vuyfer, in press). The latter source will be monitored *ex post*. It is not anticipated that fire will play a large role in project emissions since *P. afra* is naturally fire resistant as a result of its succulent and dense foliage.

GHG sinks and reservoirs:
The AR-AM0002 (V3) methodology stipulates that major carbon pools for consideration are above and below ground tree biomass, with optional inclusion of soil organic carbon, deadwood and litter. Table 4 shows the carbon pools selected for the proposed ARR project.

Table 4: Identification and justification of carbon pools.

Carbon pool	Selected (yes or no)	Justification
Above ground	Yes	Major carbon pool subject to project activities
Below ground	Yes	Major carbon pool subject to project activities
Deadwood	Yes	Carbon pool subject to the project activities
Litter	Yes	Carbon pool subject to the project activities
Soil organic carbon	Yes	Carbon pool subject to the project activities

2.4 Description of how the baseline scenario is identified and description of the identified baseline scenario:

The proposed ARR project areas are situated within two nature reserves and one national park, namely: the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the GFRNR. Thus the current land use classification of the project areas is conservation.

According to the eligibility criteria for the chosen methodology, the land is degraded and will continue to degrade in the absence of the proposed ARR project activities (see Section 1.16). Changes in the carbon stocks in the baseline are thus considered to be zero in the absence of project activities. The baseline scenario is therefore continued conservation within the project areas with no reforestation, resulting in a stable or gradually increasing state of degradation.

The baseline scenario was determined using the following steps as outlined in the AR-AM0002 (V3) methodology:

a) Step 1: Identification of plausible land uses:
See Step 2 below.

b) Step 2: Demonstration that the project areas would remain degraded:
Both Step 1 and Step 2 were carried out using the recommended tool "*Tool for the demonstration and assessment of additionality in A/R CDM activities (Version 02)*" (UNFCCC, 2007) when determining the additionality of the programme. This is detailed in Section 2.5 below. The identified baseline scenario is continued conservation on the sites with no reforestation.

c) Step 3: Demonstrate that the lands to be planted are degraded:
The "*Tool for the identification of degraded or degrading lands for consideration in CDM A/R activities*"(UNFCCC, 2008) was applied to verify that planting sites are degraded (see Section 2.2.2).

Degradation of all sites is confirmed by the study examining degradation in the Subtropical Thicket Biome (Lloyd et al., 2002) and is confirmed through initial site visits (see Section 2.2.2).

d) Step 4: Demonstration that the baseline scenarios do not alter the historical land use patterns:

All project areas are within nature reserves and national parks run by national or provincial conservation agencies, and consequently the only legal land use is conservation. Whilst alternative land uses such as grazing of livestock and agriculture were historically practiced on much of the land, these activities may no longer be pursued within the designated conservation areas. The inclusion of these historically degraded areas within the nature reserves has not led to displacement of communities.

e) Step 5: Demonstration that the chosen baseline does not lead to an increase in carbon stocks or other profitable uses:

The analysis of historical aerial imagery shows no positive change in the vegetation cover of the identified sites over a long period (30 – 51 years). In combination with several published reports on the long term effects of degradation on thicket vegetation in the area(Lechmere-Oertel et al., 2005b; Lloyd et al., 2002), this imagery analysis shows that the chosen baseline (conservation with no reforestation) does not lead to an increase in carbon stocks (Annex 15).

2.5 Description of how the emissions of GHG by source in baseline scenario are reduced below those that would have occurred in the absence of the project activity (assessment and demonstration of additionality):

Objectives of the ECPB and SANParks include undertaking restoration of the degraded land back to its original intact thicket condition, but such an initiative is prohibitively expensive for government-funded conservation reserves, and is not being undertaken. Indeed, there are currently no other landscape-scale restoration projects involving planting of indigenous tree species taking place on government-owned conservation land within the Eastern Cape. Carbon finance presents an opportunity to fund this restoration process, overcoming this financial hurdle. The steps described in the "Tool for the Demonstration and Assessment of Additionality in A/R CDM Project Activities (Version 02)" (UNFCCC, 2007) was used to assess additionality.

a) Step 0: Preliminary screening based on the starting date of the project activity:

Reforestation project activities started subsequent to 31 December 1999 and prior to the current date of registration. The project was implemented in 2004 with the specific aim of obtaining carbon finance in order to allow large scale restoration of the thicket biome. Documentation of this is provided in the business plan and MoUs presented in Annex 10. The business plan is available in full from GIB upon request. The first few pages are included in Annex 10 in the interests of brevity.

b) Step 1: Identification of plausible land uses:

Sub-step 1a: Identify credible alternative land use scenarios to the proposed CDM project activity Industrial development of the land is considered unlikely due to the distance from significant urban populations. The project areas are in a semi-arid rural area, with low rainfall, high average annual temperatures and generally poor agricultural potential. Common historical land uses in the area include goat pastoralism (Mills et al., 2005a), agricultural cultivation and establishment of leguminous pastures (Sigwela, 2004). The principal land use for the project areas is currently conservation, although land use in the surrounding areas reflects a combination of the specified

activities, with pastoralism as the principal land use. Consequently, the proposed alternative land uses are:

i. change in land use to a non-conservation-based commercial alternative such as browsing of goats or agriculture;
ii. conservation with reforestation activities that are not funded by the project; and
iii. continued conservation with no reforestation.

The feasibility of these identified alternative land uses are discussed below.

Sub-step 1b: Consistency of credible land use scenarios with enforced mandatory applicable laws and regulations
The national legislation applicable to the project areas include:

- National Environmental Management Act (107 of 1998) (NEMA).
- NEM: Biodiversity Act (10 of 2004).
- NEM: Protected Areas Act (57 of 2004).
- Nature and Environmental Conservation Ordinance (19 of 1974).
- National Forest Act (84 of 1998).
- National Veld and Forest Fire Act (101 of 1998).
- Conservation of Agricultural Resources Act (43 of 1983)
- Fencing Act (31 of 1963).
- Environment Conservation Act (73 of 1989).
- Problem Animal Control Ordinance (26 of 1957).
- National Heritage Resources Act (25 of 1999).
- Public Finance Management Act (1 of 1999).
- Restitution Act (22 of 1994).
- National Water Act (36 of 1998).

The provincial nature reserves are also subject to the Eastern Cape Provincial Parks Board Act (12 of 2003). Additionally, the Baviaanskloof Nature Reserve, as a declared World Heritage Site, is also subject to the World Heritage Convention Act (49 of 1999).

All public-owned land that is specified as a conservation area is legally bound to only undertake activities that conserve current land processes. Specifically, the Baviaanskloof Nature Reserve and GFRNR are both declared "provincial nature reserves" in terms of Section 12 of the NEM: Protected Areas Act. The Addo Elephant National Park is a "national park" in terms of the same legislation.

The Protected Areas Act of 2004 states that:
"Commercial and community activities in nature reserve and world heritage site

50. (1) The management authority of a nature reserve and world heritage site may, despite any regulation or by-law referred to in section 49, but subject to the management plan of the reserve or site—
(a) carry out or allow—
(i) a commercial activity in the reserve or site; or
(ii) an activity in the reserve or site aimed at raising revenue.
(b) enter into a written agreement with a local community inside or adjacent to the reserve or site to allow members of the community to use, in a sustainable manner, biological resources in the reserve or site; and
(c) set norms and standards for any activity allowed in terms of paragraph (a) or (b).

> *(2) An activity allowed in terms of subsection (1) (a) or (b) may not negatively affect the survival of any species in or significantly disrupt the integrity of the ecological systems of the nature reserve or world heritage site."*

In terms of this legislation, any change in the land use to agriculture, grazing or alternative commercial development would impact on species survival and ecosystem function, and consequently cannot be undertaken within the project areas. This is reflected in the strategic management plans for the Baviaanskloof Nature Reserve (Erlank et al., 2009), Addo Elephant National Park (SANParks, 2006) and GFRNR (Kotauli et al., 2006) that specify that the primary purpose of the conservation areas is to ensure ecological integrity and long term conservation of biodiversity in the region.

Consequently, scenario (i) is not feasible in terms of the laws and regulations governing the project areas.

c) Step 2: Investment analysis:

This step was deprecated in favour of the specified alternative, the barrier analysis (Step 3).

d) Step 3: Barrier analysis:

A barrier analysis was conducted to examine the feasibility of scenario (ii) and (iii), using the methodology outlined in Step 3 of the methodological tool "*Tool for the demonstration and assessment of additionality in ARR CDM activities (Version 02)*" (UNFCCC, 2007):

Barriers due to prevailing practice

- **Prior examples:** The proposed ARR project is the first of its kind in the region. No other reforestation activities have been conducted in the area, despite government interest in restoring the subtropical thicket. Due to financial restrictions, landowners typically cannot afford to undertake land management activities such as restoration of vegetation or degraded land. Furthermore, this is the first large-scale (greater than 1,000 ha) restoration project in the country.

Barriers due to local ecological conditions

- **Soil degradation:** Significant soil degradation has occurred in areas characterised by historically high levels of browsing or intensive agriculture. The reduced plant cover resulted in erosion, which in turn has caused a considerable loss of SOM *(Mills & Fey, 2004b)*. Erosion as a result of reduced ground cover has exacerbated this problem. Recovery of thicket in such degraded soils does not occur, likely as a result of the high temperatures, reduced soil quality and reduced soil moisture content of degraded landscapes (see Section 1.7). Analysis of aerial imagery has shown that even over periods of up to 50 years the extent of natural recovery is negligible (see Annex 15).

Barriers due to social conditions

- **Lack of skills:** The manual activities of the proposed ARR project are relatively simple, but the local communities in the area lack training in the necessary planting procedures for project success. Local knowledge regarding landscape management is also limited, and therefore training of the local communities is essential for the success of the proposed ARR project activities.

Investment barriers

- **Capital availability:** No private capital is presently available for restoration operations in the Eastern Cape because there are no clear financial returns. Although the seed finance for the proposed ARR project has been provided through government investment, the national government is unable to commit larger sums to this project. This project was

conceived in order to enhance the potential for restoration in these areas by providing capital from carbon finance.

- **Debt funding:** This is not available for the land use scenarios, since the land is publicly-owned.

Finally, alternative land use scenario (iii) is the most likely of the proposed scenarios. Under this scenario, land is not reforested, but left to recover naturally. All sites are historically degraded, and have remained so for a considerable period regardless of human activity or the lack thereof. This is confirmed by the analysis of historical aerial imagery, which demonstrates that despite varied historical land uses within the area, natural recruitment in degraded sites is virtually non-existent over a 30 to 50 year time period (see Annex 15). In each of the conservation areas, land degraded by prior land use regimes that has been under conservation has either continued to degrade or failed to improve for more than 40 years.
Consequently, the most plausible scenario is that the land remain degraded in the absence of project activities.

e) Step 4: Common practice analysis:

There are no other carbon market financed reforestation projects in the Eastern Cape as a whole, including in the proposed ARR project areas. As detailed earlier, the project initiation and pilot study were funded by public funds provided through the DWA with a specific focus on upscaling the activities using carbon financing (details in Annex 10). The public sector is unable to provide sufficient funds to ensure reforestation of degraded land in the Eastern Cape, and there is no alternative economic incentive or potentially viable private sector practice that can fill this gap.

The use of this tool demonstrates that project activities are additional.

3 Monitoring

3.1 Title and reference of the VCS methodology (which includes the monitoring requirements) applied to the project activity and explanation of methodology choices:

The monitoring plan follows Section III of the approved methodology AR-AM0002 (V3). The monitoring steps and procedures of the methodology are applied to the project context. Aspects of the monitoring requirements for the chosen methodology include:

- Monitoring of the project initiation.
- Monitoring of the area reforested.
- Monitoring of the forest establishment.
- Monitoring of forest management activities.
- Adoption of a monitoring frequency over which carbon pools of the project are monitored, data are collected and changes in the carbon stocks are estimated.

These aspects of the monitoring plan are discussed in detail in Section 3.4, and details relevant to measurement of individual quantities are discussed in the relevant section in Section 3.2.

3.2 Monitoring, including estimation, modelling, measurement or calculation approaches

3.2.1 Purpose of monitoring

The purpose of monitoring is to provide information to the VCS on the progress of the proposed ARR project and to improve the project's efficiency and effectiveness. It is an invaluable tool for good management and will enable the Project Manager to determine whether the resources available are sufficient and are being correctly utilised, whether the rate of planting is sufficient and appropriate, and whether the planting and management plans are being followed.

3.2.2 Monitoring roles and responsibilities

GIB will be responsible for monitoring the project. Planting of *P. afra* is undertaken by contractors according to clearly defined site boundaries and operating procedures (See Section 1.8 and Annex 10 for details).

The contract will be inspected by the Project Manager during the initial phase to ascertain that the methods and results are up to standard and that the contractor is working in the correct area. If the contractor is in breach of his/her contract, the contract will be cancelled and CSS notified. If the work is sub-standard, the Project Manager will issue instructions to improve the standard. Upon completion of the contract, the contract area is inspected to ensure that the full contract area has been planted and the completion document is then submitted to GIB. Additionally, CSS is notified to update the contract status in the spatial database.

3.2.3 Managing data quality

High quality data will be maintained by following the principles described in Section 3.2.8.

3.2.4 Stratification

The approved methodology recommends a hierarchical approach to stratification. Primary factors for *ex ante* and *ex post* stratification are regional-scale features, such as climate and geographical conditions. Additional sub-strata may be identified where there is sufficient in-stratum variation to necessitate a division to ensure stratum homogeneity. Stratification is subject to a minimum

contiguous area defined for a forest by the DNA (in the case of South Africa, this provides an effective minimum area of 0.05 ha).

a) Baseline stratification

Stratification on the basis of species planted is not relevant for the proposed ARR methodology, since only a single species (*P. afra*) is to be planted. Current land use for project areas is limited to conservation, and since the land use will not change in the future, land use is not used as a stratification criterion. However, if private land is included in the project under the VCS provisions for project grouping, an additional stratum representing alternative land use will be included.

Rainfall is a primary factor influencing the growth of plants in semi-arid ecosystems (Mucina & Rutherford, 2006). Rainfall periodicity is bimodal across the region (although the intensity of summer rains decreases in the eastern sites) so rainfall seasonality was not considered as a stratification criterion. However, there is significant variation in the mean annual rainfall of the three project areas (see Annex 12). Furthermore, maximum, minimum and mean annual temperatures differ between the project areas. This inter-area variation was used as the primary criterion for stratification, and consequently each of the project areas (i.e. Baviaanskloof Nature Reserve, Addo Elephant National Park and GFRNR) is nominated as the boundaries for this stratification.

In low rainfall regions, the impact of soil fertility on plant growth is amplified (Mucina & Rutherford, 2006). Soil fertility was therefore examined to assess its potential as a stratification criterion. Soils in the project areas are derived primarily from sedimentary rocks, including arenites and shales, with occasional conglomerate, sandstone and mudstone variants (Council for GeoScience, 1997). For the stratification study, soil types within the Baviaanskloof Nature Reserve were divided into two simple categories; nutrient-poor soils (originating largely from Table Mountain Group sandstones) and nutrient-rich soils (incorporating alluvial soils and shale-derived soils). An analysis of the variation in carbon stocks between poor and rich soils within the Baviaanskloof Nature Reserve did not demonstrate a significant variation between the two soil types. The carbon stock assessment included above ground, deadwood, litter, root carbon and soil carbon stocks (0-25 cm) under bushes, and the carbon stock data were sourced from the field surveys conducted in the Baviaanskloof Nature Reserve area (see Annex 8). (C stocks (nutrient-poor soil) = 381.27 ± 208.89 t ha^{-1}; C stocks (nutrient-rich soil) = 316.57 ± 229.81; p = 0.33 NS). It is possible that soil variations on a very small scale (as low as 0.25 ha) affect the variability of the carbon stock, but such fine scale variations cannot feasibly be included within a stratification programme. Consequently, soil fertility was not included as a stratification criterion.

Topography has not been included as a baseline stratum because there is insufficient evidence available to determine whether topography plays a significant role on *P. afra* growth in the project areas.

b) Ex ante stratification

The *ex ante* stratification makes use of the baseline strata described above (using project boundaries as a proxy for the climatic variation between each of the project areas). Additional stratification by cohort (ie: grouping age for each five years of planting) was not feasible, since there is insufficient information available to extrapolate accurate growth curves at this point. A generic growth curve was therefore used for the *ex ante* calculations.

c) Ex post stratification

The *ex post* stratification uses the same basic stratification units as the *ex ante* stratification, using the project boundaries as proxies for climatic variation across the landscape.

Strata will be divided into cohort sub-strata, with each five-year planting period being designated as a separate sub-stratum. This will allow project proponents to monitor the changing rate of carbon accumulation as the plants mature.

The *ex post* stratification will be conducted three years after planting to address the possible changes of planning activity boundary in the unlikely event of significant mortality from a fire, disease or other stochastic disturbance events. Additional strata for monitoring will be added for these disturbed areas, and for areas in which supplementary planting is undertaken. This additional stratification will allow for more accurate assessment of the effects of these disturbances on carbon sequestration rates, and will reduce the impact of such rare events on carbon sequestration calculations for the project as a whole.

3.2.5 Monitoring of carbon stocks in the carbon pools

Permanent sample plots will be established for sampling and measurement of carbon pools. Plot locations are taken by means of a GPS device, and are recorded to allow revisiting during each monitoring period. Non-obtrusive, durable permanent markers(metal pegs) will be used to demarcate these areas, reducing the likelihood of selective management practices. Details of the methods used for monitoring the required carbon stocks are as specified in the chosen methodology, and are detailed below.

a) Calculation of change in carbon stocks of pools

The verifiable change in carbon stocks is calculated by applying the stock change method to the data gathered between two monitoring events.

$$\Delta C_{ijk,t} = \left[\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t} + \Delta C_{DW,ijk,t} + \Delta C_{L,ijk,t} + \Delta C_{SOC,ijk,t}\right] \cdot [44/12] \quad \text{(M.5)}$$

where:

$\Delta C_{ijk,t}$	verifiable annual changes in the carbon stock of pools for stratum i sub-stratum j species k for year t; t CO_2e yr^{-1}
$\Delta C_{AB,ijk,t}$	average annual changes in the carbon stock of above ground biomass for stratum i sub-stratum j species k for year t; t Cyr^{-1}
$\Delta C_{DW,ijk,t}$	average annual changes in the carbon stock of deadwood for stratum i sub-stratum j species k for year t; t Cyr^{-1}
$\Delta C_{L,ijk,t}$	average annual changes in the carbon stock of litter for stratum i sub-stratum j species k in for year t; t Cyr^{-1}
$\Delta C_{SOC,ijk,t}$	average annual changes in the carbon stock of soil organic matter for stratum i sub-stratum j species k for year t; t Cyr^{-1}

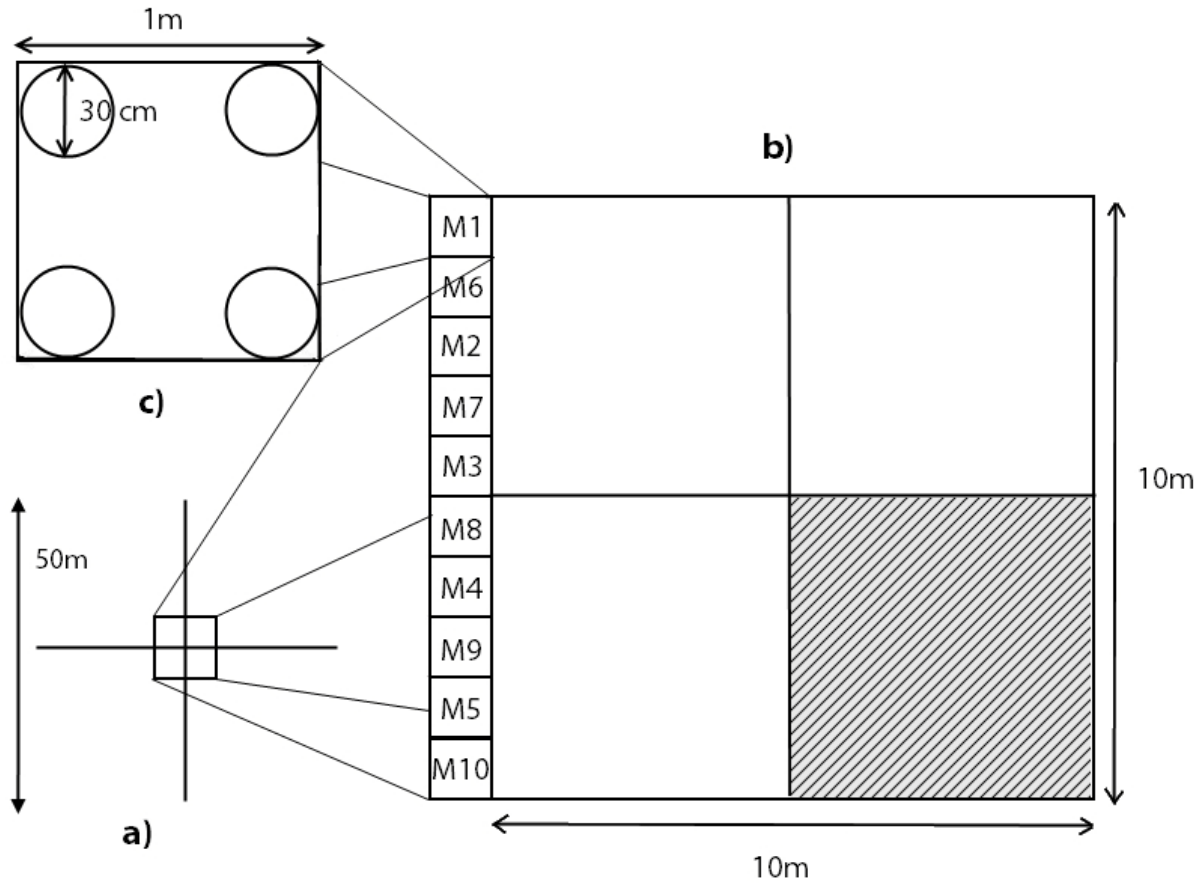

Figure 8: Diagrammatic representation of monitoring sites. a) Each site will comprise a 10m x 10m area, with two 50m long transects for deadwood monitoring bisecting the site; b) monitoring of above ground biomass will be carried out by measuring CBSA of *P. afra* plants in the site. Nested sub-plots (5m x 5m - shaded)will be used for monitoring the growth of offspring plants, and will be used instead of the full plots once stem density becomes too high; and c) litter monitoring will be carried out in peripheral 1m x 1m plots, since removal of litter from *P.afra* would affect the rate of growth of the stand (due to its method of vegetative propagation). Litter measurements will be gathered from 30cm radius circles in the corners of the litter plots, and no litter plot will be used twice. The letters in the boxes correspond to the monitoring period in which they will be used (ie M1= monitoring period 1, M2 = monitoring period 2, etc)

b) Above ground tree biomass

Changes in tree biomass are calculated from the monitoring data on individual trees in the permanent sample plots. The plots are established randomly within the sites, and the combined basal stem area (CBSA) of the trees is measured for each plot. CBSA is measured instead of diameter at breast height (DBH) since *P. afra* plants are frequently multi-stemmed, and accurate allometric equations have been developed (see Equation AL.1 below) to use the CBSA (Powell, 2009). CBSA is measured at ground level using digital callipers for each stem, since *P. afra* is a highly branched tree.

The monitoring design makes use of nested plots, as specified in AR-AM0002 (V3). Each plot is 10 m x 10 m in size, since the planting density is very high (approximately 2,500 *P. afra* cuttings will be planted per hectare), which allows the measurement of 25 cuttings. Measurement of smaller stems emerging from vegetative spreading will be conducted in nested 5 m x 5 m plots, as will future

measurements when the stands become too thick to readily penetrate for measurement purposes (see Figure 8 above).

These measurements will be used to calculate the above ground carbon stock of above ground biomass using the equations below.

$$\Delta C_{AB,ijk,t} = \left(C_{AB,m_2,ijk} - C_{AB,m_1,ijk}\right)/T_B \quad \text{(M.6)}$$

where:

$\Delta C_{AB,ijk,t}$ average annual changes in the carbon stock of above ground biomass for stratum i sub-stratum j species k for year t; t Cyr $^{-1}$

$C_{AB,m_2,ijk}$ carbon stock of above ground biomass for stratum i sub-stratum j species k at monitoring event m_2; t C

$C_{AB,m_1,ijk}$ carbon stock of above ground biomass for stratum i sub-stratum j species k at monitoring event m;t C

T_B time between monitoring events m_1 and m_2 of the biomass monitoring; yr

$$\Delta C_{AB,m,ijk} = A_{m,ijk} \cdot MC_{AB,m,ijk} \quad \text{(M.7)}$$

where:

$A_{m,ijk}$ area of stratum i sub-stratum j species k at monitoring event m; ha

$MC_{AB,m,ijk}$ mean carbon stock of above ground biomass for stratum i sub-stratum j species k at monitoring event m; t Cha^{-1}

$$MC_{AB,m,ijk} = MC_{AB\_Tree,m,ijk} + MC_{AB\_NTree\_Shrub,m,ijk} \quad \text{(M.8)}$$

where:

$MC_{AB\_Tree,m,ijk}$ mean carbon stock of above ground tree biomass in stratum i sub-stratum j species k at monitoring event m; t C ha^{-1}

$MC_{AB\_NTree\_Shrub,m,ijk}$ mean carbon stock of above ground non-tree shrub component in stratum i sub-stratum j species k at monitoring event m; t C ha^{-1}

The non-tree and shrub component is conservatively excluded from the monitoring plan, as explained in Section 3.2.5c): Non-tree biomass below. Therefore:

$MC_{AB\_NTree\_Shrub,m,ijk} = 0$

The tree component of above ground biomass is calculated as below:

$$MC_{AB_{Tree},m,ijk} = \frac{\sum_{p=1}^{P_{ijk}} C_{AB_{Tree},m,ijk,p}}{P_{ijk}} \quad \text{(M.9)}$$

where:

$C_{AB\_Tree,m,ijk,p}$ plot level above ground tree carbon stock in stratum i sub-stratum j species k plot p at monitoring event m; t C ha^{-1}

p plot number in stratum i sub-stratum j species k

P_{ijk} number of plots in stratum i sub-stratum j species k

The methodology makes use of the allometric equation method rather than the biomass expansion method.

$$C_{AB\_Tree,k} = f(DBH_k, H_k) \cdot CF_k \quad \text{(M.11)}$$

where:

$C_{AB\_Tree,k}$	carbon stock of above ground tree biomass of species k; t dm ha^{-1}
$f(DBH_k, H_k)$	allometric equation linking merchantable volume to the mean diameter at breast height (DBH) and tree height (H) meters
CF_k	carbon fraction of species k; dimensionless

For purposes of the *ex post* calculations, the project will utilise the allometric equation derived by Powell (2009) from extensive field sampling of *P. afra* (Equation AL.1). This equation correlates the above ground carbon stock of a plant to its combined basal stem area. Consequently, the merchantable volume is not recorded, but rather the carbon stock of above ground tree biomass for each site.

$$\log_{10} y = 1.1043(\log_{10} CBSA) + 2.4464 \quad \text{(Powell, 2009)} \quad \text{(AL.1)}$$

where:

y	Above ground dry plant carbon; kg C
$CBSA$	Cumulative basal stem area; m^2

$$C_{AB\_Tree,m,ijk,p} = \frac{\left(\sum_{tr=1}^{TR} C_{AB\_Tree,k} \cdot XF\right)}{1000} \quad \text{(M.12)}$$

$$XF = \frac{10{,}000}{A_p} \quad \text{(M.13)}$$

where:

XF	expansion factor to represent the per plot value to per hectare value
A_p	plot area; m^2
tr	tree (TR = total number of trees in the plot)

c) Non-tree biomass

Non-tree biomass comprises shrub biomass, and is not measured, since the shrub component of the selected degraded sites is low. Shrub biomass has been shown to increase in the restoration areas over time (van der Vuyfer, in press). Consequently, it is considered conservative to exclude the non-tree biomass from sequestration calculations, and the non-tree component is not monitored.

$$C_{AB\_NTree\_Shrub,m,ijk} = 0$$

d) Below ground biomass

No monitoring of this carbon pool is undertaken, since the below ground biomass is calculated by multiplying the estimated above ground biomass by the root to shoot ratio, as outlined in AR-AM0002 (V3). The value for this ratio (0.253) has been estimated from empirical data in literature and from field measurements, and is used in the *ex ante* and *ex post* calculations.

$$C_{BB,m,ijk} = A_{m,ijk} \cdot MC_{BB,m,ijk} \quad \text{(M.16)}$$

$$MC_{BB,m,ijk} = [MC_{AB\_Tree,m,ijk} \cdot R_{T,jk} + MC_{AB\_NTree\_Shrub,m,ijk} \cdot R_S] \quad \text{(M.17)}^{19}$$

where:

$A_{m,ijk}$	area of stratum i sub-stratum j species k at monitoring event m; ha
$MC_{BB,m,ijk}$	mean carbon stock of below ground biomass for stratum i sub-stratum j species k at monitoring event m; t C ha^{-1}
$R_{T,jk}$	root-shoot ratio for tree species k sub-stratum (age class) j; dimensionless
R_S	root-shoot ratio for shrub; dimensionless

The non-tree and shrub component is conservatively excluded from the monitoring plan, as explained in section 3.2.5c): Non-tree biomass below. Therefore:

$$MC_{AB\_NTree\_Shrub,m,ijk} = 0$$

The annual change in the carbon stock of below ground biomass is calculated using the following equation:

$$\Delta C_{BB,ijk,t} = \left(C_{BB,m_2,ijk} - C_{BB,m_1,ijk}\right)/T_B \quad \text{(M.18)}$$

where:

$\Delta C_{BB,ijk,t}$	average annual change in the carbon stock in the below ground biomass in stratum i sub-stratum j species k for year t; t Cyr^{-1}
$C_{BB,m_2,ijk}$	carbon stock of below ground biomass for stratum i sub-stratum j species k at monitoring event m_2; t C
$C_{BB,m_1,ijk}$	carbon stock of below ground biomass for stratum i sub-stratum j species k at monitoring event m_1; t C
T_B	time between monitoring events m_1 and m_2 of the biomass monitoring; yr

e) Deadwood

Underground deadwood is assumed to contribute to the soil organic content (SOC), and is consequently not monitored separately.

$$\Delta C_{DW,ijk,t} = \left(C_{DW,m_2,ijk} - C_{DW,m_1,ijk}\right)/T_{DW} \quad \text{(M.19)}^{20}$$

where:

$\Delta C_{DWijk,t}$	average annual change in the carbon stock of deadwood for stratum i sub-stratum j species k in t C yr^{-1} for year t; t C
$C_{DW,m_2,ijk}$	carbon stock of deadwood for stratum i sub-stratum j species k at monitoring event m_2; t C
$C_{DW,m_1,ijk}$	carbon stock of deadwood for stratum i sub-stratum j species k at monitoring event m_1; t C

[19] This differs from the published equation in the methodology because there is an error in the equation as printed. By including the area term in equation (M.17), the area is effectively squared, which overestimates the value significantly. The original equation is shown below.

$$MC_{BB,m,ijk} = A_{m,ijk}\left[MC_{AB_{Tree},m,ijk} \cdot R_{T,jk} + MC_{AB_{NTree_{Shrub}},m,ijk} \cdot R_S\right] \quad \text{(M.17)}$$

[20] This equation differs from the equation as published in AR-AM0002 (V3) because there is a typographical error in the published equation substituting T_W for T_{DW}. The original equation is shown below:

$$\Delta C_{DW,ijk,t} = \left(C_{DW,m_2,ijk} - C_{DW,m_1,ijk}\right)/T_W \quad \text{(M.19)}$$

T_{DW} time between monitoring events m_1 and m_2 of the deadwood monitoring; yr

The method to be followed for calculating the standing deadwood and the lying deadwood biomass are outlined below.

$$C_{DW,m,ijk} = [B_{SDW,m,ijk} + B_{LDW,m,ijk}] \cdot CF_{DW} \quad \text{(M.20)}$$

where:

$C_{DW,m,ijk}$ carbon stock of deadwood biomass in stratum i sub-stratum j species k at monitoring event m; t C

$B_{SDW,m,ijk}$ biomass of standing deadwood in stratum i sub-stratum j species k at monitoring event m; t dm

$B_{LDW,m,ijk}$ biomass of lying deadwood in stratum i sub-stratum j species k at monitoring event m; t dm

CF_{DW} carbon fraction of deadwood; dimensionless

Standing deadwood is measured using the same criteria and monitoring frequency as is used for measuring live trees. Decomposition class of a dead tree is categorised according to the following four decomposition classes:

- tree with branches and twigs that resembles a live tree (except for leaves);
- tree with no twigs but with persistent small and large branches;
- tree with large branches only; and
- bole only, no branches.

Biomass is estimated for standing deadwood in class 1, and is limited to the trunk for classes 2 to 4.

Lying deadwood is likely to be low in the early stages of the project, and consequently will only be assessed from the second monitoring period after planting. Lying deadwood is sampled by means of the line intersect method (Harmon & Sexton, 1996), as specified in the chosen CDM methodology. Two 50 m lines that bisect each sample plot are established, and the diameters of all the deadwood (≥ 5 cm) are measured (see Figure 8). Each branch is assigned to one of three density states (sound, intermediate, and rotten) for purposes of biomass calculation. The volume of lying deadwood is calculated using equation M.21 below:

$$V_{LDW,m,ijk} = 9.869 \cdot \left(\frac{{D_{ijk}}^2}{8}\right) \cdot L \quad \text{(M.21)}$$

where:

$V_{LDW,m,ijk}$ volume of lying deadwood in stratum i sub-stratum j species k; $m^3\ m^{-2}$

${D_{ijk}}^2$ squared diameter of pieces of deadwood in stratum i sub-stratum j species k; m^2

L length of the transect; m

The biomass of lying deadwood is calculated using equation M.22.

$$B_{LDW,m,ijk} = A_{ijk} \cdot \sum_{dc=1}^{dc=3} V_{LDW,m,ijk} \cdot D_{DW,dc} \cdot 10 \quad \text{(M.22)}$$

where:

$B_{LDW,m,ijk}$ biomass of lying deadwood in stratum i sub-stratum j species k at monitoring event m; t dm

$D_{DW,dc}$ basic density of deadwood in the density class – sound (1), intermediate (2) and rotten (3); kg dm m^{-3}

A_{ijk} area of stratum i sub-stratum j species k; ha

f) Litter

Litter sampling will be carried out every five years. Litter is a vital component of the proliferation of *P. afra*, which is able to propagate from cuttings and damaged branches. As a result, sampling within the sample plots could reduce the rate of thicket growth, and will be avoided. Litter sampling therefore takes place in 1 m x 1 m squares situated around the periphery of the sample plot. Litter is sampled using a 30 cm radius circular frame, placed at the four corners of the designated peripheral plot. All litter falling inside the frame is collected and weighed. It is then oven dried and weighed again in order to calculate the moisture proportion and the dry biomass. Subsequent monitoring will use the next-but-one 1 m x 1 m box (see Figure 8 for details).

$$C_{L,m,ijk} = A_{ijk} \cdot C_{L\_wet,m,ijk} \cdot (1 - MP_L) \cdot (1/a_{ijk}) \cdot (1/100) \quad \text{(M.23)}$$

where:

$C_{L,m,ijk}$ carbon in dry litter biomass at monitor time m; t C

$C_{L\_wet,m,ijk}$ carbon in wet litter biomass at monitor time m; g m^{-2}

MP_L weight fraction of moisture of litter biomass (0 to 1) [(wet weight – dry weight)/wet weight]; dimensionless

$C_{L\_wet,m,ijk}$ area of sampling frame; m^{-2}

The average annual change in the carbon stock of litter from the data at two monitoring intervals will be calculated. As recommended in the Good Practice Guidance on LULUCF (Chapter 3.2, p 3.35), the dry mass of litter is converted into carbon using 0.370 as the default value instead of the default carbon fraction (0.5) used for biomass.

$$\Delta C_{L,m,ijk,t} = [(C_{L,m_2,ijk} - C_{L,m_1,ijk})/T_L] \cdot CF_L \quad \text{(M.24)}$$

where:

$\Delta C_{L,m,ijk,t}$ average annual change in the carbon stock of litter for stratum i sub-stratum j species k at monitoring event m; t Cyr^{-1}

$C_{L,m_2,ijk}$ carbon stock of litter in stratum i sub-stratum j species k in at monitoring event m_2; t C

$C_{L,m_1,ijk}$ carbon stock of litter for stratum i sub-stratum j species k in at monitoring event m_1; t C

T_L monitoring interval for litter $T_L = m_2 - m_1$; yr

CF_L carbon fraction of litter; dimensionless

g) Soil carbon

Soil carbon will be measured every ten years. Four cores from separate locations within each plot will be extracted using a soil corer or spades/chisels if the ground is too rocky for a corer. Cores will be taken to a depth of 40 cm, with two 20 cm horizons. For each monitoring site, soil carbon will be determined through laboratory analysis. Soil carbon inflows will be estimated as the difference between the carbon stock estimates of two consecutive monitoring events.

$$\Delta C_{SOC,ijk,t} = [(C_{SOC,m_2,ijk,t} - C_{SOC,m_1,ijk})/T_S] \quad \text{(M.25)}$$

where:

$\Delta C_{SOC,ijk,t}$	annual average change in the carbon stock of the soil organic carbon pool in stratum i sub-stratum j species k for year t; t Cyr $^{-1}$
$C_{SOC,m_2,ijk,t}$	carbon stock in the soil organic pool in stratum i sub-stratum j species k in at monitoring event m_2; t C
$C_{SOC,m_1,ijk}$	carbon stock in the soil organic pool for stratum i sub-stratum j species k in at monitoring event m_1; t C
T_S	monitoring interval for soil carbon $T_S = m_2 - m_1$; yr

Additionally, bulk density will be determined using an additional core taken within the sample plot. The mass of carbon per unit volume is calculated by multiplying the carbon concentration (percent mass) and bulk density (g/cm3). The bulk density equals the oven dry weight of the soil core divided by the core volume after discounting the volume of coarse fraction of >2 mm. Initial measurements of bulk density have already been done for several sites in the Baviaanskloof Nature Reserve (see Annex 9).

$$C_{SOC,m,ijk,p} = C_{SOC\_Sample,m,ijk,p} \cdot BD_{ijk,p} \cdot Depth_{ijk,p} \cdot FC_{ijk,p} \cdot M \quad \text{(M.26)}$$

where:

$C_{SOC,m,ijk,p}$	soil organic carbon of plot in stratum i sub-stratum j species k in at monitoring event m in t C ha^{-1}
$C_{SOC\_Sample,m,ijk,p}$	soil organic carbon of the sample in plot p in stratum i sub-stratum j species k determined in laboratory in g C
$BD_{ijk,p}$	bulk density (soil mass/volume of sample) plot p in stratum i sub-stratum j species k determined in laboratory at monitoring event m; t.m^{-3}
$Depth_{ijk,p}$	soil depth at which sample is collected in stratum i sub-stratum j species k; cm
$FC_{ijk,p}$	1- (% volume of coarse fragments/100) to adjust the fraction of sample occupied by coarse fragments > 2 mm plot p in stratum i sub-stratum j species k at monitoring event m
M	multiplier to convert units into t C ha^{-1}

The mean soil organic carbon accumulation will be calculated by pooling the estimates of samples at the monitoring interval.

$$MC_{SOC,m,ijk} = \frac{\sum_{p=1}^{P_{ijk}} C_{SOC,m,ijk,p}}{P_{ijk}} \quad \text{(M.27)}$$

where:

$MC_{SOC,m,ijk}$	mean carbon stock in the soil organic pool in stratum i sub-stratum j species k at monitoring event m; t C ha^{-1}
$C_{SOC,m,ijk,t}$	soil organic carbon of plot p in stratum i sub-stratum j species k at monitoring event m; t C ha^{-1}
p	plot number in stratum i, sub-stratum j species k
P_{ijk}	number of plots in stratum i, sub-stratum j species k

In order to be conservative, the change in SOC is estimated using the Reliable Minimum Estimate (RME) (Dawkins, 1957), as outlined in AR-AM0002 (V3). Under the RME approach, the monitoring results of the plots are pooled to assess the mean at monitoring interval m_1 and m_2. The change in SOC is calculated by subtracting the maximum estimate of the mean at monitoring time m_1 from the minimum mean estimate at monitoring event m_2. The resulting difference represents the minimum change in the mean SOC with 90% confidence between the monitoring interval m_2 and m_1.

$$C_{SOC,m_2,ijk,t} = [MC_{SOC,m_2,ijk} - 90\% ConfidenceInterval] \cdot A_{ijk} \quad \text{(M.28)}$$

$$C_{SOC,m_1,ijk,t} = [MC_{SOC,m_1,ijk} + 90\% ConfidenceInterval] \cdot A_{ijk} \quad \text{(M.29)}$$

where:

$C_{SOC,m_2,ijk}$	soil organic carbon in stratum i sub-stratum j species k at monitoring event m_2; t C ha^{-1}
$C_{SOC,m_1,ijk}$	soil organic carbon in stratum i sub-stratum j species k at monitoring event m_1; t C ha^{-1}

h) Baseline

No baseline monitoring is required under the selected methodology, since in terms of the eligibility criteria the sites are degraded (and consequently are either deteriorating, or have stable carbon stocks).

i) Number of sample plots

The minimum number of sample plots was determined using the UNFCCC ARR tool "*Calculation of the number of sample plots for measurements within A/R CDM project activities (Version 02)*" (UNFCCC, 2009), using Method I (samples drawn without replacement). The cost for establishing plots was assumed to be the same for all strata, as each of the areas has similar variability in landscape structure. The formulae and calculations are shown below:

$$N = \frac{A}{AP};\ N_i = \frac{A_i}{AP} \quad (1)$$

where:

A	Total size of all strata (A), e.g., the total project area; ha
A_i	Size of each stratum *i*; ha
AP	Sample plot size (constant for all strata); ha
N	Maximum possible number of sample plots in the project area
N_i	Maximum possible number of sample plots in stratum *i*

$$E_1 = Q_1 \cdot p \quad (2)$$

where:

E_1	Allowable error of the estimated quantity Q
Q	Quantity being estimated (usually the forest carbon stocks); t C ha^{-1}
Q_1	Approximate value of the estimated quantity on a per plot basis; t C ha^{-1}
p	The target precision for the estimated quantity 10%) expressed as a fraction

$$n = \frac{\left[\sum_{i=1}^{L} N_i \cdot st_i\right]^2}{\left(N \cdot \frac{E_1}{z\alpha_{/2}}\right)^2 \cdot \sum_{i=1}^{L} N_i \cdot (st_i)^2} \quad (5)$$

$$n_i = \frac{\sum_{i=1}^{L} N_i \cdot st_i}{\left(N \cdot \frac{E_1}{z\alpha_{/2}}\right)^2 \cdot \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot N_i \cdot st_i \quad (6)$$

where:

i	Index for stratum; dimensionless
L	Total number of strata; dimensionless
st_i	Standard deviation of *Q* for each stratum *i*; dimension the same as *Q*
n	Sample size (total number of sample plots required) in the project area
n_i	Sample size for stratum *i*
α	1-α is probability that the estimate of the mean is within the error bound *E*
$z\alpha_{/2}$	Value of the statistic *z* (embedded in Excel as: inverse of standard normal probability cumulative distribution), for e.g., 1-α = 0.05 (implying a 95% confidence level) $z_{\alpha/2}$=1.9599

Table 5: Calculation of number of sample plots (n_i) required per project area.

Project area	i	Ai (ha)	Q (tC/ha)	st_i (tC/ha)	AP (ha)	Ni (ha)	n_i
Baviaanskloof Nature Reserve	1	7 000	98	59	0.01	700 000	16
Addo Elephant National Park	2	1 968	105	12	0.01	196 800	1
Great Fish River Nature Reserve	3	15 086	209	74	0.01	1 508 600	43
		A (ha)	Q (tC/ha)			N=A/AP (ha)	n
Total project area		24 054	137			2 405 400	60

These number of sample plots is assumed to be a minimum, using the available data. Initial sample plot assignment will follow these numbers with additional areas in the Addo Elephant National Park. As recommended in the specified tool, additional plots will be assigned to ensure that potential losses of plots through stochastic events such as fire or flooding damage will not severely impact the monitoring regime. In addition, this tool will be re-applied after the first monitoring event to ensure that the number of plots is sufficient to provide a standard error of less than 10% of the mean for each stratum.

j) Allocation of plots and plot location

Sample plot allocation to the planting sites will be done by selecting a random start and assigning plots to planting sites until the specified number of plots have been allocated. A grid with cells corresponding to the specified plot size (10 m x 10 m for above ground carbon stock estimation) will be superimposed over each nominated planting site, and the location of a plot within the site will be randomly assigned to one of these cells.

Since planting sites are geographically dispersed throughout the strata, no more than one plot will be assigned to a single planting site. This will reduce the likelihood of spatial autocorrelation between monitoring outputs.

In order to minimise the potential for selective management practices, permanent markers for the sampling sites will be as unobtrusive as possible (metal pegs marking the southwestern corner of the plot). Each plot will also be given a unique ID and the GPS coordinates of the site will be recorded, allowing the site to be accurately revisited.

3.2.6 Monitoring of GHG emissions by sources

According to AR-AM0002 (V3), the potential sources of project emissions are emissions from fossil fuel usage whilst carrying out ARR activities, loss of non-tree biomass (not including the herbaceous component) during the site preparation, and biomass burning due to natural fires or from management-related activities. The area subjected to biomass burning will be measured and recorded, and 10

$$GHG_{E,t} = E_{BiomassLoss,t} + E_{BiomassBurn,t} \quad \text{(M.30)}$$

where:

GHG_E	Sum of increases in GHG emissions by sources within the project boundary from the implementation of the proposed ARR project activity; t CO_2e
$E_{BiomassLoss}$	Increase in GHG emissions from the loss of biomass within the project boundary in year *t*; t CO_2e
$E_{BiomassBurn,i}$	Increase in GHG emissions from biomass burning within the project boundary in year *t*; t CO_2e

Carbon loss through clearance
The loss of carbon stock in the biomass of non-tree vegetation is calculated as follows:

$$E_{BiomassLoss,i} = \sum_i A_{NT\_BiomassLoss,i} \cdot B_{AB\_NTree,i} \cdot CF_{NTree} \cdot \frac{44}{12} \quad \forall\, t = 1$$
$$E_{BiomassLoss,i} = 0 \quad \forall\, t > 1 \quad \text{(M.31)}$$

where:

$E_{BiomassLoss,i}$	Increase in GHG emissions from the loss of biomass in the site preparation within the project boundary in year *t*; t CO_2e
$A_{NT\_BiomassLoss,i}$	area of biomass loss in stratum *i*; ha
$B_{AB\_Ntree,i}$	average biomass stock of non-tree vegetation on land to be planted before the start of a proposed ARR project activity for stratum *i*; t dm ha^{-1}
CF_{NTree} dimensionless	carbon fraction of dry biomass in non-tree vegetation in t C $(t\ dm)^{-1}$;
$44/12$	ratio of molecular weights of CO_2 and carbon; dimensionless
t	time; yr

However, under the definition of leakage, the methodology specifies that emissions from project transport are considered insignificant and are consequently not included. Furthermore, the project design calls for no removal of non-herbaceous vegetation during the preparation of land (since *P. afra* cuttings are placed in vertical holes and the land is degraded, there is no damage to extant

vegetation within the sites). The only potential source of GHG emissions in the project areas is therefore through the action of fires, detailed below.

Fires
All fires in the project areas are monitored as a matter of course by the conservation agencies. Where fires occur in the planting sites, monitoring will be conducted by project proponents within three months to assess the impact of the burn on the *P. afra* plantings. Previous experience has shown that the effects of burns on *P. afra* plantations is minimal, since they are highly fire-resistant as a result of their succulent nature.

Survivorship: This will be assessed by means of a 2 m wide transect through the burn area (50m long or the length of the burn if it is shorter). The survival status of each *P. afra* plant intersected by the transect will be recorded, in order to obtain a percentage survival rate.

Area of burn: If the burn area does not cover the entire project area, the full extent of the burn will be measured by walking the perimeter of the area with a GPS, converting the track to a polygon in a GIS programme, and calculating the relevant area.

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{Non-CO_2BiomassBurn} \quad \text{(inserted I.1)}^{21}$$

$$E_{BiomassBurn,CO_2} = \sum_i A_{BiomassBurn,i} \cdot B_{AB\_Ntree,i} \cdot CE \cdot CF_{NTree} \cdot 44/12 \quad \text{(M.32)}$$

where:

$E_{BiomassBurn,CO_2}$	Increase in CO_2 emissions as a result of biomass burning; t CO_2e yr^{-}
$E_{Non-CO_2BiomassBurn}$	Increase in non-CO_2 emissions as a result of biomass burning; t CO_2e yr^{-}
$A_{BiomassBurn,i}$	Area of biomass burn in stratum i in ha yr^{-1}
$B_{AB\_NTree,i}$	Average stock in above ground biomass for stratum i prior to burn in t dm ha^{-1}
CE	Combustion efficiency; dimensionless (IPCC default = 0.5)
CF_{NTree}	Carbon fraction of dry biomass; dimensionless

AR-AM0002 (V3) states that *"Emissions from fires under this methodology include CO2 and as well as CH4 and N_2O."* However, the methodology then specifies only the methane emissions from biomass burn, which is calculated as follows

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot GWP_{CH_4} \cdot EF_{CH_4} \cdot 12/44 \cdot 16/12 \quad \text{(M.33)}$$

where:

$E_{BiomassBurn,CH_4}$	CH_4 emission from biomass burning; t CO_2e yr^{-1}
$E_{BiomassBurn,CO_2}$	Increase in CO_2 emissions as a result of biomass burning; t CO_2e yr^{-}
GWP_{CH_4}	global warming potential for CH_4 (IPCC default = 21)
EF_{CH_4}	emission factor for CH_4, t CH_4 (t C)$^{-1}$ (IPCC default emission ratio of CH_4 = 0.012)
$12/44$	ratio of molecular weights of CO_2 and carbon; dimensionless
$16/12$	ratio of molecular weights of CH_4 and carbon; dimensionless

Furthermore, the methodology then directly contradicts the earlier statement, by showing that the non-CO_2 component of biomass burn comprises the methane component exclusively:

[21] This equation is implied in AR-AM0002 (V3), but is not specifically included.

$$E_{Non-CO_2,BiomassBurn} = E_{BiomassBurn,CH_4} \quad \text{(M.34)}$$

This contradiction is problematic, and so we propose to interpret the error conservatively, and include N_2O emissions as well:

$$E_{Non-CO_2,BiomassBurn} = E_{BiomassBurn,CH_4} + E_{BiomassBurn,N_2O} \quad \text{(M.34 revised)}$$

The N_2O component is calculated as follows:

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot GWP_{N_2O} \cdot EF_{N_2O} \quad \text{(Inserted I.2)}$$

where:

$E_{BiomassBurn,N_2O}$ N_2O emission from biomass burning; t CO_2e yr^{-1}

$E_{BiomassBurn,CO_2}$ Increase in CO_2 emissions as a result of biomass burning; t CO_2e yr^{-}

GWP_{N_2O} global warming potential for CH_4 (IPCC default = 310)

EF_{N_2O} emission factor for N_2O, t N_2O (t C)$^{-1}$ (IPCC default emission ratio of N_2O = 0.007)

NB: The molecular weights of CO_2 and N_2O are roughly equivalent, removing the necessity for a molecular weight calculation in Equation I.2)

3.2.7 Actual net GHG removals by sinks

The actual net greenhouse removals by sinks at each verification period will be calculated by subtracting the increase in GHG emissions within the project area from the verifiable changes in the carbon stocks of all carbon pools in the project boundary. It is measured in t CO_2e removed by sources as a result of the project implementation.

$$\Delta C_{ACTUAL} = \sum_{i=j} \sum_{j=1} \sum_{k=1} [\Delta C_{ijk} - GHG_E] \quad \text{(M.35)}$$

where:

ΔC_{ACTUAL} Actual net greenhouse gas removals by sinks; t CO_2e yr^{-1}

ΔC_{ijk} verifiable annual changes in the carbon stock of pools for stratum i sub-stratum j species k; t CO_2e yr^{-1}

GHG_E GHG emissions by sources within the project boundary as a result of implementation of the proposed ARR project activity; t CO_2e

3.2.8 Quality control (QC) and quality assurance (QA) procedures to be applied to the monitoring process

To ensure that the net anthropogenic GHG removals by sinks are measured precisely, credibly, verifiably and transparently, a quality assurance and quality control (QA/QC) procedure shall be implemented, including:

- Collection of reliable field measurements.
- Verification of methods used to collect field data.
- Verification of data entry and analysis techniques.
- Data maintenance and archiving.

If after implementing the QA/QC plan it is found that the targeted precision level is not met, then additional sample sites will be randomly assigned, and supplementary field measurements will be conducted until the targeted precision level is achieved.

a) Reliable field measurements

The methodology emphasises the importance of collecting reliable field measurement data as an important step in the quality assurance plan. Staff involved in the field measurement work willbe

fully trained in the field data collection and data analysis. Standard Operating Procedures (SOPs) for each step of the field measurements will be developed and adhered to at all times. These SOPs will detail all the phases of the field measurements and contain provisions for documentation for verification purposes, so that measurements are comparable over time and can be checked and repeated in a consistent fashion. To ensure the collection of reliable field data:

- Field-team staff will be fully aware of all procedures and the importance of collecting field measurement data as accurately as possible.
- Field teams will install test plots if needed in the field and measure all pertinent components using the SOPs.
- Field measurements will be checked by a qualified person to correct any errors in techniques.
- A document that details that these steps have been followed will be presented as a part of the project documents. The dated document will list all names of the field team, together with their signatures and the project leader will certify that the team is trained.
- Any new staff will be adequately trained.

b) Verification of field data collection

To verify that plots have been installed and the measurements taken correctly, 10% of plots will be randomly selected and re-measured independently. Key re-measurement elements include the location of plots, CBSA, deadwood, litter and soil carbon. The re-measured data shall be compared with the original measurement data. Any deviation between measurement and re-measurement below 5% will be considered tolerable and above 5% will be considered an error. Any errors found shall be corrected and recorded. Any errors discovered should be expressed as a percentage of all plots that have been re-checked to provide an estimate of the measurement error.

c) Verification of data entry and analysis

Reliable estimation of carbon stocks in each pool requires correct entry of data into the data analysis spreadsheets. To minimize the possible errors in this process, the entry of both field data and laboratory data will be reviewed using expert judgment and, where necessary, comparison will be taken with independent data to ensure that the data are realistic. Communication between all personnel involved in measuring and analyzing data should be used to resolve any apparent anomalies before the final analysis of the monitoring data is completed. If there are any problems with the monitoring plot data that cannot be resolved, the plot should not be used in the analysis.

d) Data maintenance and archiving

Because of the long-term nature of the ARR project activities, data will be archived and maintained safely. It will be kept for at least two years after the end of the crediting period. Data archiving shall take both electronic and hard copy forms, and copies of all data will be provided to each project participant. All electronic data and reports will also be copied on durable media such as DVDs. Copies of the DVDs will be stored in multiple locations. The archives shall include:

- copies of all original field measurement data, laboratory data, data analysis spreadsheets;
- estimates of the carbon stock changes in all pools and non-CO_2 GHG and corresponding calculation spreadsheets;
- GIS products, including geodatabases, shapefiles and linked contract information; and
- copies of the measuring and monitoring reports.

3.3 Data and parameters monitored / Selecting relevant GHG sources, sinks and reservoirs for monitoring or estimating GHG emissions and removals:

The chosen CDM methodology (AR-AM0002 (V3)) specifies that no monitoring of the baseline is required. Furthermore, within the scale of such projects, the emissions from project activities are negligible, and the methodology specifies that they can be discounted. No monitoring of the shrub component of vegetation cover is undertaken, as it is assumed to stay constant. It has been demonstrated to increase in areas under spekboom restoration (van der Vuyfer, in press), and therefore the assumption is demonstrably conservative. The data and parameters to be collected within the monitoring programme for *ex ante* estimation are detailed in Table 6, below:

Table 6: Data and variables to be monitored during project implementation.

ID number	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.03	Precision level	Sample frame	%	e	Prior to the project	1	10% precision level adopted for the purpose of QA/QC.
2.1.1.04	Standard deviation of each stratum	Sample frame	Number	e	Prior to the project; 5 years	1	To estimate the number of sample plots in each stratum & sub-stratum. Re-calculated after the first monitoring period to ensure sufficient plots have been assigned.
2.1.1.06	Plot location	Project and plot maps	Alphanumeric	m	5 years	1	Plot location is noted using permanent markers or GPS.
2.1.1.08	Age of plantation	Plot data	Year	m	5 years	100% sample plots	From the record on the year of project planting.
2.1.1.09	No. of trees	Plot measurement	Number	m	5 years	Trees in plots	Trees are counted in the plots of each stratum.
2.1.1.10	Combined Basal Stem Area (CBSA)	Plot measurement	cm	m	5 years	Trees in sample plots	Measurement of DBH at each monitoring event.

2.1.1.11	Mean CBSA	Calculated	cm	c	5 years	Trees in sample plots	Calculated using the data in 2.1.1.10.
2.1.1.18	Carbon stock of above ground tree biomass	Calculated	t C	c	5 years	100% sample plots	Calculated based on 2.1.1.11 using allometric Equation AL.1.
2.1.1.29	Mean carbon stock of above ground tree biomass	Calculated	t C	c	5 years	100% sample plots	Calculated by averaging individual tree carbon stock estimates for each plot.
2.1.1.31	Carbon stock of below ground tree biomass	GPG LULUCF	t C	c	5 years	100% sample plots	Calculated using root shoot ratio (2.1.1.30) and above ground tree biomass (2.1.1.18).
2.1.1.34	Change in the carbon stock of below ground biomass	Calculated	t C	c	5 years	100% sample plots	Calculated based on equation M.19.
2.1.1.35	Standing deadwood	Plot measurements	t C	m	5 years	100% Sample plots	It is measured in the same way as live tree measurements.
2.1.1.36	Lying deadwood	Plot measurements	t C	e	5 years	100% sample plots	It is measured using line-intersect method and estimated with equations M.22 & M.23.
2.1.1.37	Total deadwood	Plot measurements	t C	c	5 years	100% sample plots	Calculated based on 2.1.1.35 and 2.1.1.36 with equation M 19.
2.1.1.39	Soil organic carbon samples in the substratum /stratum	Plot measurements	g.C /100 g soil	m	15 – 20 years	100% sample plots taken	Stratified sampling is used to estimate the soil organic carbon using laboratory methods.

						from plots per stratum	
2.1.1.40	Bulk density	Plot measurements	100 g soil/cm-1	m	15 – 20 years	100% sample plots	Measured in the stratum /sub-stratum.
2.1.1.41	Soil depth	Plot measurement		m	15-20 years	100% sample plots	Measured in the stratum /sub-stratum.
2.1.1.42	Area of stratum & sub-stratum	Stratification map and data	ha	m	5 years	100% of strata and substrata	Actual area of each stratum and sub-stratum.
2.1.1.43	Change in the stock of soil organic carbon in the stratum / substratum	Calculated	t C	c	15-20 years	100% sample plots	Calculated based on the monitoring data of two soil monitoring events using equation M.26.
3.3.1.21	Soil organic carbon with 95% in the mean per ha	Calculated	t C	c	15-20 years	100% sample plots	Calculated based on the area of sub-stratum and stratum using equation M.29 and M.30.
2.1.1.47	Sum of changes in carbon stocks CO_2e	Calculated from plot data	t CO_2e	c	5 years	100% Project data	Calculated using the equation M.5.
2.1.1.38	Carbon in the litter biomass	Plot measurements	t C	m	5 years	100% sample plots	Litter sampling technique is used and dry weight is taken and samples and M.24 & M.25.

2.1.1.44	Soil organic carbon in the sub-stratum /stratum/species	Calculated	t C	c	15-20 years	100% sample plots	Calculated based on the area of substratum/ stratum /species and soil organic carbon estimated from sampling using equation M.27.
2.1.1.45	Mean soil organic carbon per ha	Calculated	t C ha^{-1}	c	15-20 years	100% sample plots	Calculated based on the plot level soil carbon data using equation M.28.

Table 7: Data and parameters estimated once

ID number	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data monitored	Comment	Default value
2.1.1.06	Plot ID	Plot maps	Alphanumeric	c	Prior to the project	1	Identified and mapped for each stratum and sub-stratum.	-
2.1.1.16	Wood density	Local data, GPG for LULUCF	kg/m^3	e	Prior to sampling	100% sample plots	Locally estimated or compiled from local studies, literature, and GPG/LULUCF.	-
2.1.1.18	Carbon fraction of above ground tree biomass	IPCC GPG for LULUCF	t C / t $dmha^{-1}$	e	Prior to the Project monitoring	100% tree species	The tree biomass is multiplied with the default.	IPCCC default: 0.5
2.1.1.30	Root-shoot ratio for tree biomass	Local / National GPG LULUCF	dimensionless	e	Prior to the project	100% sample plots	Value calculated from local research (see Annex 7).	0.253

3.4 Description of the Monitoring Plan

3.4.1 Monitoring of the project initiation

The proposed ARR project consists of a large number of discrete areas of land distributed across the Subtropical Thicket Biome of the Eastern Cape. The areas were identified through field surveys and remote sensing to confirm the state of degradation in relevant thicket vegetation types. Boundary coordinates for each project area were determined during the initial desktop boundary survey and scoping activities. Not all identified areas have been finalised, and consequently additional areas will be included during future operations through the provisions of VCS's grouping policy. Natural features are used as a reference, but the primary identification features are the GPS coordinates recorded for the corners of polygon sites.
Project initiation includes the following activities:

- Field surveys and remote sensing are used to determine the exact boundary of each planting site within the project area. In cases where additional sites are to be included under the provisions for project grouping under the VCS guidelines[22], additional information will be provided and projections will be adjusted *ex post*.
- The geographical coordinates (latitude and longitude) of each corner of site polygons are determined by GPS, collected, and exported to GIS software (ArcView). Maps of the actual planting site boundaries are prepared, and examination of remotely sensed data (historical and current) is undertaken to ensure planting site eligibility within the conditions outlined by the selected methodology. Contract site size is 7 ha for manual planting or 26 ha for mechanical planting.
- Manual planting is undertaken where the ground is too rocky or the gradient too steep to allow for the use of the mechanical auger. Manual planting sites are smaller because progress is slower in order to allow contract completion within an equivalent time period to mechanical planting.
- Planting contract details are attached to the spatial imagery in a geodatabase, maintained by CSS. Consequently planting data, survivorship and other additional relevant information can be obtained readily for a chosen site.
- Site preparation is implemented according to the practice documented in Section 1.8, i.e.:
    - no tillage;
    - minimum-impact plantings using a mechanical auger or manual labour to prepare holes into which the *P. afra* cuttings are planted; and
    - regular spacing of holes.
- Preparation of the cuttings in a standardised manner to maximise survivorship. This includes ensuring that no more than 30% of source plants are harvested, and storing cuttings in the shade for two days.

The project area boundary will be the boundaries of the Baviaanskloof Nature Reserve, the specified area of the northern Addo Elephant National Park and the GFRNR. Any changes to the boundaries as a result of expansion of the parks will be obtained from the Park Management Plans. Land use and economic activities that occur outside the project boundary have no influence on the project over the crediting period. The risk of fire is very low as *P. afra* is a naturally fire-resistant species due to its succulent (water-bearing) and dense foliage (Kerley et al., 1995; Vlok et al., 2003). Any fires within the project boundaries will be monitored as part of Section 3.4.3)

Personnel involved in the monitoring shall be trained in the early stage of the project so that they are equipped to implement the steps and procedures of the monitoring process.

[22] Available from: http://www.v-c-s.org/faq.html#question34

Procedures used in monitoring of the project activities are subject to quality assurance/quality control measures; as outlined in Section 3.2.8

3.4.2 Monitoring of the area reforested

Contracts are awarded for planting of specified planting sites within the project area boundaries. The area to be planted will be calculated from maps and confirmed via GPS on the ground. After completion of the contract, the contract map and measured map will be compared. The contract is only paid once the area has been checked by GIB and signed off as completed. (See Section 3.2: Monitoring Roles and Responsibilities for more detail.)

Table 8: Variables measured in each stratum for purposes of monitoring the area reforested.

ID Number	Data Variable	Data Unit	Measured (m), calculated (c), estimated (e) default (d)	Recording frequency	Number of data points / Other measure of number of collected data.	Comment
	Area planted	ha	c (maps) and m (GPS on ground)	After each contract is completed.	100%	Number of contracts multiplied by area.
	Spacing	m	m	Once		Recommended spacing for all strata.
	Deviation from recommended spacing	%	c	After each contract is completed.	Single percentage reflecting deviation from recommended spacing.	Deviations from recommended spacing may occur as a result of site topography or other local features.
	Supplemental planting	ha	c	After each supplemental planting contract is completed.	100%	Will be done in separate contracts. Area and location shown on maps
	Area burnt by fire	ha	e	Annual		From Park Management report. Area mapped in GIS. Causes, season, and duration of fire if available.
	Strata characteristic	mm/yr	m	Annual		From Park Management

	(rainfall)	report. Mapped in GIS. Details on area affected by drought or flood if applicable.

3.4.3 Monitoring of the forest establishment

In order to ensure adherence to the silvicultural practices outlined in Section 1.9 and the methodology guidelines, the following monitoring practices will be undertaken for the first three years after planting:

- Information on planting dates, drainage, frost and other climatic extremes will be recorded.
- Site preparation: the method used to plant the cuttings does not entail removal of vegetation from the site thus there are no emissions from loss of biomass activities. Consequently there will be no monitoring of site preparation.
- Survivorship monitoring by means of a 200 m x 5 m transect through each planting site: survivorship estimates will be taken within three years of planting. Survivorship data will be assessed using the equation below and supplemental planting will be undertaken based on *ex ante* targets (survivorship of at least 50% is suggested) and any carbon credits which have been forward sold to ensure that these obligations are met.

$$Su = \frac{Su_t}{A_t \cdot Dv \cdot Sp_R}$$

where

Su	Survivorship (%)
Su_t	Survivor count in transect
A_t	Transect area (ha)
Dv	Recorded deviation of site from recommended planting density (%)
Sp_R	Recommended planting density (stems ha^{-1})

Table 9: Variables measured for each stratum for purposes of monitoring the forest establishment.

ID Number	Data Variable	Data Unit	Measured (m), calculated (c), estimated (e) default (d)	Recording frequency	Number of data points / Other measure of number of collected data.	Comment
	Total planting days	day	c	Year 1 – 3		Number of contracts multiplied by 20 days per contract.
	Drainage, frost and other climatic extremes	varies		Year 1 – 3		Taken from Park Management report.

	Survival rate	%	c	Year 3	Survivorship monitoring by means of a transect through each planting site.
	Area of supplemental planting	ha	m	Year 1 - 3	

3.4.4 Monitoring of forest management activities

The selected methodology requires monitoring of all forest management procedures conducted from initiation to the end of the project implementation period. However, the selected technologies require minimal forest management after the initiation period (no harvesting, thinning or fertiliser is required).

Once *P. afra* is established there is a low risk of fire and so no fire breaks are created in the contract sites. Domestic livestock are not permitted within the project areas and thus there will be no fencing of the planting sites. Once project areas are restored, game will return to the area. SANParks and ECPB are contractually bound to employ appropriate stocking rates, which will ensure that the impact of herbivory by indigenous species is not significant. Low levels of herbivory have been shown to promote the rate of recruitment of *P. afra*, and may stimulate overall thicket growth (Aucamp et al., 1980).

The following procedures will be implemented from the fourth year after planting:

- Natural and anthropogenic disturbance (including fire and other catastrophic events) will be recorded by date, location, volume of biomass (and area) lost, and
- Supplemental planting activities recorded.

Table 10: Variables measured for purposes of monitoring the forest management activities.

ID Number	Data Variable	Data Unit	Measured (m), calculated (c), estimated (e) default (d)	Recording frequency	Number of data points / Other measure of number of collected data.	Comment
	Natural / Anthropogenic disturbance (area).	ha	c	From 4th year of planting: Following disturbance at planting site.	100%	From Park Management report. Area mapped in GIS.
	Natural / anthropogenic disturbance	tC	c	From 4th year of planting:	100%	Date, location, volume of biomass lost.

	(tons of carbon in the 5 pools).			Following disturbance at planting site.		
	Area of supplemental planting.	ha	m	From 4th year of planting: Following disturbance at planting site.	100%	Based on *ex ante* commitments.

3.4.5 Monitoring frequency

Monitoring of the area reforested and of forest establishment will be conducted as indicated in Table 8, Table 9 and Table 10 until the end of the third year, to verify that establishment is successful. Survivorship monitoring will be conducted after three years. Carbon sequestration estimation on above ground biomass will be conducted every five years to prepare for the verification process. Soil carbon monitoring will be conducted at the project start and every ten years thereafter.

After the first monitoring period, a power analysis will be conducted using the UNFCCC ARR Methodological Tool "*Calculation of the number of sample plots for measurements within A/R CDM project activities (Version 02)"* (UNFCCC, 2009). This will ensure that there are a suitable number of monitoring sites to guarantee that measured values vary no more than 10% of the mean at a 95% confidence level.

4 GHG Emission Reductions:

4.1 Explanation of methodological choice:

The proposed ARR project uses the approved afforestation and reforestation baseline methodology AR-AM0002 (V3): "Restoration of degraded lands through afforestation/reforestation".

In order to assess land eligibility for the ARR project methodology, the project utilizes the "Procedures to demonstrate the eligibility of lands for afforestation and reforestation project activities"(UNFCCC, 2007). See Section 1.16 for details.

Methodology AR-AM0002 (V3), like the proposed ARR project activities, pertains to ARR of degraded land, and includes above ground and below ground carbon pools. In addition, the methodology includes deadwood, litter and SOC as additional carbon pools.

4.2 Quantifying GHG emissions and/or removals for the baseline scenario:

The chosen methodology recognises two possible land uses in the baseline scenario: i) degraded bare lands or degraded lands that have vegetation below the thresholds of forest defined by the DNA (i.e. 4.2.1 below); and ii) degraded lands on which small amounts of afforestation occurred prior to the project and can be expected to continue in the absence of the project (i.e. 4.2.2 below).

4.2.1 Degraded bare lands and degraded lands

Baseline estimation for the first case, as outlined above, is detailed by the selected methodology as follows:

"For degraded bare lands or degraded lands with sparse non-woody or isolated pre-project vegetation, the baseline net GHG removals by sinks are set to zero for the first crediting period. The degraded lands with sparse vegetation have vegetation thresholds (area, height, and crown cover) much below those defined for forest by the DNA and the baseline net GHG removals by sinks are expected to show low steady state level of carbon stock or long-term negative changes in the carbon pools".

Consequently,

$$\Delta C_{BDL_{ijk,t}} = 0 \qquad \text{(B.1)}$$

where:

$\Delta C_{BDL_{ijk,t}}$	Average annual change in the carbon stocks of bare lands or degraded lands with spare pre-existing vegetation in stratum i sub-stratum j species k; t CO_2e yr^{-1}
i	Stratum of the baseline 1,2,3,…i
j	Sub-stratum of the baseline 1,2,3,… j
k	Species of the baseline 1,2,3,… k
t	Species of the baseline 1,2,3,… t

4.2.2 Degraded lands with pre-project ARR

In this second scenario, small amounts of ARR activities historically undertaken in the region are anticipated to continue in the absence of project activities. No areas were identified as falling within this scenario, since reforestation in the Eastern Cape is currently non-existent in the absence of project activities.

Consequently,

$\Delta C_{BAR_{ijk,t}} = 0$

where:

$\Delta C_{BAR_{ijk,t}}$ Average annual change in pre-project ARR attributable to stratum i sub-stratum j species k; t CO_2e yr^{-1}

Consequently, the baseline net GHG removals by sinks is set to zero. The baseline will be re-evaluated at the end of the first crediting period as per the EB decisions and guidance in this regard.

4.2.3 Calculation of the baseline scenario

The baseline scenario is calculated using the equation below.

$$\Delta C_{BSL_t} = \sum_i \sum_j \left[\sum_k \Delta C_{BAR_{ijk,t}} + \Delta C_{BDL_{ijk,t}} \right] \quad \text{(B.4)}$$

However, since both scenarios have a baseline estimate of 0, the baseline scenario is for no carbon sequestration over the project period.

4.3 Quantifying GHG emissions and/or removals for the project:

4.3.1 Verifiable changes in carbon stocks of pools

Empirical methods and literature studies were used to establish values for the annual change in *ex-ante* carbon stock for all project sinks, using equation B.17 from the selected methodology:

$$\Delta C_{ijk,t} = \left[\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t} + \Delta C_{DW,ijk,t} + \Delta C_{L,ijk,t} + \Delta C_{SOC,ijk,t} \right] \cdot [44/12] \quad \text{(B.17)}$$

where:

$\Delta C_{ijk,t}$ Average annual change in carbon stock in the pools for stratum i sub-stratum j species k in year t; t CO_2e

$\Delta C_{AB,ijk,t}$ Average annual change in carbon stock in the above ground biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

$\Delta C_{BB,ijk,t}$ Average annual change in carbon stock in below ground biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

$\Delta C_{DW,ijk,t}$ Average annual change in carbon stock in deadwood for stratum i sub-stratum j species k in year t; t C $yr^{-1}t$

$\Delta C_{L,ijk,t}$ Average annual change in carbon stock in litter for stratum i sub-stratum j species k in year t; t C yr^{-1}

$\Delta C_{SOC,ijk,t}$ Average annual change in carbon stock in soil organic carbon for stratum i sub-stratum j species k in year t; t C yr^{-1}

$44/12$ Ratio of molecular weights of CO_2 and carbon; dimensionless

a) Changes in the carbon stocks of above ground biomass (C_{AB})

The above ground biomass was calculated using the stock change method from the methodology, with all values for the variables sourced from literature reviews and the baseline empirical study:

$$\Delta C_{AB,ijk,t} = \left(C_{AB,ijk,t_2} + C_{AB,ijk,t_1} \right) / T_B \quad \text{(B.18)}$$

$$C_{AB,ijk} = \left(C_{AB\_Tree,ijk} + C_{AB\_NTree,ijk} \right) \quad \text{(B.19)}$$

where:

C_{AB,ijk,t_2} Carbon stock in above ground tree biomass stratum i sub-stratum j species k calculated at time t_2; t C
C_{AB,ijk,t_1} Carbon stock in above ground tree biomass stratum i sub-stratum j species k calculated at time t_1; t C
T_B Number of years between measurement at time t_2 and t_1 for biomass
$C_{AB\_Tree,ijk}$ Carbon stock of above ground biomass of living trees for stratum i sub-stratum j species k; t C
$C_{AB\_NTree,ijk}$ Carbon stock of above ground non-tree biomass for stratum i sub-stratum j species k; t C

Since no non-tree vegetation is planted by project activities, but growth of non-tree vegetation is likely to be enhanced by project activities (van der Vuyfer, in press), it is considered conservative to omit non-tree biomass accumulation.

$\Delta C_{AB\_Ntree,ijk} = 0$ (conservative)

Consequently, only the tree component of above ground biomass is quantified using the allometric equation method.

$$\Delta C_{AB_{Tree},ijk,t} = A_{ijk} \cdot nTR_{ik} \cdot f_k(DBH, H) \cdot CF_k \cdot \left(\frac{1}{1000}\right) \quad \text{(B.21)}$$

where:

$f_k(DBH, H)$ Allometric equation quantifying the relationship between above ground biomass of tree species k; kg tree^{-1} to the diameter at breast height (DBH) and tree height (H) for species k; dimensionless. Mean DBH and H values can be estimated for stratum i sub-stratum j species k
A_{ijk} Area of stratum i sub-stratum j species k; ha
nTR_{ik} Number of trees in stratum i species k; trees ha^{-1}
CF_k Carbon fraction for species k; t C (t dm)$^{-1}$

Step 1 of the allometric equation method (see page 15 of AR-AM0002 (V3)) specifies that local allometric equations relevant to the species are to be used as a priority. The allometric equation for *P. afra* growth developed by Powell (2009) is used for the *ex post* estimation due to its high correlation between estimated and observed mass (R^2= 0.9696, p=0.00224). Since this allometric equation directly provides the amount of carbon per tree, it replaces both the terms $f_k(DBH, H)$ and CF_k in Equation B.21 The allometric equation is shown below:

$$\mathrm{Log}_{10}\mathrm{C}_{\mathrm{mass}} = (1.1043 \cdot \mathrm{Log}_{10}\mathrm{CBSA}) + 2.4464 \quad \textbf{(AL.1)} \text{ (Powell, 2009)}$$

where:

$\mathrm{C}_{\mathrm{mass}}$ Mass of carbon per tree in stratum i sub-stratum j species k; kg C
$CBSA$ Combined basal surface area of the tree; m^2

For the *ex ante* determination, the term $\Delta C_{AB_{Tree},ijk,t}$ for each stratum was determined empirically from the literature review (see Annex 7).

b) Changes in the carbon stocks of below ground biomass (C_{BB})

The change in below ground biomass is specified as the sum of all changes in below ground tree biomass and non-tree biomass:

$$\Delta C_{BB,ijk,t} = \Delta C_{BB\_Tree,ijk,t} + \Delta C_{BB\_Ntree,ijk,t} \quad \text{(B.30)}$$

where:

$\Delta C_{BB\_Tree,ijk,t}$ Average annual change in carbon stock in below ground tree biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

$\Delta C_{BB\_Ntree,ijk,t}$ Average annual change in carbon stock in below ground non-tree shrub biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

As with the above ground biomass, the non-tree biomass is conservatively omitted from *ex ante* estimation:

$$\Delta C_{BB\_Ntree,ijk,t} = 0 \quad \text{(conservative)}$$

Below ground biomass is represented as a proportion of the above ground biomass. The tree biomass is calculated using the root-shoot ratio (0.253) assessed from the literature for *P. afra* growth rates in the region, following Step 1 identified in the methodology. The formula for calculation is the same as that specified for the non-tree biomass:

$$\Delta C_{BB\_Tree,ijk,t} = \Delta C_{AB\_Tree,ijk,t} \cdot R_{S,k} \qquad \text{(B.32)}^{23}$$

where:

$\Delta C_{AB\_Tree,ijk,t}$ Average annual change in carbon stock in above ground biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

$R_{S,k}$ Root-shoot ratio for species k; dimensionless

c) Deadwood (C_{DW})

The average annual change in the deadwood biomass is calculated based on natural mortality and the estimated changes in the above ground biomass:

$$\Delta C_{DW,ijk} = \Delta C_{AB\_Tree,ijk,t} \cdot M_k \cdot (1 - DC_k) \qquad \text{(B.34)}$$

where:

$\Delta C_{DW,ijk}$ Average annual change in carbon stock in above ground biomass for stratum i sub-stratum j species k in year t; t C yr^{-1}

M_k Average annual rate of natural mortality for species k; dimensionless

DC_k Decomposition factor for species k; dimensionless

It is anticipated that deadwood mass in the stands will be very low in the early stages of the restoration project, but deadwood may accumulate in the stands in later crediting periods. *P. afra* is able to root and grow from cuttings, so damage to plants often provides a means for vegetative reproduction (Aucamp et al., 1980).

d) Changes in the carbon stocks of litter (C_L)

Litter accumulation is estimated in the *ex-ante* totals, using the carbon stock change method detailed in the monitoring section of the methodology, as recommended in AR-AM0002 (v3):

[23] The original equation refers specifically to non-tree biomass. However, since the methodology specifies that the root to shoot ratio can used to calculate above ground biomass, but only specifies the volume increment calculation, the non-tree calculation was modified for tree below-ground biomass calculation. The above-ground calculation as printed is:
$\Delta C_{BB_{Tree},ijk} = I_{Tree,ijk} \cdot D_k \cdot BEF_k \cdot R_{T,k} \cdot CF_k$ **(B.31)**

$$\Delta C_{L,ijk,t} = \left[\left(C_{L,ijk,t_2} - C_{L,ijk,t_1}\right)/T_L\right] \cdot CF_L \quad \text{(M.24)}$$

where:

$\Delta C_{L,ijk,t}$	Average annual change in carbon stock in litter for stratum i sub-stratum j species k in t C yr^{-1} in year t
C_{L,ijk,t_2}	Carbon stock of litter in stratum i sub-stratum j species k in year t_1; t C yr^{-1}
C_{L,ijk,t_1}	Carbon stock of litter in stratum i sub-stratum j species k in year t_2; t C yr^{-1}
T_L	Time interval between t_2 and t_1; yr
CF_L	Carbon fraction of leaf litter; dimensionless (IPCC default: 0.370)

The average litter accumulation for the *ex ante* situation is estimated from the literature analysis (see Annex 7).

e) Changes in the stocks of soil organic carbon (C_{SOC})

Ex ante SOC changes were assessed empirically through experimental determination and through a literature analysis (see Annex 7 and Annex 8). SOC accumulation is estimated using the following equations from the chosen methodology:

$$\Delta C_{SOC,ijk} = \left[\left(C_{SOC\_For_{ijk}} - C_{SOC\_Non\_For_{ijk}}\right) \cdot A_{ijk}\right]/T_{For,ijk} \quad \text{(B.35)}$$

$$C_{SOC\_For_{ijk}} = C_{SOC\_REF_{ijk}} \cdot f_{ijk} \quad \text{(B.36)}$$

where:

$\Delta C_{SOC,ijk}$	Average annual carbon stock change in soil organic matter for stratum i sub-stratum j species k; t C yr^{-1}
$C_{SOC\_For_{ijk}}$	SOC stock of afforested/reforested area or forested area that corresponds to the stratum i sub-stratum j species k; t C ha^{-1}
$C_{SOC\_Non\_For_{ijk}}$	SOC stock of non-forested degraded lands that correspond to the stratum i sub-stratum j species k; t C ha^{-1}
A_{ijk}	Area of stratum i sub-stratum j species k; ha
$T_{For,ijk}$	Time period required for transition from $SOC\_Non\_For_{ijk}$ to SOC_For_{ijk}; yr
$C_{SOC\_REF_{ijk}}$	Reference SOC stock under the native unmanaged in t C ha^{-1}. '*SOC_REF*' refers to the stable soil organic carbon under native forests (Table 3.2.4 of Good Practice Guidance on LULUCF)
f_{ijk}	Adjustment factor for the effect of management intensity; dimensionless. The value for adjustment factor is expected to range between 0-1. Since stocking rates are designed to fully restore thicket vegetation, a value of 1 was used.

Ex post analysis of SOC changes will also be conducted using the stock change method specified above.

4.3.2 GHG emissions by sources

This quantifies the project emissions resulting from the implementation of the proposed ARR project. The methodology lists likely sources of emissions as: emissions from fossil fuels used in carrying out ARR project activities (site preparation and silvicultural operations); loss of non-tree biomass (not including herbaceous components) in the site preparation; and biomass burn due to natural fires or from management-related activities. The equation for calculation of the GHG

emissions as a result of project activities provided in AR-AM0002 (V3) does not, however, include fossil fuels. Hence they are discussed in the leakage section (see 4.3.3 below).

Table 11: Identification and justification of emission sources.

Emission sources	Gas	Included/Excluded	Justification/Explanation
Burning of biomass	CO_2	Included	
	CH_4	Included	
	N_2O	Excluded	Potential emission is negligibly small
Burning of fossil fuels	CO_2	Excluded	Potential emission is negligibly small
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small
Other mechanical fuel use	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable

The equation for calculation of emissions is:

$$GHG_E = E_{BiomassLoss} + E_{BiomassBurn} \quad \text{(B.38)}$$

where:

GHG_E Sum of increases in GHG emissions within the project boundary from the implementation of the proposed ARR project activity; t CO_2e

$E_{BiomassLoss}$ Increase in GHG emissions from the loss of biomass in the site preparation within the project boundary;t CO_2e

$A_{BiomassBurn}$ Area of biomass burn in stratum *i*; ha yr^{-1}

a) Emissions from the decline in the carbon stock of non-tree vegetation

The area affected by site preparation for the project is minimal since the *P. afra* cuttings are planted vertically by means of an auger. The hole itself is no more than 8 cm in diameter, but a conservative 20 cm x 20 cm area is used for calculation of the affected area. Calculations of the carbon stock of non-tree biomass affected are carried out using the equation below:

$$E_{BiomassLoss} = \sum_i A_{NT_{BiomassLass},i} \cdot B_{AB\_NTree,i} \cdot CF_{NTree} \cdot \frac{44}{12} \quad \forall t = 1$$
$$E_{BiomassLoss} = 0 \quad \forall t > 1 \quad \text{(B.39)}$$

where:

$E_{BiomassLoss}$ Increase in GHG emissions from the loss of biomass in the site preparation within the project boundary; t CO_2e

$A_{NT\_BiomassLass,i}$ Area of stratum i; ha

$B_{AB\_Ntree,i}$ Average biomass stock of non-tree vegetation on land to be planted before the start of a proposed ARR project activities for stratum *i*; t d m ha^{-1}

CF_{NTree}	Carbon fraction of dry biomass; t C (t d m)$^{-1}$
$44/12$	Ratio of molecular weights of CO_2 and carbon; dimensionless
t	Time; yr

b) Emissions from biomass burning

Ex ante calculation of fire risk was based on expert opinion estimates of fire susceptibility in the area. It is anticipated that there will be minimal GHG emissions from biomass burning due to *P. afra*'s fire resistance. *P. afra* is naturally highly fire-resistant, because it is a succulent with a very high moisture content, and thereafter the established *P. afra* plants will provide a natural firebreak. *Ex post* monitoring will include fire damage if it occurs, and additional strata will be introduced to deal with potential fire effects.

The equations specified by AR-AM0002 (V3) for calculation of biomass burning emissions, including an equation omitted from the methodology, are shown below:

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{Non-CO_2\_BiomassBurn} \quad \text{(inserted I.1)}$$

$$E_{BiomassBurn,CO_2} = \sum_i A_{BiomassBurn,i} \cdot B_{AB\_Ntree,i} \cdot CE \cdot CF_{NTree} \cdot 44/12 \quad \text{(B.40)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot GWP_{CH_4} \cdot EF_{CH_4} \cdot 12/44 \cdot 16/12 \quad \text{(B.41)}$$

$$E_{Non-CO_2\_BiomassBurn} = E_{BiomassBurn,CH_4} \quad \text{(B.42)}$$

where:

$B_{AB\_Ntree,i}$	Average biomass stock of non-tree vegetation on land to be planted before the start of a proposed ARR CDM project activity for stratum i; t dm ha^{-1}
CF_{NTree}	Carbon fraction of dry biomass; t C (t dm)$^{-1}$
$44/12$	Ratio of molecular weights of CO_2 and carbon; dimensionless
$A_{BiomassBurn,i}$	Area of biomass burn; stratum i; ha yr^{-1}
$B_{AB\_NTree,i}$	Average stock in above ground biomass for stratum i prior to burn; t dm ha^{-1}
CE	Combustion efficiency; dimensionless (IPCC default = 0.5)

N_2O emissions from burning are included in AR-AM0002 (V3), but equation B.42 does not include them. This contradiction is problematic, and so we propose to interpret the error conservatively, and include N_2O emissions as well:

$$E_{Non-CO_2,BiomassBurn} = E_{BiomassBurn,CH_4} + E_{BiomassBurn,N_2O} \quad \text{(B.42 revised)}$$

The N_2O component is calculated as follows:

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot GWP_{N_2O} \cdot EF_{N_2O} \quad \text{(Inserted I.2)}$$

where:

$E_{BiomassBurn,N_2O}$	N_2O emission from biomass burning; t CO_2e yr^{-1}
$E_{BiomassBurn,CO_2}$	Increase in CO_2 emissions as a result of biomass burning; t CO_2e yr^{-}
GWP_{N_2O}	global warming potential for CH_4 (IPCC default = 310)
EF_{N_2O}	emission factor for N_2O, t N_2O (t C)$^{-1}$ (IPCC default emission ratio of N_2O = 0.007)

NB: The molecular weights of CO_2 and N_2O are roughly equivalent, removing the necessity for a molecular weight calculation in Equation I.2)

4.3.3 Estimation of leakage

The project areas consist of severely degraded lands which support low living biomass, and the land use is unchanged. Consequently, the land should continue to provide the same services, and there is no anticipated leakage as a result of project activities.

$$LK_t = 0 \quad \text{(B.44)}$$

where:

LK_t CO_2 emissions from leakage in t CO_2e yr^{-1}

Under the chosen methodology, all fuel emissions for the proposed ARR project are deemed to be negligible, and can be discounted[24].

4.4 Quantifying GHG emission reductions and removal enhancements for the GHG project:

The plant weight and total carbon mass of each plant will increase in time, peaking after approximately 50 years. The growth curve was estimated from field measurements and the literature meta-analysis, and is shown below.

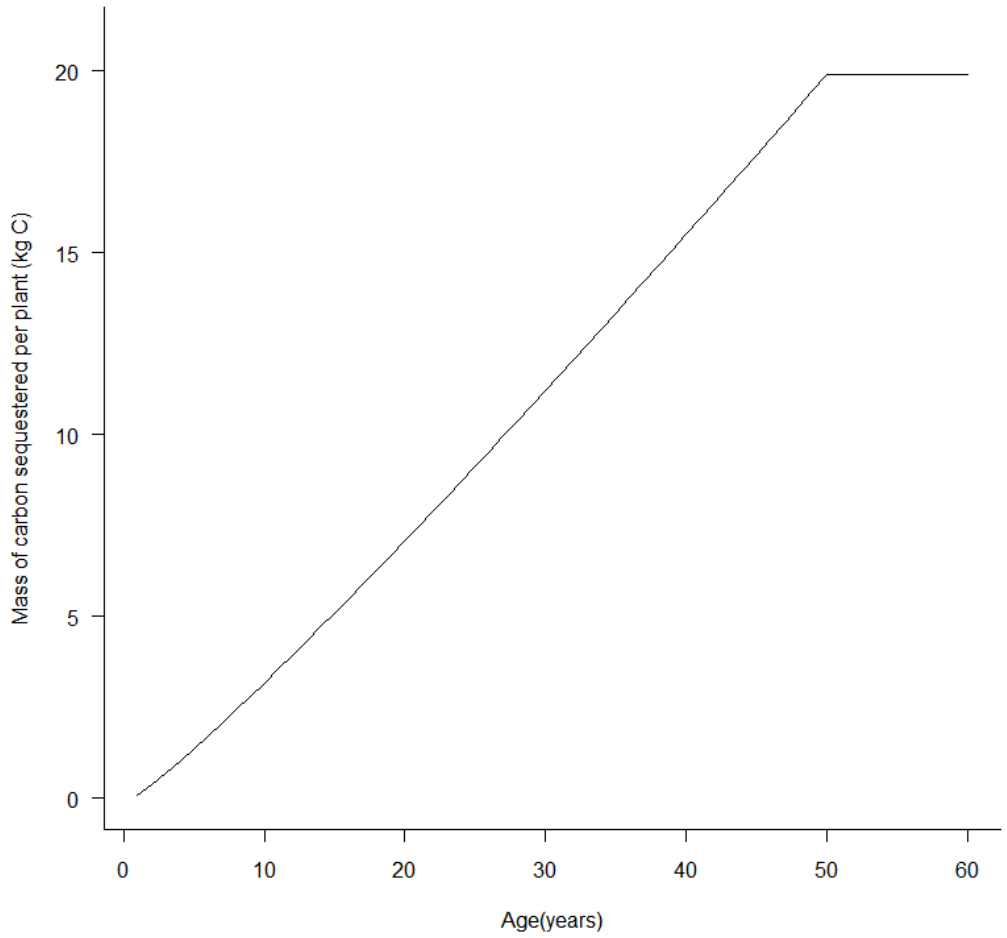

Figure 9: Curve used to estimate growth of *P. afra* (per plant).

[24] The methodology applied to the proposed ARR project, AR-AM0002 (V3), stipulates that the CO_2 generated through transport use during project activity is deemed negligible in comparison to the CO_2e sequestered.

Allometric equation for calculating carbon sequestration in *P. afra* plants:

$$\log y = 1.1043(\log CBSA) + 2.4464 \quad \text{(Powell, 2009)}$$

where:

y	Above ground dry plant carbon; kg C
$CBSA$	Cumulative basal stem area; m^2

This rate of accumulation is expected to continue for a period of 50 years after planting, and will vary according to the environmental conditions of each area. The rate of accumulation for each planted hectare is displayed in Figure 8 below.

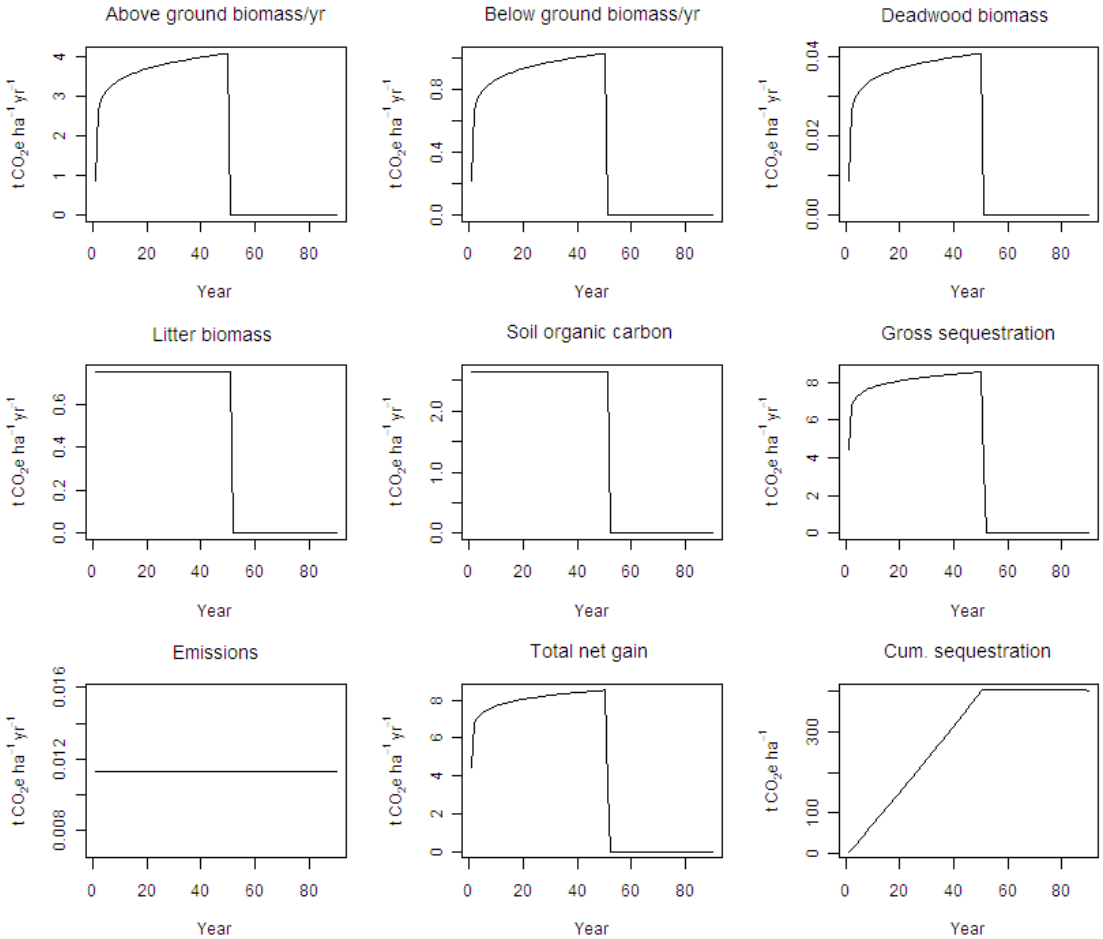

Figure 10: Carbon mass accumulation per hectare (calculated using the ex ante equations specified in AR-AMS0002 V3, and calculated using the R script appended in Annex 14).

4.4.1 Net anthropogenic greenhouse gas removals by sinks

Anthropogenic GHG removals are calculated as follows:

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK_t \quad \text{(B.45)}$$

where:

C_{AR-CDM}	Net anthropogenic GHG removals by sinks in t CO_2e yr^{-1}
ΔC_{ACTUAL}	Actual net GHG removals by sinks in t CO_2e yr^{-1}
ΔC_{BSL}	Baseline net GHG removals by sinks in t CO_2e yr^{-1}
LK_t	CO_2 emissions from leakage in t CO_2e yr^{-1}

The rate of carbon sequestration is estimated to be 8.22 t CO_2e ha^{-1} yr^{-1} for 50 years after planting. This is based on rates of carbon sequestration indicated from a review of seven peer-reviewed papers and theses (see Annex 7).

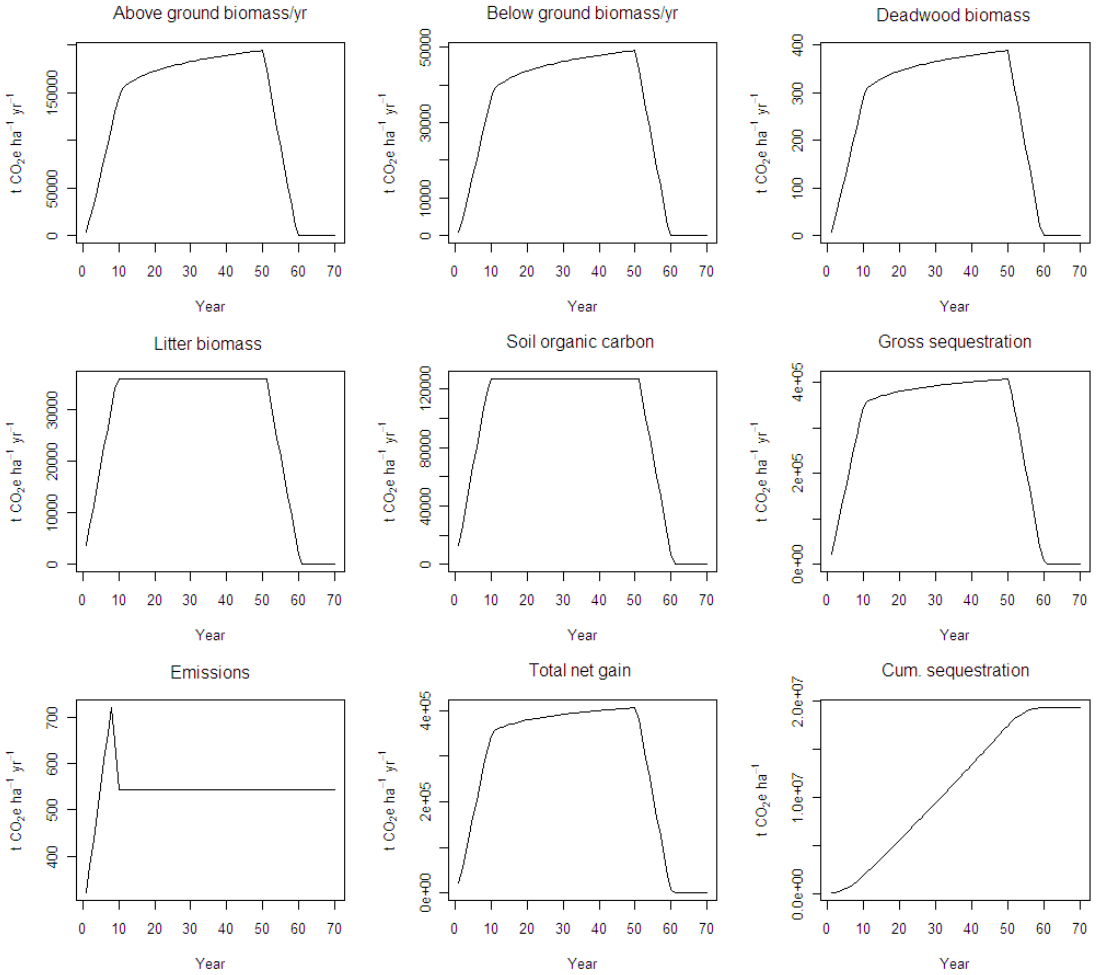

Figure 11: Calculated total project carbon sequestration for each carbon pool over the project duration.

The total carbon sequestration potential per unit land area is 411 t CO_2e ha^{-1}, as estimated from the literature review (Annex 7). The total carbon sequestration potential for the entire project (48,086 ha) over a 60 year period is calculated using the methodological equations to be 19.29 million t CO_2e (see Table 12). All calculations for this estimate were carried out using the equations from AR-AM0002 (V3), and were performed using a script in the R statistical programme (R version 2.10.1, August 2010). The script is attached as Annex 14.

Table 12: Estimation of net anthropogenic GHG removals by sinks (t CO_2e).

Year	Estimation of baseline net GHG removals by sinks (t CO_2e)	Annual estimation of baseline net anthropogenic GHG removals by sinks (t CO_2e)	GHG emissions from fossil fuel consumption on site	Estimation of leakage (t CO_2e)	Estimation of net anthropogenic GHG removals by sinks (t CO_2e)
Year 5	0	463,741	0	0	463,741
Year 10	0	1,383,660	0	0	1,383,660
Year 15	0	1,815,278	0	0	1,815,278
Year 20	0	1,877,066	0	0	1,877,066
Year 25	0	1,916,503	0	0	1,916,503
Year 30	0	1,946,351	0	0	1,946,351
Year 35	0	1,970,580	0	0	1,970,580
Year 40	0	1,991,068	0	0	1,991,068
Year 45	0	2,008,868	0	0	2,008,868
Year 50	0	2,024,637	0	0	2,024,637
Year 55	0	1,476,914	0	0	1,476,914
Year 60	0	418,678	0	0	418,678
Total (t CO_2e)	0	19,293,343	0	0	19,293,343

5 Environmental Impact:

The proposed ARR project will not cause any significant negative environmental impact. According to Sections 24 and 24D of the NEMA, 1998 (Act No. 107 of 1998), neither an EIA nor Basic Assessment is required as the project activities do not trigger any of the Environmental Impact Regulation listed activities published in Government Notice No. R 385 of 2006 (No. R. 386 and 387, 21 April 2006 including amendments 3 July and 9 October 2009).

Additionally, the project has received an EIA waiver from the Eastern Cape Provincial DEDEA (Annex 5, Figure A .6.6). The project operations are the same in all areas, and have clear environmental benefits. This waiver is indicative of legislative approval of the operations. Environmental benefits of the proposed ARR project include:

- **Reduced silt loads in dams and rivers**. Soil erosion will be reduced through the planting of *P. afra* cuttings.
- **Improved aesthetics**. The restoration of thicket will improve the aesthetic beauty of the ARR project areas.
- **Improved habitat for browsing herbivores**. Browsing herbivores will likely return to the ARR project areas following successful afforestation.
- **Improved biodiversity in terms of indigenous shrubs and trees**. Shrub and tree diversity will increase as a result of the planting of *P. afra* cuttings, as their canopy reduces soil temperatures, improves soil quality through the addition of leaf litter, reduces the incidence of frost at ground level and is likely to reduce runoff of rainwater. All of these effects will improve the microclimate and soil conditions for natural recruitment of indigenous shrubs and trees.
- **Greater ecosystem productivity**. The improved biodiversity will also result in an increase in ecosystem productivity.

Information regarding the ecology of degradation and restoration of thicket, including the benefits associated with restoration of thicket, has been published in the following scientific papers:

Hoffman, M.T., and R.M. Cowling. 1990. Desertification in the lower Sundays River Valley, South Africa. *Journal of Arid Environments* 19:105-117.

Mills, A.J. & Fey, M.V. 2004. Soil carbon and nitrogen in five contrasting biomes of South Africa. *South African Journal of Plant and Soil* 21:94-103.

Mills, A.J. & Fey, M.V. 2004. Transformation of thicket to savanna reduces soil quality in the Eastern Cape, South Africa. *Plant and Soil* 265:153-163.

Lechmere-Oertel R.G., Kerley G.I.H. and Cowling R.M. 2005a. Patterns and implications of transformation in semi-arid succulent thicket, South Africa. *Journal of Arid Environments* 62, 459–474.

Lechmere-Oertel R.G., Kerley G.I.H. and Cowling R.M. 2005b. Landscape dysfunction and reduced spatial heterogeneity in soil resources and fertility in semi-arid succulent thicket, South Africa. *Austral Ecology* 30, 615–624.

Mills, A.J., Cowling, R.M., Fey, M.V., Kerley G.I.H., Donaldson J.S., Lechmere-Oertel, R.G., Sigwela, A.M., Skowno, A.L. & Rundel, P. 2005. Effects of goat pastoralism on ecosystem carbon storage in semi-arid thicket, Eastern Cape, South Africa. *Austral Ecology* 30:797-804.

Mills, A.J., O'Connor, T.G., Donaldson J.S., Fey, M.V., Skowno, A.L., Sigwela, A.M., Lechmere-Oertel, R.G. Bosenberg, J.D. 2005. Ecosystem carbon storage under different land uses in three semi-arid shrublands and a mesic grassland in South Africa. *South African Journal of Plant and Soil* 22:183-190.

Mills, A.J., & Cowling, R.M. 2006. Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape, South Africa. *Restoration Ecology* 14:38-49.

Additional information regarding the positive environmental benefits of thicket restoration with *P. afra* are published in the MSc theses of Mike Powell (Powell, 2009) and Marius van (van der Vuyfer, in press). The proposed ARR project will improve the biodiversity status/ecosystem functioning of the land, thereby meeting national obligations within the Conventions of Biodiversity and Desertification[25]. Furthermore, the Southern African Millennium Ecosystem Assessment Report(Biggs et al., 2004) highlighted environmental degradation, including soil erosion, watercourse destruction and biodiversity loss, as a confounding influence on the regions' ability to achieve the Millennium Development Goals (MDGs). The proposed ARR project will thus also contribute to addressing environmental degradation within the project areas, thereby assisting in the achievement of the MDGs.

[25] South Africa is a signatory to both the United Nations Convention to Combat Desertification and the United Nations Convention for the Protection of Biodiversity; but to date progress in accordance with these two programmes has been limited.

6 Stakeholders comments:

6.1 Brief description of how comments by local stakeholders have been invited and compiled:

Extensive stakeholder consultation was followed for the Baviaanskloof Nature Reserve, the first project area. Stakeholder engagement will be conducted for the Addo Elephant National Park and GFRNR sites should the VER funding be obtained. The following stakeholders were identified and consulted: the local Farmers Associations, neighbouring local communities, ARR project workers, the local municipality, the Baviaanskloof Steering Committee and the Thicket Forum (an annual gathering of scientists and managers working in the Subtropical Thicket Biome). The project information was presented to stakeholders through workshops, PowerPoint presentations and meetings. The following outlines the stakeholder interactions, their comments and the project developers' responses to their comments.

18th October 2006: Dr Christo Marais (Operations Manager, Working for Water[26]) introduced the topic of carbon trading through restoration of subtropical thicket at a meeting of the Farmers Association members in the town of Patensie. The PowerPoint presentation titled "Carbon trading and subtropical thicket restoration" included the following: i) background information on climate change and carbon trading; ii) the status of subtropical thicket degradation in the Eastern Cape as well as changes over time in the Patensie (Gamtoos) valley; iii) the potential of *P. afra* to drive the ARR project in the Baviaanskloof; iv) preliminary results and major challenges; and v) the steps ahead.

11th June 2007: Yolande Vermaak (Project Officer, GIB) and Mike Powell (Rhodes University (RU) and Subtropical Thicket Restoration Programme coordinator) held a meeting for the ARR project workers to inform them about the Subtropical Thicket Restoration Project's goals and objectives and to ascertain whether the workers supported the project. Mr Powell provided an overview of the purpose of the meeting followed by a thorough description of the project. This description included the following: i) why the project needs to be undertaken; ii) the drivers behind climate change; iii) the Kyoto Protocol; iv) reducing CO_2 emissions through reforestation; and v) the guidelines which the ARR projects needs to follow. Mr Powell and Ms. Vermaak held the meeting in both English and Afrikaans to facilitate understanding between the workers.

16th - 20th July 2007: Mr Mike Powell presented the proposed ARR project for the Baviaanskloof Nature Reserve at the Thicket Forum. The Thicket Forum is an affiliation of stakeholders which includes, amongst others, research and management institutions, landowners, and private enterprises. The forum aims to facilitate the sharing of lessons regarding research, management and education within the Subtropical Thicket Biome (which includes the Addo Elephant National Park and GFRNR), and the formulation of priority actions within these disciplines to promote the conservation of landscapes and the enhancement of livelihoods in the Subtropical Thicket Biome.

8th October 2007: A meeting was held with local (indirect) stakeholders on land belonging to Chris Lamprecht, who is the Chairman of the Baviaanskloof Farmers Union in the western Baviaanskloof. The stakeholder group consisted of farmers and landowners with property adjacent to the project area (and enclosed within the greater Baviaanskloof Nature Reserve). Pieter Kruger and Dieter Van den Broeck (from PRESENCE - a network of scientists) personally invited attendees to the meeting. The meeting consisted of two presentations. Firstly, Mr Mike Powell explained the

[26] Working for Water and Working for Woodlands are part of the same group of programmes organised and run by government.

rationale and drivers for the project across the different scales. This included: i) the global outlook (climate change, Kyoto Protocol, CDM, carbon sequestration); ii) national drivers (South Africa as a signatory to Convention on Biological Diversity and Desertification, MDGs and poverty alleviation strategies); and iii) local relevance (the implications of large-scale land degradation and the potential for farmers to engage in ARR activities). Mr Mike Powell outlined the ARR project activities in the Baviaanskloof Nature Reserve specifically related to ongoing experimental activities, parties involved, results to date and the relevance for landowners adjacent to the project. The benefits of ARR and thicket restoration were discussed as well as current risks and uncertainties (including those of the carbon market). A discussion followed after the presentation.

The second presentation was given by Emmanuelle Noirtin, a M.Sc. student from Wageningen University (WUR), the Netherlands. Miss Noirtin, representing a group of four WUR students, outlined their research (focused on the Baviaanskloof Nature Reserve) on eliciting stakeholder perceptions of the socio-economic importance of the Subtropical Thicket Biome and stakeholder willingness to engage in restoration. During the meeting, an A5 information leaflet about the students' research and its relevance to subtropical thicket restoration was distributed.

October – November 2007: In line with the student presentation above, farmers and communities in the western Baviaanskloof (adjacent to project area in the reserve) received a number of informal visits from the four WUR students as part of their socio-economic and stakeholder assessments. During this field research period, considerable awareness was generated about the proposed ARR project as well as feedback from stakeholders regarding its perceived potential and ability to deliver benefits to farmers and communities.

11th - 13th November 2007: A workshop was held at Zandvlakte in the western Baviaanskloof. Scientists (from RU, Nelson Mandela Metropolitan University (NMMU), University of Pretoria (UP), Stellenbosch University, WUR, Council for Scientific & Industrial Research (CSIR)), implementers (from ECPB and GIB), Government (DWA), NGOs (from WWF-SA, EarthCollective), private consultants and students attended the event. The aim of the workshop was to identify key scientific questions and knowledge gaps related to restoration implementation. A significant amount of time during the workshop was devoted to discussing the broader implications of ARR. The pilot Baviaanskloof Thicket Restoration Project was the primary example used to gain expert input and generate discussion on approaches currently being adopted. Related presentations were given by Dr Anthony Mills and Mr Mike Powell.

17th November 2007: Yolande Vermaak (Project Officer, GIB) and Dieter Van den Broeck orally presented progress of the proposed ARR project at the quarterly western Baviaanskloof Farmer's Union meeting (held on the farm of Johan Lamprecht). Project background was presented along with the following: i) relevance to landowners; ii) carbon stocks in thicket; iii) benefits to farmer's engaging in restoration; iv) how the ARR works; v) how farmers can enter the carbon market; vi) related income opportunities; and vii) barriers to be overcome. The major objective of the presentation was to assist these farmers – as indirect stakeholders – in becoming familiar with the concept of ARR and to gain a better understanding of the proposed ARR project in the adjacent nature reserve and how they would benefit from VCS or CDM approval in the future.

29th November 2007: Mr Mike Powell delivered an oral presentation to the Sewefontein community about proposed ARR activities in the Baviaanskloof Nature Reserve. The members of both of the local communities in western Baviaanskloof (Sewefontein and Zaaimanshoek) were personally invited by both the community leaders and the WUR students who were active in these

communities with their field research. Mr Powell discussed the current status of the ARR project, relevance to these communities and potential benefits, opportunities and challenges.

5th December 2007: Matthew Zylstra delivered a brief presentation to the Baviaanskloof Steering Committee Meeting covering major outcomes of the workshop held 11-13th November, 2007. This included an update of the proposed ARR project and, with student co-presenter Ignacio de la Flor, provided an overview of the preliminary outcomes of the related socio-economic research undertaken with farmers and communities in the western Baviaanskloof.

29th January 2008: Project facilitators from the proposed ARR project and related Subtropical Thicket Restoration Programme submitted a 'Motivation Document' outlining project objectives and activities to the Baviaanskloof Municipality to seek the Steering Committees institutional support for its inclusion within the Integrated Development Planning (IDP).

19th February 2008: Dieter Van den Broeck gave a presentation to the Farmers Association in the town of Patensie. The presentation outlined the activities and opportunities related to the proposed ARR project in the Baviaanskloof.

21st February 2008: Dieter Van den Broeck (Project Manager, PRESENCE) and Matthew Zylstra (Project Facilitator, PRESENCE) met with Wayne Erlank (Regional Manager, ECPB) to report on the proposed ARR project application progress, elicit feedback and clarify any questions which may have arisen during recent months.

8th March 2008: Matthew Zylstra reported back on activities and progress to the Baviaanskloof Farmer's Union. The role of PRESENCE and the roles of various collaborating organisations feeding into PRESENCE were discussed in relation to how to make landscape restoration an on-ground reality for landowners and communities. Various avenues and opportunities for incentives were briefly discussed, such as payments for water services and carbon credits.

Summary of the comments received:
In general, no direct comments towards proposed ARR activities in the Baviaanskloof Nature Reserve were expressed. Comments predominantly relate to implications of possible future ARR roll-out to adjacent areas and not specifically to the proposed ARR activities.
The landowners of surrounding farms and the workers directly involved gave their support to the proposed ARR project (see Annex 5, Figure A.5.1and Figure A.5.8).

However, to ensure a thorough and transparent stakeholder process, the following section lists general comments and feedback elicited during the abovementioned stakeholder interaction sessions.

11th June 2007: As per Annex 5, approval of the project was given. The workers confirmed that they supported the proposed ARR project and only had questions related to logistical issues. These included:
Cedric (Project Contractor, from Zaaimanshoek community) had a problem with the carrying out of the *P. afra* cuttings;
Loretta enquired as to why they cannot fence off the area where they have planted in order to prevent baboons from causing damage to replanted areas.

16th - 20th July 2007: No comments were recorded due to the nature of the event.

8th October 2007: During the meeting, farmer Boetie Terablanche expressed his scepticism towards research projects which "come and go" in the Baviaanskloof without initial project plans ever leaving the ground. Mr Terablanche questioned whether this proposed ARR project would follow the same trajectory after the pilot phase in the Baviaanskloof Nature Reserve was completed.

October – November 2007: During the period October – November 2007, students from WUR informally contacted stakeholders in the western Baviaanskloof adjacent to the Baviaanskloof Nature Reserve and proposed ARR project area. Relevant feedback from the consultation is catalogued as follows:

Community:
Denna (inhabitant and trust member of Sewefontein community) recalled the story of when an alien cactus of Mexican origin (*Opuntia ficus – indica (L.))* was declared as an invasive weed in Baviaanskloof 30-40 years ago. Without consulting the local people, the Government of South Africa decided to eradicate the cactus by releasing a moth in Baviaanskloof Nature Reserve, which killed the cactus. As the local people ate the edible fruits of the cactus and used them as animal fodder and as a sugar source, they were unhappy with the decision to remove the cactus from their surrounds. Denna asked whether such a situation could occur with the proposed ARR project. By planting *P. afra* on a large scale, Denna questioned whether in effect one would create the same situation as when the cactus was everywhere. And if not, Denna wondered why the Government chose to remove the cactus all those years ago.

Other general comments from communities that were recounted during consultation:

- "The proposed ARR project looks promising because it is seen to bring jobs to the communities".
- "The proposed ARR project will serve to improve biodiversity in the area as many plants are currently dying and the area is becoming less green".

Workers:
Cedric (Project Contractor, from Zaaimanshoek community) said that he enjoyed his job in the pilot project (of the proposed ARR project) because it offered him the opportunity to work in nature. He thought it helped them (the workers) to better appreciate nature. Cedric believed that the proposed ARR project would improve air quality and was also important so that "nature is there for my children". Headded that although it was challenging work planting the trees every day, it was for a good purpose. Cedric also felt that the proposed ARR project was a good project because it improved job creation.

Abigail (former Project Contractor, from Zaaimanshoek community) said that her work with the pilot project had given her the opportunity to learn about nature, whereby she had become more interested in visiting the natural sites in the Baviaanskloof Nature Reserve. Abigail added that she had become more aware of the beauty of the flora and fauna in the Reserve as a result of her involvement in the pilot project. Abigail reported that she had previous frustrations with the salary contract conditions whereby payment of salaries was 30 days in arrears after completion of work.

George commented that he felt that the planting of *P. afra* was good but wondered whether there was a need to plant other vegetation in the area.

Jan Magleties (church leader, Zaaimanshoek community) said that the proposed ARR project was a good project because it created jobs and kept people busy and away from crime.

Farmers: (living adjacent to the Baviaanskloof Nature Reserve)
Boetie Terablanche and his wife expressed both interest in and criticism of the proposed ARR project (should future phased implementation extend to their lands). They queried as to why so much research had been undertaken regarding *P. afra* because *P. afra* does not always grow everywhere (e.g. not in the flat areas of the valley) and, in their view, other thicket species seemed to have been ignored. Mr Terablanche also wondered how the broader proposed ARR project would manage to plant large areas of land with all the *P. afra* – in terms of where labourers could be sourced from, how they would be paid and how seasonal work could be utilized to get a lot of work done within a short period of time. Mr Terablanche mentioned that, if the proposed ARR project were offered on his land, even though he would be prepared to take all the livestock off his land if needed, he would not be prepared to wait 20 years to see project results; the activities would need to be something that improved his livelihood.

Thys Cilliers expressed a willingness to engage in proposed ARR activities should the proposed project in the Baviaanskloof Nature Reserve be approved and a similar project offered for implementation on his property. Mr Cilliers also showed some scepticism about carbon sequestration; mainly because, on a larger scale, he felt that institutional capacity and willingness was lacking. Mr Cilliers was also concerned about the fact that research tended to be forgotten and nobody implemented the research results. According to Mr Cilliers, carbon sequestration had already been discussed for the last ten years but to date not a single project had been implemented. Mr Cilliers recommended and endorsed the idea of developing a pilot carbon sequestration project to persuade everybody and give evidence that the mechanism could actually work.

Pieter Kruger noted that there are currently no incentives for restoration and, as a result, farmers were reluctant as they did not see economical benefits from ARR activities and they needed income assurance. He added that when approved, the proposed ARR project had the potential to provide this assurance to landowners.

Quintis Bezuidenhout commented that the larger vision of the proposed ARR project appeared to be viable over the long-term and an excellent idea which had the potential to help companies reduce emissions.

An additional question which arose across various stakeholder groups was what mechanisms were available to reward farmers who had managed their land and conserved original vegetation types (i.e. avoided deforestation)? The potential of REDD activities to address this issue will be examined.

17th November 2007: Farmer Boetie Terablanche raised the question as to whether the costs invested in terms of time, research and project set-up would be recouped with accreditation gains. Mr Terablanche suggested that money invested in researching carbon credits and restoration could be better given to farmers to begin conserving their lands immediately.

Farmer Thys Cilliers expressed his opinion about carbon sequestration. According to Mr Cilliers, proposed activities are taking too long to be implemented and he was anxious about seeing and receiving results in several years.

29th November 2007: Given the historical realities of the area, many communities were wary of projects which seemed to promise much but ended up delivering little. Community members had seen such instances on numerous occasions during the recent past. In this regard, one attendee in

particular stressed the need to be aware of past realities and that all proposed activities should be done in cooperation with the local communities. During the meeting held for all community members resident in the western Baviaanskloof (living outside the Baviaanskloof Nature Reserve), the following points were raised by attendees:

- the possibilities for workers involved in the project to obtain some kind of training course with a certification;
- the length of time before community members received money related to the proposed ARR project;
- the way in which the ARR system worked: who paid and how benefits were provided;
- the decision-making process within Zaaimanshoek; in contrast to farmers/ landowners, all decisions made by Zaaimanshoek community members needed to go through the church, as the community lived on church land, and deciding by oneself would not always be appropriate;
- the situation which would arise if one community was given preference over another, resulting in neighbouring community members trying to move to another community to benefit from the newly generated employment from the proposed ARR project; and
- the promising potential of the proposed ARR project to provide new income and employment opportunities in the area over the short to mid-term timeframes.

5th December 2007: Stakeholders sitting on the Baviaanskloof Steering Committee indicated that they were familiar with the proposed ARR project. No further comments were received.

1st February 2008: The Baviaanskloof Municipality responded with positive confirmation that pilot projects related to the proposed ARR project had received support from the municipal IDP Steering Committee and were slated for inclusion within the revised IDP.

19th February 2008: No comments were received during the meeting. Merwe de Preez (Board of Directors, Patensie Farmer's Association) and Pierre Joubert (Director, GIB) provided additional points of clarification to stakeholders present. Numerous farmers contacted project facilitators informally after the date and expressed interest in being kept informed about future experimental trials of the proposed ARR project.

8th March 2008: No major comments were made in relation to *P. afra* or the proposed ARR project consultation. Comments centred more on the motives for restoring water systems in the valley. Links were made to thicket restoration and a more integrated/combined 'labelling' for restoration activities for land-owners.

6.2 Report on how due account was taken of any comments received:

Indirect stakeholders residing adjacent to the project:
The majority of comments and feedback fielded during indirect stakeholder consultation related to future scenarios of the proposed ARR project should it be VCS approved and be in a position to be trialled on adjacent lands. In many cases, the project team did not yet have information available to speculate on those scenarios. In all such cases, project facilitators maintained openness and honesty in saying that they were unable to promise anything in the early phases but would duly record all concerns and investigate them accordingly.

October – November 2007: In response to scepticism about the proposed ARR project being another "here one day, gone the next" scenario, it was emphasized that the intention is to establish the proposed ARR project on a large-scale over the long-term. The project aims to benefit

both farmers and communities and everything will be done to ensure that the scenario eventuates. However, the success of the project moving forward rests largely, if not almost entirely, on the approval of the proposed ARR project in the Baviaanskloof Nature Reserve.

Whenever possible, answers were given to other concerns raised. For example, with concerns related to planting only *P. afra*, it was emphasized that *P. afra* should be seen as the financial entity– the catalyst – for reforestation which could then allow for the return of a host of other native species to the reforested area over time. It was explained that the proposed ARR project was open to receiving anecdotal evidence from stakeholders in terms of their own experiences with growing *P. afra*.

17th November 2007: In relation to concerns raised by farmers regarding the amount of research money being allocated for research and proposed ARR project accreditation, the project team agreed that whilst it was not the ideal situation, significant research was required to find out "what works and what does not" and what is needed to be done to certify the process and fill knowledge gaps. It was pointed out that the proposed ARR project is the driver to restore lands and it is therefore essential to determine whether *P. afra* reforestation can work so that money can be spent efficiently into the future. It was also stressed that the current financing for ARR is money earmarked for research, and the conditions of financing is that research funds cannot be used for any other purposes. A comparison was given that carbon farming could be seen like any other farming technique where, initially, industry/sectoral research was needed to determine how to maximize returns and efficiency for (e.g. livestock) farming and related effects and impacts. The project officers openly admitted that whilst the team was working very hard on gaining ARR accreditation, no guaranteed timeframe could be given for financial benefits linked to reforestation and it should be seen as a mid- to long-term investment.

27th November 2007: In relation to questions and discussion raised during the community meeting, Mr Mike Powell listened to concerns and provided clarification. This included explaining how the ARR process worked, a review of the rationale behind the proposed ARR project, and the ways in which the proposed ARR project could involve the communities. Mr Powell stressed that the proposed ARR project was optional to the community; they have the power to choose whether they want to become involved or not. In addition, it was made clear that the project was dependent on certification (in terms of being able to receive money) and that, should certification be received, the derived benefits must be shared. All other comments and concerns raised were dealt in a fair and open manner between meeting attendees.

8th March 2008: The meeting was a two-way discussion which included sharing of views and opinions.

6.3 Mechanisms for on-going communication

On-going communication will be facilitated through continued presence and presentations at the Annual Thicket Forum. Continual communication and meetings will be held with labourers, workers and relevant Baviaanskloof Nature Reserve staff.

A monitoring plan will be developed to monitor the continued well-being of workers on the project. A survey will be conducted annually by GIB and every labourer working for GIB's contractors will be interviewed. The survey will include questions designed to detect changes in the communities' perception of their well-being as a result of project activities.

7 Schedule:

Table to be inserted…

Chronological plan for the date of initiating project activities, date of terminating the project, frequency of monitoring and reporting and the project period, including relevant project activities in each step of the GHG project cycle.

8 Ownership:

8.1 Proof of Title:

8.1.1 Baviaanskloof Nature Reserve

Legal title: The land is owned by the Republic of South Africa.

Current land tenure: Provincial Reserve – Protected Area

Land use: Conservation of the natural ecosystems.

Management: Eastern Cape Parks Board

The ECPB manages the Baviaanskloof Nature Reserve, one site of the proposed ARR project. Please see Annex 5 for a statement from the ECPB explaining land ownership, reasons for restoration, benefits to the environment/local community and the necessity for carbon finance.

8.1.1 Addo Elephant National Park

Legal title: The land is owned by the Republic of South Africa.

Current land tenure: National Park – Protected Area

Land use: Conservation of the natural ecosystems.

Management: South African National Parks

South African National Parks are the managers of the land for the Addo Elephant National Park site of the proposed ARR project. Please see Annex 5 for a statement from SANParks explaining land ownership, reasons for restoration, benefits to the environment/local community and the necessity for carbon finance.

8.1.2 Great Fish River Nature Reserve

Legal title: The land is owned by the Republic of South Africa.

Current land tenure: Provincial Reserve – Protected Area

Land use: Conservation of the natural ecosystems.

Management: Eastern Cape Parks Board

The ECPB manages the Great Fish River Nature Reserve, one site of the proposed ARR project. Please see Annex 5 for a statement from the ECPB explaining land ownership, reasons for restoration, benefits to the environment/local community and the necessity for carbon finance.

8.1.3 Ownership of VERs

After validation, a financial entity(e.g. a trust or not-for-profit company) will be formed with the main stakeholders (namely ECPB, GIB, DWA, SANParks) being trustees or board members. This financial entity will own and trade the VERs generated by the project and will be managed by a management company assigned by the trustees or board members at a market-related rate. The distribution of income to stakeholders will be decided by the trustees or company board. Income will be used to reinvest in thicket restoration and planting of spekboom within the project. It would thus also be channelled back to communities around the reserves through increased employment of local contractors to do the work. (See Section 1.15.1 for more information)

8.2 Projects that reduce GHG emissions from activities that participate in an emissions trading program (if applicable):

Not applicable.

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10 Annexes

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Annex 2 Information regarding public funding

Table A.2.1: Funding provided by the Department of Water Affairs (DWA)

Year	Sector	Amount (R)
2005	Research	574,000
	Management	275,882
	Operational	891,118
	Nursery	180,000
	Total	1,921,000
2006	Research	677,000
	Management	726,790
	Operational	1,537,510
	Nursery	1,545,062
	Total	4,486,362
2007	Research	1,030,000
	Management	973,898
	Operational	1,786,932
	Nursery	2,260,000
	Total	6,050,830
2008	Research	2,015,369
	Management	2,054,135
	Operational	1,930,505
	Nursery	1,745,392
	Total	7,745,401
2009	Research	
	Management	
	Operational	
	Nursery	
	Total	7,104,813

Operational budget is the budget for contractors; this includes equipment charge out, transport, wages and 20 % capacity building

Annex 3 Fulfilment of sustainable development criteria

Table A.3.1: Project impacts on and contribution towards the sustainable development criteria of South Africa (as defined by the DNA)

Criteria		Indicator	Project Contribution to Sustainable development
Environmental	Impact on local environmental quality	• Impact of the project on air quality.	• The project will sequester CO_2 by fixing carbon in plant biomass and soil.
		• Impact of the project on water pollution.	• By planting indigenous vegetation (*P. afra)*, the project will improve water resource management through improved water quality and reduced erosion and siltation and sedimentation.
		• Impact of the project on the generation or disposal of solid waste.	• No major impact – small waste generation expected from plastic bags carrying plants.
		• Any other positive or negative environmental impacts of the project (such as impacts on noise, safety, visual impacts, or traffic).	• The project will not generate any negative impact on noise, safety or visual impact. Minor traffic increases may result from project worker's commuting to project areas and other stakeholder interest in the project. The project will enhance the visual and aesthetic appeal of the landscape through increased vegetation/land cover.
	Change in usage of natural resources	• Impact of the project on community access to natural resources.	• The project does not impact on community access to natural resources as all the project activities are within the boundary of lands managed by ECPB or SANParks (protected nature reserves).
		• Impact of the project on the sustainability of use of water, minerals other non renewable natural resources.	• The project will improve water retention in the catchment thus aiding water management.
		• Impact of the project on the efficiency of resource utilisation.	• The project does not have an impact on the sustainability of use of minerals or other non renewable natural resources nor does it impact the efficiency of resources utilization.
			• Increased prevalence of wild resources may occur for local communities living adjacent to the reserve (and they may benefit from cross-boundary flows).
	Impacts on biodiversity	• Changes in local or regional biodiversity arising from the project.	• The project will increase biodiversity status; *P. afra*, as a keystone thicket species, will contribute to: improved soil quality; creating a favourable microclimate and habitat for the re-introduction of other native flora and fauna; nutrient cycling within the

	and ecosystems		ecosystem; and stimulate increased pollination activity from bees/insects.
			• In addition to biodiversity gains, the project will also improve rainfall efficiency, ecosystem functioning and thereby meet national obligations within the Conventions of Biological Diversity and Desertification.
Economic	**Economic impacts**	• Impact of the project on foreign exchange requirements.	• The project will have limited impact on foreign exchange rate requirements.
		• Impact of the project on existing economic activity in the area.	• The proposed ARR activities will contribute to improving economic activity in the area through the creation of skilled and unskilled employment opportunities. The restored areas may also aid the success of nascent community programmes such as bee-keeping.
			• The proposed ARR project should encourage other local stakeholders to also implement the ARR project activities and thereby amplify expected project benefits.
		• Impact of the project on the cost of energy.	• The proposed ARR project will not impact upon the cost of energy.
		• Impact of the project on foreign direct investment.	• The proposed ARR project will not directly impact upon foreign direct investment but may encourage greater foreign investment in ARR projects throughout South Africa's Subtropical Thicket Biome.
	Appropriate technology transfer	• Positive or negative implications for the transfer of technology to South Africa arising from the project.	• The proposed ARR project has neither positive nor negative implications for the transfer of technology to South Africa.
		• Impact of the project on local skills development.	• The project will contribute to skills development of local employees related to carbon accounting.
		• Demonstration and replication potential of the project.	• The proposed ARR project has the potential to be replicated in other areas of the degraded Subtropical Thicket Biome and be used as an example for landowners and investors to develop a financially sustainable land use option.
Social	**Alignment with national,**	• How the project is aligned with the provincial and national government objectives.	• The proposed ARR activities will contribute to the provincial and national objectives of (rural) poverty alleviation through the provision of jobs, skills transfer, capacity building and provision of micro-business opportunities. The project also aligns with important

	provincial and local development priorities		national commitments such as the National Environmental Management Act and the Biodiversity Act.
		• How the project is aligned with local development objectives.	• The restoration of the Subtropical Thicket Biome directly aids local development through skilled and unskilled employment opportunities. Adjacent to the reserve, the project is likely to stimulate tourism-derived economic opportunities as well as supporting emerging initiatives such as community bee-keeping and medicinal plant collection. It should be noted that no communities have been, or will be, relocated as a result of the proposed ARR project.
		• Impact of the project on the provision of, or access to, basic services to the area.	• The proposed ARR project will not impact on the local provision or access of services as it falls within protected areas.
		• Impact of the project on the relocation of communities if applicable.	• No communities or individuals will be relocated as a consequence of the proposed ARR project.
		• Contribution of the project to any specific sectoral objectives (for example, renewable energy targets).	• On a sectoral level, the proposed restoration activities will contribute to: i) local community employment; ii) the science and education base; iii) regional and national conservation and biodiversity targets; iv) tourism development; v) the aims of restoring critical ecosystem services such as water quality provisioning, soil retention, biodiversity, wildlife habitat and the wilderness appeal of the project areas.
	Social equity and poverty alleviation	• Impact of the project on employment levels? (specify the number of jobs created/lost; the duration of time employed, distribution of employment opportunities, types of employment, categories of employment changes in terms of skills levels and gender and racial equity).	• The proposed ARR activities will create employment of an estimated 300 jobs for local people on a seasonal basis. The employment will be on a contract basis and entails physical labour (planting of cuttings) for the majority of employees. Each team will have 13 labourers with a team leader who is trained to manage the contract, and earmarked to become a business person (carbon entrepreneur). An additional ten labourers will be trained to be field technicians, to be able to sample soils and plants, and enter data. A further 15 labourers will be employed in a nursery operated by DWA. The team composition will follow the National Government guidelines of the poverty relief principles (i.e. those taken up by the Department of Public Enterprises', "Expanded Public Works Programme") under which at least 60% of employees are required to be women and at least 25% of employees are required to be youth.
		• Impact of the project on community social structures.	• Other than the positive impacts described above, there are no foreseen negative impact on community social structures, social heritage and the provision of social amenities to the community as a result of the proposed ARR project. It is likely that these

			aspects will be enhanced during the course of the project.
		• Impact of the project on social heritage.	"
		• Impact of the project on the provision of social amenities to the community in which the project is situated.	"
		• Contribution of the project to the development of previously underdeveloped areas or specially designated development nodes.	• Future stages of the proposed ARR project are expected to have a positive impact on the development of previously underdeveloped areas or specially designated development nodes in rural areas at various scales.
General	**General project acceptability**	• Are the distribution of project benefits reasonable and fair?	• The project intends to fairly distribute expected benefits from the project between contributing stakeholder groups: reserve managers, project workers and project facilitators and in accordance with Government guidelines. The proposed ARR activities contribute to regional and national economic development.
			•The project conforms to the NEMA principles of sustainable development in that CO_2 emissions will be sequestered whilst there will be no negative impacts on natural resource requirements, the environment or local communities.
			• The project makes a tangible contribution towards the Millennium Development Goals.

Annex 4 GPS co-ordinates for ARR planting sites

Table A.4.1: GPS co-ordinates of bounding boxes for each planting site surveyed in the project areas.

Project Area	Contract Code*	Contract Size (ha)	Corner 1 (most North East)	Corner 2 (most North West)	Corner 3 (most South East)	Corner 4 (most South West)
Baviaanskloof Nature Reserve	92001083	6.2	24.409408, -33.652775	24.412102, -33.652475	24.410339, -33.654244,	24.413076, -33.654352
	92001077	5.9	24.414100, -33.654659,	24.416271, -33.654788,	24.414067, -33.657392	24.416239, -33.657384,
	92001074	5.9	24.413630, -33.654524,	24.417746, -33.654829	24.413437, -33.656754	24.419250, -33.657190
	92001041	7.8	24.404376, -33.665143	24.408190, -33.664312	24.405580, -33.666942,	24.407496, -33.666813
	92001133	3.9	24.380175, -33.671419	24.382091, -33.671055,	24.382160, -33.672833	24.383495, -33.672292
	92001134	4.9	24.379540, -33.666867	24.380941, -33.667417	24.377865, -33.668251	24.379542, -33.669519
	92001037	10.7	24.212589, -33.603307	24.213632, -33.603734	24.207271, -33.606264	24.208577, -33.608445
	92001048	5.4	24.214885, -33.604036	24.216547, -33.604525	24.213548, -33.605794	24.216154, -33.606243,
	92001044	9.5	24.208968, -33.600885	24.210114, -33.600848	24.209673, -33.603721,	24.210754, -33.604045
	92001036	2.3	24.324152, -33.640218	24.345393, -33.646107	24.332073, -33.646929,	24.345908, -33.646962
	92001067	5.0	24.303424, -33.639082	24.307303, -33.640806	24.303383, -33.640161	24.306498, -33.642996
	92001027	4.9	24.246527, -33.607902,	24.247397, -33.607158	24.245757, -33.609234	24.248864, -33.610124,
	92001056	5.4	24.290400, -33.631969,	24.294874, -33.629824	24.293086, -33.632293	24.294704, -33.631690
	92001062	4.4	24.292527, -33.632423	24.294680, -33.631697	24.290721, -33.633274	24.293284, -33.634866
	92001053	3.4	24.294748, -33.626031	24.295268, -33.626973	24.293270, -33.628848,	24.294758, -33.629567,
	92001018	3.5	24.294609, -33.627500,	24.296157, -33.628080,	24.294963, -33.629609,	24.296937, -33.629383
	92001022	3.5	24.266580, -33.624834	24.268415, -33.625777	24.265748, -33.626105	24.267806, -33.626996
	92001028	2.8	24.265772, -33.626110	24.267789, -33.626987,	24.265046, -33.627127	24.267226, -33.628133
	92001013	2.9	24.261496, -33.612755	24.262257, -33.612085	24.263774, -33.614405	24.264445, -33.613782
	92001057	5.3	24.249814, -33.619762	24.251762, -33.619508	24.249091, -33.622380	24.250567, -33.622089
	92001065	5.5	24.261811, -33.615895	24.264328, -33.616026	24.262734, -33.618023	24.265139, -33.618032,
	92001014	2.8	24.260704, -33.613308	24.261495, -33.612771	24.263012, -33.615059	24.263748, -33.614400,

	92001032	14.2	24.252595, -33.615545	24.255284, -33.615289	24.251960, -33.619211	24.256274, -33.619277
	92001043	13.8	24.604448, -33.672081	24.608945, -33.669405	24.604672, -33.673624	24.611276, -33.671698
	92001045	4.5	24.613874, -33.671675	24.614415, -33.671120	24.616251, -33.673926,	24.617833, -33.672638
	92001061	4.4	24.616447, -33.671237	24.619801, -33.671060	24.616355, -33.672203	24.620954, -33.672727
	92001005	5.7	24.573192, -33.680300	24.577803, -33.679187	24.572320, -33.681627	24.578148, -33.680735
	92001011	4.8	24.578089, -33.680828	24.582218, -33.682288,	24.580877, -33.683709	24.583404, -33.683711,
	92001015	4.5	24.580871, -33.683709	24.583408, -33.683726,	24.582168, -33.685528	24.584206, -33.685370
	92001026	3.8	24.586216, -33.681103	24.586580, -33.680850	24.586606, -33.685161,	24.588661, -33.684551
Addo Elephant National Park	0	6.3	25.237854, -33.132351	25.233352, -33.132351	25.237854, -33.135064	25.233352, -33.135064
	1	5.5	25.236789, -33.133610	25.232374, -33.133610	25.236789, -33.136158	25.232374, -33.136158
	2	5.6	25.224289, -33.144618	25.220954, -33.144618	25.224289, -33.147662	25.220954, -33.147662
	3	5.7	25.212591, -33.181332	25.209949, -33.181332	25.212591, -33.184249	25.209949, -33.184249
	4	5.5	25.210223, -33.181793	25.207540, -33.181793	25.210223, -33.184617	25.207540, -33.184617
	5	3.3	25.204695, -33.199654	25.201695, -33.199654	25.204695, -33.201650	25.201695, -33.201650
	6	5.4	25.202400, -33.202102	25.198509, -33.202102	25.202400, -33.204637	25.198509, -33.204637
	7	3.1	25.235663, -33.174899	25.230106, -33.174899	25.235663, -33.177665	25.230106, -33.177665
	8	5.9	25.243247, -33.171555	25.240127, -33.171555	25.243247, -33.174474	25.240127, -33.174474
	9	2.3	25.235182, -33.175848	25.233077, -33.175848	25.235182, -33.178793	25.233077, -33.178793
	10	2.9	25.236177, -33.175508	25.234045, -33.175508	25.236177, -33.178476	25.234045, -33.178476
	11	2.9	25.236236, -33.172390	25.233540, -33.172390	25.236236, -33.173949	25.233540, -33.173949
	12	3.6	25.239154, -33.172661	25.236270, -33.172661	25.239154, -33.174550	25.236270, -33.174550
	13	2.3	25.289462, -33.190218	25.287936, -33.190218	25.289462, -33.192529	25.287936, -33.192529
	14	5.6	25.286754, -33.189503	25.283564, -33.189503	25.286754, -33.191913	25.283564, -33.191913
	15	5.8	25.247145, -33.173897	25.242910, -33.173897	25.247145, -33.175717	25.242910, -33.175717
	16	1.4	25.269455, -33.170154	25.267849, -33.170154	25.269455, -33.171176	25.267849, -33.171176
	17	4.9	25.272998, -33.169277	25.269380, -33.169277	25.272998, -33.171114	25.269380, -33.171114
	18	4.7	25.273875, -33.170491	25.270933, -33.170491	25.273875, -33.172660	25.270933, -33.172660
	19	4.7	25.267033, -33.171273	25.263467, -33.171273	25.267033, -33.173222	25.263467, -33.173222

20	5.3	25.270156, -33.171324	25.266567, -33.171324	25.270156, -33.173310	25.266567, -33.173310
21	4.1	25.213769, -33.186824	25.208945, -33.186824	25.213769, -33.188196	25.208945, -33.188196
22	3.9	25.213775, -33.185774	25.209245, -33.185774	25.213775, -33.187562	25.209245, -33.187562
23	3.1	25.288503, -33.171278	25.285935, -33.171278	25.288503, -33.172999	25.285935, -33.172999
24	5.0	25.291236, -33.168778	25.286473, -33.168778	25.291236, -33.171668	25.286473, -33.171668
25	6.1	25.234150, -33.139324	25.229900, -33.139324	25.234150, -33.142723	25.229900, -33.142723
26	6.8	25.231123, -33.182604	25.220426, -33.182604	25.231123, -33.186364	25.220426, -33.186364
27	8.4	25.286397, -33.182467	25.280983, -33.182467	25.286397, -33.185439	25.280983, -33.185439
28	3.1	25.312980, -33.189794	25.309517, -33.189794	25.312980, -33.191452	25.309517, -33.191452
29	3.1	25.313583, -33.188336	25.310111, -33.188336	25.313583, -33.189997	25.310111, -33.189997
30	2.6	25.296953, -33.183566	25.293200, -33.183566	25.296953, -33.185018	25.293200, -33.185018
31	1.2	25.288440, -33.176466	25.287313, -33.176466	25.288440, -33.178249	25.287313, -33.178249
41	0.9	25.314143, -33.188180	25.312822, -33.188180	25.314143, -33.189105	25.312822, -33.189105
42	30.1	25.324957, -33.195126	25.316950, -33.195126	25.324957, -33.199851	25.316950, -33.199851
43	37.1	25.317396, -33.194390	25.306578, -33.194390	25.317396, -33.199491	25.306578, -33.199491
44	37.1	25.300193, -33.191524	25.290527, -33.191524	25.300193, -33.197998	25.290527, -33.197998
45	30.2	25.307655, -33.172805	25.295870, -33.172805	25.307655, -33.176157	25.295870, -33.176157
46	29.7	25.285108, -33.168745	25.277567, -33.168745	25.285108, -33.174573	25.277567, -33.174573
48	30.1	25.316385, -33.174427	25.304570, -33.174427	25.316385, -33.180910	25.304570, -33.180910
49	28.1	25.307995, -33.195635	25.298183, -33.195635	25.307995, -33.199627	25.298183, -33.199627
50	23.1	25.314229, -33.183276	25.306562, -33.183276	25.314229, -33.188325	25.306562, -33.188325
51	23.1	25.294577, -33.187110	25.287811, -33.187110	25.294577, -33.193012	25.287811, -33.193012
52	26.1	25.289768, -33.178621	25.285031, -33.178621	25.289768, -33.186927	25.285031, -33.186927
53	26.1	25.298531, -33.176487	25.288842, -33.176487	25.298531, -33.182366	25.288842, -33.182366
0	26.0	25.326233, -33.168342	25.313801, -33.168342	25.326233, -33.172194	25.313801, -33.172194
1	26.0	25.324933, -33.171895	25.311807, -33.171895	25.324933, -33.176052	25.311807, -33.176052
3	26.0	25.300708, -33.173512	25.289870, -33.173512	25.300708, -33.179533	25.289870, -33.179533
4	26.0	25.307027, -33.179772	25.298070, -33.179772	25.307027, -33.184923	25.298070, -33.184923

	5	26.0	25.293290, -33.189762	25.284173, -33.189762	25.293290, -33.197976	25.284173, -33.197976
	6	26.0	25.322021, -33.202504	25.312718, -33.202504	25.322021, -33.205310	25.312718, -33.205310
	7	26.0	25.312575, -33.200869	25.303683, -33.200869	25.312575, -33.204810	25.303683, -33.204810
	8	1.9	25.285447, -33.188681	25.283153, -33.188681	25.285447, -33.190454	25.283153, -33.190454
	9	2.3	25.298903, -33.184377	25.296275, -33.184377	25.298903, -33.185699	25.296275, -33.185699
	10	8.7	25.303592, -33.190358	25.295522, -33.190358	25.303592, -33.195668	25.295522, -33.195668
Great Fish River Nature Reserve	0	1.3	26.637968, -33.094397	26.636213, -33.094397	26.637968, -33.095735	26.636213, -33.095735
	1	3.5	26.639313, -33.095281	26.635170, -33.095281	26.639313, -33.097353	26.635170, -33.097353
	2	8.2	26.634981, -33.095197	26.630487, -33.095197	26.634981, -33.098113	26.630487, -33.098113
	3	3.1	26.635350, -33.097383	26.630487, -33.097383	26.635350, -33.099674	26.630487, -33.099674
	4	6.9	26.632620, -33.097183	26.628856, -33.097183	26.632620, -33.100285	26.628856, -33.100285
	5	3.4	26.654550, -33.108213	26.650683, -33.108213	26.654550, -33.109429	26.650683, -33.109429
	6	3.2	26.656161, -33.104867	26.653639, -33.104867	26.656161, -33.108289	26.653639, -33.108289
	7	2.4	26.663955, -33.104452	26.661069, -33.104452	26.663955, -33.106111	26.661069, -33.106111
	8	2.9	26.667951, -33.105284	26.663907, -33.105284	26.667951, -33.106228	26.663907, -33.106228
	9	3.7	26.673744, -33.127602	26.672032, -33.127602	26.673744, -33.130919	26.672032, -33.130919
	10	4.3	26.675077, -33.127707	26.672954, -33.127707	26.675077, -33.130978	26.672954, -33.130978
	11	7.1	26.633890, -33.091500	26.629533, -33.091500	26.633890, -33.094322	26.629533, -33.094322
	12	5.2	26.628966, -33.098984	26.625106, -33.098984	26.628966, -33.102216	26.625106, -33.102216
	13	7.5	26.628249, -33.097553	26.624152, -33.097553	26.628249, -33.101526	26.624152, -33.101526
	14	22.5	26.632680, -33.090963	26.624653, -33.090963	26.632680, -33.099654	26.624653, -33.099654
	15	0.0	26.635088, -33.093360	26.635072, -33.093360	26.635088, -33.093375	26.635072, -33.093375
	16	1.9	26.636350, -33.093317	26.634520, -33.093317	26.636350, -33.094937	26.634520, -33.094937
	17	6.3	26.636111, -33.093659	26.631488, -33.093659	26.636111, -33.096292	26.631488, -33.096292
	18	13.6	26.636414, -33.088633	26.630353, -33.088633	26.636414, -33.095219	26.630353, -33.095219

* Contract codes are not provided for the plantings in Addo Elephant National Park and GFRNR in this table, However they are available from the project implementer.

Table A.4.2: GPS coordinates of sample sites in the Baviaanskloof Nature Reserve used to collect field data on carbon sequestration in spekboom thicket.

	GPS coordinates (decimal degrees)			GPS coordinates (decimal degrees)	
Site Code	X	Y	Site Code	X	Y
RHST15	24.43172	-33.65266	RHOL24	24.41584	-33.65557
RHST13	24.43026	-33.65319	RHOL22	24.41567	-33.65557
RHST12	24.43009	-33.65347	RHOL13	24.41372	-33.65529
RHST11	24.42993	-33.65374	RHOL14	24.41388	-33.65516
RHST14	24.43074	-33.65388	RHOL15	24.41404	-33.65502
RHST21	24.40272	-33.65569	RHOL17	24.41454	-33.65490
RHST25	24.40402	-33.65542	RHOL18	24.41470	-33.65476
RHST23	24.40386	-33.65556	RHOL20	24.41485	-33.65476
RHST22	24.40370	-33.65583	RHOL25	24.41583	-33.65530
RHST24	24.40403	-33.65584	RHST3	24.36907	-33.66735
RHST16	24.42545	-33.65735	RHST1	24.36860	-33.66803
RHST17	24.42643	-33.65803	RHST2	24.36874	-33.66802
RHST18	24.42723	-33.65790	RHST4	24.36973	-33.66668
RHST19	24.42804	-33.65749	RHST5	24.37037	-33.66776
RHST20	24.42853	-33.65737	RHST7	24.35370	-33.65444
RHOL1	24.40992	-33.65287	RHST6	24.35352	-33.65538
RHOL3	24.41008	-33.65315	RHST10	24.35402	-33.65537
RHOL2	24.41007	-33.65328	RHST9	24.35384	-33.65551
RHOL4	24.41057	-33.65287	RHST8	24.35384	-33.65579
RHOL5	24.41088	-33.65329	KASS5	24.27587	-33.63557
RHOL6	24.41105	-33.65329	KASS1	24.27569	-33.63572
RHOL7	24.41138	-33.65288	KASS2	24.27649	-33.63640
RHOL8	24.41169	-33.65289	KASS3	24.27698	-33.63639
RHOL10	24.41218	-33.65316	KASS4	24.27732	-33.63532
RHOL9	24.41218	-33.65329	KRC3	24.20931	-33.60192
RHOL11	24.41234	-33.65397	KRC1	24.20897	-33.60315
RHOL12	24.41282	-33.65410	KRC2	24.20913	-33.60315
RHDST21	24.42462	-33.66636	KRC4	24.21043	-33.60275
RHDST22	24.42592	-33.66582	KRC5	24.21094	-33.60207
RHDST23	24.42624	-33.66570	KQ3	24.33339	-33.64716
RHDST24	24.42640	-33.66542	KQ1	24.33305	-33.64769
RHDST25	24.42722	-33.66529	KQ2	24.33340	-33.64770
RHDST16	24.41109	-33.66712	KQ4	24.33371	-33.64743
RHDST19	24.41190	-33.66780	KQ5	24.33451	-33.64757
RHDST18	24.41174	-33.66793	KKK1	24.21363	-33.61279
RHDST17	24.41139	-33.66820	KKK2	24.21377	-33.61320
RHDST20	24.41221	-33.66808	KKK3	24.21445	-33.61239
RHDST11	24.40286	-33.66854	KKK4	24.21476	-33.61211
RHDST13	24.40401	-33.66896	KKK5	24.21510	-33.61281
RHDST12	24.40319	-33.67044	KKO2	24.31440	-33.64283
RHDST14	24.40431	-33.67045	KKO1	24.31440	-33.64362

RHDST15	24.40529	-33.67004	KKO3	24.31537	-33.64350
RHDST6	24.37878	-33.66863	KKO4	24.31555	-33.64322
RHDST7	24.37926	-33.66877	KKO5	24.31586	-33.64404
RHDST8	24.37942	-33.66836	KAD5	24.29387	-33.63090
RHDST9	24.38040	-33.66810	KAD4	24.29371	-33.63118
RHDST10	24.38056	-33.66823	KAD7	24.29501	-33.63091
RHDST1	24.41431	-33.65649	KAD8	24.29566	-33.63118
RHDST3	24.41463	-33.65675	KAD10	24.29387	-33.63198
RHDST2	24.41445	-33.65689	KAD6	24.29436	-33.63213
RHDST4	24.41705	-33.65717	KAD9	24.29370	-33.63361
RHDST5	24.41785	-33.65758	KCAB5	24.24847	-33.63172
RHOL16	24.41452	-33.65557	KCAB3	24.24814	-33.63226
RHOL19	24.41485	-33.65598	KCAB2	24.24782	-33.63253
RHOL21	24.41533	-33.65597	KCAB1	24.24748	-33.63280
RHOL23	24.41583	-33.65586	KCAB4	24.24830	-33.63320
KAD1	24.29508	-33.62811	GHST15	24.62641	-33.66047
KAD2	24.29528	-33.62892	GHST10	24.62787	-33.66060
KAD3	24.29530	-33.62921	GHST6	24.62576	-33.66154
KGHB1	24.25313	-33.61595	GHST13	24.62593	-33.66182
KGHB2	24.25476	-33.61640	GHST7	24.62642	-33.66155
KGHB5	24.25447	-33.61709	GHST9	24.62788	-33.66101
KGHB3	24.25339	-33.61730	GHST4	24.60490	-33.67451
KGHB4	24.25393	-33.61798	GHST2	24.60382	-33.67473
KDH3	24.26670	-33.62531	GHST3	24.60461	-33.67563
KDH1	24.26649	-33.62562	GHST1	24.60381	-33.67675
KDH4	24.26724	-33.62572	GHST5	24.60652	-33.67611
KDH2	24.26664	-33.62621	GHOL2_1	24.62695	-33.65838
KDH5	24.26690	-33.62676	GHOL2_2	24.62711	-33.65866
KLK1	24.24637	-33.60917	GHOL2_3	24.62840	-33.65920
KLK3	24.24719	-33.60787	GHOL2_5	24.62970	-33.66003
KLK2	24.24718	-33.60808	GHOL2_4	24.62857	-33.66014
KLK6	24.24769	-33.60830	GHOL3_2	24.61526	-33.65708
KLK5	24.24771	-33.60852	GHOL3_3	24.61574	-33.65749
KLK4	24.24743	-33.60942	GHOL3_	24.61913	-33.65912
KLK7	24.24797	-33.60966	GHOL3_1	24.61429	-33.65708
KLK8	24.24851	-33.60964	GHOL3_4	24.61801	-33.65750
KLK9	24.24880	-33.60921	GHOL1_3	24.61460	-33.67079
KLK10	24.24879	-33.60898	GHOL1_1	24.61443	-33.67188
CNST1	24.57411	-33.68215	GHOL1_2	24.61459	-33.67242
CNST3	24.57526	-33.68126	GHOL1_4	24.61604	-33.67148
CNST5	24.57611	-33.68217	GHOL1_6	24.61733	-33.67162
CNST4	24.57580	-33.68269	GHOL1_7	24.61750	-33.67216
CNST2	24.57551	-33.68268	GHOL1_5	24.61669	-33.67311
CEST3	24.57865	-33.68270	GHOL1_8	24.61864	-33.67135
CEST4	24.57839	-33.68291	GHOL1_9	24.61944	-33.67203
CEST1	24.57803	-33.68334	GHOL1_10	24.61977	-33.67162

CEST2	24.57830	-33.68337	GHST12	24.62496	-33.65992
CEST5	24.57888	-33.68316	GHST8	24.62674	-33.65965
COLN6	24.57378	-33.68053			
COLN5	24.57397	-33.68026			
COLN4	24.57427	-33.68038			
COLN3	24.57488	-33.68009			
COLN2	24.57574	-33.68005			
COLE1	24.58092	-33.68311			
COLE4	24.58229	-33.68269			
COLE5	24.58282	-33.68317			
COLE3	24.58192	-33.68406			
COLE2	24.58133	-33.68431			
GHST11	24.62448	-33.65882			
GHST16	24.62529	-33.65938			
GHST14	24.62611	-33.65911			

Annex 5 Letters of A/R Project approval from stakeholders

Figure A.5.1: Letter from the Eastern Cape Parks Board (EPCB)

EASTERN CAPE
PARKS

STATEMENT ON THE SUBTROPICAL THICKET RESTORATION PROJECT

1) The Subtropical Thicket Restoration Project is taking place within the confines of the Baviaanskloof Nature Reserve and the Great Fish River Nature Reserve.
2) Project land is owned by the Republic of South Africa and managed by the Eastern Cape Parks Board.
3) The open degraded landscapes that are being restored by planting spekboom (*Portulcaria afra*) were cleared in the past, prior to a protected area being proclaimed, and were formed either through goat pastoralism or intensive agriculture.
4) These landscapes are no longer used for agriculture, and are being managed as nature reserve land.
5) The Eastern Cape Parks Board would like to restore these open degraded landscapes back to the original vegetation; however, unless costs are recouped from carbon credits, such an initiative would not happen. This is because restoration on such a large scale is prohibitively expensive for government biodiversity budgets. In other words: without carbon finance, these landscapes would remain in a degraded condition. In part this is evident because there are no other large-scale restoration projects taking place on conservation land within the Eastern Cape or indeed South Africa.
6) The benefits of restoration include job creation, reduced silt loads in dams and rivers, greater ecosystem productivity, improved aesthetics, improved habitat for many forms of biodiversity, and improved biodiversity in terms of shrubs and trees.
7) The Subtropical Thicket Restoration Project is a VSC project based on a small-scale CDM methodology; consequently a significant proportion of the funds received from VER's will be channelled back to local communities that live adjacent to or within the Baviaanskloof and Great Fish River Nature Reserves. This will be through the employment of local contractors to conduct the work.

07/06/2010

D. Balfour
Acting Director: Conservation
Eastern Cape Parks Board

07/06/2010

N. Rangee
Acting CEO
Eastern Cape Parks Board

WE PROMISE THE EARTH

6 St Marks Road | Southernwood
East London | 5213

P.O.Box 11235 | Southernwood
East London | 5213

Tel: +27 (0) 43 705 4400

www.ecparks.co.za

Eastern Cape Parks Board trading as Eastern Cape Parks

Figure A.5.2: Letter from the Department of Water

Figure A.5.3: Letter from the Gamtoos Irrigation Board (GIB)

GAMTOOS-
BESPROEIINGSRAAD
Posbus 237 P.O.Box
6335 Patensie

GAMTOOS
IRRIGATION BOARD
Telefoon/Telephone: (042) 283 0329
Faks/Fax:: (086) 675 0113
E-pos/E-mail: gamtoos@lantic.net

2008 National award winner: Water Conservation and Water Demand Management
Implementing Agent for Working for Water and Working for Wetlands projects

29 July 2010

To whom it may consern

The Gamtoos Irrigation Board (GIB) is responsible for implementation of the VCS ARR project entitled "Spekboom Thicket Restoration Project" GIB is directly responsible for the following:

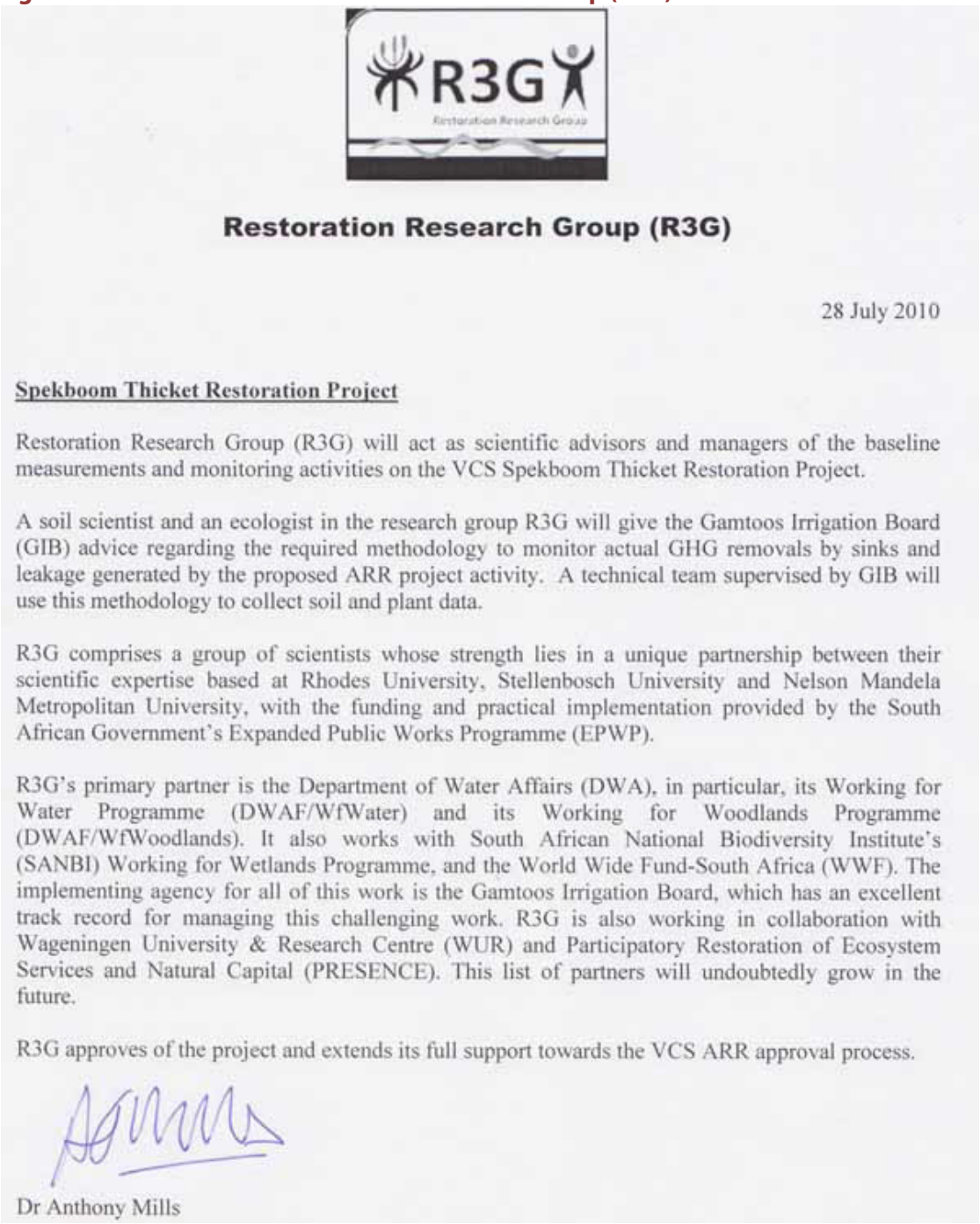
- Selecting sites for planting;
- Appointing contractors:
- Harvesting and planting of *Portulacaria afra* cuttings.
- Sampling of soils and biomass for carbon accounting;
- Monitoring the project in accordance with the procedures set out in the project document.
- Ensuring the safe keeping of any data or methodology in their possession.

GIB approves of the project and extends its full support towards the VCS ARR approval process.

Yours sincerely

Rienette Colesky
Aministration Manager

Figure A.5.4: Letter from Restoration Research Group (R3G)



Restoration Research Group (R3G)

28 July 2010

Spekboom Thicket Restoration Project

Restoration Research Group (R3G) will act as scientific advisors and managers of the baseline measurements and monitoring activities on the VCS Spekboom Thicket Restoration Project.

A soil scientist and an ecologist in the research group R3G will give the Gamtoos Irrigation Board (GIB) advice regarding the required methodology to monitor actual GHG removals by sinks and leakage generated by the proposed ARR project activity. A technical team supervised by GIB will use this methodology to collect soil and plant data.

R3G comprises a group of scientists whose strength lies in a unique partnership between their scientific expertise based at Rhodes University, Stellenbosch University and Nelson Mandela Metropolitan University, with the funding and practical implementation provided by the South African Government's Expanded Public Works Programme (EPWP).

R3G's primary partner is the Department of Water Affairs (DWA), in particular, its Working for Water Programme (DWAF/WfWater) and its Working for Woodlands Programme (DWAF/WfWoodlands). It also works with South African National Biodiversity Institute's (SANBI) Working for Wetlands Programme, and the World Wide Fund-South Africa (WWF). The implementing agency for all of this work is the Gamtoos Irrigation Board, which has an excellent track record for managing this challenging work. R3G is also working in collaboration with Wageningen University & Research Centre (WUR) and Participatory Restoration of Ecosystem Services and Natural Capital (PRESENCE). This list of partners will undoubtedly grow in the future.

R3G approves of the project and extends its full support towards the VCS ARR approval process.

Dr Anthony Mills

Figure A.5.5: Letter from CSS

CSS Geographical Information Specialists
PO Box 504 · Grahamstown · 6140
61 New Street · Grahamstown · 6139
Tel: +27 (46) 6224526
Fax: +27 (46) 6227931
info@cssgis.co.za

8 October 2010

To Whom It May Concern:

Conservation Support Services (CSS) has been contracted by Gamtoos Irrigation Board (GIB) as the mapping and GIS service provider for the Spekboom Thicket Restoration Project. CSS will conduct all the spatial development work for the project, as well as house and maintain the database and archive the data spatial, attribute and social (worker) data. CSS has been contracted as the mapping and GIS service provider by GIB for various projects over the last 8 years.

CSS approves and commits itself to the project and its contract with GIB, and extends its full support towards the VCS ARR approval process.

Yours sincerely

Martin Bekker
Director

Reg number: 2006/027716/07, Vat number 4290184110
Directors: M. Bekker; B. Cobbing, C Hlope, Acacia Karoo Trust
www.cssgis.co.za

Figure A.5.6: Letter from the Eastern Cape provincial Department of Economic Development and Environmental Affairs (DEDEA): NEMA EIA Waiver

From: Andries Struwig [mailto:Andries.Struwig@deaet.ecape.gov.za]
Sent: 24 July 2008 14:30
To: Dr A.M. Sigwela
Cc: Davalan Govender; mills@sun.ac.za
Subject: RE: EIA exemption request

Dr. Sigwela

It is hereby confirmed that the rehabilitation of degraded land in order to attempt to restore naturally functioning plant communities and ecosystems, is not a specific listed activity as contemplated in the NEMA EIA Regulations and therefore would not require authorisation from this department. You are however advised to take cognizance of specific listed activities that may be relevant depending on the scope of individual projects e.g. any rehabilitation that may take place within a river course/wetland or rehabilitation that takes place within 100m from the high water mark of the sea etc.

I trust that this answers your query.

Regards.

Andries Struwig
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Western Region
Department of Economic Development & Environmental Affairs
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6057
Tel: +27 41 5085844
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Figure A.5.7: Statement on the modalities of communication with the UNFCCC secretariat .

January 21, 2008

STATEMENT ON THE MODALITIES OF COMMUNICATING WITH THE CDM EXECUTIVE BOARD AND THE UNFCCC SECRETARIAT

Further to the proposed registration of the South African government's Department of Water Affairs and Forestry (DWAF) Thicket Restoration Project, please note that:

- The Rhodes Restoration Group, a project participant, will be responsible for all communication with the CDM Executive Board and UNFCCC secretariat.
- The individual contact will be Dr. Anthony Mills who has been authorized, by all project participants, to communicate with the Executive Board and UNFCCC Secretariat.

Dr. Anthony Mills shall be authorized to instruct the Executive Board and UNFCCC Secretariat regarding allocations and/or distribution of CERs upon issuance of the same. The project participants confirm that they shall, on request, without demur, provide such letter, document, paper, writing or instrument required, and such form as requested, for the above purpose.

This statement shall be valid until a new statement, superseding this statement, is signed by the project participants and has been submitted to the Executive Board and UNFCCC Secretariat.

Dr Anthony Mills — *signature*
Rhodes Restoration Research Group

Authorized Signatory Specimen Signatures

Name — *signature*
Department of Water Affairs and Forestry (National Working for Water Programme)

Name — *signature*
Eastern Cape Parks Board
W. M. ERLANK

Name — *signature*
Gamtoos Irrigation Board

Figure A.5.8: Indication of support for the A/R project from the GIB contract workers.

MINUTES OF THE WORKERS SUPPORT MEETING
SUBTROPICAL THICKET RESTORATION PROJECT
11th OF JUNE 2007

Location: Gamtoos Irrigation Board Hall

Time: 10h00 to 11h00

Present: Mike Powell (Technical Advisor), Yolande Vermaak (Project Manager), all project contractors and their workers (see Appendix I)

Aim of meeting: to inform workers on the Subtropical Thicket Restoration Project goals and objectives; and to ascertain whether the workers support the project.

Minutes

Mike opened by giving the group a brief overview of what the meeting was about. To increase funding for future projects, there are certain guidelines that must be followed including ensuring that the workers are well informed of the project that they are working on.

Mike: Where does petrol come from?

Yolande: From oil

Mike: Oil comes from deep underground where dead trees sank to the bottom of the sea and combined with minerals to form oil. This happened slowly over millions of years and it is now very valuable as a source of energy. When we drive a car, the gases that come from the exhaust pipe build up in the Earth's atmosphere and work like a greenhouse – the gases let the sun's rays come through but they trap the heat inside. The more fuel we use, the more gases in the atmosphere and the warmer the Earth is going to become. This is a very significant issue for everyone because the temperatures everywhere will become hotter; however, we still rely heavily on burning oil for fuel and electricity.

To solve this problem, countries have to reduce their use of fuel. In 1997, many countries around the world came together and signed an agreement called the Kyoto Protocol where they agreed to reduce their country's carbon levels in the air.

What can developing countries do? Planting trees is a very effective way of working towards lowering the levels of carbon in the atmosphere as well as employing large numbers of local people. Trees need carbon to grow so they use their leaves to take carbon from the air which then reduces carbon in the atmosphere. That is why Kiewiet's team did soil surveys to find out the level of carbon in the soil and Johanna's team did the allometry work to find out the level of carbon in the trees. Spekboom has been found to absorb large amounts of carbon when it grows, more than most plants. If we can prove that by planting spekboom we can harvest a large amount of carbon per hectare, we can sell that carbon to companies and larger countries to balance out all the carbon that they are burning and releasing into the air. On the carbon market, 1 tonne of carbon is worth up to 20 Euro (200 Rand).

To continue this research and create more jobs in the future, we need to apply for more funding from overseas. To apply, we need a letter from the workers who are conducting the work on the ground which says that they understand what they are doing and what the project is focused on.

Mike used both English and Afrikaans so that everyone was able to follow what was being said. The workers confirmed that they supported the project and only had questions about logistical issues. These included:

i) Cedric had a problem with the carrying out of the spekboom cuttings.
ii) Loretta wanted to know why they cannot fence off the area where they have planted, to prevent the baboons from causing damage.

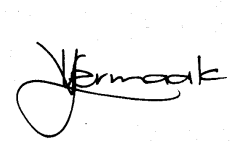
Mike responded as follows:

i) Perhaps they should cut fewer truncheons during the stockpiling phase. It is, however, important that the truncheons do not lie more than five days before planting.
ii) Cost wise it is not feasible, the teams will have to come up with a proposal.

The contractors and workers were then asked whether they understood and supported the project to which all responded positively. The register (Appendix I) was signed to indicate their support.

Signed:

Date:



Yolande Vermaak
Project Manager

Edwill Moore
Finance Manager

SUBTROPICAL THICKET RESTORATION PROJECT WORKERS

Attendance Register **Date:** 11/6/07

Name & Surname	Designation	ID number	Signature
Sherelene Tarentaal	G.Worker-Nursery	8702100112088	Tarentaal
Kaatjie Tarentaal	G.Worker-Nursery	5602240164085	Klarentaal
Charmand Swarts	^	8508250160086	Swarts
Suné Magielies	^	8605190224087	S.Magielies
Lenelia Boardman	^	7107070263084	L.Boardman
Angela Windvoël	^	6907071220081	A. Windvoël
Siena Mapoe	^	6906150260083	S Mapoe
Ragel Pietersen	Contractor-Nursery	6704210554086	R. Pietersen
Thanduxolo Anton	G.Worker-Nursery	8004045340084	T.Anton
Brian Prins	Stock Controller Nursery	8306105266087	B Prins
Franchwa Zana	G.Worker-Nursery	8512115247088	Zana
Enrico Zana	Herbicide App. Nursery	8008175227086	[illegible]
Ryno Zana	G.Worker-Nursery	8809205164086	[illegible]
Elroy Swarts	Herbicide App. Nursery	8404145318081	[illegible]
Malin Jafta	G.Worker-Nursery	8910305235089	M Jafta
Edwin Malgas	G.Worker-Nursery	8612215177084	Malgas
Christopher Stefaans	^	8907215333087	T Stefaans
Cedric Kleinbooi	Contractor	6905195246081	[illegible]
Michael Ruka	Contractor	7504215352083	[illegible]
Michelle Human	G. Worker	8311160228082	M.Human
Hermia Boes	G. Worker	7607100157085	Boes
Marelene Rautenbach	^	8304020281083	M.Rautenbach
Jolene Prins	^	8110080168080	J Prins
Pina Pietersen	^	6206180150085	Petersen
Brunhilda Magielies	^	7807100177089	B Magielies
Elmarie Umstang	^	8009241066086	E. Umstang
Desmond Coetzee	^	5802265224083	D Coetzee
Jonathan Kietas	^	8008315001086	J. Kietas
Hendry Witbooi	^	8003015302084	Witbooi
Henry Ruiters	^	7412025239088	H Ruiters
Jonathan Plaatjies	Driver	7803165099086	Plaatjies
Mthetheleli Mhlabasa	G. Worker	8102026714085	[illegible]
Xolile Wagesa	^	8407185775086	[illegible]
Richard Dlamini	^	7004075653084	MR. Dlamini
Elias Mandela	^	6701255514082	E Mandela
Jim Sali	^	7106295606089	J Sali
Douglas Gungulu	^	5709085746080	G U N Gulu
K Matebese	^	6910305636080	K. Matebese
Charlton Malgas	Technician	8404175282082	C Malgas
Pieter Rossouw	^	7903165253087	[illegible]
Koos Dlomo	Driver	3510215187084	N K Dlomo
Henrico Prins	Technician	8601135214085	Henrico
Victoria Nolokwe	G.Worker	6412240603085	V Nolokwe

Annex 6 Climate, Community and Biodiversity Association Validation

The proposed ARR project will be validated against the Climate, Community and Biodiversity (CCB) Standards, and subsequently verified should the design of the proposed ARR project meet the required criteria, as determined by an independent auditor. The proposed ARR project is detailed below according to the sections stipulated in the Climate, Community and Biodiversity Project Design Standards Second Edition(CCBA, 2008). The background and context of the proposed ARR project are provided in the main report.

SECTION G: GENERAL SECTION

G1. Original Conditions in the Project Area

G1.1. The location of the project and basic physical parameters (e.g., soil, geology, climate).

The location of the proposed ARR project and basic physical parameters of each project area are described in Annex 12.

G1.2. The types and condition of vegetation within the project area.

The types and condition of vegetation within each project area are described in Annex 12.

G1.3. The boundaries of the project area and the project zone.

The boundaries of the project areas are described in Section 1.5 and Annex 12. The surrounding communities within the project zone are listed in Section 1.5.

Concept

G1.4. Current carbon stocks within the project area(s), using stratification by land use or vegetation type and methods of carbon calculation (such as biomass plots, formulae, default values) from the Intergovernmental Panel on Climate Change's 2006 Guidelines for National GHG Inventories for Agriculture, Forestry and Other Land Use (IPCC 2006 GL for AFOLU) or a more robust and detailed methodology.

The baseline stratification is described in Section 3.2.4a. The method of carbon calculation and baseline GHG scenario are described in Sections 4.1 and 4.2, respectively.

G1.5. A description of communities located in the project zone, including basic socio-economic and cultural information that describes the social, economic and cultural diversity within communities (wealth, gender, age, ethnicity etc.), identifies specific groups such as Indigenous Peoples and describes any community characteristics.

The communities living within the project zone are poor. Unemployment rates are high and there are limited economic opportunities available to community members. The unemployment rate for the Eastern Cape is 39.5 %, the second highest for any province in South Africa (StatsSA, 2007). The high unemployment rate is in part due to habitat degradation, which has resulted in a decline of the agricultural sector in this region (Kerley et al., 1999).

G1.6. A description of current land use and customary and legal property rights including community property in the project zone, identifying any ongoing or unresolved conflicts or

disputes and identifying and describing any disputes over land tenure that were resolved during the last ten years (see also G5).

The current land use of all the project areas is conservation, as described in Sections 1.5, 2.5 and 8. The three project areas are in two nature reserves and a national park, classified as Protected Areas, which are state owned.

G1.7. A description of current biodiversity within the project zone (diversity of species and ecosystems) and threats to that biodiversity, using appropriate methodologies, substantiated where possible with appropriate reference material.

A description of the biodiversity of the project areas is provided in Annex 12, which details the vegetation and rare and endangered flora and fauna. All areas to be restored are currently considered to be moderately or severely degraded (see Section 1.4). Current environmental conditions do not permit natural recovery of thicket within these areas, due to the high soil temperatures as a result of the lack of canopy, reduced soil quality and reduced soil moisture content of degraded landscapes (Mills & Fey, 2004b). This represents a continued threat to the biodiversity of the degraded areas.

G1.8. An evaluation of whether the project zone includes any of the following High Conservation Values (HCVs) and a description of the qualifying attributes:

1.8.1. Globally, regionally or nationally significant concentrations of biodiversity values;

a. protected areas; b. threatened species; c. endemic species; and d. areas that support significant concentrations of a species during any time in their lifecycle (e.g. migrations, feeding grounds, breeding areas).

All three project areas are Protected Areas under the protected Areas Act of 2004. In addition, the Baviaanskloof Nature Reserve is World Heritage Site under the World Heritage Convention Act (49 of 1999). The rare and endangered species of each of the project areas (including a number of endemic species i.e. *Aloe pictifolia, Gasteria ellaphieae, Gasteria glomerata* and *Gasteria rawlinsonii*) are listed in Annex 12.

1.8.2. Globally, regionally or nationally significant large landscape-level areas where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance;

All three project areas are in biodiversity hotspots[27], first defined by Myers[28]. The Addo National Elephant Park and Great Fish River Nature Reserve project areas are in the Maputaland-Pondoland-Albany biodiversity hotspot, as well as in the Albany Centre of Floristic Endemism (Victor & Dold, 2003). The Baviaanskloof Nature Reserve project area falls within the Cape Floristic Region biodiversity hotspot (Myers, 1990). These areas are characterized both by exceptional levels of plant endemism and by serious levels of habitat loss, and are thus regionally, nationally and globally significant.

1.8.3. Threatened or rare ecosystems;

[27] See http://www.biodiversityhotspots.org/Pages/default.aspx.
[28] (Myers, 1988)

The project areas fall within the planning domain of Subtropical Thicket Ecosystem Project (STEP; Vlok & Euston-Brown, 2002). STEP defines the following biodiversity priority classifications (a measure of ecosystem status)[29]:

- Least threatened: Ecosystems which cover most of their original extent and which are mostly intact, healthy and functioning.
- Vulnerable: Ecosystems which cover much of their original extent but where further disturbance or destruction could harm their health and functioning.
- Endangered: Ecosystems whose original extent has been severely reduced, and whose health, functioning and existence is endangered.
- Critically endangered: Ecosystems whose original extent has been so reduced that they are under threat of collapse or disappearance.

All four categories are represented in the project areas. In addition, all selected planting sites in the planting areas are classified as moderately or severely degraded by the landscape-level transformation study undertaken by Lloyd et al. in 2002.

1.8.4. Areas that provide critical ecosystem services (e.g., hydrological services, erosion control, fire control);

The project areas are important water catchments for downstream and surrounding communities and towns. A restoration of the ecosystem through the planting of *P.afra* will result in improved water retention and increased and regulated water flow and supply from the project areas. This will result in improved water security for the local communities as well as the farms surrounding the project areas. The economic benefit from improved water supplies is significant in the drought-prone region, and may reduce the number of expensive engineering solutions required for increasing water supply. The value of the benefits of restoring the water regulation services of thicket is detailed in Annex 11, as is the surrounding communities' dependence on thicket. Whilst communities cannot harvest resources from the project areas (as they are in two nature reserves and a national park), cross boundary flow from the restored thicket to surrounding areas will benefit local communities through the ecosystem services provided.

1.8.5. Areas that are fundamental for meeting the basic needs of local communities (e.g., for essential food, fuel, fodder, medicines or building materials without readily available alternatives); and

The project areas are situated within two nature reserves and a national park and thus no consumptive use by the local communities is permitted within the project areas. Cross boundary flow from the restored thicket to surrounding areas, however, will benefit local communities who rely on thicket to meet some of their basic needs. This reliance is detailed in Annex 11.

1.8.6. Areas that are critical for the traditional cultural identity of communities (e.g., areas of cultural, ecological, economic or religious significance identified in collaboration with the communities).

The socio-cultural value of thicket and economic importance to surrounding communities is detailed in Annex 11. Whilst there are no religious or culturally important sites in the specific planting sites within the project areas, as they were excluded during site selection, the cross

[29] See http://bgis.sanbi.org/STEP/project.asp.

boundary flow from the restored areas will improve the quality of lives of the surrounding communities.

G2. Baseline Projections

G2.1. Describe the most likely land use scenario in the absence of the project following IPCC 2006 GL for AFOLU or a more robust and detailed methodology, describing the range of potential land use scenarios and the associated drivers of GHG emissions and justifying why the land use scenario selected is most likely.

The most likely land use scenario in the absence of the proposed ARR project activities is described in Section 2.5.

G2.2. Document that project benefits would not have occurred in the absence of the project, explaining how existing laws or regulations would likely affect land use and justifying that the benefits being claimed by the project are truly 'additional' and would be unlikely to occur without the project.18

The assessment and demonstration of additionality of the proposed ARR project is undertaken in Section 2.5.

G2.3. Calculate the estimated carbon stock changes associated with the 'without project' reference scenario described above. This requires estimation of carbon stocks for each of the land use classes of concern and a definition of the carbon pools included, among the classes defined in the IPCC 2006 GL for AFOLU. The timeframe for this analysis can be either the project lifetime (see G3) or the project GHG accounting period, whichever is more appropriate. Estimate the net change in the emissions of non-CO2 GHG emissions such as CH4 and N2O in the 'without project' scenario. Non-CO2 gases must be included if they are likely to account for more than 5% (in terms of CO2-equivalent) of the project's overall GHG impact over each monitoring period. Projects whose activities are designed to avoid GHG emissions (such as those reducing emissions from deforestation and forest degradation (REDD), avoiding conversion of non-forest land, or certain improved forest management projects) must include an analysis of the relevant drivers and rates of deforestation and/or degradation and a description and justification of the approaches, assumptions and data used to perform this analysis. Regional-level estimates can be used at the project's planning stage as long as there is a commitment to evaluate locally-specific carbon stocks and to develop a project-specific spatial analysis of deforestation and/or degradation using an appropriately robust and detailed carbon accounting methodology before the start of the project.

The baseline scenario is no carbon sequestration over the project period of 60 years, as detailed in Section 4.2.3

G2.4. Describe how the 'without project' reference scenario would affect communities in the project zone, including the impact of likely changes in water, soil and other locally important ecosystem services.

The dependence of the communities on thicket surrounding the project areas is described in Section 6 and Annex 11. In a degraded state, the communities are not able to utilize the thicket.

G2.5. Describe how the 'without project' reference scenario would affect biodiversity in the project zone (e.g., habitat availability, landscape connectivity and threatened species).

In the absence of the proposed ARR project activities, the landscape to be restored would remain degraded. Current environmental conditions would not permit natural recovery of thicket within these areas, due to the high soil temperatures as a result of the lack of canopy, reduced soil quality and reduced soil moisture content of degraded landscapes (Mills & Fey, 2004b). There would be no increase in the biodiversity of the project areas and none of the benefits of the proposed ARR project (see Sections 1.16.2 and 5) would be realised.

G3. Project Design and Goals

G3.1. Provide a summary of the project's major climate, community and biodiversity objectives.

The objectives of the proposed ARR project include:

- Planting approximately 48,086 ha of moderately and severely degraded thicket with *P. afra* cuttings.
- Removing approximately 19.29 million t CO_2e from the atmosphere.
- Creating an estimated 300 jobs in a province of 39.5 % unemployment.
- Resulting in the return of ecosystem carbon (in above ground biomass, below ground biomass, deadwood, litter and SOC).
- Increasing biodiversity in the project areas, by:
    - increasing soil quality and SOM content, through the addition of leaf litter;
    - reducing soil temperatures due to an improved canopy cover;
    - increasing water retention through improved infiltration into soils;
    - attracting (indigenous) flora and fauna to the previously degraded areas due a favourable environment; and
    - dispersing trees and shrubs through the project area by browsers, birds and insects (see section 1.8).
- Improving ecosystem services in surrounding areas through cross boundary flows from the restored thicket ecosystems, and through improved water retention in the restored areas.

G3.2. Describe each project activity with expected climate, community and biodiversity impacts and its relevance to achieving the project's objectives.

The proposed ARR project activities include:

- The planting of the *P. afra* cuttings, which involves the following actions (see Section 1.8 for details on each point);
    - selection of contract (planting) sites;
    - appointment of contractors;
    - harvesting of *P. afra* cuttings from within the project area;
    - planting of *P. afra* cuttings within the planting sites; and
    - supplemental planting of *P. afra* cuttings where required.
- Monitoring after planting (see Section 3).

The planting of the *P.afra* cuttings is the principle activity of the proposed ARR project, and its subsequent growth and expected dispersal will realise the objectives listed in G3.1.

G3.3. Provide a map identifying the project location and boundaries of the project area(s), where the project activities will occur, of the project zone and of additional surrounding locations that are predicted to be impacted by project activities (e.g. through leakage).

Maps outlining the project areas are provided in Annex 12.

G3.4. Define the project lifetime and GHG accounting period and explain and justify any differences between them. Define an implementation schedule, indicating key dates and milestones in the project's development.

The proposed ARR project lifetime will be 60 years. The project schedule is detailed in Section 7.

G3.5. Identify likely natural and human-induced risks to the expected climate, community and biodiversity benefits during the project lifetime and outline measures adopted to mitigate these risks.

The risks to the proposed ARR project are detailed in Section 1.11.

G3.6. Demonstrate that the project design includes specific measures to ensure the maintenance or enhancement of the High Conservation Value attributes identified in G1 consistent with the precautionary principle.

All proposed ARR project activities will take place within two nature reserves and a national park, and in keeping with the relevant management plans. The proposed ARR project activities will therefore not be to the detriment of the identified High Conservation Value attributes.

G3.7. Describe the measures that will be taken to maintain and enhance the climate, community and biodiversity benefits beyond the project lifetime.

The restored thicket will be within the boundaries of two nature reserves and a national park, and therefore protected by the relevant legislation (see Section 2.5) for the duration of the proposed ARR project and beyond.

G3.8. Document and defend how communities and other stakeholders potentially affected by the project activities have been identified and have been involved in project design through effective consultation, particularly with a view to optimizing community and stakeholder benefits, respecting local customs and values and maintaining high conservation values. Project developers must document stakeholder dialogues and indicate if and how the project proposal was revised based on such input. A plan must be developed to continue communication and consultation between project managers and all community groups about the project and its impacts to facilitate adaptive management throughout the life of the project.

The stakeholder engagement process is detailed in Section 6 as well as Annex 11.

G3.9. Describe what specific steps have been taken, and communications methods used, to publicize the CCBA public comment period to communities and other stakeholders and to facilitate their submission of comments to CCBA. Project proponents must play an active role in distributing key project documents to affected communities and stakeholders and hold widely publicized information meetings in relevant local or regional languages.

GIB will ensure that the CCBA public comment period is publicized and understood by the communities listed in Section 1.5. This will be through verbal communication, through the contractors and workers already working for GIB, as well as through direct engagement with the relevant communities.

G3.10. Formalize a clear process for handling unresolved conflicts and grievances that arise during project planning and implementation. The project design must include a process for hearing, responding to and resolving community and other stakeholder grievances within a reasonable time period. This grievance process must be publicized to communities and other stakeholders and must be managed by a third party or mediator to prevent any conflict of interest. Project management must attempt to resolve all reasonable grievances raised, and provide a written response to grievances within 30 days. Grievances and project responses must be documented.

The mechanism for on-going communication is described in Section 6.3.

G3.11. Demonstrate that financial mechanisms adopted, including projected revenues from emissions reductions and other sources, are likely to provide an adequate flow of funds for project implementation and to achieve the anticipated climate, community and biodiversity benefits.

Public funding information is provided in Annex 2. Management of VERs and generated funds will be undertaken according to the system described in Section 1.15.1.

G4. Management Capacity and Best Practices

Concept

G4.1. Identify a single project proponent which is responsible for the project's design and implementation. If multiple organizations or individuals are involved in the project's development and implementation the governance structure, roles and responsibilities of each of the organizations or individuals involved must also be described.

The roles and responsibilities of all project proponents are listed in Section 1.15. The proposed ARR project will be implemented by the GIB, a well-established organisation that is based in the region.

G4.2. Document key technical skills that will be required to implement the project successfully, including community engagement, biodiversity assessment and carbon measurement and monitoring skills. Document the management team's expertise and prior experience implementing land management projects at the scale of this project. If relevant experience is lacking, the proponents must either demonstrate how other organizations will be partnered with to support the project or have a recruitment strategy to fill the gaps.

GIB will manage the activities listed in Section 1.8. The technical requirements for the project are relatively simple, and have been proved in the field. Field managers have been trained in monitoring operations, and collected data is housed in a custom-built spatial database that is regularly backed up. Subsequent to planting, the management requirements of the proposed ARR project are minimal due to the resilience of the *P. afra* plantings. With regard to prior experience, GIB has a long track record of successful projects, which is highlighted by the following awards:

- In 2007, GIB was awarded the Water Conservation and Demand Management Trophy (the only award in the agricultural sector on a national basis).

- In 2007, the GIB-run Sand/Bulk Alien Vegetation Clearing Project was awarded winner of the National Project Flagship Competition.
- In 2006, the Working for Water Project in Port Elizabeth (run by GIB) won the Airport Managers Award for Excellence.

G4.3. Include a plan to provide orientation and training for the project's employees and relevant people from the communities with an objective of building locally useful skills and knowledge to increase local participation in project implementation. These capacity building efforts should target a wide range of people in the communities, including minority and underrepresented groups. Identify how training will be passed on to new workers when there is staff turnover, so that local capacity will not be lost.

The capacity building, skills transfer and poverty alleviation aspects of the proposed ARR project are discussed in Section 1.16.2.

G4.4. Show that people from the communities will be given an equal opportunity to fill all employment positions (including management) if the job requirements are met. Project proponents must explain how employees will be selected for positions and where relevant, must indicate how local community members, including women and other potentially underrepresented groups, will be given a fair chance to fill positions for which they can be trained.

The composition of the teams and principles of selection are explained in Section 1.16.2.

G4.5. Submit a list of all relevant laws and regulations covering worker's rights in the host country. Describe how the project will inform workers about their rights. Provide assurance that the project meets or exceeds all applicable laws and/or regulations covering worker rights and, where relevant, demonstrate how compliance is achieved.

South African labour legislation provides a substantial package of labour rights for workers. The principle statutes providing these protections are presented in the table below(Benjamin, 2008).

Statute	**Labour Protections**
Labour Relations Act 66 of 1995	Freedom of association, organisational rights, collective bargaining; right to strike; and protection against unfair dismissal
Basic Conditions of Employment Act 75 of 1997	Hours of work, annual leave, sick leave, maternity leave, severance pay, notice pay; sectoral determinations
Employment Equity Act 55 of 1998	Anti-discrimination and affirmative action
Unemployment Insurance Act of 2001	Skills development and training
Skills Development Act 97 of 1998	Unemployment and maternity benefits
Compensation for Occupational Diseases Act 130 of 1993	Compensation for work-related injuries and diseases
Occupational Safety and Health| Act 85 of 1993; Mine Health and Safety Act 29 of 1996	Health and safety in the workplace

GIB routinely informs all workers of their rights, when contracts are signed.

G4.6. Comprehensively assess situations and occupations that pose a substantial risk to worker safety. A plan must be in place to inform workers of risks and to explain how to minimize such risks. Where worker safety cannot be guaranteed, project proponents must show how the risks will be minimized using best work practices.

There is very little risk associated with the activities undertaken by the workers. Workers using the mechanical auger will be properly trained by the contractors to minimise risks.

G4.7. Document the financial health of the implementing organization(s) to demonstrate that financial resources budgeted will be adequate to implement the project.

Funding for the implementation of the proposed ARR project by GIB has been through the Department of Water Affairs (DWA, formerly the Department of Water Affairs and Forestry), as detailed in Section 1.6.

G5. Legal Status and Property Rights

Concept

G5.1. Submit a list of all relevant national and local laws and regulations in the host country and all applicable international treaties and agreements. Provide assurance that the project will comply with these and, where relevant, demonstrate how compliance is achieved.

The relevant environmental legislation for sustainable development and over-arching international and national treaties with which the proposed ARR project activities will comply are listed in Section 1.10.

G5.2. Document that the project has approval from the appropriate authorities, including the established formal and/or traditional authorities customarily required by the communities.

Letters of approval for the proposed ARR project are presented in Annex 5. Approval of proposed ARR the project by surrounding communities is documented in Section 6.

G5.3. Demonstrate with documented consultations and agreements that the project will not encroach uninvited on private property, community property, or government property and has obtained the free, prior, and informed consent of those whose rights will be affected by the project.

All proposed ARR project activities will be on state land (two nature reserves and a national park; see Section 8). Letters of approval for the proposed ARR project are presented in Annex 5.

G5.4. Demonstrate that the project does not require the involuntary relocation of people or of the activities important for the livelihoods and culture of the communities. If any relocation of habitation or activities is undertaken within the terms of an agreement, the project proponents must demonstrate that the agreement was made with the free, prior, and informed consent of those concerned and includes provisions for just and fair compensation.

No communities or individuals have been or will be relocated as a consequence of the proposed ARR project.

G5.5. Identify any illegal activities that could affect the project's climate, community or biodiversity impacts (e.g., logging) taking place in the project zone and describe how the project will help to reduce these activities so that project benefits are not derived from illegal activities.

There are no such illegal activities taking place in the project areas, which are in two nature reserves and a national park.

G5.6. Demonstrate that the project proponents have clear, uncontested title to the carbon rights, or provide legal documentation demonstrating that the project is undertaken on behalf of the carbon owners with their full consent. Where local or national conditions preclude clear title to the carbon rights at the time of validation against the Standards, the project proponents must provide evidence that their ownership of carbon rights is likely to be established before they enter into any transactions concerning the project's carbon assets.

The management and ownership of the carbon rights is detailed in Section 1.15.1.

SECTION CL: CLIMATE SECTION

CL1. Net Positive Climate Impacts
Concept
CL1.1. Estimate the net change in carbon stocks due to the project activities using the methods of calculation, formulae and default values of the IPCC 2006 GL for AFOLU or using a more robust and detailed methodology. The net change is equal to carbon stock changes with the project minus carbon stock changes without the project (the latter having been estimated in G2). This estimate must be based on clearly defined and defendable assumptions about how project activities will alter GHG emissions or carbon stocks over the duration of the project or the project GHG accounting period..

The net change in carbon stock as a result of the proposed ARR project is summarized in Section 4.4.1. The method and calculations used are explained in Section 4.

CL1.2. Estimate the net change in the emissions of non-CO_2 GHG emissions such as CH_4 and N_2O in the with and without project scenarios if those gases are likely to account for more than a 5% increase or decrease (in terms of CO_2-equivalent) of the project's overall GHG emissions reductions or removals over each monitoring period.

The emission of non-CO_2 GHG will be less than 5 % of the overall GHG removal for the proposed ARR project, as detailed in Section 4.3.2.

CL1.3. Estimate any other GHG emissions resulting from project activities. Emissions sources include, but are not limited to, emissions from biomass burning during site preparation, emissions from fossil fuel combustion, direct emissions from the use of synthetic fertilizers, and emissions from the decomposition of N-fixing species.

Non-CO_2 GHG emissions are estimated in Section 4.3.2.

CL1.4. Demonstrate that the net climate impact of the project is positive. The net climate impact of the project is the net change in carbon stocks plus net change in non-CO_2 GHGs where appropriate minus any other GHG emissions resulting from project activities minus any likely project-related unmitigated negative offsite climate impacts (see CL2.3).

The net climate impact of the proposed ARR project is positive, as detailed in Section 4.4.1.

CL1.5. Specify how double counting of GHG emissions reductions or removals will be avoided, particularly for offsets sold on the voluntary market and generated in a country with an emissions cap.

Not applicable.

CL2. Offsite Climate Impacts ('Leakage')

CL2.1. Determine the types of leakage that are expected and estimate potential offsite increases in GHGs (increases in emissions or decreases in sequestration) due to project activities. Where relevant, define and justify where leakage is most likely to take place.

The project areas consist of severely degraded lands with low biomass levels, and the land use is unchanged. Consequently, the land should continue to provide the same services, and there is no anticipated leakage as a result of project activities (see Section 4.3.3).

CL2.2. Document how any leakage will be mitigated and estimate the extent to which such impacts will be reduced by these mitigation activities.

Not applicable.

CL2.3. Subtract any likely project-related unmitigated negative offsite climate impacts from the climate benefits being claimed by the project and demonstrate that this has been included in the evaluation of net climate impact of the project (as calculated in CL1.4).

Not applicable.

CL2.4. Non-CO_2 gases must be included if they are likely to account for more than a 5% increase or decrease (in terms of CO_2-equivalent) of the net change calculations (above) of the project's overall off-site GHG emissions reductions or removals over each monitoring period.

The emission of non-CO_2 GHG will be less than 5 % of the overall GHG removal of the overall project, as detailed in Section 4.3.2.

CL3. Climate Impact Monitoring

CL3.1. Develop an initial plan for selecting carbon pools and non-CO_2 GHGs to be monitored, and determine the frequency of monitoring. Potential pools include aboveground biomass, litter, dead wood, belowground biomass, wood products, soil carbon and peat. Pools to monitor must include any pools expected to decrease as a result of project activities, including those in the region outside the project boundaries resulting from all types of leakage identified in CL2. A plan must be in place to continue leakage monitoring for at least five years after all activity displacement or other leakage causing activity has taken place. Individual GHG sources may be considered 'insignificant' and do not have to be accounted for if together such omitted decreases in carbon pools and increases in GHG emissions amount to less than 5% of the total CO_2-equivalent benefits generated by the project. Non-CO_2 gases must be included if they are likely to account for more than 5% (in terms of CO_2-equivalent) of the project's overall GHG

impact over each monitoring period. Direct field measurements using scientifically robust sampling must be used to measure more significant elements of the project's carbon stocks. Other data must be suitable to the project site and specific forest type.

The monitoring plan, which includes details regarding the purpose of monitoring, responsibilities, carbon pools to be monitored, quality control/assurance procedures, parameters and frequency of monitoring is detailed in Section 3.

CL3.2. Commit to developing a full monitoring plan within six months of the project start date or within twelve months of validation against the Standards and to disseminate this plan and the results of monitoring, ensuring that they are made publicly available on the internet and are communicated to the communities and other stakeholders.

The monitoring plan presented in Section 3 will be finalised within 12 months of validation against the Standards, and make publically available on the appropriate internet website.

SECTION CM: COMMUNITY SECTION

CM1. Net Positive Community Impacts

CM1.1. Use appropriate methodologies to estimate the impacts on communities, including all constituent socio-economic or cultural groups such as indigenous peoples (defined in G1), resulting from planned project activities. A credible estimate of impacts must include changes in community well-being due to project activities and an evaluation of the impacts by the affected groups. This estimate must be based on clearly defined and defendable assumptions about how project activities will alter social and economic well-being41, including potential impacts of changes in natural resources and ecosystem services identified as important by the communities (including water and soil resources), over the duration of the project. The 'with project' scenario must then be compared with the 'without project' scenario of social and economic well-being in the absence of the project (completed in G2). The difference (i.e., the community benefit) must be positive for all community groups.

The community engagement methods used are described in Section 6, and the four MSc theses resulting from the community interaction are summarized in Annex 11. The major benefit of the proposed ARR project on surrounding communities will be the creation of an estimated 300 jobs and the resultant poverty alleviation. This is significant in a region of 39.5 % unemployment. Employment details and worker team composition and training are described in Section 1.16.2.

Adjacent to the project areas, the proposed ARR project is likely to stimulate tourism-derived economic opportunities as well as supporting emerging initiatives such as community bee-keeping and medicinal plant collection. Although utilization of the restored thicket is not permitted within the project areas because they are in two nature reserves and a national park, surrounding communities will benefit from cross-boundary flows as a result of the restored thicket ecosystem. The reliance of the surrounding communities on the ecosystem services provided by the thicket is detailed in Annex 11.

The project activities will generate net positive community benefits, when compared to the 'without project' scenario, most notably through the creation of jobs.

CM1.2. Demonstrate that no High Conservation Values identified in G1.8.4-6 will be negatively affected by the project.

The proposed ARR project will not negatively affect areas that provide critical ecosystem services, areas that are fundamental for the livelihoods of local communities, or areas that are critical for the traditional cultural identity of communities.

Whilst all proposed ARR project activities will be in two nature reserves and a national park which prohibits resource utilization within the project areas, cross boundary flows will result in improved thicket conditions outside of the project areas. Ecosystem services, such as access to clean drinking water, will therefore be improved outside of the project areas as a result of the restored thicket, thereby benefiting the surrounding communities (see Annex 11).

CM2. Offsite Stakeholder Impacts

CM2.1. Identify any potential negative offsite stakeholder impacts that the project activities are likely to cause.

The proposed ARR project will not cause any negative offsite stakeholder impacts.

CM2.2. Describe how the project plans to mitigate these negative offsite social and economic impacts.

Not applicable.

CM2.3. Demonstrate that the project is not likely to result in net negative impacts on the well-being of other stakeholder groups.

The proposed ARR project will not cause any negative impacts for any stakeholders in the project.

CM3. Community Impact Monitoring
Concept
CM3.1. Develop an initial plan for selecting community variables to be monitored and the frequency of monitoring and reporting to ensure that monitoring variables are directly linked to the project's community development objectives and to anticipated impacts (positive and negative).

A community impact monitoring plan is currently being developed by GIB to monitor the well-being of workers benefitting from the project activities. Monitoring will be in the form of a questionnaire/interview, designed to understand the changes in the workers' perception of their well-being as a result of the project activities, as well as their perception of the impact on the communities in which they live. Monitoring will be undertaken on an annual basis, and every labourer employed by GIB's contractors will be interviewed.

CM3.2. Develop an initial plan for how they will assess the effectiveness of measures used to maintain or enhance High Conservation Values related to community well-being (G1.8.4-6) present in the project zone.

The proposed ARR project will not negatively affect areas that provide critical ecosystem services, areas that are fundamental for the livelihoods of local communities, and areas that are critical for

the traditional cultural identity of communities will not be negatively affected by the proposed ARR project. An assessment of the enhancement of these areas with respect to community well-being will be incorporated into the questionnaire.

CM3.3. Commit to developing a full monitoring plan within six months of the project start date or within twelve months of validation against the Standards and to disseminate this plan and the results of monitoring, ensuring that they are made publicly available on the internet and are communicated to the communities and other stakeholders.

An assessment of the effectiveness of the questionnaire will be undertaken after the first interview process, and a full monitoring plan will be developed within 12 months of validation against the CCB Standards. The plan and the results of the monitoring process will be made publically available on the appropriate internet website, and printed reports will be given to the workers to take back to their respective communities. Comments and suggestions received will be used to strengthen the effectiveness of the monitoring process.

BIODIVERSITY SECTION

B1. Net Positive Biodiversity Impacts
Indicators
B1.1. Use appropriate methodologies to estimate changes in biodiversity as a result of the project in the project zone and in the project lifetime. This estimate must be based on clearly defined and defendable assumptions. The 'with project' scenario should then be compared with the baseline 'without project' biodiversity scenario completed in G2. The difference (i.e., the net biodiversity benefit) must be positive.

The proposed ARR project will restore degraded thicket by planting cuttings of *P. afra*, which is able to re-establish from cuttings and grow rapidly into tall dense vegetation, without irrigation. *P. afra* is particularly suitable for restoring degraded thicket due to:

- the ability of *P.afra* to produce approximately 4.6 tonnes of litter per hectare per year, which is comparable to wet forest ecosystems and five to 35 times higher than that of other semi-arid ecosystems(Mills & Cowling, 2010);
- the dense canopy, which maintains a microclimate of cool and dry conditions, conducive to the slow decomposition of leaf mulch on the thicket floor and in the soil (Mills & Fey 2004a; 2004b); and
- the fact that *P.afra* is fire-resistant (see Section 1.4).

These factors enable large amounts of carbon to accumulate within the soil and consequently improve soil fertility. This will facilitate natural ecosystem recovery and increase shrub and tree recruitment and thus diversity. This increased diversity will induce grazing and browsing by game within the project areas, which will promote *P. afra* growth (see Section 1.8). The overall affect will be an increase in biodiversity of the previously degraded areas. Such an increase has been observed at several restoration sites (van der Vuyfer, in press).

In the absence of the proposed ARR project activities, the landscape to be restored would remain degraded. Current environmental conditions would not permit natural recovery of thicket within these areas, due to the high soil temperatures as a result of the lack of canopy, reduced soil quality and reduced soil moisture content of degraded landscapes (Mills & Fey, 2004b). As a result, there would be no increase in the biodiversity and none of the benefits of the project (see Sections 1.16.2 and 5) would be realised.

The net biodiversity difference for the 'with project' scenario is thus positive, when compared to the 'without project' scenario.

B1.2. Demonstrate that no High Conservation Values identified in G1.8.1-3 will be negatively affected by the project.

The proposed ARR project will not negatively affect globally, regionally or nationally significant concentrations of biodiversity values, large landscape-level areas where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance, or threatened or rare ecosystems will not be negatively affected by the proposed ARR project.

The proposed ARR project activities will take place within two nature reserves and a national park (all Protected Areas), which were formed to protect biodiversity. The project activities will preserve and increase this biodiversity. The project areas contain several threatened species, including the Black Rhinoceros (*Diceros bicornis*). Thicket forms part of its diet and thus Black Rhinoceros populations will benefit from the project activities(Brown, 2008). The project areas contain a number of endemic species, including *inter alia*: *Aloe pictifolia, Gasteria ellaphieae, Gasteria glomerata* and *Gasteria rawlinsonii*, all of which are Red Data List species. Through the restoration of thicket in the project areas, the proposed ARR project will benefit these rare and vulnerable species. Full Red Data lists per project area are provided in Annex 12.

B1.3. Identify all species to be used by the project and show that no known invasive species will be introduced into any area affected by the project and that the population of any invasive species will not increase as a result of the project.

P. afra is the only species to be used in the proposed ARR project. *P. afra* is a native and often dominant species within the project areas (Mucina & Rutherford, 2006). The *P. afra* cuttings used in the proposed ARR project are obtained from wild plants within 50 km of each the project areas, in order to reduce risks of 'genetic pollution'. These cuttings are obtained through a sustainable harvesting process, thereby minimising the impacts of harvesting on wild plants.

B1.4. Describe possible adverse effects of non-native species used by the project on the region's environment, including impacts on native species and disease introduction or facilitation. Project proponents must justify any use of non-native species over native species.

Not applicable.

B1.5. Guarantee that no GMOs will be used to generate GHG emissions reductions or removals.

No GMOs will be used in the proposed ARR project.

B2. Offsite Biodiversity Impacts
Indicators
B2.1. Identify potential negative offsite biodiversity impacts that the project is likely to cause.

The proposed ARR project activities are not expected to result in any negative offsite biodiversity impacts. Through an increase in biodiversity within the project areas and the expected cross-boundary flow to surrounding areas, offsite biodiversity will be positively impacted by the proposed ARR project activities. Improved water retention of the restored areas will result in an

increased and regulated flow to surrounding areas, further benefitting biodiversity (see Section 1.16.2).

B2.2. Document how the project plans to mitigate these negative offsite biodiversity impacts.

Not applicable.

B2.3. Evaluate likely unmitigated negative offsite biodiversity impacts against the biodiversity benefits of the project within the project boundaries. Justify and demonstrate that the net effect of the project on biodiversity is positive.

Not applicable.

B3. Biodiversity Impact Monitoring

Indicators

B3.1. Develop an initial plan for selecting biodiversity variables to be monitored and the frequency of monitoring and reporting to ensure that monitoring variables are directly linked to the project's biodiversity objectives and to anticipated impacts (positive and negative).49

A biodiversity monitoring plan is currently being developed by GIB, with input from thicket specialists. Species counts in transects through a selection of the sample plots (see Section 3.2.5i) will be undertaken by an ecologist. Plant species within the transects, and bird, mammal and reptile species within the sample plots will be recorded. Insect traps will be used to count the number of insects in each transect. Monitoring will occur every five years during the growth monitoring (Section 3) surveys. A baseline species count will be made for each biodiversity sample plot planted subsequent to validation against the CCB Standards. The results will be compared to counts every five years thereafter to gain an understanding of the expected increase in biodiversity in the project areas.

B3.2. Develop an initial plan for assessing the effectiveness of measures used to maintain or enhance High Conservation Values related to globally, regionally or nationally significant biodiversity (G1.8.1-3) present in the project zone.

The above monitoring plan will assess the effectiveness of restored thicket in enhancing the biodiversity of the project areas, which qualify as High Conservation Value areas.

B3.3. Commit to developing a full monitoring plan within six months of the project start date or within twelve months of validation against the Standards and to disseminate this plan and the results of monitoring, ensuring that they are made publicly available on the internet and are communicated to the communities and other stakeholders.

The biodiversity monitoring plan currently being developed will be reviewed after implementation in the field and a full biodiversity monitoring plan will be developed within 12 months of validation against the CCB Standards. The plan and results will be made publically available on the appropriate internet website, and printed copies will be provided to stakeholders upon specific request.

GOLD LEVEL SECTION

GL1. Climate Change Adaptation Benefits

The proposed ARR project is not applying for Gold Level Climate Change Adaptation Benefits validation at this stage.

GL2. Exceptional Community Benefits

Concept

The proposed ARR project is not applying for Gold Level Exceptional Community Benefits validation at this stage.

GL3. Exceptional Biodiversity Benefits

GL3.1. Vulnerability

Regular occurrence of a globally threatened species (according to the IUCN Red List) at the site:

3.1.1. Critically Endangered (CR) and Endangered (EN) species - presence of at least a single individual; or

3.1.2. Vulnerable species (VU) - presence of at least 30 individuals or 10 pairs.

The project areas (collectively) contain:

- 2 Critically Endangered (CR) species;
- 6 Endangered (EN) species; and
- 41 Vulnerable (VU) species.

Red Data Lists for flora and fauna for each project area are provided in Annex 12.

Or,

GL3.2. Irreplaceability

A minimum proportion of a species' global population present at the site at any stage of the species' lifecycle according to the following thresholds:

3.2.1. Restricted-range species - species with a global range less than 50,000 km2 and 5% of global population at the site; or

3.2.2. Species with large but clumped distributions - 5% of the global population at the site; or

3.2.3. Globally significant congregations - 1% of the global population seasonally at the site; or

3.2.4. Globally significant source populations - 1% of the global population at the site;

The proposed ARR project is applying for Gold Level Exceptional Biodiversity Benefits validation based on GL3.1 only at this stage.

Annex 7 Carbon stocks meta-analysis from literature sources

There has been considerable research in the field of carbon sequestration potential in the Subtropical Thicket Biome, and particularly in terms of spekboom, over the last ten years. A meta-analysis of these sequestration rates was undertaken to obtain realistic estimates of the rate of carbon accumulation from degraded lands to intact thicket, over a 50-year period. An overview of this literature review is presented here. Final (50 year) carbon stock figures are taken from analyses of both old *P. afra* planting sites and pristine spekboom thicket. The gradient of the slopes is used as an estimate of the annual carbon accumulation rate in each of the carbon pools, and for the *ex ante* calculations.

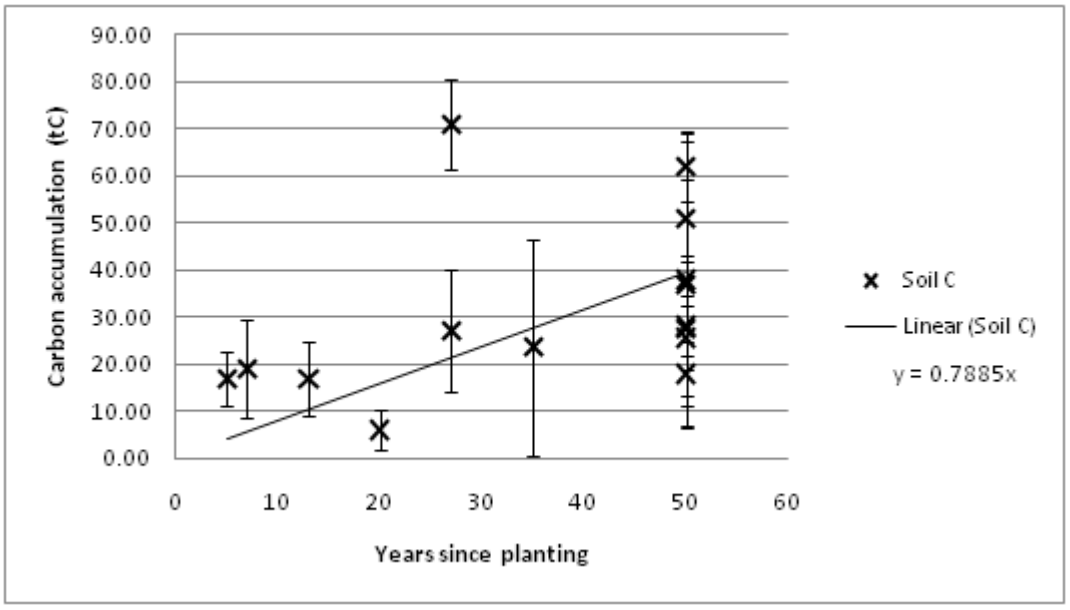


Figure A.7.1: The rate of accumulation of carbon in the soil of degraded or bare land replanted with *P. afra* (obtained from multiple literature sources, see Table A.7.1).

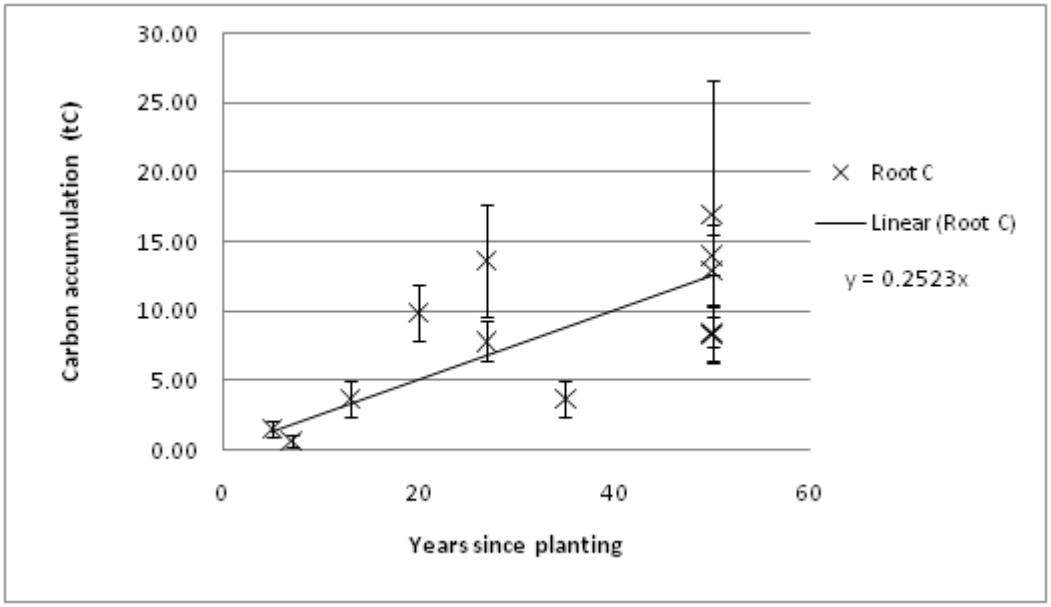


Figure A.7.2: The rate of carbon accumulation in the roots of *P. afra* planted on degraded land (obtained from multiple literature sources, see Table A.7.1).

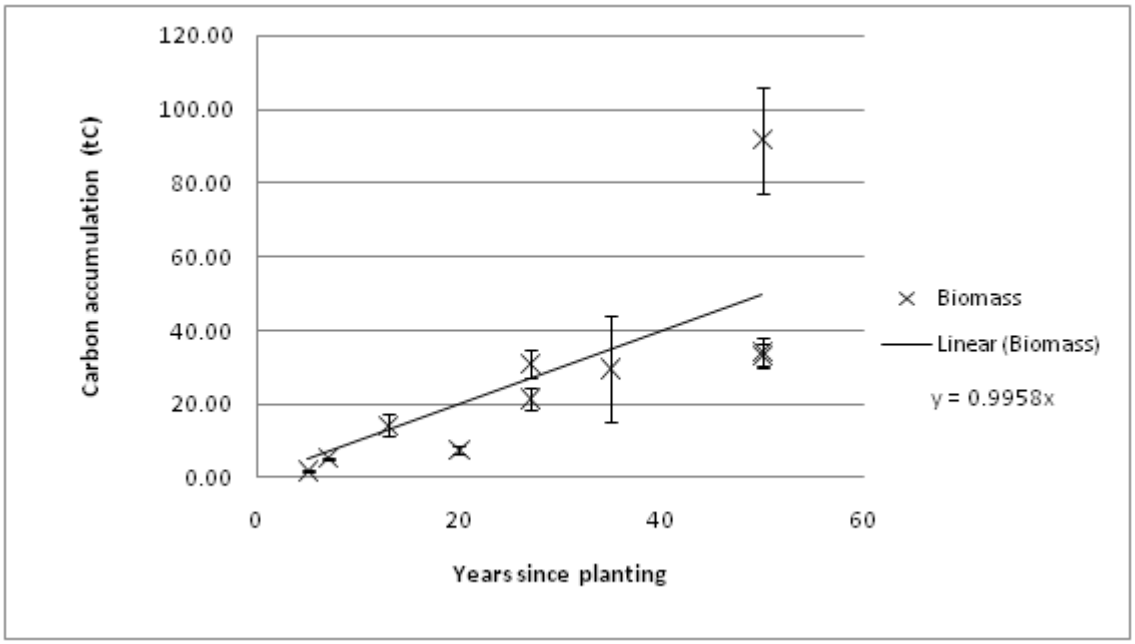


Figure A.7.3: The rate of carbon accumulation in the above ground biomass of *P. afra* planted on degraded land (obtained from multiple literature sources, see Table A.7.1).

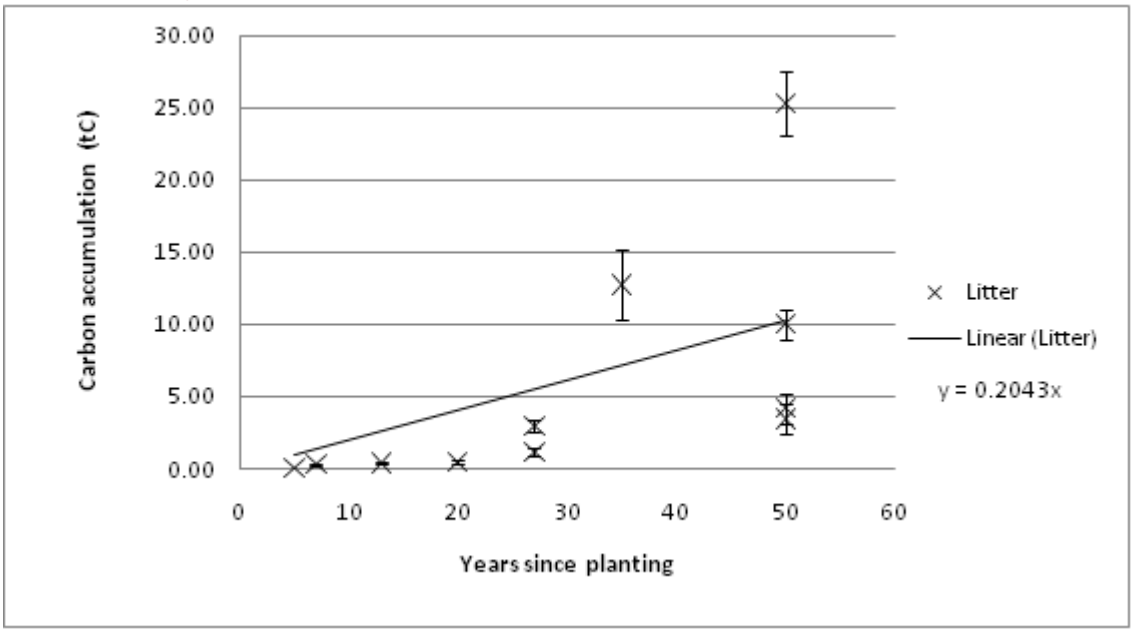


Figure A.7.4: The rate of carbon accumulation in litter generated by *P. afra* planted on degraded land (obtained from multiple literature sources, see Table A.7.1).

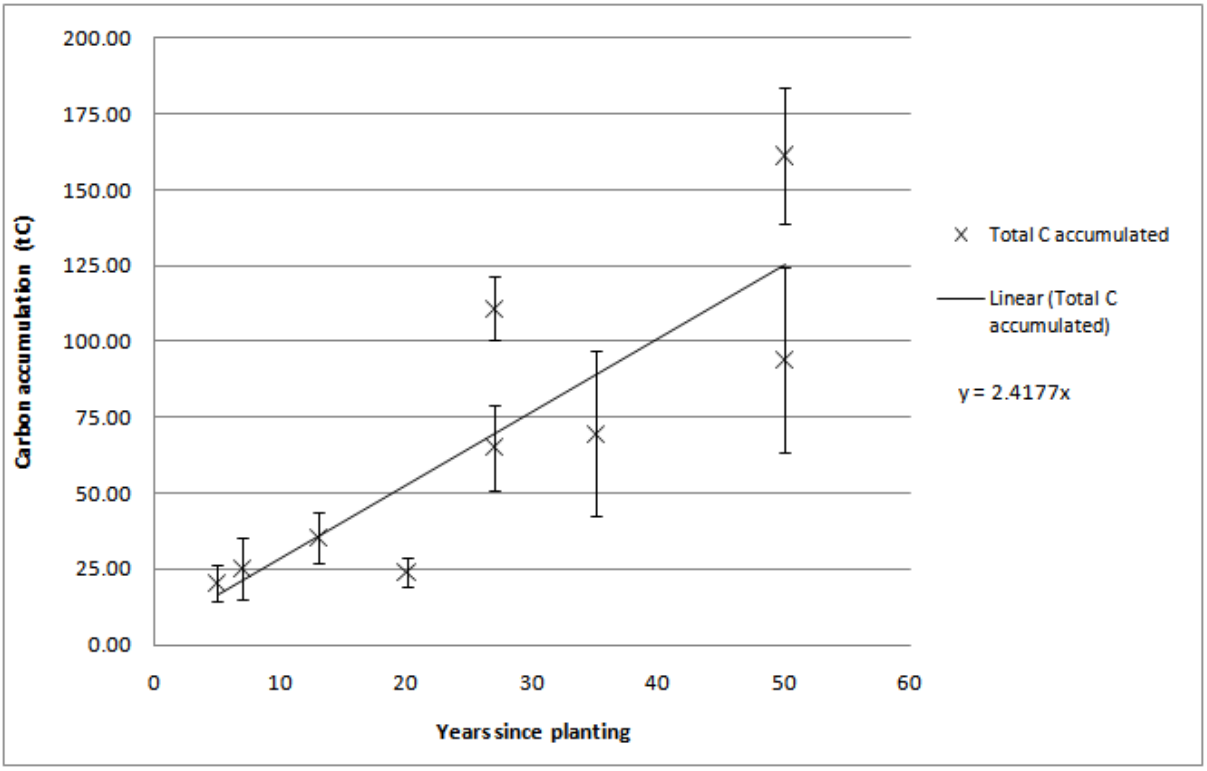


Figure A.7.5: Total carbon accumulation rate by *P. afra* planted on degraded land (obtained from multiple literature sources, see Table A.7.1).

Table A.7.1: Literature review of carbon stocks in multiple thicket sites in the Eastern Cape.

Site	Comments	GPS coordinates	Soil (t C ha^{-1})	Depth (cm)	Roots (t C ha^{-1})	AGB (t C ha^{-1})	Litter (t C ha^{-1})	Reference
Rhinosterhoek (Warren Rudman)	50 year old restored site		100.55 ±10.9	60	17.33 ±9.59	107.63 ±10.7	25.29 ±2.2	(van der Vuyfer, in press)
	35 year old restored site		96.75 ±20.95	60	4.07 ±1.33	45.41 ±10.58	12.76 ±2.41	
	Degraded land adjacent to restored site		73.1 ±9.3	60	0.38 ±0.08	15.89 ±9.81	0.03 ±0.01	
Baviaanskloof (Baviaans Spekboom Thicket)	Intact thicket		93 ±7	100	11 ±2	–	–	Mills & Cowling, 2010
	Degraded thicket		31 ±2	100	2.7 ±0.3	–	–	
	Old lands		42 ±4	100	2.6 ±0.3	–	–	
Xeric Succulent Thicket (8 Kirkwood sites)	Intact		168 ±26	50	25 ±1.3	–	–	(Mills et al., 2005b)
	Degraded		131 ±16	50	11 ±0.6	–	–	
	Intact		133 ±27	30	–	40 ±3	11 ±1	(Mills et al., 2005a)
	Degraded		95 ±15	30	–	7 ±1	1 ±0.4	
Krompoort	27 year old restored site (berg spekboom)		118 ±8	100	9.3 ±1.4	30.9 ±4	1.2 ±0.3	(Mills & Cowling, 2006)
	27 year old restored site (local spekboom)		74 ±12	100	15.1 ±4	21.5 ±3	3 ±0.4	
	13 year old restored site		64 ±6	100	5.2 ±1.3	14.2 ±3	0.4 ±0.01	
	7 year old restored site		66 ±9	100	2.1 ±0.3	5.3 ±0.2	0.3 ±0.1	
	5 year old restored site		64 ±3	100	3 ±0.5	1.9 ±0.2	0.03 ±	
	Degraded		47 ±5	100	1.5 ±0.3	–	–	
Fish River Reserve	Intact thicket		69 ±6	100	16.3 ±3.3	34.2 ±4	–	(Mills & Cowling, 2006)
	Open bare land		51 ±3	100	3.4 ±0.3	–	–	
	20 year old restored site		57 ±3	100	13.3 ±2	7.7 ±1	0.5 ±0.1	
Baviaanskloof (Baviaans	Intact thicket		49.68 ±6.21	25	3.6 ±0.58	29 ±3.32	4.85 ±0.99	(Powell, 2009)
	Degraded thicket		21.56 ±1.67	25	2.62 ±0.63	4 ±0.72	1.39 ±0.31	

Spekboom Thicket)	Old lands	24.06 ±2.34	25	3.34 ±0.78	5.4 ±1.58	0.66 ±0.25

Annex 8 Carbon stocks field analysis

Although the chosen methodology does not require quantification of GHG emissions for the baseline scenario; the effects of degradation on carbon pools in thicket ecosystems have been explored by this project. This afforded GIB the opportunity to develop a project specific root-shoot ratio and calculate annual increases in SOC. Carbon baselines (above ground biomass, below ground biomass and SOM to a depth of 110 cm) were measured in permanent plots in intact thicket (n=76), old fields (n=66) and degraded lands (n=100) in the Baviaanskloof Nature Reserve. The baseline carbon pools were measured in permanent, unplanted plots during the period 2004-2007. The measurements were taken according to the methodologies from the IPCC Good Practice Guidance for LULUCF (2003). GPS co-ordinates and soil data for each of the planting sites sampled for the baseline can be found in Annex 4 and Annex 8, respectively. The baseline study was completed on the 1st December 2007. The consultants used to establish this baseline were Mike Powell (Department of Environmental Science, Rhodes University, Grahamstown) and Dr Anthony Mills (Department of Soil Science, Stellenbosch University, Stellenbosch).

Baseline carbon pools collected were for:

- Above ground biomass;
- Below ground biomass; and
- Soil organic carbon.

Above ground tree biomass

Changes in tree biomass are calculated from monitoring data on individual trees in the permanent sampling plots. These plots were randomly selected in the different strata. The geographic coordinates of each plot were archived and the plots were marked with metal pegs in the field.

Nested plots, comprising small plots within larger plots, were used for monitoring the changes in stem diameter and tree density. Large plots were used for stem diameters greater than 10 cm, and small plots were used for stem diameters less than 10 cm. A minimum sample size of 10 large stem diameters and 10 small stem diameters in each plot was achieved. In the first ten years of the project there were very few trees with stem diameters greater than 10 cm in the restored planting sites. To achieve a minimum sample size of ten stems per plot, the sizes of permanent monitoring plots in some sites were increased.

Allometric equations that relate stem diameter at ground level to total carbon storage have been developed for *P. afra*. These equations were developed over the period 2004-2007 using at least 40 individual trees across a wide stem diameter range. AR-AM0002 (V3) uses allometric equations for determining carbon stocks based on tree diameter at breast height. The proposed ARR project allometric equations were parameterised on stem diameter at ground level. This is because stands of *P. afra* are multi-stemmed and a ground-level measurement is consequently more practical.

The allometric equation developed for *P. afra* is as follows:

$$Log_{10}y(C) = 1.1043(Log_{10}CBSA) + 2.4464$$

where:

$CBSA$ Cumulative basal stem area of plants (m^2).

The carbon stock in above ground tree biomass in the permanent monitoring plots was then calculated according to the following equation:

$$C_{AB,i,sp,j,t} = \sum_{l=1}^{N_{j,sp}} CF_j \cdot f_j(DBH) \quad (8)$$

where:

$C_{AB,i,sp,j,t}$	Carbon stock in above ground biomass of trees of species *j* on sample plot *sp* for stratum *I* at time *t*; t C
CF_j	Carbon fraction of dry matter for species or group of species type *j*, t C (t dm)$^{-1}$; IPCC default value = 0.5
$f_j(DBH, H)$	An allometric equation linking above ground biomass of living trees (t d.m tree^{-1}) to mean diameter at breast height (DBH) and possibly tree height (H) for species *j*, at time t; t dm tree^{-1}
i	1, 2, 3, ... M_{PS} strata in the project scenario
j	1, ... S_{PS} tree species in the project scenario; *P. afra* is the only species planted, therefore S_{PS} =1
I	1, 2, 3, ... $N_{j,sp}$ sequence number of individual trees of species *j* in sample plot sp
t	1, 2, 3, ... t* years elapsed since the start of the A/R project activity

The average carbon stock of above ground biomass for each stratum was calculated by averaging across the plots in a stratum.

Below ground biomass

Most of the below ground biomass gain from the proposed ARR project has accrued from the planted *P. afra* cuttings. This carbon gain was measured directly using destructive sampling.

The destructive sampling was divided into two substrata: i) sample pits under the planted *P. afra* canopy; and ii) sample pits outside of the *P. afra* canopy. Samples were taken to a depth of 1 m from 10 cm x 10 cm holes. Roots were separated from soil using wet-sieving and were dried in an oven at 65 °C until constant mass was achieved. The roots were then weighed and the following equation[30] was used to calculate the root carbon stock:

$$C_{BB,i,sp,j,t} = \sum_{l=1}^{N_{j,sp}} CF_j \cdot W_j$$

where:

$C_{BB,i,sp,j,t}$	Carbon stock in below ground biomass of trees of species *j* on sample plot *sp* for stratum *I* at time *t*; t C
W_j	Weight of the roots an individual tree of species *j*; kg C

The average carbon stock of below ground biomass for each stratum was calculated by averaging across the plots in a stratum.

Soil organic carbon

Soil samples were collected from a depth of 1 m in 10 cm x 10 cm holes from under and outside of the *P. afra* canopy for purposes of bulk density measurement. The volume of each of these sample holes was determined using river sand of known bulk density. The mass of the rock fraction (i.e. > 2

[30] This equation was derived independently using the mathematical principles in equation (8).

mm) in each sample was removed by wet sieving and subsequently dried in an oven at 65 °C. The volume of the rock fraction was determined by placing the rock fraction into water within a measuring cylinder. Mean bulk density values for each land use category (as opposed to bulk density values in each soil pit) were used to calculate total soil C stocks at different soil depths.

The mass of carbon per unit volume was calculated by multiplying the carbon concentration (percentage mass) and bulk density. SOC on an equal volume basis was calculated using equation 4.3.3 from the IPCC Good Practice Guidance for LULUCF. The equation is as follows:

$$SOC = [SOC] \cdot Bulk\ Density \cdot Depth \cdot CoarseFragments \cdot M \qquad (4.3.3)$$

where:

SOC	Soil organic carbon in for soil of interest; t C ha^{-1}
$[SOC]$	Soil organic carbon (percentage mass) of the sample determined in the laboratory; g C $(kg\ soil)^{-1}$
$Bulk\ Density$	Bulk density (soil mass/volume of sample); Mg m^{-3}
$Depth$	Sampling depth of soil profile; m
$CoarseFragments$	Factor to adjust the fraction of sample occupied by coarse fragments (>2 mm) [1-(% volume of coarse fragments/100)] to area of sampling frame; m^{-2}
M	Multiplier to convert units into t C ha^{-1}

The average soil organic carbon accumulation for each stratum was calculated by averaging across the plots in a stratum.

Root-shoot ratio

Calculations for the root-shoot ratio were done using the above and below ground biomass results from intact sample sites. Values for the average above and below ground biomass per hectare were used as above and below ground measurements were not correlated to individual plants. Below ground biomass for root carbon stocks were taken from the 0-25 cm soil layer as this soil layer contains 97 % of the below ground root carbon stock. The equation used is as follows:

$$R_j = \frac{C_{AB,i,sp,j,t}}{C_{BB,i,sp,j,t}}$$

where:

R_j	Root-shoot ratio for species *j*; dimensionless
$C_{AB,i,sp,j,t}$	Carbon stock in above ground biomass of trees of species j on sample plot sp for stratum I at time t; t C
$C_{BB,i,sp,j,t}$	Carbon stock in below ground biomass of trees of species j on sample plot sp for stratum i at time t; t C

The above ground biomass carbon stock value was calculated by averaging the 2nd column of Table A.8.5, Table A.8.10 and Table A.8.15 and multiplying by 12/44. The below ground biomass carbon stock value was calculated by averaging the 5th column of Table A.8.3, Table A.8.4, Table A.8.8, Table A.8.9, Table A.8.13 and Table A.8.14, and multiplying by 12/44. The root-shoot ratio was thus calculated as:

$R_j = 0.35$

Annual changes in soil organic carbon

The average annual SOC change in degraded planting sites was calculated by dividing the difference between degraded and intact SOC by the time to reach equilibrium (50 years). The SOC change in old fields was calculated in the same manner. Values for degraded, old and intact SOC were taken from the 0-25 cm soil layer as this soil layer contains 65 %, 46 % and 59 % respectively, of the total SOC.

The degraded SOC value was calculated by averaging the 5th column of Table A.8.1 and Table A.8.2 and multiplying by 12/44. The old land SOC value was calculated by averaging the 5th column of Table A.8.6 and Table A.8.7 and multiplying by 12/44. The intact land SOC value was calculated by averaging the 5th column of Table A.8.11 and Table A.8.12 and multiplying by 12/44. The average annual SOC change in degraded and old fields was calculated as 0.89 and 0.76 t C ha^{-1} yr^{-1} respectively.

Table A.8.1: Degraded lands soil carbon stocks (0-25 cm).

	Soil carbon stock (t CO_2 ha^{-1})			
Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25cm)	Total (0-25 cm)
KAD1	10	13	19	42
KAD2	22	38	33	93
KAD4	17	87	71	176
KAD5	26	32	58	117
KAD6	21	22	56	99
KAD7	23	37	12	71
KAD8	16	13	53	83
KAD9	24	31	50	105
KAD10	18	17	23	58
KDH1	11	16	21	48
KDH2	8	18	26	53
KDH3	9	18	26	54
KDH4	8	12	23	43
KDH5	13	24	49	86
KGHB1	16	10	24	51
KGHB2	6	6	18	30
KGHB3	7	15	21	43
KGHB4	8	11	10	29
KGHB5	11	15	18	44
KRC1	9	27	60	96
KRC2	4	9	21	34
KRC4	8	22	26	55
KRC5	2.6	10	4	16
RHDST1	10	13	38	61
RHDST2	12	10	19	41
RHDST3	13	32	27	72
RHDST4	14	5	16	34
RHDST5	17	17	54	87
RHDST6	5	12	17	35

RHDST7	13	32	35	80
RHDST9	10	23	35	68
RHDST10	12	42	17	71
RHDST11	15	27	48	90
RHDST13	20	39	44	104
RHDST14	18	30	77	125
RHDST15	15	52	76	143
RHDST16	5	1.8	12	18
RHDST17	8	8	11	27
RHDST18	4	2	4	10
RHDST19	5	8	16	29
RHDST20	8	6	13	27
RHDST22	8	17	31	56
RHDST23	14	25	39	78
RHDST24	8	8	26	42
RHDST25	10	27	42	80

Table A.8.2: Degraded lands soil carbon stocks (25- 110 cm).

	Soil carbon stock (t CO_2 ha^{-1})				
	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
RHDST6	33.0	21.5	14.8	16.4	85.7
RHDST7	16.2	8.6	12.9	16.4	54.1
RHDST8	37.8	4.8	11.0	4.8	58.4
RHDST9	19.2	5.3	11.0	5.3	40.7
RHDST10	16.2	16.7	7.6	23.6	64.2
RHDST11	16.2	11.0	4.8	5.3	37.3
RHDST12	15.6	5.7	5.2	8.7	35.3
RHDST13	24.0	10.0	5.2	5.3	44.6
RHDST14	18.6	4.8	12.9	5.3	41.6
RHDST15	30.0	4.8	13.8	5.3	53.9
KDH1	4.2	4.3	3.3	19.3	31.1
KDH3	12.0	3.3	3.3	3.4	22.1
KGHB3	34.2	4.8	6.7	8.2	53.9
KGHB4	8.4	16.7	6.2	5.3	36.6

Table A.8.3: Degraded lands root carbon stocks (0-25 cm).

	Root carbon stock (t CO_2 ha^{-1})			
Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25 cm)	Total (0-25 cm)
KAD1	0.02	0.04	0.01	0.07
KAD3	0.02	0.42	0.13	0.57
KAD4	0.15	2	0.88	2.80
KAD5	0.07	0.06	0.03	0.16

KAD6	0.10	0.09	0.24	0.44
KAD7	0.25	0.08	0.04	0.37
KAD8	0.02	0.03	0.13	0.18
KAD9	0.03	0.03	0.03	0.08
KAD10	0.17	0.05	0.10	0.32
KDH1	0.38	1	1	3
KDH2	1	0.71	2.80	5
KDH3	2	4	3	9
KDH4	1	0.03	4	5
KDH5	0.00	0.00	3	3
KGH1	6	5	8	18
KGH2	0.01	4	6	11
KGH3	0.47	25	2	28
KGH4	0.00	0.66	2	3
KRC1	0.13	6	1	7
KRC2	0.07	1	2	3
KRC3	0.04	2	0.57	3
KRC4	0.09	0.05	0.07	0.21
RHDST2	2	2	2	7
RHDST3	1	3	1	6
RHDST4	2	2	3	6
RHDST5	3	2	8	13
RHDST6	0.76	1	1	3
RHDST7	3	4	2	9
RHDST8	0.20	0.41	1	2
RHDST9	3	5	3	11
RHDST10	0.07	4	3	7
RHDST11	0.01	0.72	0.42	1
RHDST12	1	0.70	0.72	2
RHDST13	0.23	1.28	3	5
RHDST14	0.11	0.64	3	4
RHDST15	5	0.78	2	7
RHDST16	0.05	0.63	0.68	1
RHDST17	0.05	0.41	3	4
RHDST18	0.53	0.38	6	7
RHDST19	0.81	1	2	4
RHDST20	0.01	0.14	0.29	0.44
RHDST21	0.20	0.41	0.42	1

Table A.8.4: Degraded lands root carbon stocks (25-110 cm).

	Root carbon stock (t CO_2 ha^{-1})				
	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
KDH1	0.49	0.35	0.23	0.21	1.29
KDH3	0.48	0.02	0.11	0.10	0.72
KGH3	0.28	0.22	0.15	0.10	0.75

KGH4	0.42	0.20	0.15	0.07	0.84
KRC3	0.15	0.20	0.41	0.02	0.79
KRC4	0.32	0.10	0.08	0.16	0.66
RHDST6	0.24	0.13	0.11	0.02	0.50
RHDST7	0.87	0.15	0.28	0.04	1.34
RHDST8	0.05	0.02	0.03	0.42	0.52
RHDST9	0.08	0.02	0.02	0.02	0.14
RHDST10	1.07	0.27	0.03	0.02	1.38
RHDST16	15.24	0.02	0.06	0.04	15.37
RHDST17	0.32	0.09	0.26	0.17	0.85
RHDST18	0.77	0.68	0.41	0.68	2.54
RHDST19	2.51	0.70	0.14	0.09	3.44
RHDST20	0.09	0.23	0.36	2.77	3.45

Table A.8.5: Degraded land above ground, deadwood and litter carbon.

Code	Above ground ($t\ CO_2\ ha^{-1}$)	Deadwood ($t\ CO_2\ ha^{-1}$)	Litter ($t\ CO_2\ ha^{-1}$)
0KAD1	13	0	0.58
KAD2	10	0	2
KAD3	10	0	5
KAD4	29	0	10
KAD5	63	0	6
KAD6	34	0	7
KAD7	56	0	4
KAD8	10	0	6
KAD9	8	0	2
KAD10	134	0	9
KDH1	5	0	0.80
KDH2	4	0	0.70
KDH3	20	0	1
KDH4	7	0	4
KDH5	7	0	4
KGHB1	9	0	2
KGHB2	7	0	1
KGHB3	18	0	3
KGHB4	8	0	0.59
KGHB5	7	0	2
KRC1	6	0	14
KRC2	49	0	6
KRC3	9	0	1
KRC4	8	0	18
KRC5b	42	0	0.44
RHDST1	4	0	2
RHDST2	33	0	6
RHDST3	24	0	3
RHDST4	14	0	3
RHDST5	18	0	0.83

RHDST6	6	0	43
RHDST7	2	0	1
RHDST8	4	0	3
RHDST9	0.18	0	2
RHDST10	0.18	0	0.16
RHDST11	7	0	0.70
RHDST12	12	0	2
RHDST13	57	0	12
RHDST14	14	0	9
RHDST15	11	0	0.93
RHDST16	4	0	1
RHDST17	6	0	0.94
RHDST18	17	0	0.47
RHDST19	24	0	3
RHDST20	0.94	0	2
RHDST21	10	0	2
RHDST22	7	0	2
RHDST23	85	0	22
RHDST24	1	0	0.37
RHDST25	9	0	3

Table A.8.6: Old fields soil carbon stocks (0-25 cm).

	Soil carbon stock (t CO_2 ha^{-1})			
Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25 cm)	Total (0-25 cm)
RHOL1	8	73	161	242
RHOL2	18	41	42	101
RHOL3	12	38	48	99
RHOL4	16	28	83	127
RHOL5	10	14	26	50
RHOL6	14	14	22	50
RHOL7	13	4	14	31
RHOL8	12	9	8	30
RHOL9	14	11	32	57
RHOL10	18	27	47	92
RHOL11	23	40	51	114
RHOL12	21	48	84	153
RHOL13	19	25	58	102
RHOL14	15	24	44	82
RHOL15	13	16	43	72
RHOL16	17	10	7	35
RHOL17	10	12	20	42
RHOL18	13	14	51	78
RHOL19	8	35	42	85
RHOL20	13	14	12	39

RHOL21	8	22	18	49
RHOL22	8	19	39	66
RHOL23	10	5	31	46
RHOL24	8	6	19	34
RHOL25	7	11	10	28
GHOL2_1	12	18	35	65
GHOL2_2	16	22	35	73
GHOL2_4	11	19	44	73
GHOL2_5	4	13	29	46
KLK1	7	17	38	63
KLK2	6	13	24	43
KLK3	16	10	24	50
KLK4	12	23	36	70
KLK5	12	15	27	54
KLK6	5	8	19	32
KLK7	7	5	14	25
KLK8	9	22	47	77
KLK9	11	12	31	55
KLK10	8	10	27	45
COLE1	19	47	140	205
COLE2	27	62	77	167
COLE3	24	35	49	108
COLE4	32	28	40	100
COLE5	8	12	98	119
COLN1	35	48	71	154
COLN2	21	34	105	160
COLN3	34	34	66	133
COLN4	21	25	84	130
COLN5	29	44	126	198
COLN6	19	23	73	114
GHOL1_1	13	26	31	70
GHOL1_2	9	17	11	37
GHOL1_3	12	35	38	85
GHOL1_4	18	21	33	72
GHOL1_5	16	36	55	106
GHOL1_6	7	13	24	44
GHOL1_7	12	27	43	82
GHOL1_8	12	32	61	105
GHOL1_9	20	12	22	54
GHOL1_10	11	25	27	63

Table A.8.7: Old fields soil carbon stocks (25-110 cm).

	Soil carbon stock (t CO_2 ha^{-1})

	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
COLE4	24.9	8.5	12.3	8.7	54.4
COLE5	142.5	83.8	36.2	41.3	303.8
COLN4	123.4	9.2	21.6	13.5	167.7
COLN5	94.7	43.8	7.7	8.7	154.9
CSTN5	51.5	35.4	92.8	97.4	277.1
GHOL1_6	39.2	9.2	23.1	30.9	102.5
GHOL1_7	22.0	8.5	20.0	16.7	67.2
GHOL1_8	74.6	40.7	9.2	8.7	133.3
GHOL1_9	38.3	7.7	8.5	7.9	62.4
GHOL1_10	64.1	20.8	8.5	7.9	101.2
GHOL2_1	11.5	20.0	8.5	11.1	51.0
GHOL2_2	10.5	15.4	8.5	8.7	43.1
GHOL2_3	33.5	7.7	8.5	7.9	57.6
GHOL2_4	11.5	14.6	7.7	7.9	41.7
GHOL2_5	22.0	8.5	8.5	8.7	47.7
RHOL3	24.9	5.4	20.8	28.6	79.6
RHOl4	6.7	5.4	5.4	11.1	28.6
RHOL6	35.4	26.1	8.5	32.5	102.5
RHOL8	29.6	15.4	17.7	5.6	68.3
RHOL12	44.0	17.7	45.5	53.9	161.1
RHOL19	54.5	8.5	23.1	8.7	94.8
RHOL22	13.4	8.5	8.5	7.9	38.3
RHOL25	10.5	9.2	8.5	8.7	36.9

Table A.8.8: Old fields root carbon stocks (0-25 cm).

	Root carbon stock (t CO_2 ha^{-1})			
Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25 cm)	Total (0-25 cm)
RHOL1	2	3	7	12
RHOL2	0.91	2	0.36	3
RHOL3	7	3	2	12
RHOL4	0.50	2	3	6
RHOL5	0.95	0.84	0.78	3
RHOL6	0.19	0.26	1	2
RHOL7	6	3	4	13
RHOL8	3	0.18	1	4
RHOL9	1	0.28	1	3
RHOL10	2	2	3	7
RHOL11	0.40	3	4	7
RHOL12	3	5	10	17
RHOL13	4	3	4	11
RHOL14	2	3	3	8
RHOL15	4	4	3	11

RHOL16	0.96	7	1	9
RHOL17	2	2	2	6
RHOL18	2	4	5	11
RHOL19	3	1	1	5
RHOL20	0.88	2	1	4
RHOL21	0.52	0.65	2	3
RHOL22	2	1	1	5
RHOL23	0.70	2	2	4
RHOL24	1	1	2	4
RHOL25	4	2	1	8
GHOL2_1	0.86	1	2	4
GHOL2_2	0.26	0.77	0.84	2
GHOL2_3	5.50	0.76	0.61	7
GHOL2_4	0.65	2	2	5
KLK1	0.09	0.05	0.07	0.21
KLK2	0.00	0.02	0.02	0.04
KLK3	0.33	0.13	0.07	0.53
KLK4	0.01	0.06	0.04	0.11
KLK5	0.02	0.00	0.01	0.03
KLK6	0.04	0.05	0.05	0.14
KLK7	0.06	0.11	0.03	0.20
KLK8	0.08	0.05	0.23	0.36
KLK9	0.06	0.06	0.02	0.14
KLK10	0.06	0.02	0.04	0.12
GHOL3_1	1	0.57	1	3
GHOL3_2	0.51	1	1	3
GHOL3_3	0.21	1	2	3
GHOL3_4	0.50	2	1	4
GHOL3_5	0.18	1	1	2
COLN1	3	1	2	6
COLN4	1	0.42	0.83	2
COLN5	0.41	0.45	0.59	1
COLN6	1	2	3	5
GHOL1_5	5	3	3	11
GHOL1_6	0.93	0.51	0.69	2
GHOL1_8	0.89	0.48	1	3
GHOL1_9	0.29	1	0.69	2
GHOL1_10	1	1	1	4

Table A.8.9: Old fields root carbon stocks (25-110 cm).

	Root carbon stock (t CO_2 ha^{-1})				
	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
KCAB1	0.84	0.99	0.36	0.77	2.97
KCAB4	0.98	0.06	0.37	0.21	1.62
KKK1	0.38	0.19	0.12	7.20	7.89

KKK2	0.51	0.18	0.17	0.66	1.51
RHST2	0.39	0.70	0.23	0.05	1.37
RHST4	0.75	0.23	0.00	0.00	0.98
RHST6	0.41	0.51	0.32	0.04	1.29
RHST8	13.13	0.08	0.12	0.16	13.49
RHST11	0.13	8.65	0.37	6.29	15.44
RHST13	3.22	1.18	0.11	0.17	4.68
RHST15	3.58	0.51	0.22	1.24	5.55
RHST19	0.30	0.20	0.29	0.82	1.61
RHSR22	1.74	0.50	2.14	4.88	9.26
RHST25	1.38	0.05	0.00	0.09	1.52
GHST8	1.30	0.17	0.02	0.02	1.51
GHST9	1.09	0.85	0.05	0.05	2.03
GHST10	0.50	0.05	0.02	0.08	0.65
GHST11	0.03	0.51	0.07	0.19	0.79
GHST14	0.89	0.26	0.05	0.02	1.22
CSTN1	1.00	2.20	0.60	0.22	4.02
CSTN2	0.13	0.25	0.08	0.18	0.64
CSTN3	8.93	0.74	0.05	0.08	9.79
CSTN4	0.18	0.80	0.54	0.09	1.61
CSTN5	0.56	0.03	0.09	0.18	0.86

Table A.8.10: Old fields above ground, deadwood and litter carbon.

Code	Above ground ($t CO_2 ha^{-1}$)	Deadwood ($t CO_2 ha^{-1}$)	Litter ($t CO_2 ha^{-1}$)
GHOL1_1	4	0	3
GHOL1_2	2	0	7
GHOL1_3	2	0	16
GHOL1_4	3	0	10
GHOL1_5	3	0	1
GHOL1_6	7	0	36
GHOL1_7	4	0	1
GHOL1_8	8	0	0.25
GHOL1_9	13	0	0.68
GHOL1_10	3	0	0.38
GHOL2_1	12	0	1
GHOL2_2	49	0	8
GHOL2_3	2	0	3
GHOL2_4	5	0	1
GHOL2_5	3	0	0.52
GHOL3_1	2	0	1
GHOL3_2	0.84	0	0.00
GHOL3_3	0.46	0	0.44
GHOL3_4	10	0	2
GHOL3_5	2	0	1
COLE1	9	0	1
COLE2	16	0	1
COLE3	5	0	0.76

COLE4	11	0	5
COLE5	23	0	0.87
COLN2	5	0	0.39
COLN3	7	0	0.34
COLN4	2	0	1
COLN5	4	0	0.41
COLN6	3	0	0
KLK1	101	0	2
KLK2	5	0	3
KLK3	3	0	4
KLK4	1	0	4
KLK5	2	0	6
KLK6	1	0	2
KLK7	0.70	0	2
KLK8	1	0	0.85
KLK9	0.42	0	5
KLK10	0.19	0	2
RHOL1	15	0	2
RHOL2	5	0	0.73
RHOL3	0.92	0	0.52
RHOL4	9	0	0.87
RHOL5	12	0	1
RHOL6	7	0	0.41
RHOL7	25	0	15
RHOL8	41	0	0.46
RHOL9	8	0	0.37
RHOL10	56	0	6
RHOL11	14	0	4
RHOL12	1	0	0.23
RHOL13	34	0	0.51
RHOL14	8	0	0.25
RHOL15	60	0	18
RHOL16	1	0	1
RHOL17	2	0	0.11
RHOL18	25	0	0.28
RHOL19	3	0	0.23
RHOL20	11	0	0.66
RHOL21	39	0	2
RHOL22	1	0	1
RHOL23	9	0	3
RHOL24	5	0	0.16
RHOL25	2	0	0.28

Table A.8.11: Intact thicket soil carbon stocks (under bush) (0-25 cm).

	Soil carbon stock (t CO_2 ha^{-1})

Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25 cm)	Total (0-25 cm)
KADSS1	62.7	273.7	406.1	742.5
KADSS2	67.0	292.1	537.1	896.3
KADSS3	69.4	173.6	187.8	430.8
KADSS4	59.4	138.3	322.3	520.0
KADSS5	31.2	94.2	114.6	240.0
KCAB1	15.6	33.1	94.9	143.6
KCAB2	5.0	65.3	52.7	123.0
KCAB3	18.4	64.8	135.0	218.2
KCAB4	15.8	24.8	78.2	118.8
KCAB5	63.2	104.2	419.6	586.9
KKO2	68.7	120.7	293.8	483.2
KKO3	25.1	38.5	71.0	134.6
KKO4	21.1	40.1	48.1	109.2
KKO5	27.3	32.8	88.6	148.6
KKK1	22.9	75.8	137.9	236.6
KK2	10.8	42.3	88.6	141.7
KKK2	13.1	37.9	101.1	152.2
KK3	10.8	32.8	81.9	125.5
KKK3	21.8	38.6	70.6	131.0
KQ1	14.5	39.6	61.9	115.9
KQ2	14.8	28.3	51.8	95.0
KQ3	14.5	41.6	41.8	97.8
KQ4	23.1	80.0	198.9	302.0
KQ5	22.5	42.3	89.4	154.2
RHST1	21.8	45.3	79.8	146.9
RHST2	13.4	44.5	29.7	87.6
RHST3	6.7	79.5	102.4	188.5
RHST4	21.5	44.7	165.5	231.7
RHST6	26.1	62.7	78.2	167.0
RHST7	17.3	63.5	181.4	262.2
RHST8	23.0	42.1	65.6	130.8
RHST9	25.3	43.4	107.4	176.1
RHST11	19.9	67.9	109.5	197.3
RHST12	23.8	54.3	91.9	170.1
RHST13	29.5	39.4	63.9	132.8
RHST14	23.6	88.3	93.6	205.5
RHST15	14.4	5.0	104.5	123.9
RHST16	32.1	74.3	170.5	277.0
RHST17	17.3	25.2	75.2	117.8
RHST18	17.1	38.3	102.4	157.8
RHST19	30.7	44.2	92.8	167.6
RHST20	35.6	65.3	100.3	201.2
RHST21	29.2	51.2	84.4	164.7
RHST22	32.9	75.4	106.6	214.9
RHST23	16.2	39.4	83.6	139.2

RHST24	37.7	50.1	91.1	178.9
RHST25	31.0	40.1	111.2	182.2
GHST6	14.9	31.2	58.4	104.6
GHST7	19.5	115.9	102.1	237.5
GHST8	13.7	36.6	58.0	108.3
GHST9	15.6	27.8	47.6	91.0
GHST10	13.5	36.3	87.8	137.6
GHST11	12.2	14.4	24.7	51.2
GHST12	16.6	34.9	51.8	103.3
GHST13	9.7	21.0	38.2	68.8
GHST14	8.8	44.5	92.2	145.5
GHST15	14.6	29.3	52.2	96.1
GHST16	15.7	37.0	55.7	108.5
CSTE1	12.5	3.7	58.5	74.7
CSTE3	5.1	1.8	83.6	90.6
CSTE5	25.7	63.0	129.7	218.4
CSTN1	20.6	58.5	122.9	202.0
CSTN3	22.0	63.0	97.5	182.5
CSTN4	13.9	9.2	37.6	60.8
GHST1	27.9	42.3	108.7	178.9
GHST2	26.4	51.5	104.5	182.4
GHST3	24.2	49.7	104.5	178.4
GHST4	27.2	12.9	125.4	165.4

Table A.8.12: Intact thicket soil carbon stocks (under bush) (25-110 cm).

	Soil carbon stock (t CO_2 ha^{-1})				
	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
GHST8	24.8	4.4	7.1	5.2	41.5
GHST9	6.5	11.4	5.1	5.7	28.7
GHST10	33.9	7.9	5.1	5.7	52.6
GHST11	18.9	18.8	24.0	5.7	67.4
GHST14	110.9	37.1	58.6	15.6	222.3
KCAB1	200.9	85.2	14.3	13.5	313.9
KCAB4	63.9	28.4	5.6	5.7	103.6
KKK1	76.3	4.8	13.3	7.3	101.7
KKK2	58.0	30.6	24.0	14.1	126.7
KKK3	11.5	12.3	5.4	5.6	34.7
KKK5	6.7	5.4	5.4	5.6	23.0
KKR4	46.8	5.3	8.6	17.3	78.0
RHST2	37.2	21.0	8.2	27.6	93.9
RHST4	33.3	55.9	6.1	12.0	107.3
RHST6	101.7	81.3	69.4	35.4	287.8
RHST8	78.3	31.0	34.2	32.3	175.7
RHST11	70.4	28.8	16.3	5.7	121.3

RHST13	121.3	39.3	33.1	32.3	226.1
RHST15	102.4	76.9	55.1	25.5	259.9
RHST19	103.0	48.5	5.1	20.3	176.9
RHST22	82.8	24.0	5.6	6.8	119.2
RHST25	44.3	62.5	31.6	20.8	159.3

Table A.8.13: Intact thicket root carbon stocks (under bush) (0-25 cm).

	Root carbon stock (t CO_2 ha^{-1})			
Code	Depth A (0-3 cm)	Depth B (3-10 cm)	Depth C (10-25 cm)	Total (0-25 cm)
KADSS1	0.31	1	1	2
KADSS2	0.11	0.19	2	2
KADSS3	0.09	0.07	0.19	0.34
KADSS4	0.07	0.26	0.30	0.63
KADSS5	0.22	0.24	0.53	0.99
KCAB3	0.63	10	1	12
KCAB5	0.12	0.18	0.87	1
KKO2	26	3	3	31
KKO4	0.87	0.87	12	14
KKK1	1.6	12.0	9	22
KKK2	0.76	28	3	33
KKK3	2	16	14	32
KQ3	0.52	3	19	23
RHST1	1	2	4	7
RHST2	2	2	5	9
RHST3	1	4	4	9
RHST4	4	13	3	20
RHST5	4	2	4	9
RHST6	2	9	0.94	12
RHST7	2	32	3	36
RHST8	7	3	3	13
RHST11	25	0.68	2	28
RHST12	2	6	7	15
RHST13	3	6	4	13
RHST15	1	4	3	9
RHST16	3	1	3	7
RHST17	0.59	4	4	9
RHST18	2	0.71	63	66
RHST19	2	2	6	11
RHST20	0.83	0.76	24	26
RHST21	3	19	2	24
RHST22	0.55	5	3	8
RHST23	2	2	59	63
RHST24	2	7	3	12
RHST25	2	5	14	21
GHST6	0.81	4	20	24

GHST7	6	8	3	17
GHST8	2	2	22	26
GHST9	2	2	2	7
GHST11	0.60	18	6	24
GHST12	10	11	9	30
GHST13	2	3	44	49
GHST14	0.24	2	0.98	3
GHST16	4	11	6	21
CSTN1	2	2	1	5
CSTN3	1	0	14	16
CSTN4	2	1	23	26
CSTN5	2	3	3	8
GHST10	1	419	2	423
RHST14	1	112	27	141
KKO3	0.25	77	2	79
GHST15	3	21	156	180

Table A.8.14: Intact thicket root carbon stocks (In the open)* (25-110 cm).

	Root carbon stock (t CO_2 ha^{-1})				
	Depth D (38-42 cm)	Depth E (58-62 cm)	Depth F (78-82 cm)	Depth G (98-102 cm)	Total
RHOL3	1.04	0.43	0.14	0.09	1.71
RHOL4	0.24	0.10	0.01	0.06	0.41
RHOL6	0.35	0.24	0.05	0.05	0.69
THOL8	0.51	0.09	0.03	0.03	0.66
RHOL12	0.30	0.10	0.02	0.02	0.43
RHOL13	0.39	0.02	0.02	0.09	0.53
RHOL15	0.26	0.29	0.04	0.06	0.65
RHOL19	0.07	0.09	0.04	0.04	0.24
RHOL22	0.38	0.10	0.02	0.04	0.54
RHOL25	0.70	0.21	0.14	0.07	1.13
GHOL2_2	0.04	0.02	0.05	0.10	0.21
GHOL2_4	0.02	0.02	0.34	0.02	0.39
GHOL2_5	0.23	0.02	0.18	0.02	0.44
KLK3	0.81	0.59	0.24	0.26	1.89
KLK5	0.37	0.09	0.04	0.08	0.59
GHOL2_1	0.50	0.09	0.11	0.04	0.74
COLE1	0.77	0.21	0.15	0.02	1.15
COLE2	0.41	0.10	0.02	0.02	0.55
COLE4	0.20	0.02	0.02	0.02	0.27
COLE5	0.86	0.38	0.18	0.06	1.49
COLN2	2.43	0.15	0.43	0.01	3.03
COLn3	0.17	0.06	0.13	0.05	0.40
COLN4	0.61	0.12	0.08	0.06	0.87
COLN5	0.28	0.06	0.08	0.05	0.47

COLn6	0.47	0.29	0.07	0.30	1.13
GHOL1_6	0.10	0.10	0.02	0.03	0.26
GHOL1_7	0.91	0.41	0.02	0.11	1.45
GHOL1_8	0.16	0.06	0.16	0.04	0.42
GHOL1_9	0.73	0.20	0.09	0.04	1.06
GHOL1_10	1.55	0.34	0.30	0.13	2.33

Table A.8.15: Intact thicket above ground, deadwood and litter carbon.

Code	Above ground ($t CO_2 ha^{-1}$)	Deadwood ($t CO_2 ha^{-1}$)	Litter ($t CO_2 ha^{-1}$)
CSTE1	24	0	15
CSTE2	48	0	3
CSTE3	13	0	1
CSTE4	33	0	3
CSTE5	290	0	25
CSTN1	52	0	0
CSTN2	101	0	4
CSTN3	34	0	12
CSTN4	13	0	4
CSTN5	84	0	5
GHST 16	103	0	2
GHST1	31	0	7
GHST10	9	0	1
GHST11	9	0	8
GHST12	23	0	4
GHST13	15	0	2
GHST14	50	0	9
GHST15	193	0	2
GHST2	25	0	7
GHST3	171	0	23
GHST4	71	0	0.85
GHST5	38	0	5
GHST6	892	0	15
GHST7	26	0	0.80
GHST8	19	0	0.32
GHST9	79	0	2
KADSS1	81	0	9
KADSS2	44	0	5
KADSS3	49	0	16
KADSS4	28	0	3
KADSS5	71	0	0.86
KCAB1	56	0	10
KCAB2	51	0	7
KCAB3	87	0	10
KCAB4	59	0	26
KCAB5	305	0	4
KKK1	329	0	36

KKK2	131	0	66
KKK3	205	0	6
KKK4	113	0	40
KKK5	145	0	16
KKO1	32	0	5
KKO2	23	0	5
KKO3	52	0	17
KKO4	28	0	0.93
KKO5	22	0	5
KQ1	79	0	18
KQ2	44	0	8
KQ3	57	0	2
KQ4	47	0	5
KQ5	44	0	1
RHST1	119	0	10
RHST10	40	0	39
RHST11	124	0	41
RHST12	158	0	34
RHST13	108	0	33
RHST14	55	0	17
RHST15	85	0	13
RHST16	16	0	4
RHST17	0.6	0	3
RHST18	78	0	4
RHST19	410	0	80
RHST2	58	0	10
RHST20	40	0	4
RHST21	197	0	11
RHST22	23	0	0.79
RHST23	58	0	10
RHST24	142	0	6
RHST25	78	0	1
RHST3	116	0	8
RHST4	131	0	37
RHST5	52	0	52
RHST6	61	1.19	5
RHST7	85	0	9
RHST8	50	0	28
RHST9	65	0	48

Table A.8.16: Intact thicket bulk density under the bush at Depth A.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KASS3	0.7	RHST4	0.5	RHST22	1.9	CSTE5	0.8
KASS4	0.8	RHST5	0.7	RHST23	1.0	CSTN1	0.6
KCAB2	0.6	RHST6	1.0	RHST24	1.7	CSTN2	0.6
KCAB4	0.5	RHST7	0.5	RHST25	1.3	CSTN3	0.6
KKK2	0.5	RHST8	0.5	GHST6	0.7	CSTN4	0.6

KKK4	0.6	RHST9	1.1	GHST13	0.9	CSTN5	0.7
KKK5	0.5	RHST14	0.5	GHST16	1.2	GHST1	1.2
KQ3	0.5	RHST16	0.5	CSTE1	0.9	GHST2	0.9
RHST1	0.6	RHST17	0.7	CSTE2	0.7	GHST3	0.9
RHST2	0.7	RHST19	0.5	CSTE3	1.0	GHST5	0.6
RHST3	0.5	RHST20	0.6	CSTE4	0.8		

Table A.8.17: Intact thicket Root density under the bush at Depth A.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KASS1	0.0006	KKK2	0.0014	RHST11	0.0458	GHST7	0.0114
KASS2	0.0002	KKK3	0.0032	RHST12	0.0037	GHST8	0.0038
KASS3	0.0002	KKK4	0.0008	RHST13	0.0048	GHST9	0.0041
KASS4	0.0001	KKK5	0.0006	RHST14	0.0026	GHST10	0.0026
KASS5	0.0004	KQ1	0.0024	RHST15	0.0025	GHST11	0.0011
KCAB1	0.0045	KQ2	0.0021	RHST16	0.0058	GHST12	0.0177
KCAB2	0.0017	KQ3	0.0009	RHST17	0.0011	GHST13	0.0037
KCAB3	0.0011	RHST1	0.0026	RHST18	0.0044	GHST14	0.0004
KCAB4	0.0018	RHST2	0.0033	RHST19	0.0044	GHST15	0.0057
KCAB5	0.0002	RHST3	0.0020	RHST20	0.0015	GHST16	0.0073
KKO1	0.0004	RHST4	0.0067	RHST21	0.0060	CSTN1	0.0039
KKO2	0.0465	RHST5	0.0068	RHST22	0.0010	CSTN2	0.0070
KKO3	0.0005	RHST6	0.0039	RHST23	0.0028	CSTN3	0.0024
KKO4	0.0016	RHST7	0.0038	RHST24	0.0028	CSTN4	0.0038
KKO5	0.0423	RHST8	0.0128	RHST25	0.0036	CSTN5	0.0039
KKK1	0.0029	RHST9	0.0043	GHST6	0.0015		

Table A.8.18: Intact thicket stone volume under the bush at Depth A

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
KASS1	10	KKK4	24	RHST17	11	GHST16	1
KASS2	6	KKK5	9	RHST18	16	CSTE1	7
KASS3	22	KQ3	28	RHST19	12	CSTE2	7
KASS4	55	KQ4	21	RHST20	35	CSTE3	17
KASS5	43	RHST1	11	RHST22	15	CSTE4	8
KCAB1	6	RHST2	12	RHST23	8	CSTE5	25
KCAB2	10	RHST3	9	RHST24	5	CSTN1	20
KCAB3	11	RHST4	7	RHST25	16	CSTN2	7
KCAB4	12	RHST5	2	GHST6	10	CSTN3	11
KCAB5	35	RHST6	10	GHST7	50	CSTN4	30
KKO1	19	RHST7	11	GHST8	4	CSTN5	6
KKO2	23	RHST8	12	GHST9	1	GHST1	27
KKO3	29	RHST9	13	GHST10	1	GHST2	0
KKO4	2	RHST11	2	GHST11	0.0	GHST3	0
KKO5	16	RHST12	3	GHST12	4	GHST5	2
KKK1	4	RHST13	2	GHST13	11		
KKK2	2	RHST14	11	GHST14	7		

KKK3	10	RHST16	39	GHST15	2		

Table A.8.19: Intact thicket mean organic carbon under the bush at Depth A.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KASS1	9	KKK5	3	RHST15	2	GHST13	1
KASS2	9	KQ1	2	RHST16	4	GHST14	1
KASS3	9	KQ2	2	RHST17	2	GHST15	2
KASS4	8	KQ3	2	RHST18	2	GHST16	2
KASS5	4	KQ4	3	RHST19	4	CSTE1	2
KCAB1	2	KQ5	3	RHST20	5	CSTE3	0.7
KCAB2	0.7	RHST1	3	RHST21	4	CSTE5	4
KCAB3	3	RHST2	2	RHST22	4	CSTN1	3
KCAB4	2	RHST3	0.9	RHST23	2	CSTN2	2
KCAB5	9	RHST4	3	RHST24	5	CSTN3	3
KKO2	9	RHST6	4	RHST25	4	CSTN4	2
KKO3	3	RHST7	2	GHST6	2	GHST1	4
KKO4	3	RHST8	3	GHST7	3	GHST2	4
KKO5	4	RHST9	3	GHST8	2	GHST3	3
KKK1	3	RHST11	3	GHST9	2	GHST5	4
KKK2	1	RHST12	3	GHST10	2		
KKK3	2	RHST13	4	GHST11	2		
KKK4	1	RHST14	3	GHST12	2		

Table A.8.20: Intact thicket bulk density under the bush at Depth B.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KASS1	0.6	RHST2	0.5	RHST19	0.7	GHST16	1.2
KASS2	0.5	RHST3	0.4	RHST20	1.0	CSTE1	1.0
KASS3	0.8	RHST4	0.7	RHST21	1.1	CSTE2	1.0
KASS5	0.8	RHST5	0.9	RHST23	0.6	CSTE3	0.9
KCAB1	0.7	RHST6	1.0	RHST24	1.8	CSTE4	1.0
KCAB2	0.6	RHST7	1.0	RHST25	0.9	CSTE5	0.8
KCAB3	0.7	RHST8	0.7	GHST6	0.4	CSTN1	0.9
KKO1	0.7	RHST10	0.8	GHST8	1.5	CSTN2	0.7
KKK3	0.6	RHST11	0.6	GHST9	1.5	CSTN3	0.6
KKK4	0.5	RHST13	0.6	GHST10	1.5	CSTN4	0.7
KKK5	0.6	RHST14	0.6	GHST11	1.5	CSTN5	0.9
KQ1	0.6	RHST15	0.5	GHST12	1.3	GHST1	1.1
KQ2	0.7	RHST16	1.0	GHST13	1.3	GHST2	1.2
KQ3	0.6	RHST17	1.0	GHST14	1.3	GHST3	0.9
KQ5	0.4	RHST18	1.1	GHST15	1.6	GHST5	0.7
RHST1	0.7						

Table A.8.21: Intact thicket bulk density under the bush at Depth B.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KASS1	0.000830	KKK4	0.000578	RHST12	0.004759	GHST7	0.006456
KASS2	0.000145	KKK5	0.000031	RHST13	0.005059	GHST8	0.001469
KASS3	0.000054	KQ1	0.001317	RHST14	0.087474	GHST9	0.001784
KASS4	0.000201	KQ3	0.002172	RHST15	0.003485	GHST10	0.326350
KASS5	0.000190	RHST1	0.001582	RHST16	0.001049	GHST11	0.013683
KCAB2	0.000308	RHST2	0.001587	RHST17	0.003397	GHST12	0.008815
KCAB3	0.007842	RHST3	0.003112	RHST18	0.000552	GHST13	0.002525
KCAB5	0.000142	RHST4	0.010157	RHST19	0.001807	GHST14	0.001585
KKO1	0.000288	RHST5	0.001265	RHST20	0.000592	GHST15	0.016310
KKO2	0.001957	RHST6	0.007159	RHST21	0.014677	GHST16	0.008831
KKO3	0.059906	RHST7	0.024565	RHST22	0.003554	CSTN1	0.001741
KKO4	0.000677	RHST8	0.002519	RHST23	0.001802	CSTN2	0.004452
KKO5	0.000217	RHST9	0.006181	RHST24	0.005795	CSTN3	0.000114
KKK1	0.009374	RHST10	0.001526	RHST25	0.003779	CSTN4	0.001002
KKK2	0.022187	RHST11	0.000532	GHST6	0.003085	CSTN5	0.002064
KKK3	0.012525						

Table A.8.22: Intact thicket stone volume under the bush at Depth B.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
KASS1	45	KQ2	24	RHST16	15	GHST14	0.6
KASS2	35	KQ3	19	RHST17	51	GHST15	0
KASS3	50	KQ4	54	RHST18	6	GHST16	1
KASS5	37	KQ5	16	RHST19	11	CSTE1	8
KCAB1	48	RHST1	16	RHST20	15	CSTE2	10
KCAB2	12	RHST2	9	RHST21	9	CSTE3	21
KCAB3	20	RHST3	23	RHST22	0.0	CSTE4	7
KKO1	0	RHST4	17	RHST23	15	CSTE5	24
KKO2	83	RHST5	6	RHST24	43	CSTN1	15
KKO3	21	RHST6	14	RHST25	14	CSTN2	19
KKO4	59	RHST7	26	GHST6	47	CSTN3	8
KKO5	42	RHST8	6	GHST7	52	CSTN4	17
KKK1	4	RHST10	19	GHST8	0.5	CSTN5	5
KKK2	8	RHST11	6	GHST9	0.5	GHST1	7
KKK3	14	RHST12	22	GHST10	0.6	GHST2	0
KKK4	10	RHST13	8	GHST11	0.6	GHST3	9
KKK5	14	RHST14	6	GHST12	3	GHST5	5
KQ1	27	RHST15	18	GHST13	11		

Table A.8.23: Intact thicket mean organic carbon under the bush at Depth B

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KASS1	15	KKK5	2	RHST14	5	GHST11	0.8

KASS2	16	KQ1	2	RHST15	0.3	GHST12	2
KASS3	9	KQ2	2	RHST16	4	GHST13	1
KASS4	8	KQ3	2	RHST17	1	GHST14	2
KASS5	5	KQ4	4	RHST18	2	GHST15	2
KCAB1	2	KQ5	2	RHST19	2	GHST16	2
KCAB2	4	RHST1	2	RHST20	4	CSTE1	0.2
KCAB3	4	RHST2	2	RHST21	3	CSTE3	0.1
KCAB4	1	RHST3	4	RHST22	4	CSTE5	3
KCAB5	6	RHST4	2	RHST23	2	CSTN1	3
KKO2	7	RHST6	3	RHST24	3	CSTN3	3
KKO3	2	RHST7	3	RHST25	2	CSTN4	0.5
KKO4	2	RHST8	2	GHST6	2	GHST1	2
KKO5	2	RHST9	2	GHST7	6	GHST2	3
KKK1	4	RHST11	4	GHST8	2	GHST3	3
KKK2	2	RHST12	3	GHST9	2	GHST5	0.7
KKK3	2	RHST13	2	GHST10	2		
KKK4	2						

Table A.8.24: Intact thicket bulk density under the bush at Depth C.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KASS1	0.8	KQ3	0.8	RHST20	0.7	GHST16	1.7
KASS2	1.0	KQ5	0.7	RHST21	0.9	CSTE1	1.0
KASS3	1.1	RHST2	0.6	RHST22	0.9	CSTE2	0.6
KASS4	0.9	RHST3	1.1	RHST23	0.8	CSTE3	1.0
KASS5	1.1	RHST4	0.5	RHST24	1.1	CSTE4	1.1
KCAB1	0.6	RHST5	1.1	RHST25	0.8	CSTE5	1.0
KCAB2	0.9	RHST6	0.9	GHST6	1.0	CSTN1	0.7
KCAB3	0.5	RHST7	0.7	GHST7	1.0	CSTN2	0.7
KCAB4	0.8	RHST11	0.6	GHST8	1.7	CSTN3	0.9
KCAB5	0.7	RHST13	0.4	GHST9	1.1	CSTN4	1.0
KKO1	1.3	RHST14	0.6	GHST10	1.7	CSTN5	1.0
KKK1	0.9	RHST15	0.7	GHST11	1.2	GHST1	1.3
KKK2	0.9	RHST16	1.2	GHST12	1.5	GHST2	1.2
KKK3	1.0	RHST17	0.8	GHST13	1.2	GHST3	1.2
KQ1	0.8	RHST18	0.8	GHST14	1.4	GHST5	0.8
KQ2	0.9	RHST19	0.9				

Table A.8.25: Intact thicket root density under the bush at Depth C.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KASS1	0.000379	KQ3	0.007062	RHST15	0.001015	GHST9	0.000803
KASS2	0.000566	RHST1	0.001382	RHST16	0.000973	GHST10	0.000810
KASS3	0.000069	RHST2	0.001845	RHST17	0.001506	GHST11	0.002050
KASS4	0.000108	RHST3	0.001534	RHST18	0.022957	GHST12	0.003151
KASS5	0.000192	RHST4	0.001217	RHST19	0.002145	GHST13	0.015897
KCAB3	0.000399	RHST5	0.001489	RHST20	0.008775	GHST14	0.000356

KCAB5	0.000316	RHST6	0.000340	RHST21	0.000682	GHST15	0.056519
KKO2	0.001130	RHST7	0.000916	RHST22	0.000925	GHST16	0.002203
KKO3	0.000626	RHST8	0.001076	RHST23	0.021539	CSTN1	0.000301
KKO4	0.004531	RHST10	0.009786	RHST24	0.000994	CSTN3	0.005192
KKK1	0.003092	RHST11	0.000835	RHST25	0.005141	CSTN4	0.008249
KKK2	0.001208	RHST12	0.002382	GHST6	0.007114	CSTN5	0.001065
KKK3	0.005063	RHST13	0.001288	GHST7	0.001032		
KQ2	0.001058	RHST14	0.009879	GHST8	0.007905		

Table A.8.26: Intact thicket stone volume under the bush at Depth C.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
KASS1	21	KQ2	45	RHST19	20	GHST15	0.4
KASS2	16	KQ3	29	RHST20	17	GHST16	4
KASS3	42	KQ5	23	RHST21	21	CSTE1	13
KASS4	43	RHST2	15	RHST22	27	CSTE2	11
KASS5	25	RHST3	21	RHST23	30	CSTE3	28
KCAB1	34	RHST4	27	RHST24	25	CSTE4	7
KCAB2	21	RHST5	10	RHST25	21	CSTE5	14
KCAB3	15	RHST6	23	GHST6	39	CSTN1	19
KCAB4	18	RHST7	15	GHST7	21	CSTN2	11
KCAB5	43	RHST11	6	GHST8	0.8	CSTN3	22
KKO2	22	RHST12	21	GHST9	0.3	CSTN4	16
KKO3	45	RHST13	20	GHST10	0.4	CSTN5	18
KKO4	49	RHST14	36	GHST11	23	GHST1	26
KKK1	2	RHST15	25	GHST12	36	GHST2	0
KKK2	5	RHST16	42	GHST13	2	GHST3	0
KKK3	14	RHST17	16	GHST14	13	GHST5	5
KQ1	22	RHST18	19				

Table A.8.27: Intact thicket mean organic carbon under the bush at Depth C.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KASS1	10	KKK4	2	RHST13	2	GHST10	2
KASS2	13	KKK5	2	RHST14	2	GHST11	0.6
KASS3	4	KQ1	1	RHST15	3	GHST12	1
KASS4	8	KQ2	1	RHST16	4	GHST13	0.9
KASS5	3	KQ3	1	RHST17	2	GHST14	2
KCAB1	2	KQ4	5	RHST18	2	GHST15	1
KCAB2	1	KQ5	2	RHST19	2	GHST16	1
KCAB3	3	RHST1	2	RHST20	2	CSTE1	1.4
KCAB4	2	RHST2	0.7	RHST21	2	CSTE3	2.0
KCAB5	10	RHST3	2	RHST22	3	CSTE5	3
KKO2	7	RHST4	4	RHST23	2	CSTN1	3
KKO3	2	RHST6	2	RHST24	2	CSTN3	2
KKO4	1	RHST7	4	RHST25	3	CSTN4	0.9

KKO5	2	RHST8	2	GHST6	1	GHST1	3
KKK1	3	RHST9	3	GHST7	2	GHST2	3
KKK2	2	RHST11	3	GHST8	1	GHST3	3
KKK3	2	RHST12	2	GHST9	1	GHST5	3

Table A.8.28: Old lands bulk density at Depth A.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
RHOL1	0.6	RHOL13	0.6	RHOL23	1.1	COLE1	0.9
RHOL2	1.2	RHOL14	0.9	GHOL2_2	1.5	COLE2	0.9
RHOL3	1.3	RHOL15	0.9	KLK1	1.3	COLE3	1.2
RHOL4	1.1	RHOL16	0.9	KLK3	0.6	COLE4	0.7
RHOL6	1.4	RHOL17	1.2	KLK4	1.0	COLN1	1.0
RHOL7	0.7	RHOL18	1.1	KLK5	0.6	COLN2	1.1
RHOL8	1.7	RHOL19	1.3	KLK6	1.1	COLN3	1.1
RHOL9	1.1	RHOL20	1.1	KLK8	1.0	COLN4	1.2
RHOL11	1.2	RHOL21	1.7	KLK9	1.3	COLN6	1.1
RHOL12	1.1	RHOL22	1.0	KLK10	1.7		

Table A.8.29: Old lands root density at Depth A.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
RHOL1	0.003648	RHOL16	0.001747	KLK1	0.000160	COLN6	0.001234
RHOL2	0.001649	RHOL17	0.004067	KLK2	0.000009	GHOL1_1	0.001208
RHOL3	0.012468	RHOL18	0.003476	KLK3	0.000606	GHOL1_3	0.008133
RHOL4	0.000907	RHOL19	0.005491	KLK4	0.000021	GHOL1_4	0.001419
RHOL5	0.001733	RHOL20	0.001591	KLK5	0.000044	GHOL1_5	0.008258
RHOL6	0.000353	RHOL21	0.000937	KLK6	0.000071	GHOL1_6	0.001698
RHOL7	0.010820	RHOL22	0.003905	KLK7	0.000108	GHOL1_7	0.004070
RHOL8	0.005525	RHOL23	0.001278	KLK8	0.000150	GHOL1_8	0.001616
RHOL9	0.002167	RHOL24	0.002046	KLK9	0.000112	GHOL1_9	0.000532
RHOL10	0.002883	RHOL25	0.007962	KLK10	0.000115	GHOL1_10	0.001870
RHOL11	0.000730	GHOL2_1	0.001564	COLN1	0.005200	GHOL3_1	0.002174
RHOL12	0.005040	GHOL2_2	0.000472	COLN2	0.004862	GHOL2_2	0.000927
RHOL13	0.006604	GHOL2_3	0.000811	COLN3	0.002808	GHOL3_2	0.000389
RHOL14	0.003572	GHOL2_4	0.009988	COLN4	0.002199	GHOL2_3	0.000904
RHOL15	0.006950	GHOL2_5	0.001177	COLN5	0.000745	GHOL3_3	0.000323

Table A.8.30: Old lands stone volume at Depth A.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
RHOL1	3	RHOL16	9	KLK3	5	COLN3	24
RHOL2	4	RHOL17	5	KLK4	14	COLN4	31
RHOL3	8	RHOL18	2	KLK5	7	COLN5	0
RHOL4	5	RHOL19	8	KLK6	11	COLN6	22
RHOL5	0	RHOL20	1	KLK7	21	GHOL1_1	1

RHOL6	4	RHOL21	3	KLK8	4	GHOL1_2	0.7
RHOL7	1	RHOL22	35	KLK9	6	GHOL1_3	2
RHOL8	8	RHOL23	4	KLK10	8	GHOL1_4	1
RHOL9	7	RHOL24	2	COLE1	21	GHOL1_5	1
RHOL10	5	RHOL25	5	COLE2	2	GHOL1_6	23
RHOL11	43	GHOL2_1	3	COLE3	11	GHOL1_7	2
RHOL12	10	GHOL2_2	2	COLE4	13	GHOL1_8	1
RHOL13	15	GHOL2_3	0	COLE5	0	GHOL1_9	39
RHOL14	6	KLK1	5	COLN1	22	GHOL1_10	6
RHOL15	2	KLK2	3	COLN2	30		

Table A.8.31: Old lands mean organic carbon at Depth A.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
RHOL1	0.7	RHOL16	1.5	KLK2	0.5	COLN2	1.8
RHOL2	1.5	RHOL17	0.9	KLK3	1.3	COLN3	2.9
RHOL3	1.1	RHOL18	1.2	KLK4	1.0	COLN4	1.8
RHOL4	1.4	RHOL19	0.7	KLK5	1.0	COLN5	2.5
RHOL5	0.8	RHOL20	1.1	KLK6	0.4	COLN6	1.6
RHOL6	1.2	RHOL21	0.7	KLK7	0.6	GHOL1_1	1.1
RHOL7	1.1	RHOL22	0.7	KLK8	0.8	GHOL1_2	0.8
RHOL8	1.1	RHOL23	0.9	KLK9	1.0	GHOL1_3	1.0
RHOL9	1.2	RHOL24	0.7	KLK10	0.7	GHOL1_4	1.5
RHOL10	1.6	RHOL25	0.6	COLE1	1.6	GHOL1_5	1.4
RHOL11	1.9	GHOL2_1	1.0	COLE2	2.4	GHOL1_6	0.6
RHOL12	1.8	GHOL2_2	1.4	COLE3	2.1	GHOL1_7	1.0
RHOL13	1.6	GHOL2_3	0.9	COLE4	2.8	GHOL1_8	1.0
RHOL14	1.3	GHOL2_4	0.3	COLE5	0.7	GHOL1_9	1.7
RHOL15	1.1	KLK1	0.6	COLN1	3.0	GHOL1_10	1.0

Table A.8.32: Old lands bulk density at Depth B.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
RHOL1	0.9	RHOL14	1.3	RHOL25	1.4	COLE2	1.0
RHOL2	1.4	RHOL15	1.3	KLK1	1.6	COLE3	1.4
RHOL3	1.2	RHOL16	1.2	KLK2	1.5	COLE4	0.8
RHOL4	1.3	RHOL17	1.4	KLK3	1.2	COLE5	1.3
RHOL5	1.3	RHOL18	1.3	KLK4	1.3	COLN2	1.1
RHOL6	1.3	RHOL19	1.5	KLK5	1.1	COLN3	0.9
RHOL7	1.2	RHOL20	1.2	KLK6	1.4	COLN4	1.1
RHOL9	1.3	RHOL21	0.9	KLK7	1.5	COLN5	1.2
RHOL10	1.2	RHOL22	1.6	KLK8	1.3	COLN6	1.1
RHOL12	1.1	RHOL23	1.7	KLK9	1.5	GHOL1_7	1.7
RHOL13	0.8	RHOL24	1.7	COLE1	1.0		

Table A.8.33: Old lands root density at Depth B.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
RHOL1	0.002512	RHOL16	0.005335	KLK2	0.000015	GHOL1_1	0.000999
RHOL2	0.001691	RHOL17	0.001364	KLK3	0.000099	GHOL1_2	0.000938
RHOL3	0.002631	RHOL18	0.003166	KLK4	0.000047	GHOL1_3	0.005475
RHOL4	0.001253	RHOL19	0.000936	KLK5	0.000002	GHOL1_4	0.000690
RHOL5	0.000653	RHOL20	0.001359	KLK6	0.000039	GHOL1_5	0.002214
RHOL6	0.000204	RHOL21	0.000508	KLK7	0.000089	GHOL1_6	0.000394
RHOL7	0.002717	RHOL22	0.001066	KLK8	0.000036	GHOL1_8	0.000371
RHOL8	0.000140	RHOL23	0.001348	KLK9	0.000043	GHOL1_9	0.000988
RHOL9	0.000214	RHOL24	0.000835	KLK10	0.000015	GHOL1_10	0.001133
RHOL10	0.001459	RHOL25	0.001600	COLN1	0.000889	GHOL3_1	0.000441
RHOL11	0.002152	GHOL2_1	0.000970	COLN2	0.003740	GHOL2_2	0.000903
RHOL12	0.003506	GHOL2_2	0.000596	COLN3	0.001474	GHOL3_2	0.000980
RHOL13	0.002269	GHOL2_4	0.000589	COLN4	0.000328	GHOL2_3	0.001835
RHOL14	0.002010	GHOL2_5	0.001333	COLN5	0.000347	GHOL3_3	0.000788
RHOL15	0.003456	KLK1	0.000042	COLN6	0.001544		

Table A.8.34: Old lands stone volume at Depth B.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
RHOL1	8	RHOL15	4	KLK1	6	COLE5	10
RHOL2	7	RHOL16	17	KLK2	3	COLN2	24
RHOL3	5	RHOL17	4	KLK3	8	COLN3	15
RHOL4	4	RHOL18	4	KLK4	18	COLN4	35
RHOL5	11	RHOL19	13	KLK5	17	COLN5	8
RHOL6	7	RHOL20	2	KLK6	8	COLN6	15
RHOL7	5	RHOL21	4	KLK7	14	GHOL1_1	0.5
RHOL8	4	RHOL22	8	KLK8	4	GHOL1_3	26
RHOL9	10	RHOL23	6	KLK9	4	GHOL1_4	1
RHOL10	5	RHOL24	7	KLK10	13	GHOL1_5	24
RHOL11	30	RHOL25	4	COLE1	15	GHOL1_6	0.7
RHOL12	8	GHOL2_1	0	COLE2	20	GHOL1_7	2.4
RHOL13	26	GHOL2_2	1	COLE3	15	GHOL1_8	0.0
RHOL14	9	GHOL2_3	0	COLE4	44	GHOL1_10	0.8

Table A.8.35: Old lands mean organic carbon at Depth B.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
RHOL1	2.3	RHOL16	0.3	KLK2	0.4	COLN2	1.1
RHOL2	1.3	RHOL17	0.4	KLK3	0.3	COLN3	1.1
RHOL3	1.2	RHOL18	0.4	KLK4	0.7	COLN4	0.8
RHOL4	0.9	RHOL19	1.1	KLK5	0.5	COLN5	1.4
RHOL5	0.5	RHOL20	0.5	KLK6	0.3	COLN6	0.7
RHOL6	0.5	RHOL21	0.7	KLK7	0.2	GHOL1_1	0.8

RHOL7	0.1	RHOL22	0.6	KLK8	0.7	GHOL1_2	0.6
RHOL8	0.3	RHOL23	0.2	KLK9	0.4	GHOL1_3	1.1
RHOL9	0.4	RHOL24	0.2	KLK10	0.3	GHOL1_4	0.7
RHOL10	0.9	RHOL25	0.4	COLE1	1.5	GHOL1_5	1.2
RHOL11	1.3	GHOL2_1	0.6	COLE2	2.0	GHOL1_6	0.4
RHOL12	1.5	GHOL2_2	0.7	COLE3	1.1	GHOL1_7	0.9
RHOL13	0.8	GHOL2_3	0.6	COLE4	0.9	GHOL1_8	1.0
RHOL14	0.8	GHOL2_4	0.4	COLE5	0.4	GHOL1_9	0.4
RHOL15	0.5	KLK1	0.6	COLN1	1.5	GHOL1_10	0.8

Table A.8.36: Old lands bulk density at Depth C.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
RHOL1	1.0	RHOL14	1.6	KLK1	1.7	COLE5	1.2
RHOL2	1.5	RHOL15	0.6	KLK2	1.8	COLN1	1.4
RHOL3	1.6	RHOL16	1.8	KLK3	1.5	COLN2	1.9
RHOL4	1.3	RHOL17	1.6	KLK5	1.4	COLN3	0.9
RHOL5	1.3	RHOL18	1.5	KLK6	1.6	COLN4	1.1
RHOL6	1.6	RHOL19	1.5	KLK7	1.0	COLN5	1.2
RHOL7	1.6	RHOL20	1.5	KLK8	0.7	COLN6	1.1
RHOL8	1.6	RHOL21	1.2	KLK9	1.7	GHOL1_2	1.7
RHOL9	1.5	RHOL22	1.7	KLK10	1.6	GHOL1_3	1.5
RHOL10	1.3	RHOL23	0.5	COLE1	1.1	GHOL1_5	1.4
RHOL11	1.1	RHOL24	1.2	COLE3	1.5	GHOL1_6	1.7
RHOL12	1.1	RHOL25	1.8	COLE4	1.2	GHOL1_7	1.4
RHOL13	1.1						

Table A.8.37: Old lands root density at Depth C.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
RHOL1	0.002498	RHOL16	0.000392	KLK1	0.000025	GHOL1_5	0.001260
RHOL2	0.000132	RHOL17	0.000734	KLK2	0.000006	GHOL1_6	0.000250
RHOL3	0.000681	RHOL18	0.001883	KLK3	0.000025	GHOL1_8	0.000476
RHOL4	0.001235	RHOL19	0.000457	KLK4	0.000014	GHOL1_9	0.000251
RHOL5	0.000285	RHOL20	0.000402	KLK5	0.000003	GHOL1_10	0.000399
RHOL6	0.000412	RHOL21	0.000574	KLK6	0.000018	GHOL3_1	0.000391
RHOL7	0.001286	RHOL22	0.000495	KLK7	0.000010	GHOL2_2	0.000425
RHOL8	0.000423	RHOL23	0.000640	KLK8	0.000084	GHOL3_2	0.000678
RHOL9	0.000472	RHOL24	0.000682	KLK9	0.000008	GHOL2_3	0.000460
RHOL10	0.001142	RHOL25	0.000459	KLK10	0.000015	GHOL3_3	0.000436
RHOL11	0.001335	GHOL2_1	0.000855	COLN1	0.000552		
RHOL12	0.003566	GHOL2_2	0.000305	COLN4	0.000301		
RHOL13	0.001516	GHOL2_3	0.000447	COLN5	0.000214		
RHOL14	0.001177	GHOL2_4	0.000223	COLN6	0.001011		
RHOL15	0.000953	GHOL2_5	0.000891	GHOL1_2	0.000165		

Table A.8.38: Old lands stone volume at Depth C.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
RHOL1	30	RHOL16	16	KLK3	10	COLN4	28
RHOL2	8	RHOL17	5	KLK4	20	COLN5	22
RHOL3	7	RHOL18	3	KLK5	12	COLN6	19
RHOL4	3	RHOL19	8	KLK6	11	GHOL1_1	0.0
RHOL5	19	RHOL20	2	KLK7	4	GHOL1_2	0.3
RHOL6	4	RHOL21	14	KLK8	2	GHOL1_3	0.3
RHOL7	5	RHOL22	8	KLK9	15	GHOL1_4	1
RHOL8	7	RHOL23	4	KLK10	7	GHOL1_5	0.3
RHOL9	9	RHOL24	4	COLE1	15	GHOL1_6	12
RHOL10	16	RHOL25	3	COLE3	16	GHOL1_7	1
RHOL11	37	GHOL2_1	0	COLE4	31	GHOL1_8	1
RHOL12	12	GHOL2_2	0	COLE5	19	GHOL1_9	0.3
RHOL13	22	GHOL2_3	6	COLN1	8	GHOL1_10	14
RHOL14	12	KLK1	7	COLN2	7		
RHOL15	2	KLK2	5	COLN3	18		

Table A.8.39: Old lands mean organic carbon at Depth C.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
RHOL1	2.3	RHOL16	0.1	KLK2	0.3	COLN2	1.5
RHOL2	0.6	RHOL17	0.3	KLK3	0.3	COLN3	0.9
RHOL3	0.7	RHOL18	0.7	KLK4	0.5	COLN4	1.2
RHOL4	1.2	RHOL19	0.6	KLK5	0.4	COLN5	1.8
RHOL5	0.4	RHOL20	0.2	KLK6	0.3	COLN6	1.0
RHOL6	0.3	RHOL21	0.3	KLK7	0.2	GHOL1_1	0.5
RHOL7	0.2	RHOL22	0.6	KLK8	0.7	GHOL1_2	0.2
RHOL8	0.1	RHOL23	0.4	KLK9	0.4	GHOL1_3	0.5
RHOL9	0.5	RHOL24	0.3	KLK10	0.4	GHOL1_4	0.5
RHOL10	0.7	RHOL25	0.1	COLE1	2.0	GHOL1_5	0.8
RHOL11	0.7	GHOL2_1	0.5	COLE2	1.1	GHOL1_6	0.3
RHOL12	1.2	GHOL2_2	0.5	COLE3	0.7	GHOL1_7	0.6
RHOL13	0.8	GHOL2_3	0.6	COLE4	0.6	GHOL1_8	0.9
RHOL14	0.6	GHOL2_4	0.4	COLE5	1.4	GHOL1_9	0.3
RHOL15	0.6	KLK1	0.6	COLN1	1.0	GHOL1_10	0.4

Table A.8.40: Degraded bulk density carbon at Depth A.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KAD1	0.6	KDH5	1.2	RHDST7	1.7
KAD2	1.7	KGHB1	1.5	RHDST11	1.0
KAD3	1.1	KGHB2	1.0	RHDST12	1.0
KAD4	0.7	KGHB3	1.2	RHDST13	0.9
KAD5	0.8	KGHB4	0.9	RHDST14	0.6

KAD6	0.5	KRC1	0.7	RHDST15	1.2
KAD7	0.6	KRC4	0.6	RHDST16	1.0
KAD8	0.5	KRC5	0.5	RHDST20	1.9
KAD10	1.2	RHDST2	1.1	RHDST24	0.5
KDH1	0.8	RHDST3	0.6	RHDST25	0.8
KDH2	1.8	RHDST4	0.9		
KDH3	0.8	RHDST5	0.8		
KDH4	1.5	RHDST6	0.8		

Table A.8.41: Degraded root density carbon at Depth A.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KAD1	0.000030	KDH3	0.003417	RHDST1	0.008428	RHDST13	0.001131
KAD2	0.000011	KDH4	0.002033	RHDST2	0.003749	RHDST14	0.001855
KAD3	0.000038	KDH5	0.000008	RHDST3	0.002707	RHDST15	0.000416
KAD4	0.000277	KGHB1	0.010035	RHDST4	0.003508	RHDST16	0.000203
KAD5	0.000131	KGHB2	0.000012	RHDST5	0.005632	RHDST17	0.008702
KAD6	0.000184	KGHB3	0.000863	RHDST6	0.001373	RHDST18	0.000094
KAD7	0.000451	KGHB4	0.000005	RHDST7	0.003719	RHDST19	0.000096
KAD8	0.000040	KGHB5	0.000009	RHDST8	0.004876	RHDST20	0.000956
KAD9	0.000047	KRC1	0.000235	RHDST9	0.000371	RHDST22	0.000501
KAD10	0.000308	KRC2	0.000127	RHDST10	0.004814	RHDST23	0.001470
KDH1	0.000685	KRC4	0.000078	RHDST11	0.000126	RHDST24	0.000025
KDH2	0.002420	KRC5	0.000163	RHDST12	0.000027	RHDST25	0.000370

Table A.8.42: Degraded stone volume at Depth A.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
KAD1	17	KDH3	30	RHDST1	3	RHDST13	33
KAD2	33	KDH4	67	RHDST2	9	RHDST14	42
KAD3	26	KDH5	13	RHDST3	3	RHDST15	28
KAD4	9	KGHB1	5	RHDST4	14	RHDST16	15
KAD5	19	KGHB2	11	RHDST5	17	RHDST17	8
KAD6	23	KGHB3	24	RHDST6	3	RHDST18	7
KAD7	11	KGHB4	20	RHDST7	18	RHDST19	2
KAD8	30	KGHB5	44	RHDST8	19	RHDST20	3
KAD9	46	KRC1	24	RHDST9	7	RHDST22	12
KAD10	28	KRC2	13	RHDST10	46	RHDST23	15
KDH1	16	KRC4	21	RHDST11	33	RHDST24	43
KDH2	33	KRC5	41	RHDST12	26	RHDST25	13

Table A.8.43: Degraded mean organic carbon at Depth A.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KAD1	1.2	KDH4	1.0	RHDST2	1.4	RHDST15	1.7

KAD2	2.6	KDH5	1.5	RHDST3	1.5	RHDST16	0.6
KAD3	1.6	KGHB1	1.9	RHDST4	1.6	RHDST17	0.9
KAD4	2.1	KGHB2	0.7	RHDST5	2.0	RHDST18	0.4
KAD5	3.0	KGHB3	0.8	RHDST6	0.6	RHDST19	0.6
KAD6	2.4	KGHB4	0.9	RHDST7	1.5	RHDST20	1.0
KAD7	2.7	KGHB5	1.3	RHDST8	1.5	RHDST22	1.0
KAD8	1.9	KRC1	1.0	RHDST9	1.2	RHDST23	1.6
KAD9	2.8	KRC2	0.5	RHDST10	1.4	RHDST24	0.9
KAD10	2.1	KRC4	0.9	RHDST11	1.8	RHDST25	1.2
KDH1	1.3	KRC5	0.3	RHDST13	2.4		
KDH2	1.0	RHDST1	1.2	RHDST14	2.2		
KDH3	1.1						

Table A.8.44: Degraded mean bulk density at Depth B.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KAD1	0.6	KDH3	0.7	KRC5	0.6	RHDST13	0.9
KAD2	0.7	KDH4	0.8	RHDST2	0.9	RHDST14	0.5
KAD3	0.5	KGHB1	1.4	RHDST3	1.2	RHDST15	1.1
KAD4	0.9	KGHB2	0.8	RHDST4	1.1	RHDST16	1.6
KAD5	1.3	KGHB3	0.9	RHDST5	1.1	RHDST18	1.9
KAD6	1.2	KGHB4	0.9	RHDST6	1.8	RHDST19	1.4
KAD7	0.8	KGHB5	0.7	RHDST8	1.7	RHDST20	1.6
KAD8	1.0	KRC1	0.9	RHDST9	1.6	RHDST22	1.2
KAD10	1.0	KRC2	0.8	RHDST11	1.5	RHDST24	1.3
KDH2	1.4	KRC3	0.7	RHDST12	1.0	RHDST25	0.8

Table A.8.45: Degraded root density at Depth B.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KAD1	0.000034	KDH4	0.000027	RHDST1	0.002519	RHDST14	0.000547
KAD3	0.000325	KDH5	0.000003	RHDST2	0.001918	RHDST15	0.000999
KAD4	0.001378	KGHB1	0.003795	RHDST3	0.002244	RHDST16	0.000495
KAD5	0.000047	KGHB2	0.003486	RHDST4	0.001452	RHDST18	0.000491
KAD6	0.000072	KGHB3	0.019776	RHDST5	0.001696	RHDST19	0.000316
KAD7	0.000061	KGHB4	0.000516	RHDST6	0.000822	RHDST20	0.000296
KAD8	0.000024	KGHB5	0.000619	RHDST8	0.003442	RHDST22	0.006278
KAD9	0.000026	KRC1	0.004681	RHDST9	0.000318	RHDST23	0.001002
KAD10	0.000037	KRC2	0.001024	RHDST10	0.003840	RHDST24	0.000106
KDH1	0.000983	KRC3	0.000235	RHDST11	0.002758	RHDST25	0.000316
KDH2	0.000551	KRC4	0.001875	RHDST12	0.000561		
KDH3	0.003395	KRC5	0.000038	RHDST13	0.002483		

Table A.8.46: Degraded stone volume at Depth B.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)

KAD1	26	KDH4	34	RHDST1	9	RHDST14	28
KAD2	21	KDH5	28	RHDST2	26	RHDST15	20
KAD3	30	KGHB1	47	RHDST3	5	RHDST16	1
KAD4	8	KGHB2	56	RHDST4	15	RHDST18	5
KAD5	58	KGHB3	35	RHDST5	14	RHDST19	1
KAD6	45	KGHB4	52	RHDST6	28	RHDST20	3
KAD7	36	KGHB5	48	RHDST8	19	RHDST22	10
KAD8	28	KRC1	38	RHDST9	11	RHDST23	33
KAD10	21	KRC2	28	RHDST10	3	RHDST24	17
KDH1	19	KRC3	22	RHDST11	44	RHDST25	22
KDH2	48	KRC4	57	RHDST12	21		
KDH3	16	KRC5	36	RHDST13	26		

Table A.8.47: Degraded mean organic carbon at Depth B.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KAD1	0.7	KDH4	0.6	RHDST2	0.5	RHDST15	2.6
KAD2	1.9	KDH5	1.2	RHDST3	1.6	RHDST16	0.1
KAD4	4.3	KGHB1	0.5	RHDST4	0.2	RHDST18	0.1
KAD5	1.6	KGHB2	0.3	RHDST5	0.8	RHDST19	0.4
KAD6	1.1	KGHB3	0.7	RHDST6	0.6	RHDST20	0.3
KAD7	1.8	KGHB4	0.6	RHDST7	1.6	RHDST22	0.8
KAD8	0.7	KGHB5	0.7	RHDST8	0.5	RHDST23	1.2
KAD9	1.5	KRC1	1.3	RHDST9	1.1	RHDST24	0.4
KAD10	0.8	KRC2	0.4	RHDST10	2.1	RHDST25	1.4
KDH1	0.8	KRC4	1.1	RHDST11	1.3		
KDH2	0.9	KRC5	0.5	RHDST13	1.9		
KDH3	0.9	RHDST1	0.6	RHDST14	1.5		

Table A.8.48: Degraded bulk density at Depth C.

Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)	Code	Bulk Density (g/cm^3)
KAD3	0.4	KRC1	0.8	RHDST13	0.8
KAD5	0.7	KRC3	0.7	RHDST14	0.5
KAD6	0.8	KRC4	0.5	RHDST15	1.6
KAD7	0.7	RHDST4	1.3	RHDST18	1.6
KAD8	0.9	RHDST5	1.2	RHDST19	1.4
KAD9	1.1	RHDST7	1.9	RHDST20	1.3
KAD10	0.6	RHDST8	1.0	RHDST23	1.3
KDH2	1.9	RHDST10	0.9	RHDST24	0.6
KDH4	1.3	RHDST11	0.9	RHDST25	0.8
KDH5	1.5	RHDST12	0.8		

Table A.8.49: Degraded root density at Depth C.

Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)	Code	Root Density (g/cm^3)
KAD1	0.000005	KDH3	0.000981	RHDST2	0.000885	RHDST15	0.001135
KAD2	0.000018	KDH4	0.001347	RHDST3	0.000524	RHDST16	0.001205
KAD3	0.000047	KDH5	0.000978	RHDST4	0.000911	RHDST17	0.000626
KAD4	0.000320	KGHB1	0.002744	RHDST5	0.002807	RHDST18	0.000248
KAD5	0.000010	KGHB2	0.002312	RHDST6	0.000419	RHDST19	0.001159
KAD6	0.000088	KGHB3	0.000605	RHDST7	0.005504	RHDST20	0.002078
KAD7	0.000014	KGHB4	0.000820	RHDST8	0.000801	RHDST23	0.000619
KAD8	0.000046	KRC1	0.000446	RHDST9	0.000379	RHDST24	0.000105
KAD9	0.000009	KRC2	0.000714	RHDST10	0.001270	RHDST25	0.000153
KAD10	0.000037	KRC3	0.000071	RHDST11	0.001085		
KDH1	0.000414	KRC4	0.000206	RHDST12	0.000153		
KDH2	0.001019	KRC5	0.000026	RHDST14	0.000260		

Table A.8.50: Degraded stone volume at Depth C.

Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)	Code	Stone Volume (%)
KAD1	35	KDH2	67	KRC5	17	RHDST12	12
KAD2	35	KDH3	45	RHDST1	5	RHDST13	29
KAD3	18	KDH4	54	RHDST2	58	RHDST14	20
KAD4	30	KDH5	15	RHDST3	46	RHDST15	32
KAD5	43	KGHB1	84	RHDST4	21	RHDST18	24
KAD6	5	KGHB2	67	RHDST5	18	RHDST19	1
KAD7	6	KGHB3	62	RHDST7	32	RHDST20	1
KAD8	45	KGHB4	52	RHDST8	13	RHDST22	20
KAD9	57	KRC1	30	RHDST9	35	RHDST23	24
KAD10	37	KRC3	38	RHDST10	24	RHDST24	26
KDH1	56	KRC4	30	RHDST11	26	RHDST25	45

Table A.8.51: Degraded mean organic carbon at Depth C.

Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)	Code	Mean Organic Carbon (%)
KAD1	0.5	KDH3	0.7	KRC5	0.1	RHDST13	1.1
KAD2	0.8	KDH4	0.6	RHDST1	1.0	RHDST14	2.0
KAD3	1.6	KDH5	1.2	RHDST2	0.5	RHDST15	2.0
KAD4	1.8	KGHB1	0.6	RHDST3	0.7	RHDST16	0.3
KAD5	1.5	KGHB2	0.5	RHDST4	0.4	RHDST18	0.1
KAD6	1.4	KGHB3	0.5	RHDST5	1.4	RHDST19	0.4
KAD7	0.3	KGHB4	0.3	RHDST6	0.4	RHDST20	0.3
KAD8	1.4	KGHB5	0.5	RHDST7	0.9	RHDST22	0.8
KAD9	1.3	KRC1	1.5	RHDST9	0.9	RHDST23	1.0
KAD10	0.6	KRC2	0.5	RHDST10	0.4	RHDST24	0.7
KDH1	0.5	KRC4	0.7	RHDST11	1.2	RHDST25	1.1
KDH2	0.7						

Table A.8.52: *Ex ante* carbon storage per hectare for degraded and old fields in the Baviaanskloof (based on the difference between intact and degraded/old fields).

	Ex ante (degraded) (t CO_2e ha^{-1})	Ex ante (old fields) (t CO_2e ha^{-1})
Root (0-25 cm)*	27.5	27.6
Root (25-110 cm)*	1.72	3.01
Soil (0-25 cm)*	130	112
Soil (25-110 cm)*	85.7	59.6
Deadwood	0.02	0.02
Litter	8.32	10.0
Above ground	72.9	80.5
Total mean	327	293
Combined Uncertainty	19	22

* Soil and root samples are split into two groups based on the two different sampling methodologies used (see Section 3.2: sampling).

Table A.8.53: Mean carbon storage per hectare in the Baviaanskloof.

	Mean (t CO_2eq ha^{-1})	Standard Deviation	N	Standard Error	95% confidence interval	Uncertainty (%)
Root (0-25 cm)*						
Degraded thicket	4.8	5.4	42	0.8	1.6	34
Old fields	4.7	4.0	53	0.6	1.1	23
Intact	32.3	63.9	52	9.0	17.5	54
Root (25-110 cm)*						
Degraded thicket	2.2	3.7	16	0.9	1.9	86
Old fields	0.9	0.7	30	0.1	0.2	28
Intact	3.9	4.2	24	0.9	1.7	45
Soil (0-25 cm)*						
Degraded thicket	64.5	35.2	45	5.3	10.4	16
Old fields	83.0	47.2	60	6.1	12.0	15
Intact	194.9	148.1	68	18.1	35.5	18
Soil (25-110 cm)*						
Degraded thicket	47.1	16.1	14	4.5	8.7	19
Old fields	73.2	36.3	23	7.7	15.1	21
Intact	132.8	85.4	22	18.6	36.5	27
Deadwood						
Degraded thicket	0	0	50	0	0	-
Old fields	0	0	65	0	0	-
Intact	0.02	0.14	76	0.02	0.03	197
Litter						
Degraded thicket	4.7	7.1	50	1.0	2.0	42
Old fields	3.0	5.5	65	0.7	1.4	45
Intact	13.0	15.9	76	1.8	3.6	28
Above ground						
Degraded thicket	18.8	24.6	50	3.5	6.9	37
Old fields	11.3	17.5	65	2.2	4.3	38

Intact	91.7	120.3	76	13.9	27.2	30

* Soil and root samples are split into two groups based on the two different sampling methodologies used for the two different depths (0-25 cm and 25-110 cm).

Annex 9 Calibration of bulk density measurements

Table A.9.1: Calibrationof bulk density measurements between 60°C and 100°C.

	60°C			100°C			% change
N	4h	8h	10h	1h	12h	18h	
1	64.82	64.82	64.82	64.82	64.78	64.77	0.08
2	66.35	66.36	66.36	66.36	66.34	66.34	0.03
3	69.94	69.92	69.92	69.91	69.82	69.81	0.16
4	70.86	70.86	70.86	70.85	70.83	70.82	0.06
5	70.64	70.64	70.64	70.65	70.6	70.59	0.07
6	69.59	96.57	69.56	69.55	69.48	69.47	0.13
7	53.54	53.51	53.5	53.48	53.36	53.35	0.28
8	72.34	72.32	72.32	72.3	72.21	72.2	0.17
9	84.42	84.40	84.4	84.37	84.27	84.27	0.15
10	53.39	53.36	53.36	53.35	53.26	53.26	0.19
11	72.81	72.77	72.77	72.75	72.64	72.64	0.18
12	79.10	79.08	79.08	79.07	78.97	78.96	0.15
13	68.05	68.04	68.05	68.03	67.95	67.94	0.16
14	68.33	68.31	68.31	68.3	68.21	68.21	0.15
15	78.41	78.39	78.4	78.37	78.3	78.3	0.13
16	63.66	63.65	63.66	63.65	63.62	63.62	0.06
17	71.98	71.94	71.94	71.93	71.86	71.86	0.11
18	60.02	59.96	59.97	59.95	59.8	59.79	0.30
19	62.71	62.70	62.7	62.68	62.61	62.61	0.14
20	69.19	69.19	69.2	69.19	69.12	69.11	0.13
Average % change in mass							0.14

Annex 10 Contracts and business plan

The following documents are appended to indicate the nature of agreements entered into, as well as the start date of the project. The Business Plan for the "Eastern Cape Subtropical Thicket Rehabilitation Pilot Project" dated 5 August 2004 indicates that although the Kyoto Protocol had yet to be ratified, carbon trading was already happening at that stage. The Business Plan states that the aims of the pilot project were to assess carbon storage through rehabilitation of spekboom, and to study the economic, social and ecological impacts of the project. It was funded by DWAF specifically to assess and develop methods of thicket rehabilitation for carbon trading.

Figure A.10.1: Business plan for the thicket restoration project. The full plan is available on request from GIB.

PILOT PROJECT

Eastern Cape Subtropical Thicket Rehabilitation

REVISED BUSINESS PLAN
2004/5 – 2007

Initial Project Donors:

WORKING FOR WATER PROGRAMME (EASTERN CAPE)

Complied by: **Gamtoos Irrigation Board**
Date: **5 August 2004**

Approved by:
Date:

Department of Water Affairs and Forestry

The Eastern Cape Subtropical Thicket Rehabilitation Pilot Project

List of Acronyms

BMR	Baviaanskloof Megareserve
CDM	Clean Development Mechanism
DEAET	Department of Economic Affairs, Environment and Tourism
DWAF	Department of Water Affairs and Forestry
GIB	Gamtoos Irrigation Board
KPI	Key Performance Indicators
STEP	Subtropical Thicket Ecosystem Planning
TA	Technical Advisor
TORs	Terms of reference
WF	Wilderness Foundation
WfW	Working for Water Programme

2

Final Business Plan 2004/5 – 2006/7
Gamtoos Irrigation Board

Executive Summary

This project aims to develop cost-effective mechanisms for rehabilitation of subtropical thicket across a number of land use classes within the Eastern Cape. Ultimately the pilot-project proposes to kick-start a larger, biome-level rehabilitation initiative and thereby meet a number of local, regional and national needs (Marais 2004). It is generally accepted that areas that have been degraded of biodiversity are more prone to invasion by alien species. Rehabilitation of degraded areas therefore acts as a preventative measure to the emergence of invader species, in this case with specific reference to invasive grasses and prickly pears, simultaneously developing exit strategy opportunities for the WfW programme in the region. It is structured to be a pilot project and has a secondary role to explore and better understand, as well as develop the potential economies of carbon sequestration, biodiversity conservation and combating desertification.

The rehabilitation project is part of a long-term holistic management strategy in the rehabilitation of the vegetation of the area. The economic factors and variables of the rehabilitation project will be rigorously measured and modelled.

Gamtoos Irrigation Board (GIB) will be responsible for the implementation of the pilot project. The Wilderness Foundation (WF), through the contractual responsibility of managing the Baviaanskloof Megareserve Project, will partner the GIB on the project and will assume responsibility for the development protocols for the project and related scientific and project management inputs into the rehabilitation sites.

Project Budgets:

The budget summary below indicates the total projected costs of this project. The EC WfW, the Cape Action for People and the Environment (CAPE) and The Wilderness Foundation (WF) contributed to the capacity building in 2003/2004.

1. Introduction

1.1 Historical Background

With the advent of increased mechanisation and industrialisation, it is becoming apparent that the excessive use of fossil fuels, primarily through combustion is creating unnaturally high concentrations of gases in the atmosphere. These gases, ozone, nitrogen-oxide and a few others, notably carbon dioxide, are causing a steady rise in mean global temperatures – in the form of a heat retaining "blanket". It is reported that there has been an accumulated 30% increase since the industrial revolution (Appenzeller 2004). This could have colossal impacts for the planet's climate, biodiversity and primary production. The greenhouse gases, especially carbon are becoming important economic and trade issues (Shea *et al.* 1998).

The seriousness of the situation is clearly evident in the stipulations of the United Nations Framework Convention for Climate Change (i.e. Kyoto Protocol). All signatories to the protocol are required to reduce emissions of these greenhouse gases to pre 1990 levels. Developed nations that are unable or reluctant to achieve these targets will be required to trade carbon penalties with developing nations who are able to capture carbon – mostly through sustainable forest management practices. Furthermore, article 12 of the Kyoto Protocol provides for the operation of Clean Development Mechanism (CDM). In essence it encourages developed nations to sponsor carbon emission reduction projects in developing countries. Carbon sequestration (long term) and carbon storage (shorter term), as well as rehabilitation could qualify accordingly. This effectively introduces a massive global carbon economy. The sequestration of carbon through the rehabilitation of natural woodlands and forests can make a relatively small but significant contribution to the carbon economy.

Although the Kyoto protocol has not been ratified (yet), carbon trading around the world is happening and increasing volumes are being traded. The Herald Sun (24 May 2004) indicates that Russia is very likely to sign – this will enforce the protocol

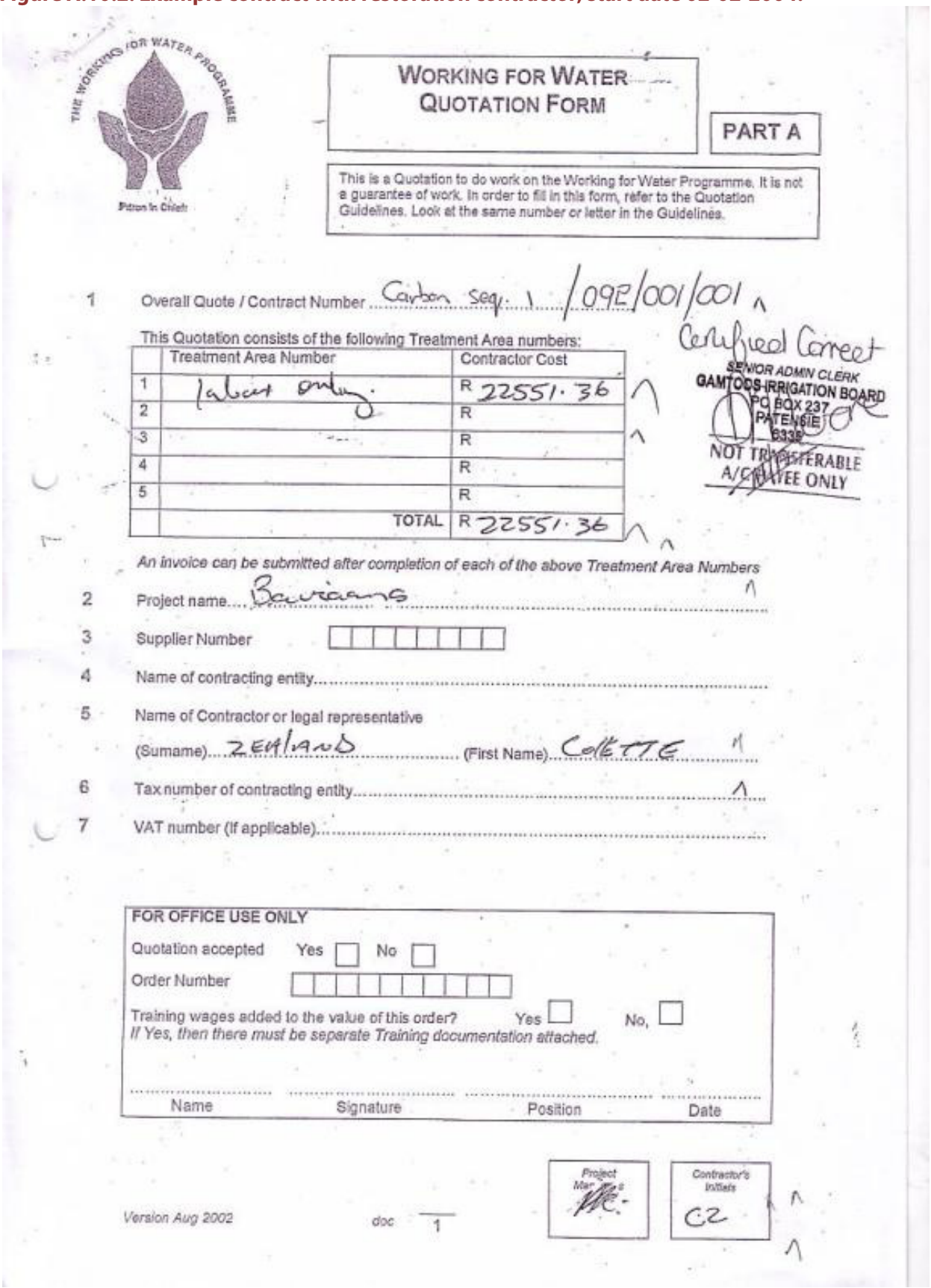
and drastically accelerate the carbon trading. South Africa can expect to face stiff competition from other developing nations – especially South America and the East. A major benefit to the rehabilitation of subtropical thicket is the rehabilitation of biodiversity, ecosystem processes and improving the resilience of natural systems (Eastern Cape Sub Tropical Thicket in this case), while providing work opportunities, skills transfer and capacity building in the rural areas. This will help negate the influx of unemployed people into urban squalour and is in line with the STEP vision of "keeping people on the land in living landscapes" (Knight *et al.* 2003). The bioregional planning exercise conducted by the STEP Project is entering the implementation phase and will be infused into the Integrated Development Plans (IDPs) of numerous local municipalities within the Eastern Cape.

Concurrently international conventions on biodiversity and combating desertification have created the potential for the trade of biodiversity and soil conservation credits. The nature and dynamics of these budding economies are very unclear at this stage, but merit further investigation. It is worth noting that projects that have a focus on carbon storage/sequestration, but have secondary aims to conserve biodiversity, transfer skills and improve livelihoods are receiving favourable attention. It is very often being referred to as "carbon with a face". Even though the potential extent of sequestration might not be at the same level as the potential for a cut in emissions, it is being looked at favourably by the international markets.

South Africa is a signatory to the conventions on Biodiversity, Combating Desertification and Kyoto. This project has the potential to provide tangible deliverables on all three conventions

The thicket biome until relatively recently did not receive much attention from the scientific community (only being recognised as a biome in 1996), and was regarded by many farmers as less desirable than savanna or grassland. STEP vegetation scientists have identified 112 different thicket types (Vlok & Euston-Brown 2002).

Figure A.10.2: Example contract with restoration contractor, start date 02-02-2004.



THE WORKING FOR WATER PROGRAMME
Patron in Chief

WORKING FOR WATER
QUOTATION FORM

PART A

This is a Quotation to do work on the Working for Water Programme. It is not a guarantee of work. In order to fill in this form, refer to the Quotation Guidelines. Look at the same number or letter in the Guidelines.

1 Overall Quote / Contract Number Carbon seq. 1 /092/001/001

This Quotation consists of the following Treatment Area numbers:

	Treatment Area Number	Contractor Cost
1	labour only.	R 22551.36
2		R
3		R
4		R
5		R
	TOTAL	R 22551.36

Certified Correct
SENIOR ADMIN CLERK
GAMTOOS IRRIGATION BOARD
PO BOX 237
PATENSIE
6338
NOT TRANSFERABLE
A/C PAYEE ONLY

An invoice can be submitted after completion of each of the above Treatment Area Numbers

2 Project name Bavianns

3 Supplier Number

4 Name of contracting entity

5 Name of Contractor or legal representative

(Surname) ZEALAND (First Name) COLETTE

6 Tax number of contracting entity

7 VAT number (If applicable)

FOR OFFICE USE ONLY

Quotation accepted Yes ☐ No ☐

Order Number

Training wages added to the value of this order? Yes ☐ No, ☐
If Yes, then there must be separate Training documentation attached.

Name Signature Position Date

Project Manager's Initials MC

Contractor's Initials CZ

Version Aug 2002 doc 1

WORKING FOR WATER QUOTATION FORM

Treatment Area Number CARBON SEQ01/002/001/001 **PART B**

Complete **PART B** after you have completed **PART C** of the Quotation Form. **PART D** is the map and description of the work to be done. Attach it to this Quotation.

Item	Contractor's Costs	*Working for Water* costs
Wage cost to clear site	K 13309.80	
18 Capital Build-up	2661.96	
Regional Services Levy *(must show proof of registration if this amount is quoted)*	M 0	
Personal Protective Equipment	O1 2934.80	O2 0
Tools and Equipment	P1 0	P2 0
Transport	Q1 3644.80	Q2 0
Administration / bookkeeping	R 0	
Chemicals supplied by *Working for Water*		S 0
	0	0
19 Sub-Total	22551.36	0
20 VAT (14%) (If VAT Number supplied) VAT No.:	0	
21 TOTAL QUOTATION COST	22551.36	0
TOTAL CONTRACT VALUE *(add the Contractor Total and the WfW Total)*	22551.36	

22 I declare that all work will be done in accordance with the *Working for Water* Self Assessment Standards and Rules and Regulations that I signed when registering with *the Working for Water* Programme.

Qeraland Contractor Name	Qeraland Signature	02:02:04 Date
A. Kogara WfW Project Manager	Signature	2.2.04 Date
R. Colesky Implementing Agent	Signature	2002/02/02 Date

Gw Water

Version 2: 27 Dec 02 Quotation Form.doc

Proof of Registration

Contractor's Initials CC

22.04.

WORKING FOR WATER QUOTATION FORM

PART C

Team costs

8 Job type	Number of workers in each job type	9 Daily equivalent task-rate	10 Cost per day
Contractor (Supervisory fee)		150.00	150.00
Machine Operator			
Herbicide Applicator			
General Worker	10	40.00	400.00
Driver	1	55	55.00
Total number of working team members	A 12	Sub-total wages per day	B 605.00
		Sick-leave fund B x 12 / 260 = C	C 27.92
		Family responsibility leave fund B x 3 / 260 = D	D 6.98
		Public Holiday fund B x 11 / 260 = E	E 25.59
		Total wage costs per day B + C + D + E = F	F 665.49

12 Wage costs to complete the Contract

Total Persondays required including additional works *(From WIMS tables in the Description of Work)*		G 240
Team days to clear site	(G ÷ A = H)	H 20
Total wage costs	(H x F = K)	K 13309.80

13 Personal Protective Equipment (PPE)

Description	Daily rate *(for 1 item)*	Quantity supplied by Contractor	Cost to Contractor *(daily rate x quantity x number of days (H))*	Quantity supplied by *Working for Water*	Cost to *Working for Water* *(daily rate x quantity x number of days (H))*
Boots	9.47	11	104.17		
Goggles	0.45	22	9.90		
Contisuits	2.97	11	32.67		
		Cost to Contractor	O1 146.74	Cost to WfW	O2

X 20

2934.80

Project Manager

Contractor's Initials C.C

WORKING FOR WATER QUOTATION FORM

14 Tools and Equipment

Description	Daily rate (for 1 item)	Quantity supplied by Contractor	Cost to Contractor (daily rate x quantity x number of days (H))	Quantity supplied by Working for Water	Cost to Working for Water (daily rate x quantity x number of days (H))
		Cost to Contractor	P1 0	Cost to WfW	P2

15 Transport

Description of vehicle (2x4, 4x4, trailer)	Number of days (H)	Rate	Cost to Contractor (Days x Rate)	Cost to Working for Water (Days x Rate)
Ford	20	182.24	3644.80	
			Q1 3644.80	Q2

16 Administration

Description	Cost to Contractor
Book keeping	R 0

17 Chemicals to be supplied by *Working for Water* *(Get estimates from Part D)*

Description of chemical	Estimated liters	Cost per liter	Cost to Working for Water
		Total Cost	S 0

Cost per Personday and Cost per Hectare (useful when doing future quick quote estimations for work)

Cost per Personday	
Total Contract Value (from Part B)	T 22551.36
Total number of persondays (from Part D)	G 240
Cost per Personday T / G = V	V 93.96

Cost per Hectare	
Total Contract Value (from Part B)	T
Total number of Hectares (from Part D)	X
Cost per Hectare T / X = Y	Y

Project Manager

Contractor's Initials C.Z

"PART D"

092/001/001

Spekboom Rehabilitasie Kontrak Spefikasies

Kontrak dimensies:

Die kontrak blok sal deur die projek bestuurder uitgewys word en sal presies 200 meter lank en 100m wyd wees.

Plante Versameling:

Die kontakteur sal deur die projek bestuurder gewys word waar die plante gesamel mag word. Allenlik vanaf hiedie plekke mag plant material versamel word.
Meer as 95% van die versamel materiaal moet Spekboom takke wees. Ander plant spesies (e.g. plakkies) sal deur die projek bestuurder uitgewys word. Slegs die spesies wat uitgewys word mag geplant word. Die verskillende spesies moet versamel en geplant word in min of meer die selde getalle as wat in die natuur voorkom.
Elke plant wat geoes word, mag nie meer as 25% van sy totalle volume of takke veloor nie.
Alle plant material moet vir 2 dae le en uitdroog.

Grond Voorbereiding
Die kontrakteur moet verseker dat alle gate ten minste 20cm diep is. Gate moet nie in rye gemaak word nie, en ook nie presies eweredig gespasieer nie.

Plant van Steggies
Die gesnyde plant steggies moet in die gate geplant word, en die omliggende grond stewig getrap. Geen stande inheemse bome mag beskaadig word. Mooite moet gedoen word by die opslag plante, om so min as moontlik die plante te versteur en liewer op kaal grond te plant.

Digthede van die geplante material:

Die plante moet tussen 1 en 2 meter uitmekaar wees – oor die hele twee hektaar.

Rommel Verwydering

Die kontrakteur moet ook verseker dat all papier, platstiek, glas en draad van die terrain verwyder word. All uitheemse boome en plante moet uitgerou word en van die terrain verwyder word.

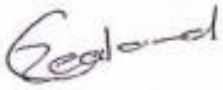


Table A.10.1: Contract example, start date 17-03-2006.

THE WORKING FOR WATER PROGRAMME
Patron in Chief:

WORKING FOR WATER QUOTATION FORM

PART A

This is a Quotation to do work on the Working for Water Programme. It is not a guarantee of work. In order to fill in this form, refer to the Quotation Guidelines. Look at the same number or letter in the Guidelines.

1 Overall Quote / Contract Number 092 001 065

This Quotation consists of the following Treatment Area numbers:

	Treatment Area Number	Contractor Cost
1	Labour Only	R 22261.20
2		R
3		R
4		R
5		R
	TOTAL	R 22261.20

Certified Correct

An invoice can be submitted after completion of each of the above Treatment Area Numbers

2 Project name Carbon Speckboom

3 Supplier Number

4 Name of contracting entity

5 Name of Contractor or legal representative

(Surname) Kleinbooi (First Name) George

6 Tax number of contracting entity 1742/361/14/8

7 VAT number (If applicable)

FOR OFFICE USE ONLY

Quotation accepted Yes ☐ No ☐

Order Number

Training wages added to the value of this order? Yes ☐ No, ☐

If Yes, then there must be separate Training documentation attached.

Name | Signature | Position | Date

Project Manager's Initials

Contractor's Initials

Version Aug 2002 doc 1

WORKING FOR WATER QUOTATION FORM

PART B

Treatment Area Number 092001 06

Complete **PART B** after you have completed **PART C** of the Quotation Form. **PART D** is the map and description of the work to be done. Attach it to this Quotation.

Item	Contractor's Costs	*Working for Water* costs
Wage cost to clear site	K 14124.00	
18 Capital Build-up	2824.80	
Regional Services Levy *(must show proof of registration if this amount is quoted)*	M –	
Personal Protective Equipment	O1 911.00	O2
Tools and Equipment	P1 43.00	P2
Transport	Q1 3648.40	Q2
Administration / bookkeeping	R 700.00	
Chemicals supplied by *Working for Water*		S
19 Sub-Total	22 251.20	
20 VAT (14%) (If VAT Number supplied) VAT No.:	–	
21 TOTAL QUOTATION COST	22 251.20	
TOTAL CONTRACT VALUE (*add the Contractor Total and the WfW Total*)	R22 251.20	

22 I declare that all work will be done in accordance with the *Working for Water* Self Assessment Standards and Rules and Regulations that I signed when registering with *the Working for Water* Programme.

George Kleinbooi — Contractor Name — Signature — 17/3/'06 Date

Yolande Vermaak — WfW Project Manager — Vermaak — Signature — 17/3/'06 Date

ADMIN BESTUURDER / MANAGER
GAMTOOS IRRIGATION BOARD
GAMTOOS BEGIMENGINGSRAAD
POSBUS/P. BOX 237
WfW Regional Office — Signature — 17/03/06 Date

EW Moore

22.03.06

Project Manager's Initials — Contractor's Initials

092/001/005

WORKING FOR WATER QUOTATION FORM

PART C

Team costs

8 Job type	Number of workers in each job type	9 Daily equivalent task-rate	10 Cost per day
Contractor (Supervisory fee)		145.00	145.00
Machine Operator			
Herbicide Applicator	2	46.00	92.00
General Worker	8	43.00	344.00
Driver	1	61.00	61.00
Total number of working team members	A 11	Sub-total wages per day	B 642.00
		Sick-leave fund B x 12 / 260 = C	C 29.63
		Family responsibility leave fund B x 3 / 260 = D	D 7.41
		Public Holiday fund B x 11 / 260 = E	E 27.16
		Total wage costs per day B + C + D + E = F	F 706.20

12 **Wage costs to complete the Contract**

Total Persondays required including additional works *(From WfWS tables in the Description of Work)*		G 220
Team days to clear site	(G ÷ A = H)	H 20
Total wage costs	(H x F = K)	K 14124.00

ADMIN CLERK GAMTOOS IRRIGATION BOARD P.O. BOX 237 PATENSIE 6335

13 **Personal Protective Equipment (PPE)**

Description	Daily rate *(for 1 item)*	Quantity supplied by Contractor	Cost to Contractor *(daily rate x quantity x number of days (H))*	Quantity supplied by *Working for Water*	Cost to *Working for Water (daily rate x quantity x number of days (H))*
Overalls	0.77	11	169.40		
Safety Boots	2.79	11	613.80		
Hard Hats	0.06	11	13.20		
Gloves	0.15	11	33.00		
Masks	1.46	2	58.40		
Rain Suits	0.48	2	19.20		
Goggles	0.10	2	4.00		
		Cost to Contractor	O1 911.00	**Cost to WfW**	O2

Project Manager's Initials	*Contractor's Initials*
	GK.

Version 2: 27 Dec 02 Quotation Form.doc 3

Wage Cost excl. Contractor Cost & Profit R 10934,00

Contractor Wage incl. Profit R 6014,80.

ADMIN CLERK GAMTOOS IRRIGATION BOARD P.O. BOX 237 PATENSIE 6335

WORKING FOR WATER QUOTATION FORM 092-001-005

14 **Tools and Equipment**

Description	Daily rate (for 1 item)	Quantity supplied by Contractor	Cost to Contractor (daily rate x quantity x number of days (H))	Quantity supplied by Working for Water	Cost to Working for Water (daily rate x quantity x number of days (H))
Knapsack(Herb)	0.70	1	14.00	^	
First Aid	1.45	1	29.00	^	
		Cost to Contractor	P1 43.00	Cost to WfW	P2

15 **Transport**

Description of vehicle (2x4, 4x4, trailer)	Number of days (H)	Rate	Cost to Contractor (Days x Rate)	Cost to Working for Water (Days x Rate)
Toyota	20	182.42	3648.40	
			^	
			Q1 3648.40	Q2

16 **Administration**

Description	Cost to Contractor
Book keeping	R 700.00

17 **Chemicals to be supplied by *Working for Water*** *(Get estimates from Part D)*

Description of chemical	Estimated liters	Cost per liter	Cost to *Working for Water*
		Total Cost	S

Cost per Personday and **Cost per Hectare** (useful when doing future quick quote estimations for work)

Cost per Personday		**Cost per Hectare**	
Total Contract Value *(from Part B)*	I 22251.20	Total Contract Value *(from Part B)*	T
Total number of persondays *(from Part D)*	G 220	Total number of Hectares *(from Part D)*	X
Cost per Personday T / G = V	V 101.14	**Cost per Hectare** T / X = Y	Y

Project Manager's Initials | Contractor's Initials

Version 2: 27 Dec 02 Quotation Form.doc 4

Spekboom Rehabilitasie Kontrak Spefikasies

Koleskeplaas Kontrak – March 2006

George Klienbooi se span

092-001-005

Kontrak dimensies:

Die kontrak blok sal deur die projek bestuurder uitgewys word en sal ook op n foto uitgedruk word. Die kontrak sal ongeveer 5.5 hektaar in grootte wees.

Plante Versameling:

Die kontrakteur sal deur die PROJEK bestuurder gewys word waar die plante vesamel mag word. Alleenlik vanaf hierdie plekke mag plant materiaal versamel word. 100% van die versamel materiaal moet Spekboom takke wees. Die takke se deursnee moet tussen **0.5cm** en **1cm groot wees – nie kleiner en nie grootter**.

Geen stukke van die steggie mag afgekap word nie. Alle steggies moet al hulle takke nog he.

GEEN PLANT MATERIAAL MAG AFGEKAP WORD EN IN DIE VELD GELOS WORD. ALLES WAT GEKAP WORK MOET GEPLANT WORD. VERSAMEL NET DIE REGTE GROOTE SPEK. MORS VAN SPEK SAL BAIE ERNSTIG TEEN DIE SPAN GETEL WORD.

Grond Voorbereiding

All gate moet diep genoeg wees om ter verhoed dat plante oorval in die wind, or uitgetrek work deur diere. **GEEN spekke word plat op die grond gele nie.**

Die kontrak is gedeel in twee helftes. AL die gate in die eerste helfte moet klaar gegrou word voor spekboom geoes of geplant mag word.
Slegs na die projek bestuurder inspeksie gedoen het en al die gate is ge-identifiseer as 15cm diep, kan die span begin om spekboom takke to snv en te plant.
Daarna moet al die gate vir die tweede helfte gegrou word en geinspekteer word deur die projek bestuurder voor enige plant van spekboom kan plaasvind.

092-001-066

5 (vyf) spekboom takke moet in sirkels van 2 meter deursnnee GEPLANT word. Elke sirkel moet 3 meter van die ander sirkels wees. DAAR MOET 4 sirkels (ALLE 4 rigtings) ongeveer 3 meter van elke sirkel wees. Waar n bos of n boom in die pad staan, moet die sirkel links of regs geskuif word.

Plant van Steggies

Geen staande inheemse bome, struike of bolplante mag beskaadig word nie. Moeite moet gedoen word by die opslag plante, om so min as moontlik die plante te versteur en liewer op kaal grond te plant.

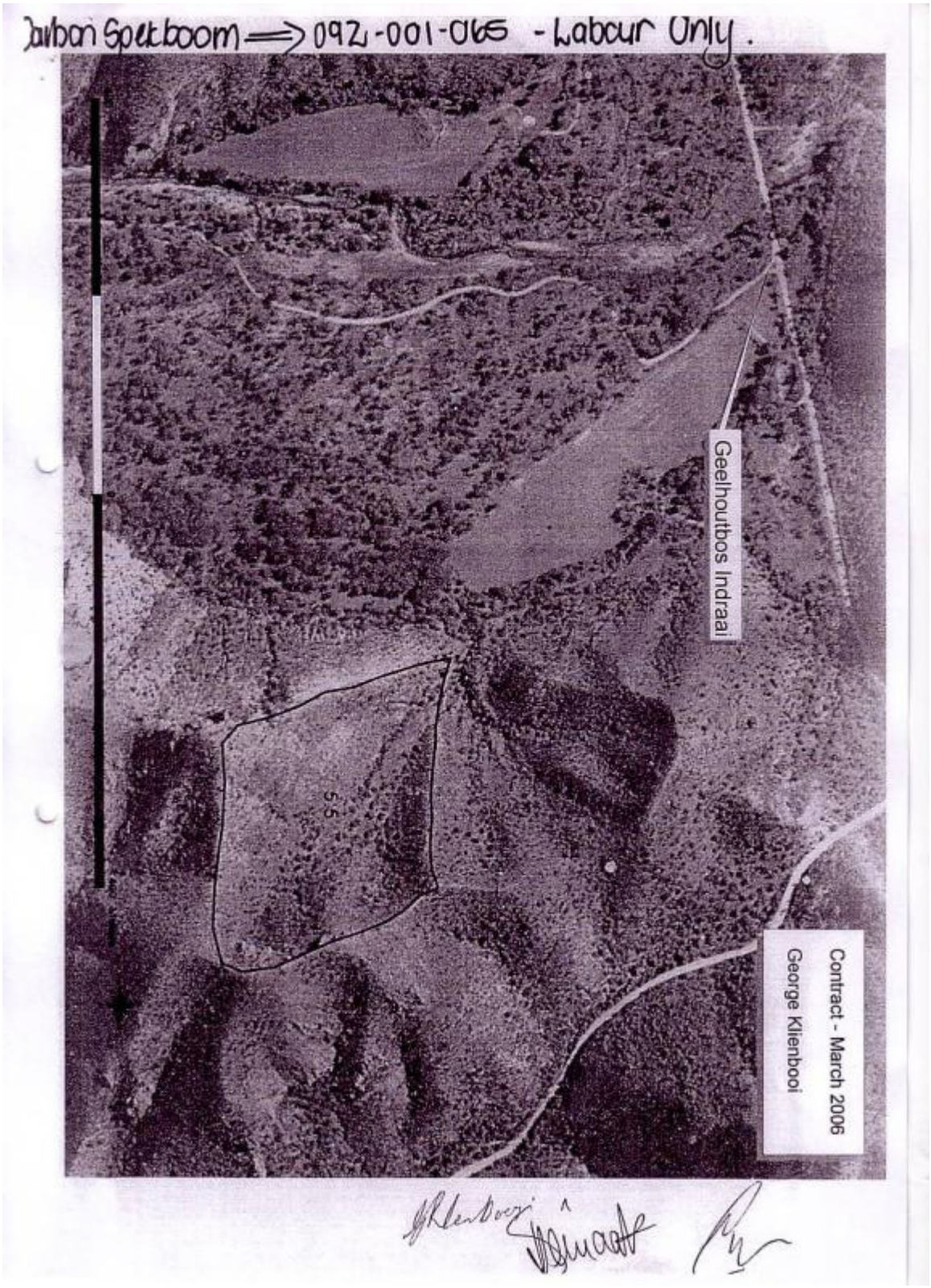
Waar die wind en diere die steggies oorwaai of uitstamp, moet hulle weer geplant word – tot die projek bestuurder klaar inspeksie gedoen het.

Digthede van die geplante material:

Soos uitgespel bo.

Rommel en uitheemse plante verwydering

Die kontrakteur moet ook verseker dat alle papier, plastiek, glas en draad van die terrein verwyder word. Alle **uitheemse bome en plante moet uitgeroei word en van die terrein verwyder word**.


Carbon Spekboom ⟹ 092-001-065 - Labour Only.
Geelhoutbos Indraai
5.5
Contract - March 2006
George Klienbooi

Annex 11 Socio-economic studies

The Subtropical Thicket Restoration Programme (STRP) collaborates with the PRESENCE project, which is coordinated by Earth Collective, to address key scientific issues in ecosystem restoration in the western Baviaanskloof Nature Reserve. Four theses conducted by MSc students have provided a major contribution to this project, as well as to this ARR Project Description submission. The theses use the concept of ecosystem services in an integrated assessment of opportunities for conservation and sustainable development. Whilst the focus of the work encompasses a wider area than just the Baviaanskloof Nature Reserve, the results are relevant to this ARR project. In particular, all the studies indicate considerable benefit to communities, through the restoration of natural vegetation and the consequent restoration and maintenance of ecosystem services. The communities in question live adjacent to and in close proximity to the Baviaanskloof Nature Reserve, and therefore reflect the opinions of local communities and the socio-economic impacts of the project activities on these communities. Some of the more pertinent findings are described below:

Thesis 1: Valuation of goods and services provided by the thicket ecosystem[31]*:*

This research answers the following questions:

1. What are the main services provided by the thicket ecosystem that have current and potential economic value?
2. What are the current and potential use levels of the selected services?
3. Who are the main stakeholders involved and how they depend on these thicket services?
4. What are the current economic (and monetary) benefits of selected ecosystem services?
5. What would be the potential economic (and monetary) benefits of ecosystem services in the study area?

In the western Baviaanskloof, local stakeholders' economies and livelihoods depend on ecosystem (thicket) services. The main services for local communities are fuelwood, construction material, medicinal plants, fodder, and water, representing 20 – 25 % of their monthly income. For farmers, fodder, water and tourism represents approximately 50 – 60 % of their gross annual income (Table A.11.1: Current total economic value and potential economic value of thicket services.). However, not all of these services are used in a sustainable way, as appears to be the case of fodder and water, as well as fuelwood (in Zaaimanshoek), which may compromise the availability of other services.

Stakeholders depend differently on thicket ecosystem goods and services. For local communities, thicket services represent a 'safety net'. They depend mainly on fuelwood, construction material, medicinal plants, fodder, and water for daily subsistence. Farmers mainly depend on fodder, water and eco-tourism for commercial purposes.

The dependence of local communities on thicket is high (Figure A.11.1:Value of thicket ecosystem services according to the Pebble Distribution Method (PDM).). Therefore, the restoration of thicket may imply long-term livelihood assurance and a return of lost natural capital.

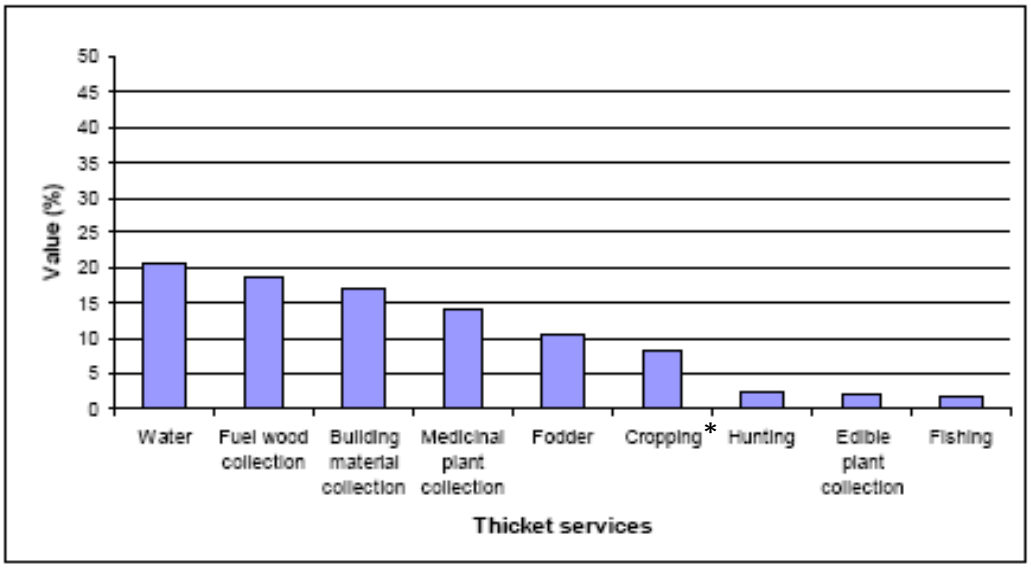
[31] De la Flor Tejero, I. 2008. Valuation of the goods and services provided by the thicket ecosystem in the western Baviaanskloof, South Africa. M.Sc. thesis. Wageningen University, The Netherlands.

Table A.11.1: Current total economic value and potential economic value of thicket services.

Current Total Economic Value								
Functions/ Services	**Quantity used/year**	**Employment workers**	**Gross Value year communities (R)**	**Gross value year farmers (R)**	**Total Gross Value year (R)**	**Gross value/ year-ha (R)**	**Potential Economic Value**	**Ecological impact**
Production								
Fuelwood	239 220 kg	1	63 154	-	63 154	1.26	Low	*
Construction material	14784 kg	-	1889	-	1889	0.04	Low	x
Medicinal plants	270 kg	-	3848	-	3848	0.077	Low	x
Fodder*	1730LSU	91 full-time /39seasonal	206 283	2 891 217	3 097 500	62	Low	xx
Hunting	?	-	?	?	?	?	High	x
Honey	180 kg	-	2250	2250	4500	0.09	High	x
Regulation								
Pollination	25	-	-	11 250	11 250	0.225	High	+
CO2 sequestration	-	-	-	-	-	-	High	+
Water supply & regulation	m3	?	?	?	?	?	High	xx
Information								
Recreation eco-tourism)*	11 000 tourist	?	-	4 484 400	4 484 400	90	High	x
TOTAL	-	91 full time/40 seasonal	277 424	7 389 117	**7 666 541** or US$999 717	**153** or US$20	-	-

x: Sustainable
xx: Non-sustainable
+: Positive impact
* Fuelwood collection in Sewefontein is sustainable, but not in Zaaimanshoek
** Workers working in livestock management account for the workers living in Zaaimanshoek and Sewfontein, but also for the community memeers living on the farmers' farms.
*** Workers in livestock management diversify their activities and collaborate with farmers in the tourism business. Current value of water was not estimated as no scientific data about the

benefits that thicket vegetation has on water availability were available at the time of publication of this study.



*Cropping is not an ecosystem service but it has a large influence on the livelihoods of communities (Sewefontein). Water can be considered that the main input of cropping.

Figure A.11.1:Value of thicket ecosystem services according to the Pebble Distribution Method (PDM).

Thesis 2: The relevance of socio-cultural values of ecosystem services to restoration planning and implementation[32]:

The objective of this thesis was to perform a socio-cultural valuation of the thicket ecosystem for primary stakeholders and a preliminary Social Impact Assessment (SIA) of the STRP project.

Primary data collection methods in this study included semi-structured and qualitative interviews, focus group sessions, observation, desk research and several participatory research tools. Socio-cultural valuation, participatory rural appraisal (PRA; including the Pebble Distribution Method or PDM), SIA, participatory geographic information systems (PGIS) and stakeholder analysis were used to analyse the data.

The results show a broad range of socio-cultural values for both farmer and local communities in the western Baviaanskloof. The most important results are:

- Both communities appear to maintain strong 'sense of place' and cultural landscapes values; over 63 % of the farmers and over 95 % of the local inhabitants have lived in the Baviaanskloof valley most of their lives, and many even their whole lives.
- All communities refer to the importance of the suitability of thicket to support livestock and wild animals. All of the farmers and one local community keep livestock for commercial purposes and their own consumption (a cultural-traditional activity); game farming is practiced by 27 % of the farmers.
- For the local communities, the top four most important resources related to thicket to maintain their livelihoods and well-being are water (13.6 %), firewood (12.2 %), building

[32] Janssen, K. 2008. The relevance of socio-cultural planning and implementation in the Baviaanskloof. M.Sc. thesis. Wageningen University, The Netherlands.

material (11.2 %), and medicinal thicket resources (9.2 %). Whilst these resources are not directly available to the communities within the project areas, since they are protected areas, the project will restore the flow of water regionally, and act as a seed bank to promote the recruitment of thicket in adjacent areas.

This study shows that the implementation of STRP under voluntary carbon market regulation would have considerable impacts on socio-cultural values and quality of lives of both farmers and coloured communities (Figure A.11.2).

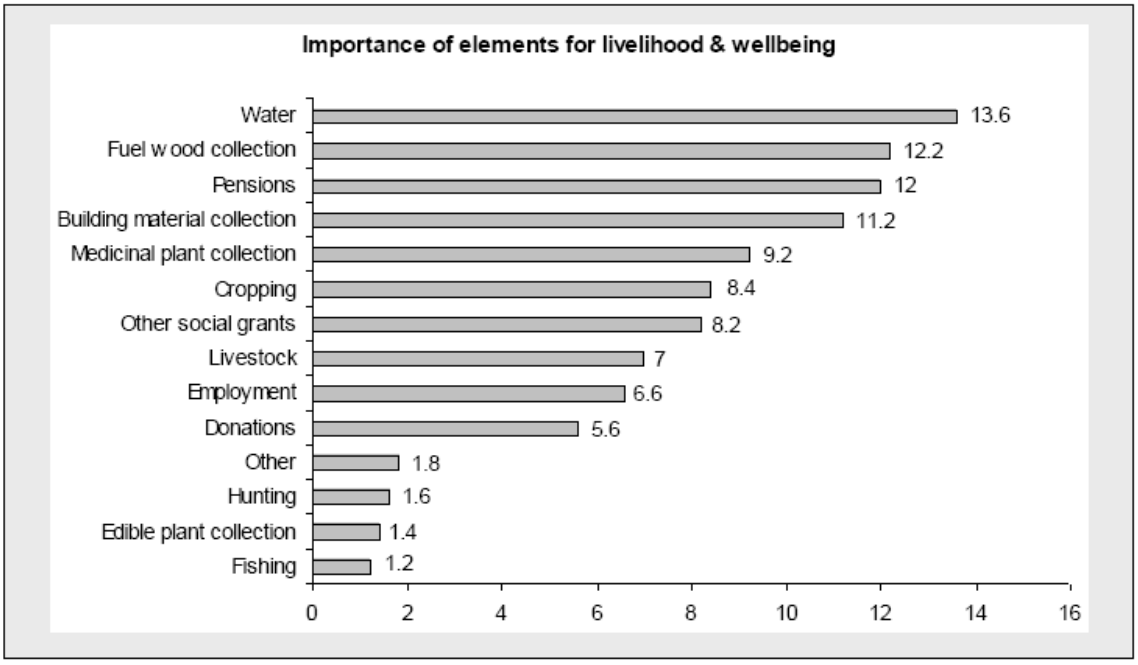


Figure A.11.2: Relative importance of socio-elements according to the local communities in the Western Baviaanskloof. Based on 10 PDM exercises with a total of 44 individual participants.

Thesis 3: Valuing the benefits of restoring water regulation services in the Subtropical Thicket Biome[33]:

This thesis focused on valuing the watershed services provided by thicket and wetland restoration and the insights into their relative importance for the local economy. The research focused on the water services provided by the Baviaanskloof watershed, to the downstream beneficiaries in the Gamtoos valley. The restoration of thicket in the Baviaanskloof Nature Reserve may increase water supply in the Gamtoos valley, and the outcomes of this ARR project are therefore linked to water supply and associated issues. The full thesis is not included in this document due to its size, but is available upon request.

Thesis 4: Willingness to restore land in the Baviaanskloof[34]:

The main objective of this thesis was to evaluate the involvement of stakeholders in land restoration in relation to the thicket ecosystem of the western Baviaanskloof. A general awareness

[33] Van der Burg, L. 2008. Valuing the benefits of restoring water regulation service in the Subtropical Thicket Biome. M.Sc. Thesis. Wageningen University, The Netherlands.
[34] Noirtin, E. 2008. Who is willing to restore and why? Stakeholder analysis in the Western Baviaanskloof, South Africa. M.Sc. Thesis. Wageningen University, The Netherlands.

about the necessity to restore the ecosystem was found to be developing amongst all the stakeholders. A number of different incentives may aid land owners in implementing restoration (Figure A.11.3), financial payment being one of the more acceptable and successful incentives. This finding indicates the role that VERs can play in this community in the future. The full thesis is not included in this document due to its size, but is available upon request.

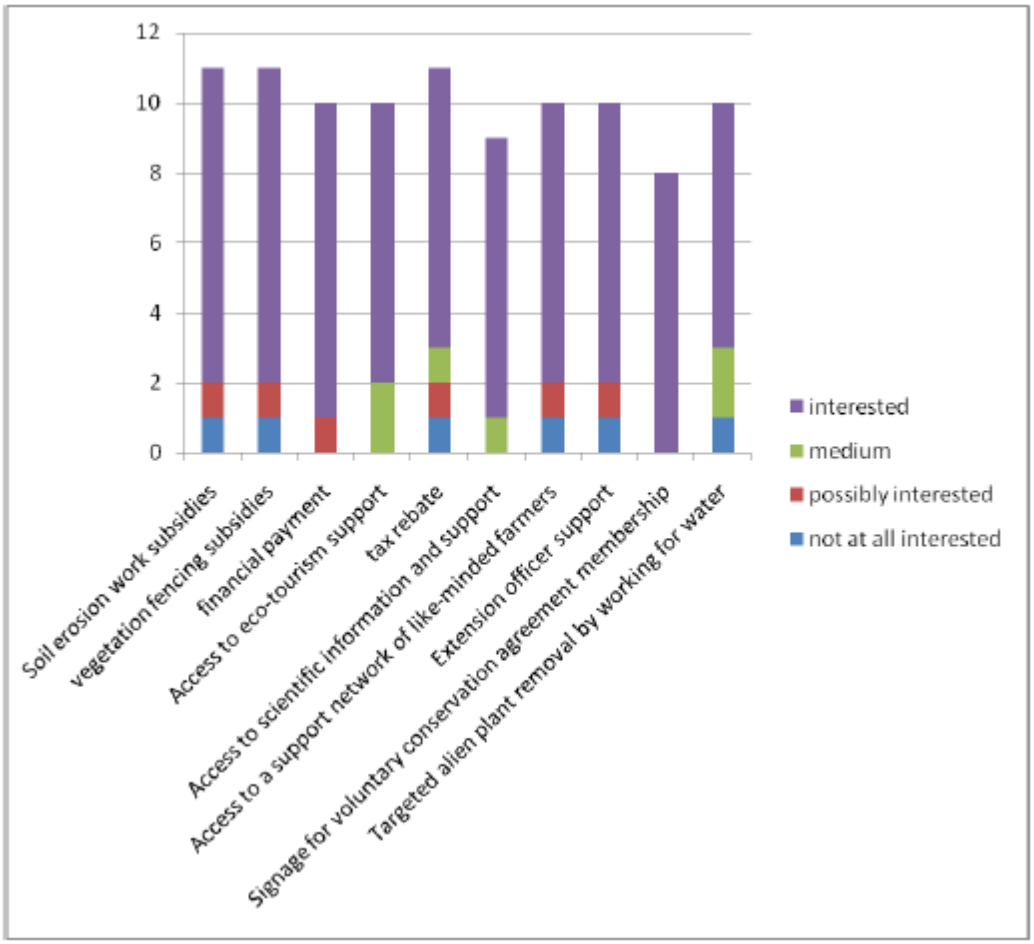


Figure A.11.3: Farmers' interest in various incentives.

Annex 12 Project area background information

Since the early 1900s, several million ha of semi-arid thicket vegetation in the Eastern Cape, South Africa, have been degraded by intensive goat farming(Lloyd et al., 2002). Despite a long association with large, indigenous herbivores, the thicket is surprisingly sensitive to goat pastoralism. Unsustainable browsing of thicket by goats has transformed the vegetation in many areas in the selected nature reserves from a dense assemblage of trees and shrubs covering most of the landscape to an open 'pseudo-savanna' of thicket patches (Lechmere-Oertel et al., 2005a; Lechmere-Oertel et al., 2005b). In the case of extreme degradation, a depleted and dying canopy tree layer is the only remnant of the original perennial vegetation. This degradation results in reduction of species diversity, above and below ground carbon stocks, soil quality and plant productivity (and hence livestock and game stocking capacity). Restoration of thicket by planting cuttings of *P. afra* results in the return of ecosystem carbon (in above ground biomass, below ground biomass, litter and SOM).

Figure A.12.1: Fence line contrast, showing the extent of degradation (on the left) caused by goat pastoralism.

In 2003, the South African government's then Department of Water Affairs and Forestry (DWAF – now the Department of Water Affairs) recognised the opportunity to fund restoration of degraded thicket through the sale of accrued carbon credits. Consequently, DWAF funded an ARR project in 2004 in degraded thicket landscapes in the Eastern Cape, with the purpose of earning carbon credits in order to fund further ARR efforts (Figure A.5.2: Letter from the Department of Water). Without this incentive to earn carbon credits, this project would not have been funded, as ARR of degraded thicket is costly (approximately US$500 ha^{-1}).

Initial restoration efforts have focused on three conservation (project) areas in which planting sites have been identified (the Baviaanskloof Nature Reserve, the Addo Elephant National Park, and the GFRNR; see Figure A.13.2); these are discussed in some detail below. Additional sites in these conservation areas as well as areas on private land within the region that meet the eligibility criteria will be included as the project progresses. All project areas are located in the Eastern Cape of South Africa, in an area that is semi-arid and susceptible to frequent droughts.

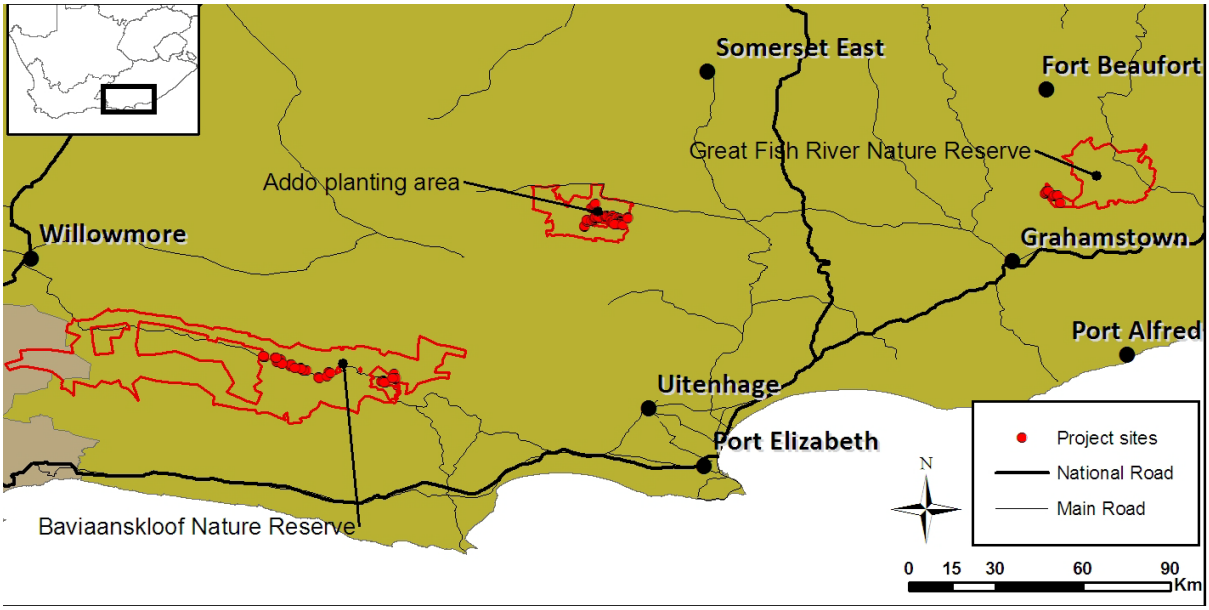


Figure A.12.2: Location of project areas in the Eastern Cape Province of South Africa.

A 1.1 Baviaanskloof Nature ReserveHistory

The Baviaanskloof Nature Reserve is managed by the Eastern Cape Parks Board, and is the centre of the Baviaanskloof Mega-Reserve, a cluster of conservation sites and nature reserves, as well as private land engaged in minimum-impact agricultural and pastoral activities. The Baviaanskloof Mega-Reserve was declared a World Heritage Site in 2004 because of its significant ecological processes and biodiversity. Much of the mountain land in the Baviaanskloof Nature Reserve has never been privately-owned. In 1923 the Baviaanskloof Forest Reserve was created to maintain the mountain catchment area, and in 1970 the mandate of the area was extended to include nature conservation and public recreation. In 1977 the Kouga Dam was built, and the state purchased parcels of private land along the Kouga River and close to the dam, transferring ownership to the Department of Forestry.

The Baviaanskloof Nature Reserve was formally created in 1987 when ownership was transferred from the Department of Forestry to the Eastern Cape Provincial government, and in 2004 the Eastern Cape Parks Board took over the management of the reserve for the Eastern Cape Provincial Government. Since 1987, nearly 16,000 ha of land has been purchased by or donated to the State, and an additional 15,332 ha has been purchased with the aid of private funds to expand the size of the reserve. Much of the purchased land was subjected to poor land management practices prior to incorporation into the nature reserve. In total, 12% of the thicket vegetation in the Baviaanskloof Mega-Reserve has been severely degraded by goat farming.

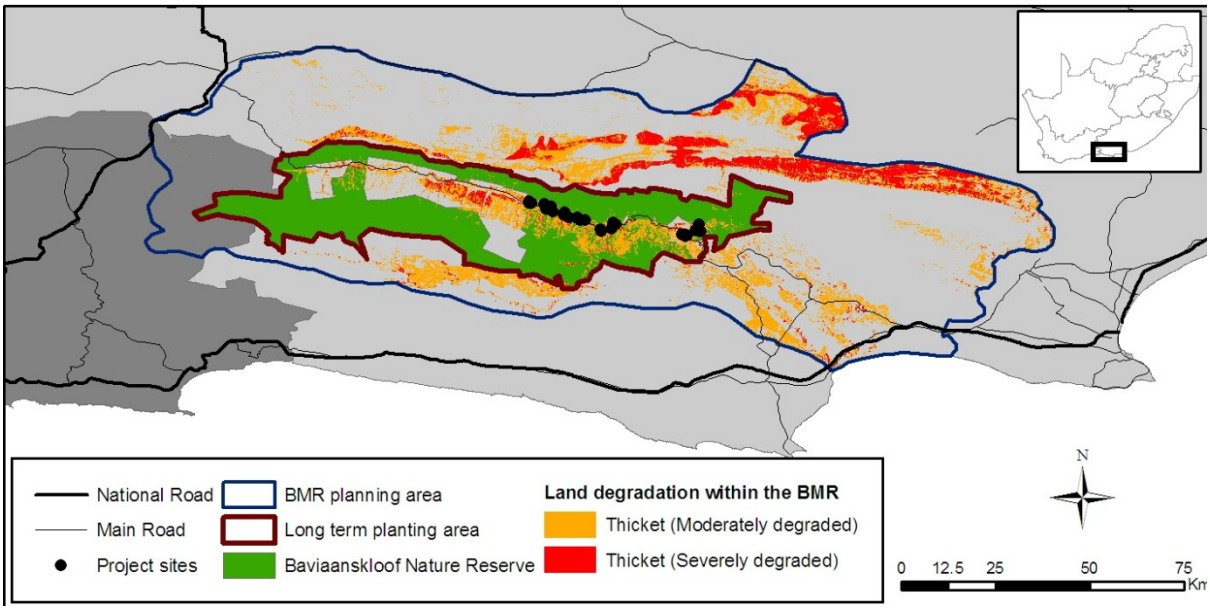


Figure A.12.3: Extent of land degradation within the Baviaanskloof Mega-Reserve. 19% of thicket vegetation in the Baviaanskloof Nature Reserve and 12% in the Baviaanskloof Mega-Reserve are severely degraded.

Climate

The climate of the proposed ARR project area is semi-arid. Mean annual temperatures for the eastern and western extremes of the study area, modelled from rainfall station data and altitude, are 18 °C and 17 °C, respectively (Schulze et al., 2008).

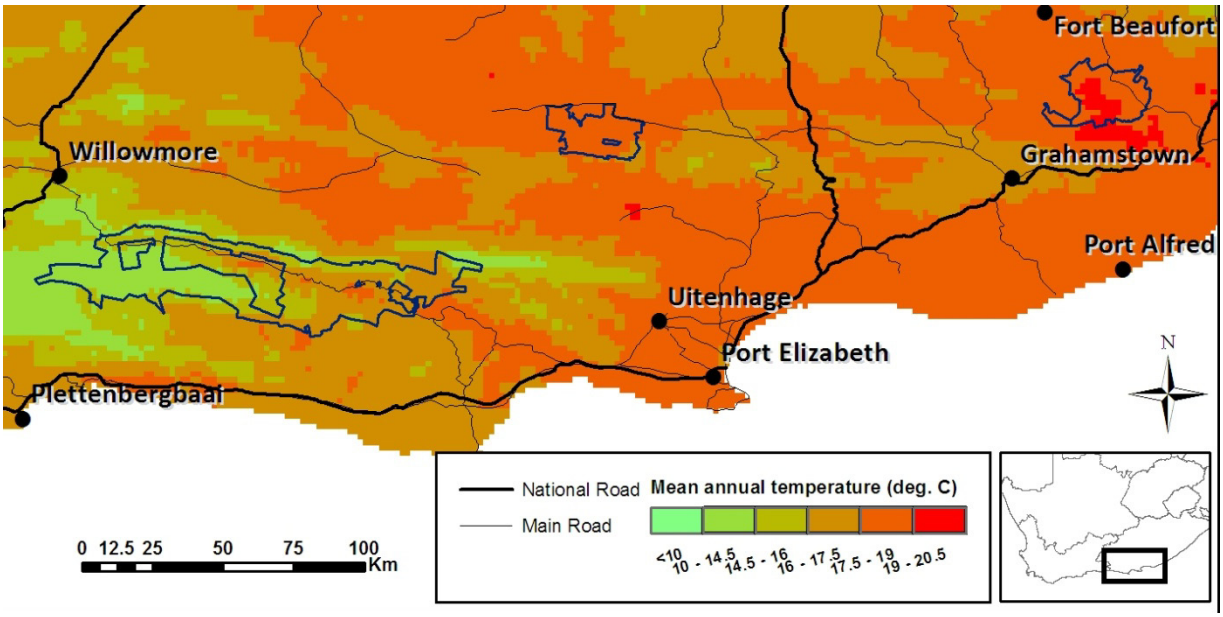


Figure A.12.4: Mean annual temperature in the STEP region of the Eastern Cape. Long term planting areas in the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the GFRNR are outlined from west to east.

The mean annual precipitation and coefficient of variation (in brackets) (also modelled), are 418 mm (32%) (eastern side) and 349 mm (34%) (western side). Rainfall is cyclonic and orographic, has bimodal peaks (spring and autumn) and is relatively unreliable – rainfall events often occur as

thunder storms; prolonged droughts are not uncommon. Proportionately, more summer rainfall occurs in the east, and more winter rainfall occurs in the west. Frost occurs occasionally in winter in bottomland locations and snow is relatively common on the high peaks during winter. Restoration activities in this project will occur on mid to low slopes and thus will not be affected by frost and snow.

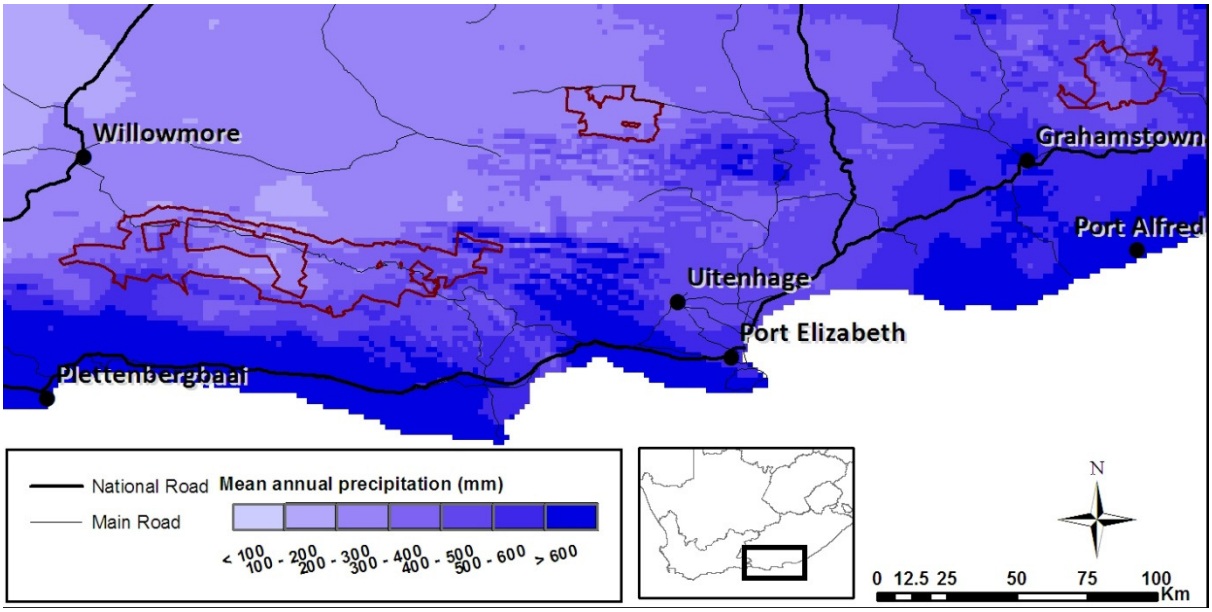


Figure A.12.5: Mean annual rainfall in the STEP region of the Eastern Cape. Long term planting areas in the Baviaanskloof Nature Reserve, the Addo Elephant National Park and the GFRNR are outlined from west to east.

Hydrology

The major river systems are the Baviaans, Gamtoos, Kouga, and Groot Rivers. Although flooding does occur in the landscape, it is uncommon. There are extensive agricultural irrigation systems in the Gamtoos Valley, obtained from the Kouga Dam, a major impoundment within the catchment, which also supplies the water needs of a large proportion of the Nelson Mandela Bay Metropol (Port Elizabeth and surrounding areas).

Geology and soils

The geology across the study area is highly varied (Figure A.12.6) but is predominantly of sedimentary origin, including conglomerates, sandstones, mudstones, siltstones and shales(Council for GeoScience, 1997). In the valley, there is an assortment of sedimentary rocks including Bokkeveld group shale and sandstone (Ceres subgroup), Table Mountain group quartzitic sandstone, shale and tillite (Nardouw subgroup), Gamtoos group limestone, phyllite, granulestone and quartzite, Uitenhage group conglomerate and sandstone (Enon formation) and alluvial deposits of sand, mud and gravel(Council for GeoScience, 1997). Soils across the Baviaanskloof are also varied as a result of a varied geology and a highly dissected terrain, and include *inter alia* Xerosols, Yermosols, Cambisols, Calcisols, Aridisols, Luvisols and Regosols[35]). Furthermore, soils in the region tend to be free-draining, rich in organic matter (under intact thicket only) (4-8 % soil carbon), nutrient-rich (including the macronutrients N, P, K, S, Ca, Mg, as well as micronutrients Mn, Fe, Zn, Cu and B(Council for GeoScience, 1997)) and have intermediate

[35] FAO. 1998. World reference base for soil resources. Food and Agricultural Organisation of the United Nations, Rome.

pH values (approximately 6.5-7.5). Many of the soils in the drier southern part of the project area have calcareous B horizons

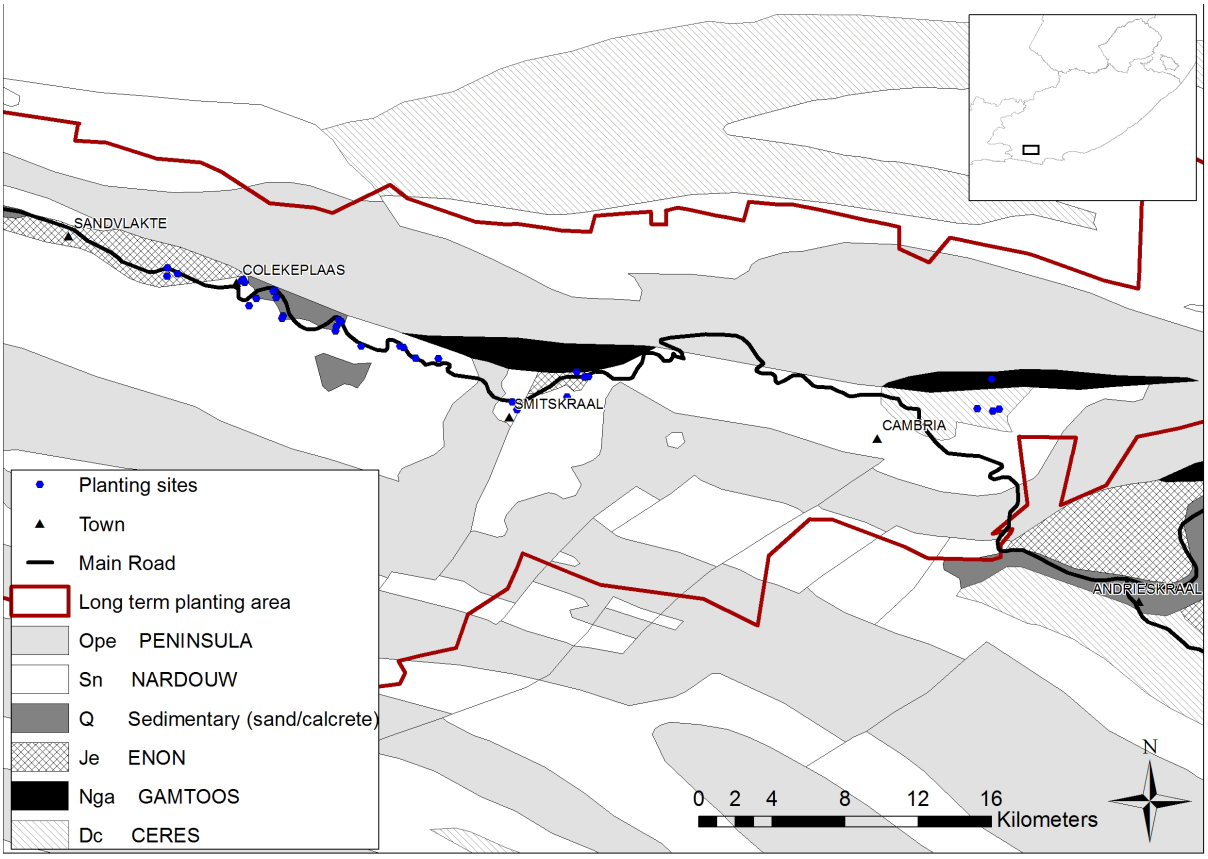


Figure A.12.6: Geology of the Baviaanskloof planting sites.

Vegetation

The vegetation in the Baviaanskloof Nature Reserve is predominantly fynbos and associated shrublands, such as renosterveld. Subtropical thicket is restricted to bottomlands and lower, colluvial slopes. Numerous benefits are offered by the thicket, namely i) in its intact state, it can support an exceptionally high natural diversity and abundance of large browsing mammals, such as black rhinoceros, African elephant (although there are no elephants present in the BNR) and antelope species (including kudu and bushbuck); ii) it is often harvested by local people for wood, fruit, and medicines; iii) it can sustain appropriately managed goat pastoralism; iv) it is the centre of a growing tourism industry; and v) it stores an unusually large quantity of ecosystem carbon for a semi-arid region(Mills et al., 2005a). It should be noted, however, that neither harvesting nor pastoralism are undertaken within the nature reserve boundary.

Subtropical thicket is composed of succulent (e.g. *P. afra*) and spinescent trees/shrubs less than 5 m tall (e.g. *Azima tetracantha*, *Gymnosporia polyacantha*, *Putterlickia pyracantha*, *Rhus longispina*, *Pappea capensis*, *Euclea undulata*, and *Schotia afra*). The main thicket vegetation types within the Baviaanskloof Nature Reserve include: Baviaanskloof Spekboom Thicket, Baviaanskloof Thicket Savanna, Gamtoos Valley Thicket, Gamtoos Bontveld, Baviaanskloof Renoster Sandolienveld and Baviaanskloof Sandolienveld(Vlok et al., 2003). The vegetation types within the project area include two solid (or pure) valley thicket types(Vlok et al., 2003), namely Baviaans Spekboom Thicket and Gamtoos Valley Thicket, which are the focal vegetation types for the Baviaanskloof area. The latter occurs under higher rainfall conditions than the former and has a lower cover of *P.*

afra, which is the dominant species in Baviaans Spekboom Thicket. Indicator species within Baviaans Spekboom Thicket are *Aloe speciosa, Pappea capensis, Putterlickia pyracantha* and *Schotia latifolia*. Gamtoos Valley Thicket indicator species are *Cussonia gamtoosensis*, *Euphorbia grandidens*, *Aloe speciosa, Sideroxylon inerme* and *Ptaeroxylon obliquum.* Additional vegetation types found in the project area include two mosaic types (where thicket elements are blended with elements from other biomes), namely Gamtoos Bontveld (a mosaic of Gamtoos Valley Thicket and succulent karoo) and Baviaans Thicket Savanna (a mosaic of thicket and savanna associated with alluvial soils of the valley bottoms) (Figure A.14.7). Indicator species for thicket clumps in Gamtoos Bontveld are *Pappea capenis*, *Euclea undulata*, *Schotia latifolia*, *Carissa haematocarpa*, and *Aloe africana*, and *Pteronia incana*. Indicator species in the thicket savanna are *Acacia karoo, Celtis africana, Rhus tomentosa, Plumbago auriculata* and *Lycium spp*..

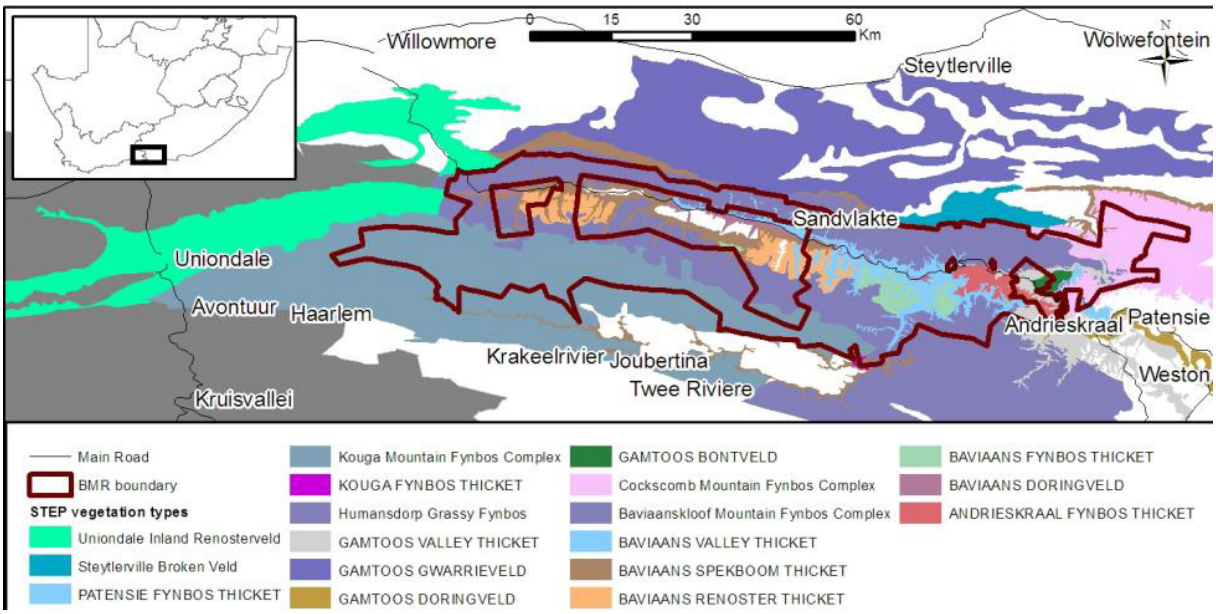


Figure A.12.7: Subtropical Thicket vegetation types of the Baviaanskloof Megareserve.

Rare or endangered species

The Baviaanskloof Nature Reserve contains several rare and vulnerable species. Included in these are 31 rare plant species, 8 vulnerable plant species, 2 rare animal species, 4 vulnerable animal species and 7 vulnerable bird species. Full lists of the rare and vulnerable species are given in Table A.12.1 and Table A.12.2[36]. These rare and vulnerable species will benefit from the project activities The restoration of thicket will improve habitat conditions for these species.

Table A.12.1: Baviaanskloof Nature Reserve Red Data List species: flora

Status	Species
Rare	Acrolophia barbata
	Agathosma affinis
	Agathosma unicarpellata
	Aloe microcantha
	Aloe pictifolia
	Atalaya capensis

[36]The South African Plant Red Data List is currently being updated, the most current version can be found at: http://www.sanbi.org/biodiversity/reddata.htm

	Crassula socialis
	Cussonia gamtoosensis
	Cyrtanthus clavatus
	Cyrtanthus flamosus
	Diascia patens
	Diosma passerinoides
	Encephalartos lehmannii
	Encephalartos longifolius
	Euryops integrifolius
	Gasteria ellaphieae
	Gasteria glomerata
	Gasteria rawlinsonii
	Geissorhiza elsiea
	Gladiolus geardii
	Ischyrolepis karooica
	Leucadendron loeriense
	Leucadendron nobile
	Leucadendron rourkei
	Otholobium macradenium
	Otholobium pictum
	Paranomus esterhuyseniea
	Psoralea trullata
	Spiloxene maximiliana
	Stapelia baylissii
	Sterculia alexandrii
Vulnerable	Agathosma spinosa
	Aloe longistyla
	Cyrtanthus spiralis
	Dioscorea elephantipes
	Herschelianthus lugens var. lugens
	Leucadendron sorocephalodes
	Paranomus reflexus
	Widdringtonia schwarzii

Table A.12.2: Baviaanskloof Nature Reserve Red Data List species: fauna.

Status	Species
Rare	Panthera pardus
	Proteles cristata
Vulnerable	Anthropoides paradiseus
	Ardeotis kori
	Circus ranivorus
	Diceros bicornis bicornis
	Equus zebra
	Falco naumanni

	Mellivora capensis
	Neotis denhami
	Neotis ludwigii
	Orycteropus afer
	Polemaetus bellicosus

A 1.2 Addo Elephant National Park

History

The Addo Elephant National Park was first created in 1931, in response to the extensive culling of elephants by local landowners. The original 2,000 hectares was host to only 11 elephants, and in 1954 the park was expanded to 2,750 hectares and ringed with an elephant-proof fence. Since this time the park boundaries have been extended a number of times through purchase of private land, until it reached its current size of nearly 1,640 km^2.

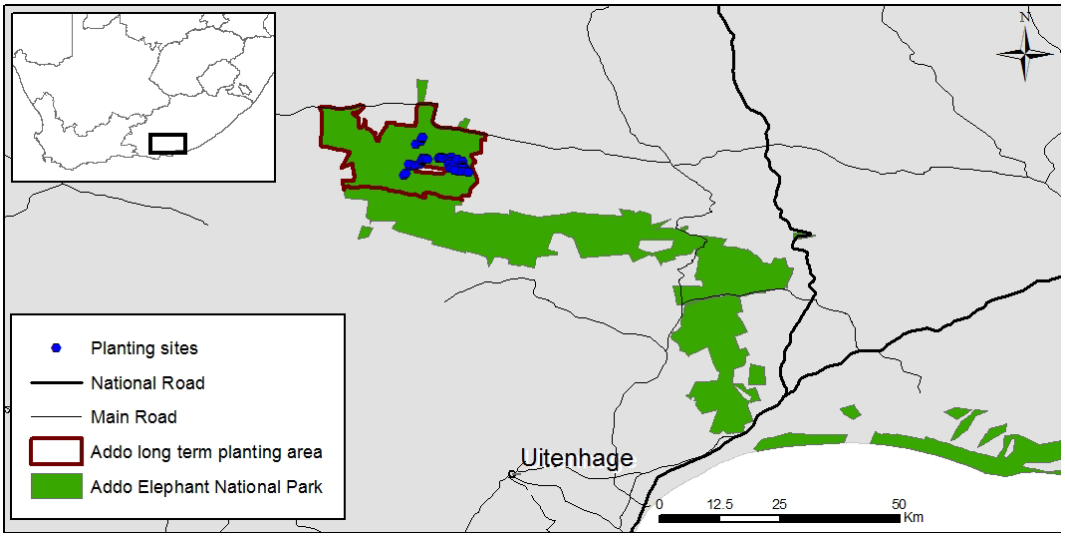


Figure A.12.8: Location of the Addo Elephant National Park and the planned long term planting area in the Eastern Cape of South Africa.

The long term planting (project) area is based in the northern area of the Addo Elephant National Park. This area was purchased from private landowners over a period of years, in order to expand the area available for conservation, particularly of elephants. The purchased land had previously undergone severe degradation due to unsustainable land management practices over a long period of time. Consequently, at present, much of the selected project area is severely degraded (see Figure A.12.9 below). As a consequence of this, no elephants are currently stocked in the project area, although as recovery progresses they may be introduced at low stocking rates.

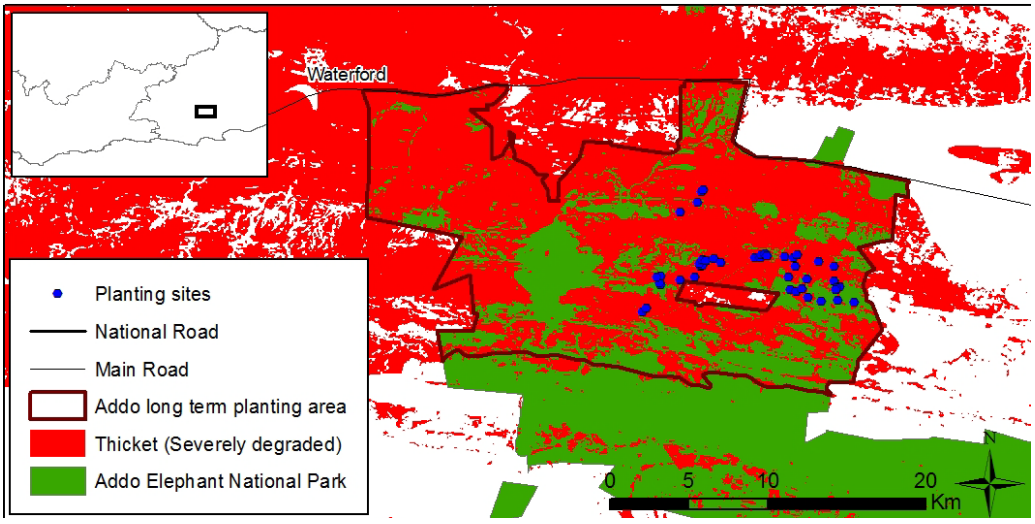


Figure A.12.9: Extent of land degradation within the northern region of the Addo Elephant National Park.

Despite the fact that the land is now protected as a conservation area under national legislation, no recovery of the natural vegetation has been observed (Annex 15). Herbivory is limited, since most large herbivores within the park are located in the southern sections, and consequently more localised factors must be responsible for the current slow rate of recovery.

Climate

The climate of the proposed ARR project area is semi-arid. Mean annual temperatures for the national park are between 16 °C and 19 °C (Figure A.12.4) modelled from rainfall station data and altitude(Schulze et al., 2008). The mean annual precipitation (also modelled) is approximately 385 mm, varying between 242 mm and 429 mm within the long term planting area (Figure A.12.5). Rainfall is cyclonic and orographic, and has bimodal peaks in spring and autumn. Rainfall events often occur as thunder storms and prolonged droughts are not uncommon.

Geology and soils

The project area has a varied geology, although it is almost exclusively of sedimentary origin, comprising sandstones, shale, mudstone and tillites. The majority of the geological formations within the area fall under the Karoo supergroup, including the Waterford shales and arenites, the Beaufort mudstones and the Ecca and Fort Brown shales. The Witteberg Group (Lake Mentz and Witteberg subgroups) make up the Zuurberg mountain range in the south of the project area, and are comprised primarily of shale and arenite, with some diamictite. Sandwiched between these two groups is the Dwyka glacial sediment group, with its archetypical tillites. The soils in the area are primarily fine textured soils derived from the mudstones and shales, with occasional patches of sandstone- and conglomerate-derived sandy soils. The soils tend to be moderately fertile, and fall within the mid range of soil fertility strata (4 and 5) as defined by Fey (1993).

Figure A.12.10: Geology of the Addo Elephant National Park planting area.

Vegetation(Vlok & Euston-Brown, 2002)

The vegetation in the long-term planting (project) area within the Addo Elephant National Park is predominantly shrubby thicket typified by the Sundays Noorsveld and Sundays Spekboomveld. The Sundays Noorsveld is largely restricted to the arid zone within the Sundays River basin, typified by the heavy clays of the Ecca group rocks. It has sparse tree content (primarily *Pappea capensis, Boscia oleoides*, *Euclea undulata,* and *Rhus longispina*), with abundant woody shrubs

(predominantly *Gymnosporia polyacantha* and *Rhigozum abovatum*, with occasional *Nymania capensis*) and a dominant *Euphorbia coerulescens*. Originally the pristine habitat boasted a number of perennial grasses (*Cenchrus ciliaris*, *Digitaria argyrograpta, Fingerhuthia africana* and *Panicum maximum*), but there are few areas that have not been overgrazed through goat farming. In degraded land, the open areas are typically filled by short-lived grasses such as *Aristida adscensionis, Aristida congesta, Cynodon dactylon* and *Enneapogon desvauxii*. Spekboom does occur in the Sundays Noorsveld, but tends not to be a major component of the pristine vegetation.

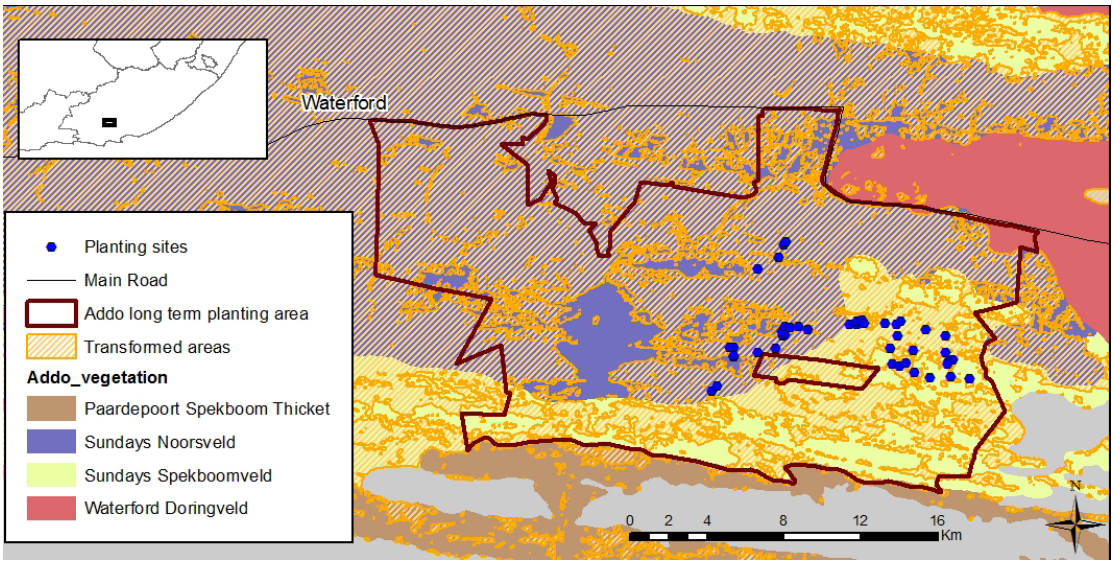


Figure A.12.11: Vegetation types of the Addo Elephant National Park.

In the Sundays Spekboomveld, the dominant *Euphorbia coerulescens* is replaced almost entirely by spekboom, which grows in thick stands. Apart from this notable difference, the Spekboomveld is structurally similar to the Noorsveld, with a slight shift in the makeup of the woody cover (*Pappea capensis* and *Schotia afra* usually more abundant, and *Acacia karoo* generally absent). The Spekboomveld occurs in the southern and eastern part of the project area. When degraded, Sundays Spekboomveld retains only a few woody trees in a matrix of karroid shrubs (*e.g. Pentzia incana* and the alien weed *Atriplex lindleyi*) and annual grasses, as well as the resilient herb *Sansevieria aethiopica*. The latter is generally considered a good indicator of where the Sundays Spekboomveld was once found.

Additional minor vegetation types in the long term planting area are the Pardepoort Spekboom Thicket found in the southernmost areas, and small areas of Waterford Doringveld in the northeast. The Doringveld is structurally similar to the Noorsveld, with the shrubby component largely replaced by short karroid shrubs (*Pentzia incana* is dominant). Typical tree species include *Euclea undulata*, *Gymnosporia polyacantha*, and *Rhus longispina*, with abundant *Acacia karoo* and *Rhus lancea* along the rivers. The Pardepoort Spekboom Thicket is dominated by *Portulacaria afra*, with a well-developed woody component (*Boscia oleoides*, *Pappea capensis, Schotia afra* and occasionally *Schotia latifolia)* and abundant succulents (primarily *Aloe speciosa* and *Crassula ovata*). The upper slopes of Pardepoort Spekboom Thicket tend to have localised endemics such as *Tromotriche longii*, and a different subset of species such as *Ficus burtt-davyi*.

Rare or Endangered species

The Addo Elephant National Park contains several rare and vulnerable species. Included in these are 1 critically endangered plant species, 3 endangered plant species, 6 vulnerable plant species, 6 rare animal species, 5 vulnerable animal species and 7 vulnerable bird species. Full lists of the rare

and vulnerable species are given in Table A.12.3 and Table A.13.12.4. These rare and vulnerable species will benefit from the project activities. The restoration of spekboom thicket will improve habitat conditions for these species.

Table A.12.3: Addo Elephant National Park Red Data List species: flora.

Status	Species
Critically Endangered	Aloe bowiea
Endangered	Adromischus mammillaris
	Haworthia springbokvlakensis
	Senecio scaposus var. addoensis
Vulnerable	Agathosma stenopetala
	Anacampseros subnuda subsp. lubbersii
	Cotyledon tomentosa subsp. tomentosa
	Strelitzia juncea
	Trichodiadema aureum
	Trichodiadema pygmaeum

Table A.13.12.4: Addo Elephant National Park Red Data List species: fauna.

Status	Species
Rare	Bitis albanica
	Dendrohyrax arboreus
	Felis nigripes
	Hippopotamus amphibius
	Panthera pardus
	Proteles cristata
Vulnerable	Anthropoides paradiseus
	Ardeotis kori
	Circus ranivorus
	Diceros bicornis bicornis
	Equus zebra
	Falco naumanni
	Felis lybica
	Mellivora capensis
	Neotis denhami
	Neotis ludwigii
	Orycteropus afer
	Polemaetus bellicosus

A 1.3 Great Fish River Nature Reserve

History

The GFRNR is a well-established conservation area that has been operational since 1994. It comprises three historical nature reserves that have been combined into a single reserve (Sam Knott Nature Reserve, Andries Vosloo Nature Reserve and Double Drift Nature Reserve).

The Andries Vosloo Kudu Reserve, named after a former Administrator of the Eastern Cape, was established in 1973 after the purchase, by the state, of the Kentucky, Double Drift Outspan and Grasslands farms from Mr Basil Kent. Lowestof Farm was later purchased from Mr W Smith in 1976, bringing the total area of the reserve to 6,500 ha.

Sam Knott 'Nature Reserve' was created in 1987, when the late Sam Knott bequeathed several farms to the Southern African Nature Foundation (now WWF-SA) under an agreement that the Cape Provincial Administration (now the Provincial Administration of the Eastern Cape) would manage the area.

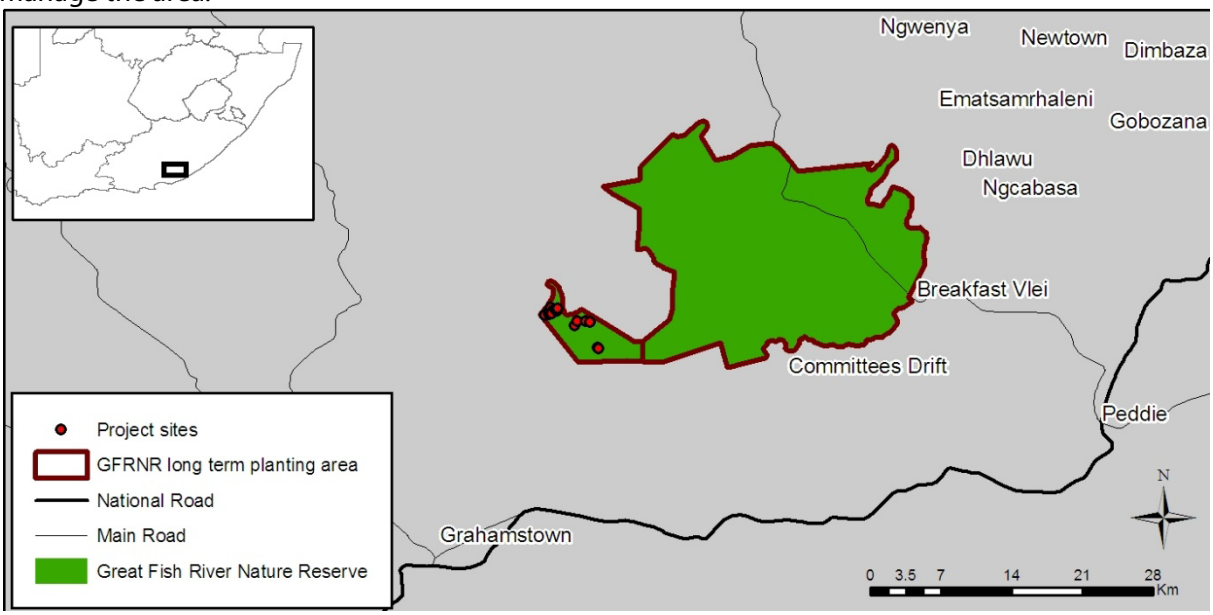


Figure A.12.12: Location of the Great Fish River Nature Reserve and the planned long term planting area in the Eastern Cape of South Africa.

On the eastern side of the Great Fish River, formerly the Ciskei, the L.L. Sebe Game Reserve was established when ten farms were purchased by the South African Development Trust in 1982. In 1985 the area was handed over to the Ciskei government to be managed by the Ciskei Wildlife and Resources section of Ulimocor. In 1990 the name changed to Double Drift Game Reserve.

In 1993 a joint management committee was established to manage the three reserves as a single unit, and in 1994 management of the reserve was assigned to the Eastern Cape Tourism Board and subsequently to the Eastern Cape Parks Board. The first joint management plan was implemented in 1995.

Prior to conservation, the principle land use was grazing and scattered agriculture on a number of farms, which is responsible for the degradation still present within the nature reserve. The extent of degradation is not as extreme as in Addo Elephant National Park, but much of the reserve is still moderately degraded (see Figure A.12.13). Despite long-term conservation efforts and low stocking rates of indigenous herbivores, the thicket vegetation has not recovered, and consequently restoration presents a clear opportunity to increase the biological diversity of the Nature Reserve.

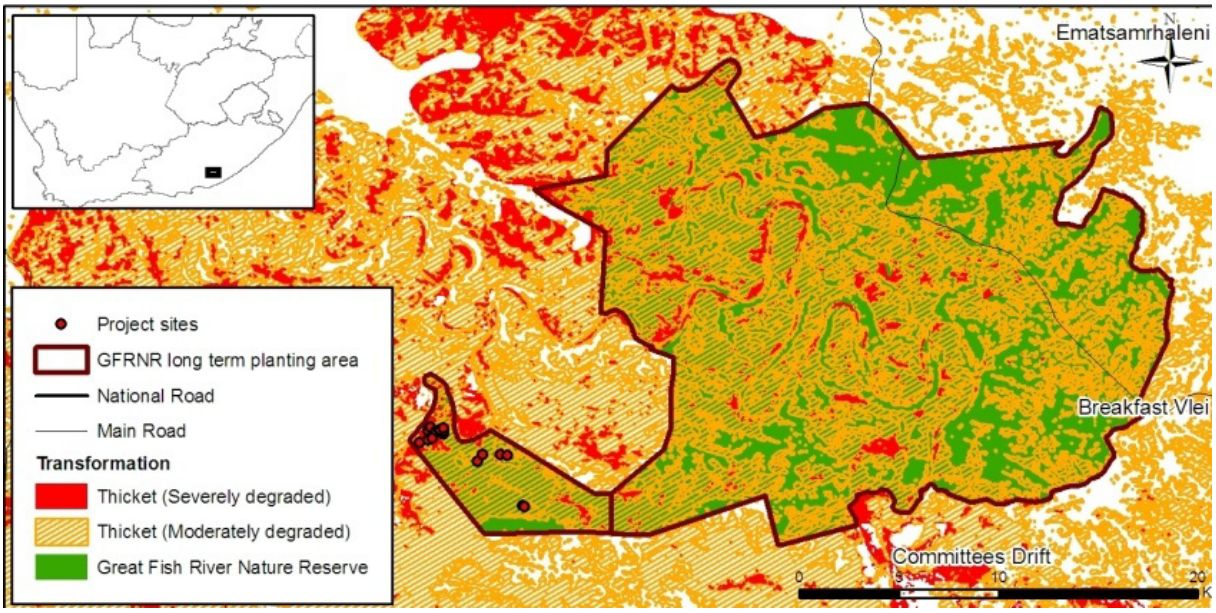


Figure A.12.13: Extent of land degradation within the Fish River Nature Reserve.

Climate

The climate in the GFRNR is semi-arid, with some variability in temperature and rainfall throughout the year and across the reserve. Variation in altitude throughout the reserve accounts for much of the variation in climatic conditions. As is typical for the region, rainfall is generally low. The mean annual precipitation is approximately 440 mm, varying between 340 mm and 561 mm within the nature reserve (Figure A.12.5). Precipitation is cyclonic and orographic, and generally unreliable, tending to fall in short, intense storms. Rainfall is also typically bimodal, peaking in October and March, with cool, dry winters.

Mean annual temperatures (Figure A.12.4) modelled from rainfall station data and altitude, are between 18°C and 20°C(Schulze et al., 2008) Frost occurs occasionally in winter in bottomland locations during winter.

Geology and soils

The geology of the GFRNR is not highly variable. The southern part of the nature reserve is dominated by the Fort Brown shale formation of the Ecca Group, whilst the northern part is exclusively Beaufort Group mudstones and arenites of the Karoo supergroup. Both formations produce largely clay-dominated soils of moderate fertility. Soils in the southwest of the GFRNR tend towards a more loamy texture. Current planting in the GFRNR is limited to the southern part of the reserve, but future planting will occur in different soil types. Overall fertility of the soils is moderate, and all planting areas within the reserve have been assigned a fertility rating of 4 according to the methodology defined by Fey (1993).

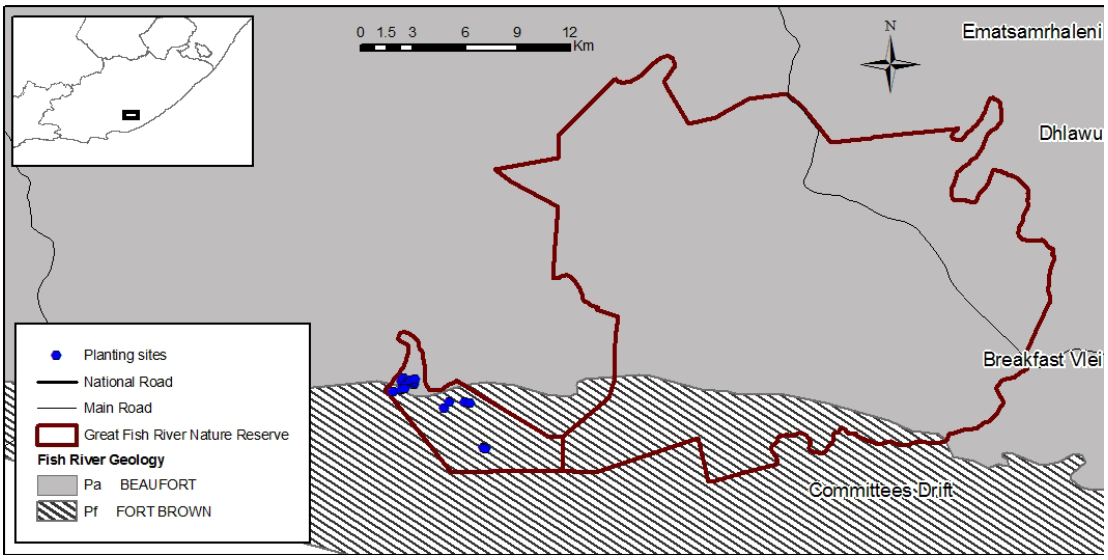


Figure A.12.14: Geology of the Great Fish River Nature Reserve.

Vegetation(Vlok & Euston-Brown, 2002)

The vegetation of the GFRNR is somewhat varied, but it is dominated by thicket vegetation. The principle vegetation type is Fish Spekboom Thicket, with a strong component of Doubledrift Karroid Thicket. Fish Spekboom Thicket is dominated by *P. afra*, with some woody tree species typical of the Fish Thicket (see below). Palatable perennial grasses, such as *Digitaria argyrograpta, Panicum deustum, Panicum maximum, Setaria neglecta* and *Themeda triandra* often grow in this thicket, but there is little pristine vegetation left. In degraded thicket, *P. afra* is rarely found, and only the woody tree component remains. *Aloe striata* is common in these areas. Fish Spekboom Thicket has a number of rare and localised endemics that are found in this vegetation type, including species typically found in the thicket component such as *Crassula intermedia, Crassula socialis, Faucaria felina ssp. Britteniae, Bergeranthus albomarginatus, Crassula decidua* and *Tetradenia barberae*. Other rare species found in open patches amongst the thicket vegetation include *Brachystelma huttoniae, Cyrtanthus smithiae, Euryops gracilipes, Monsonia vanderietiae, Ornithogalum acharophylla, Thesium junceum* and *Zaluzianskya vallispiscis*.

Fish Thicket is also found in the GFRNR. The principle difference between this vegetation type and the Fish Spekboom Thicket is the prevalence of a larger woody tree component (primarily *Scutia myrtina* and *Olea europaea*) in place of the shrubby vegetation. It has abundant *Euphorbia triangularis* and *Cussonia spicata*, with occasional occurrence of *Calodendron capense* and *Harpephyllum caffrum* in moist conditions along drainage lines. More open sites host smaller woody species such as *Brachylaena ilicifloia* and *Caddia rudis*.

Doubledrift Karroid Thicket is typified by relatively small thickets clumps dominated by *Euphorbia curviram* and *Euphorbia tetragona*. Other prominent elements include *Bulbine frutescens* and *Aloe tenuior*, with many small succulents (*Bulbine narcissifolia, Euphorbia pugniformis* and *Haworthia cooperi*) and geophytes. High fire frequency or grazing pressure can reduce the size of thicket clumps and increase the incidence of karroid shrubby species, but the occurrence of such pressures is low within the nature reserve.

The Karroid Thicket gives way to Crossroads Grassland Thicket adjacent to the Fish Spekboom Thicket. This vegetation type is typified by small clumps of thicket vegetation, without *Acacia karoo*, but dominated by *Cussonia spicata*, *Scutia myrtina*, *Ptaeroxylon obliquum* and occasionally *Euphorbia triangularis*. The southwestern corner of the Reserve has a patch of Fish Noorsveld,

which is readily identified by the abundance of a local endemic, *Euphorbia bothae*. It is particularly abundant on the valley floors, but this abundance may be due to removal of *P. afra*, which is more abundant on the hill slopes. Thicket clumps include abundant *Boscia oleoides*, *Euclea undulata*, *Gymnosporia polyacantha*, *Pappea capensis, Rhus longispina* and *Schotia afra*, although these species rarely form a closed canopy. Succulent species include *Aloe africana, Cotyledon orbiculata, Crassula ovata, Euphorbia pentagona* and *Sarcostemma viminale*, and there is a well-developed grassy component between thicket clumps (*Digitaria argyrograpta, Panicum coloratum* and *Sporobolus fimbriata*).

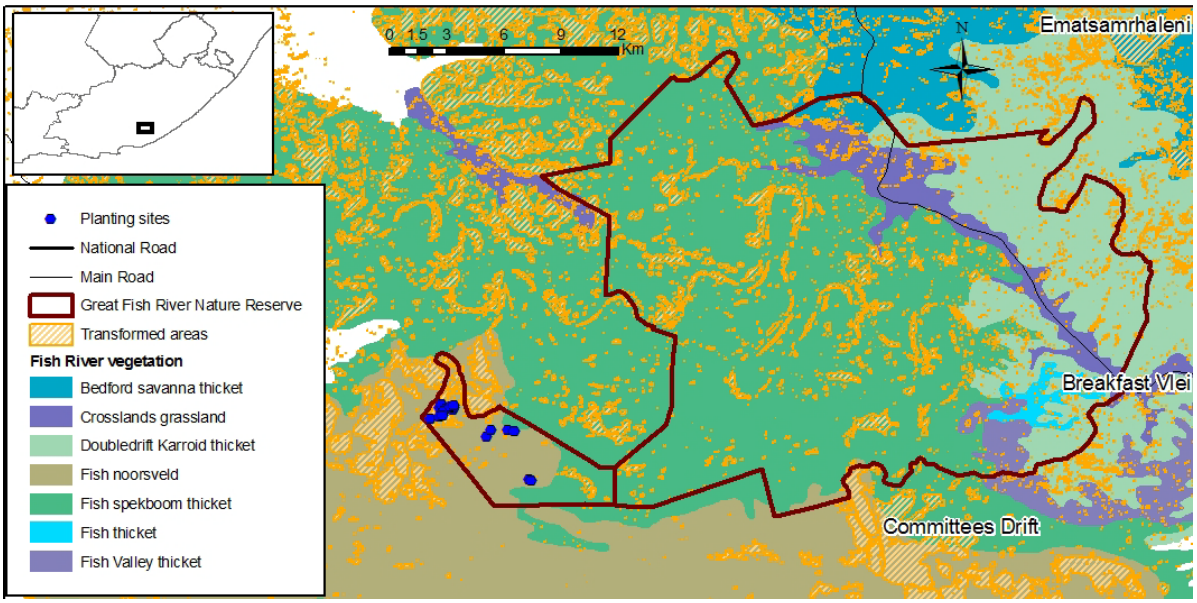


Figure A.12.15: Vegetation types of the Great Fish River Nature Reserve.

A small patch of Bedford Savanna Thicket is found in the north of the GFRNR. This thicket type strongly resembles small patches of Fish River Thicket scattered amongst a grassland matrix. The thicket is typified by *Rhus longispina*, *Schotia afra*, *Scutia myrtina* and *Azima tetracantha*, whilst the grassland often has abundant *Acacia karoo*.

Small areas of Fish Valley Thicket also occur in the southeastern corner of the GFRNR. Fish River Valley Thicket is typified by dense, tall stands of *Euphorbia curvirama* and *Euphorbia tetragona* that tend to tower over the woody component. However, this vegetation type tends to be very diverse, with an abundant series of spinescent shrubs and climbers, as well as a rich variety of grasses, herbs and succulents, forming dense cover. Woody species include the dominant *Rhus longispina*, *Pappea capensis, Schotia afra* and *Euclea undulata* trees as well as abundant *Boscia oleoides*, *Cussonia spicata* and *Ptaeroxylon obliquum*.

Rare or Endangered species

The GFRNP contains several rare and vulnerable species. Included in these is 1 critically endangered plant species, 2 endangered plant species, 11 vulnerable plant species, 1 endangered bird species and 11 vulnerable bird species. Full lists of the rare and vulnerable species are given in Table A.12.5 and Table A.12.6. These rare and vulnerable species will benefit from the project activities The restoration of spekboom thicket will improve habitat conditions for these species.

Table A.12.5: Great Fish River Nature Reserve Red Data List species: flora.

Status	Species

Critically Endangered	Corpuscularia lehmannii
Endangered	Agathosma bicornuta
	Haworthia attenuata var. attenuata
Vulnerable	Apodolirion macowanii
	Aspalathus arenaria
	Aspalathus steudeliana
	Brachystelma luteum
	Ceropegia fimbriata subsp. fimbriata
	Encephalartos trispinosus
	Eriospermum bracteatum
	Euryops gracilipes
	Haworthia herbacea var. herbacea
	Nerine huttoniae
	Prunus africana

Table A.12.6: Great Fish River Nature Reserve Red Data List species: fauna.

Status	Species
Endangered	Poicephalus robustus
Vulnerable	Anthropoides paradiseus
	Ardeotis kori
	Balearica regulorum
	Circus ranivorus
	Eupodotis senegalensis
	Falco naumanni
	Gyps coprotheres
	Neotis denhami
	Neotis ludwigii
	Podica senegalensis
	Polemaetus bellicosus

Annex 13 Literature review

A large amount of research has been conducted in the subtropical thicket of the Eastern Cape, and into the impacts of restoration by means of planting *P. afra* in particular. Much of this is referenced in this document, and the abstracts for several of the seminal works are included in this section for review.

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Patterns and implications of transformation in semi-arid succulent thicket, South Africa

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Abstract

Transformation of South African succulent thicket in response to grazing is widespread and characterized by the extensive replacement of dense closed-canopy thicket with a 'pseudo-savanna' of remnant trees with an ephemeral field layer. In this study, we examined the patterns of transformation in a semi-arid succulent thicket ecosystem using replicated fence line contrasts. We quantified the changes in plant species and functional diversity, physiognomy and biomass. We tested whether the remnant tree guild of the transformed thicket is in a stable state, using aerial photographs and ground-truthing to track the survivorship of canopy trees over 60 years in transformed landscapes. We investigated the impacts of transformation on recruitment into the canopy tree guild by measuring seedling establishment across the fence line contrasts. Transformation results in a significant loss of plant and functional diversity. There is a significant reduction in the biomass and structural complexity of the vegetation, both vertically and horizontally. The canopy tree guild in transformed thicket is not stable owing to ongoing adult mortality and little successful recruitment. These results are interpreted in a framework of ecosystem functioning and long-term stability. We suggest that the pseudo-savanna typical of transformed succulent thicket is

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Figure A.13.1: Lechmere-Oertel *et al.*, 2005. Patterns and implications of transformation in semi-arid succulent thicket, South Africa. Journal of Arid Environments 62:459-474.

Austral Ecology (2005) **30**, 615–624

Landscape dysfunction and reduced spatial heterogeneity in soil resources and fertility in semi-arid succulent thicket, South Africa

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Abstract Succulent thicket in the Eastern Cape of South Africa is one of many rangeland ecosystems in the world that displays evidence of unsustainable grazing pressure. Widespread transformation of succulent thicket has resulted in the replacement of the typical two-phase perennial vegetation patches with a structurally simple field layer of ephemeral and weakly perennial grasses and forbs. We hypothesized that (i) transformation of succulent thicket leads to a switch from a spatially heterogeneous landscape to a homogenous and relatively infertile state; and (ii) that this loss of fertility is associated with a breakdown in the processes that conserve resources and promote water use efficiency. We tested these hypotheses at five fenceline contrast sites in Sundays River Thicket, an arid form of succulent thicket. We compared soil fertility (organic carbon, available nitrogen and phosphorus), texture, matric potential, and surface microtopography in the two main microhabitats on either side of the fencelines using a nested anova. Our results show that intact Sundays River thicket has a distinct spatial pattern of soil fertility where nutrients and organic carbon are concentrated under the patches of perennial shrubs, compared with under canopy trees. Transformation results in a significant homogenization of this pattern and an overall reduction in the fertility of the landscape. The proportion of the landscape surface that promotes infiltration due to a distinct litter layer decreases from 60% to 0.6%. Soil moisture retention (matric potential) also decreases with transformation. We interpret these patterns within the framework of semi-arid landscape functionality.

Key words: desertification, landscape function, matric potential, microtopography, soil nutrient.

INTRODUCTION

There has been considerable interest in the long term impact of livestock on semi-arid rangelands across the world. This arises from the perception that large areas of these rangelands have become transformed through unsustainable livestock production. In the semi-arid and arid rangelands of the world, such transformation is termed desertification (Arnalds & Archer 2000), and is primarily recognized through physical changes in the environment, such as loss of vegetation cover, loss of soil and organic matter and reduced water use efficiency (Whitford 2002). Such physical changes are often accompanied by a significant reduction in plant and animal production, upon which much human livelihood in those areas relies. As up to 75% of landscapes that can be desertified have become so to some degree (Karrar & Stiles 1984), there is an urgent need to understand the dynamics of transformation in semi-arid rangelands. This is particularly so in the succulent thicket in South Africa (described below) where up to 80% has been transformed by reduced cover of perennial shrubs (Lloyd *et al.* 2002) due to unsustainable stocking of domestic goats.

The landscape functionality framework developed in Australia (Ludwig *et al.* 1997; Ludwig & Tongway 2000), which builds on earlier work by Noy-Meir (1973) and Westoby *et al.* (1989), provides powerful insight into the dynamics of semi-arid rangelands and how to recognize transformation of these systems. Importantly, the framework provides testable predictions that allow comparisons of the extent of landscape dysfunction under different management treatments. The framework suggests that healthy landscapes conserve resources and have processes that enrich fertile patches in an infertile matrix. A prediction from the framework is that functional landscapes have a high degree of spatial organization at a patch scale (Ludwig & Tongway 1995a; Holm *et al.* 2002a), with resource-rich soils associated with perennial vegetation patches, surrounded by infertile bare patches, that is, a two-phase mosaic.

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Figure A.13.2: Lechmere-Oertel *et al.*, 2005b. Landscape dysfunction and reduced spatial heterogeneity in soil resources and fertility in semi-arid succulent thicket, South Africa. *Austral Ecology* 30: 615-624.

Rate of Carbon Sequestration at Two Thicket Restoration Sites in the Eastern Cape, South Africa

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Abstract

Ecosystem carbon storage in intact thicket in the Eastern Cape, South Africa exceeds 20 kg/m^2, which is an unusually large amount for a semiarid ecosystem. Heavy browsing by goats transforms the thicket into an open savanna and can result in carbon losses greater than 8.5 kg/m^2. Restoration of thicket using cuttings of the dominant succulent shrub *Portulacaria afra* could return biodiversity to the transformed landscape, earn carbon credits on international markets, reduce soil erosion, increase wildlife carrying capacity, improve water infiltration and retention, and provide employment to rural communities. Carbon storage in two thicket restoration sites was investigated to determine potential rates of carbon sequestration. At the farm Krompoort, near Kirkwood, 11 kg C/m^2 was sequestered over 27 years (average rate of 0.42 ± 0.08 kg C m^{-2} yr^{-1}). In the Andries Vosloo Kudu Nature Reserve, near Grahamstown, approximately 2.5 kg C/m^2 was sequestered over 20 years (0.12 ± 0.03 kg C m^{-2} yr^{-1}). Slower sequestration in the Kudu Reserve was ascribed to browsing by black rhinoceros and other herbivores, a shallower soil and greater stone volumes. Planting density and *P. afra* genotype appeared to affect sequestration at Krompoort. Closely-packed *P. afra* planting may create a positive feedback through increased infiltration of rainwater. The rate of sequestration at Krompoort is comparable to many temperate and tropical forests. Potential earnings through carbon credits are likely to rival forest-planting schemes, but costs are likely to be less due to the ease of planting cuttings, as opposed to propagating forest saplings.

Key words: biomass, carbon sequestration, *Portulacaria afra*, restoration, semiarid landscapes, soil carbon, thicket.

Introduction

Ecosystem carbon storage in the arid form of South African succulent thicket (Vlok et al. 2003), found in areas receiving 250–350 mm mean annual rainfall, exceeds 20 kg/m^2 (Mills, O'Connor, et al. 2003, 2005). This is an exceptional amount of carbon for a warm, semiarid region and is more akin to mesic forest ecosystems (Mills, Cowling, et al. 2005). In its untransformed state, xeric thicket has an almost complete cover of dense, relatively tall (3–4 m) evergreen vegetation and has a much higher biomass than would be expected under semiarid conditions (Lechmere-Oertel 2004; Mills, Cowling, et al. 2005; Lechmere-Oertel et al. 2005*b*). Much of the biomass comprises the succulent shrub *Portulacaria afra*, known locally as spekboom (Acocks 1953; Vlok et al. 2003). The vegetation has been used for farming goats since the early 1900s. Heavy browsing by goats has resulted in the loss of *P. afra*, which is highly palatable to livestock, and the transformation of thicket to an open "savanna." The transformed savanna comprises ephemerals and short-lived grasses (known locally as "opslag"), whose abundance tracks rainfall events, and scattered remnant trees (Hoffman & Cowling 1990; Lechmere-Oertel et al. 2005*b*). Approximately 45% of *P. afra*–dominated thicket in South Africa (5,519 km^2 out of a total of 12,624 km^2) has been altered in this manner (Lloyd et al. 2002).

Carbon lost as a result of degradation in the arid succulent thicket near Kirkwood, Eastern Cape was estimated to be approximately 4.0 kg/m^2 in soils to a depth of 500 mm and 4.5 kg/m^2 in biomass (above- and belowground) (Mills 2003; Mills, O'Connor, et al. 2005). Effective restoration of transformed thicket could be achieved by planting *P. afra* cuttings because this species propagates vegetatively in nature and takes root from cuttings rapidly (Swart & Hobson 1994). Restoration could potentially return greater than 8.5 kg C/m^2 to transformed sites, but the potential rate of return is unknown. Two lines of evidence suggest that return of carbon may occur faster than in other transformed semiarid systems. Lechmere-Oertel et al. (2005*a*) found that the leaf litter productivity of *P. afra* (0.45 kg m^{-2} yr^{-1}, dry matter [DM]) was similar to mesic forest systems, and Aucamp and Howe (1979) found that the net primary production of thicket was approximately 1.1 kg m^{-2} yr^{-1} wet aboveground biomass (0.45 kg DM m^{-2} yr^{-1} assuming a dry:wet ratio of 0.4). Benefits associated with restoration would include restoration of ecosystem services such as carbon sequestration, herbivore browse and flood control, the restoration of biodiversity, control of soil erosion, and the provision of jobs in

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Figure A.13.3: Mills & Cowling, 2006. Rates of Carbon Sequestration at Two Thicket Restoration Sites in the Eastern Cape, South Africa. *Restoration Ecology* 14(1):38-49.

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Soil carbon and nitrogen in five contrasting biomes of South Africa exposed to different land uses

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Stocks of soil C to a depth of 50 cm in untransformed, indigenous veld ranged from 21 t ha^{-1} in karoo to 168 t ha^{-1} in thicket and stocks of N ranged from 3.4 t ha^{-1} in karoo to 12.8 t ha^{-1} in grassland. Mean soil C in thicket (5.6%, 0-10 cm) was approximately five times greater than expected for a semi-arid region. Removal of vegetation due to cultivation, grazing or burning reduced soil C and N at all sites. Soil C under intact thicket was greater than at sites degraded by goats (71 vs 40 t ha^{-1}, 0-10 cm). Restoration of thicket could potentially sequester ~40 t C ha^{-1}. The sale of this sequestered carbon to the international market may make restoration of thousands of hectares of degraded thicket financially feasible. Soil C under plant cover was greater than in exposed soil in renosterveld (28 vs 15 t ha^{-1}) and in karoo (7 vs 5 t ha^{-1}). Parent material was also related to soil C content. In grassland, soil C was greater in dolerite-derived than sandstone-derived soils (54 vs 27 t ha^{-1}); and in bushveld it was greater in basalt-derived than granite-derived soils (28 vs 14 t ha^{-1} in unburnt plots). Annual burning in bushveld reduced soil C, particularly at the surface. Soil C in the 0-1 cm layer of unburnt plots was 2 to 3 times greater than in burnt plots.

Keywords: land use, sequestration, soil carbon, soil nitrogen, South African biomes

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Introduction

The increase in atmospheric CO_2 and associated concerns of global warming have turned the world's attention towards the global C cycle (Lal, 2001). Sequestering C into biomass or soil could buy time to address the problem but the production of biomass in a mostly semi-arid country such as South Africa is limited by available water. Consequently stocks of soil C per unit area in South Africa are typically lower than in temperate, mesic regions (Du Preez & Snyman, 1993; Du Toit & Du Preez, 1995; Schulze, 2000). Soil with a cover of vegetation tends to have more C than exposed soil because plants recycle C and they may suppress mineralisation by releasing antibacterial exudates (Theron, 1951; 1963), and reduce mineralisation catalysed by wetting and drying of the soil (Birch, 1958) by shading and cooling and by intercepting rainfall. Removal of vegetation by ploughing, grazing, browsing or burning reduces soil organic matter. Declines in C due to cultivation have been recorded in grasslands of the highveld (Du Toit *et al.*, 1994; Nel *et al.*, 1996) but the extent to which land use affects soil C in other South African regions is largely unknown. In this paper, soil C is examined in five contrasting biomes and stocks of soil C under vegetation, in open, bare soils and in soils exposed to a variety of land use practices (including cultivation, livestock husbandry, pastures, forestry and veld burning) are compared.

Materials and methods

Study areas

The study sites (Figure 1) were named after the characteristic natural vegetation types for each area as defined by Low & Rebelo (1996) and included: West Coast Renosterveld (renosterveld), Central Nama Karoo (karoo); Xeric Succulent Thicket (thicket); Moist Upland Grassland (grassland); and Mixed Lowveld Bushveld (bushveld). A summary of geographic features including climate, vegetation, geology, soils, and land uses is presented in Tables 1 and 2.

Figure 1 The location of the five study sites.

Sampling

Composite samples, comprising 15-20 subsamples, were taken at least 10 m apart with an auger to a depth of 10 cm as described below:

(a) **Renosterveld** - Dwyka sediment-derived soils were sampled from (i) open renosterveld i.e., on bare ground outside of bush clumps; (ii) below renosterbos bushes (*Elytropappus rhinocerotis* [L.f.] Less.); and (iii) old wheatlands planted to medic (*Medicago* spp.); and (iv) cultivated wheat fields. Dolerite-derived soils were sampled from (i) virgin veld and (ii) cultivated wheat fields. All sites were at least 500 m apart.

Figure A.13.4: Mills & Fey, 2004a. Soil carbon and nitrogen in five contrasting biomes of South Africa exposed to different land uses. *South African Journal of Plant and Soil* 21(2):94-103.

Plant and Soil **265:** 153–163, 2004.

Transformation of thicket to savanna reduces soil quality in the Eastern Cape, South Africa

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Key words: soil crusting, soil organic matter, soil quality, succession, thicket

Abstract

Xeric succulent thicket in the Eastern Cape, South Africa has been used for farming goats since the early 1900s. This habitat is characterised by a dense cover of the succulent bush *Portulacaria afra* and by a warm, semi-arid climate with evenly distributed annual rainfall of 250–400 mm. Heavy browsing by goats results in the loss of *P. afra* and transforms the thicket to an open savanna dominated by annual grasses. Eight fence-line comparisons between thicket and savanna were used to investigate differences in soil quality associated with the vegetation change. Composite soil samples were taken to a depth of 10 cm from 1 ha plots on either side of the fence-line. Associated with the change from thicket to savanna, a significant decrease (paired *t*-test, $P < 0.05$) was found in total C (respective means of 5.6 vs. 3.0%), total N (0.33 vs. 0.24%), labile C (2.8 vs. 1.5%), CO_2 flux (1.9 vs. 0.5 μmol m^{-2} s^{-1}), soil respiration in the laboratory (144 vs. 79 ng C kg^{-1} s^{-1}), (NH_4)OAc-extractable Mg (55 vs. 28 $mmol_c$ kg^{-1}), and laboratory infiltration rate (51 vs. 19 mm h^{-1}). In the same direction there was a similarly significant increase in modulus of rupture (16 vs. 34 kPa), water-soluble Ca (2.3 vs. 3.4 $mmol_c$ kg^{-1}) and pH (6.7 vs. 7.7). The soil C content of 5.6% in thicket is surprisingly high in this warm, semi-arid climate and suggests that the dense *P. afra* bush strongly regulates soil organic matter through microclimate, erosion control, litter quantity and perhaps chemistry. Savanna soils had a greater tendency to crust (as evident in a lower rate of laboratory infiltration and greater modulus of rupture) than thicket soils. This was attributed to their lower organic matter content, which probably reduced aggregate stability. Savannas are likely to be more prone to runoff and erosion not only because of sparser vegetation but also because of a decline in soil quality.

Introduction

Patches of vegetation in semi-arid regions are usually hotspots of soil organic matter and nutrients (Schlesinger et al., 1990). This is because vegetation shades the surface, protects the soil from raindrop impact, replenishes soil organic matter through litter and root sloughing, traps atmospheric dust and provides cover for birds and mammals (Kellman, 1979; Belsky et al., 1989; Frost and Edinger, 1991; Vetaas, 1992; Roos and Allsopp, 1997; Scholes and Archer, 1997; Allsopp, 1999). Belsky et al. (1989), for example, found in a Kenyan savanna that N, P, K, total C and soil water content were greater under the canopy of *Acacia tortilis* than outside it. Livestock farming has lead to bush encroachment and a reduction in carrying capacity in many semi-arid grasslands and savannas (Archer et al., 1988; Asner et al., 2003). Despite a decline in carrying capacity, soil quality is often improved because soil organic matter tends to increase with increasing bush cover (Hibbard et al., 2001; Hudak et al., 2003). The direction of change is not, however, predictable and the ecological processes involved are controversial (Hibbard et al., 2001). High livestock stocking rates can also result in a loss of vegetation cover and an associated decrease in soil nutrient status, organic matter, water content and infiltrability (Seitlheko et al., 1993; Mworia et al., 1997; Allsopp, 1999). Robin-

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Figure A.13.5: Mills & Fey, 2004b. Transformation of thicket to savanna reduces soil quality in the Eastern Cape, South Africa. *Plant and Soil* 265:153-163.

Austral Ecology (2005) **30**, 797–804

Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa

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Abstract Intensive pastoralism with goats transforms semiarid thicket in the Eastern Cape, South Africa from a dense vegetation of tall shrubs to an open landscape dominated by ephemeral grasses and forbs. Approx. 800 000 ha of thicket (which prior to the introduction of goats had a closed canopy and a *Portulacaria afra* Jacq. component) have been transformed in this manner. Ecosystem C storage in intact thicket and loss of C due to transformation were quantified. Carbon storage in intact thicket was surprisingly high for a semiarid region, with an average of 76 t C ha^{-1} in living biomass and surface litter and 133 t C ha^{-1} in soils to a depth of 30 cm. Exceptional C accumulation in thicket may be a result of *P. afra* dominance. This succulent shrub switches between C_3 and CAM photosynthesis, produces large quantities of leaf litter (approx. 450 g m^{-2} $year^{-1}$) and shades the soil densely. Transformed thicket had approx. 35% less soil C to a depth of 10 cm and approx. 75% less biomass C than intact thicket. Restoration of transformed thicket landscapes could consequently recoup more than 80 t C ha^{-1}.

Key words: biomass, carbon stocks, goats, pastoralism, soil carbon, thicket.

INTRODUCTION

Semiarid solid thicket (characterized by a dense canopy of tall shrubs and a *Portulacaria afra* Jacq. component) occupies approx. 1.7 million hectares in the Eastern Cape, South Africa (Lloyd *et al.* 2002). Despite a long association with a diverse assemblage of large and medium-sized indigenous herbivores (Midgley 1991; Kerley *et al.* 1995), thicket is surprisingly sensitive to injudicious pastoralism (Stuart-Hill & Danckwerts 1988; Stuart-Hill 1992). Heavy browsing by goats can transform thicket from a dense closed-canopy shrubland into an open savanna-like system with a cover of ephemeral grasses and forbs within a few decades, and possibly even within a decade (Hoffman & Cowling 1990; Kerley *et al.* 1995; Lechmere-Oertel *et al.* 2005a). Approximately 800 000 ha of semiarid thicket has been transformed in this manner, and the process of transformation is evident in another 600 000 ha (Lloyd *et al.* 2002). We hypothesized that transformation reduces total ecosystem C storage, as loss of above-ground biomass is highly visible (Fig. 1), and soil C is likely to be reduced where canopy cover is removed (Allsopp 1999; Mills & Fey 2003, 2004a). We asked the question: how much C is lost when thicket is transformed?

Warm, semiarid landscapes are not where one would intuitively expect to find large stocks of ecosystem C. Ecologists are accustomed to a pattern of increasing biomass along a rainfall gradient from deserts to forests (Woodward 1987). The common perception is that low water availability in warm, semiarid landscapes limits accumulation of biomass because water demand tends to increase with an increase in biomass. While this is true, multiple exceptions to such a pattern occur in semiarid and arid lands where water is not the primary limiting factor. Decoupling from water as a limiting factor occurs, for example, in desert areas dominated by phreatophytic species of *Prosopis* which tap groundwater pools. Moreover, with this example, nitrogen fixation by root nodules reduces limitations due to nitrogen as well. Physiological decoupling from water limitation can also occur where crassulacean acid metabolism (CAM) metabolic systems can allow highly efficient use of water and thus relatively high productivity and biomass in areas with very low rainfall. Accumulation of soil C also tends to be limited in these landscapes (Post *et al.* 1982) because soils are exposed to sunlight (as a result of limited plant cover), which enhances rates of mineralization of soil organic matter (via temperature effects) (Jenkinson 1981) and photo-

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Figure A.13.6: Mills et al., 2005a. Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa. *Austral Ecology* 30:797-804.

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Ecosystem carbon storage under different land uses in three semi-arid shrublands and a mesic grassland in South Africa

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Carbon (C) storage in biomass and soils is a function of climate, vegetation type, soil type and land management. Carbon storage was examined in intact indigenous vegetation and under different land uses in thicket (250-400 mm mean annual precipitation), xeric shrubland (350 mm), karoo (250 mm), and grassland (900-1200 mm). Carbon storage was as follows: (i) mean soil C (0-50 cm): thicket (T) = grassland (G) > xeric shrubland on Dwyka sediments (XS) > xeric shrubland on dolerite (XSD) > karoo (K) (168, 164, 65, 34 & 26 t ha^{-1}, respectively); (ii) mean root C: T > G > XS = XSD (25.4, 11.4, 7.2 & 7.1 t ha^{-1}); (iii) mean above-ground C including leaf litter: T > XS > G > K > XSD (51.6, 12.9, 2.0, 1.7 & 1.5 t ha^{-1}). Carbon stocks in intact indigenous vegetation were related more to woodiness of vegetation and frequency of fire than to climate. Biomass C was greatest in woody thicket and soil C stocks were greatest in thicket and grassland. Total C storage of 245 t ha^{-1} in thicket is exceptionally high for a semi-arid region and is comparable with mesic forests. Soil C dominated ecosystem C storage in grassland and was influenced more by soil parent material than land use. The semi-arid sites (xeric shrubland and thicket) were more sensitive to effects of land use on C storage than the grassland site. Effects of land use on C stocks were site- and land use-specific and defied prediction in many instances. The results suggest that modelling of national C stocks would benefit from further research on the interactions between C storage, land use, and soil properties.

Keywords: carbon stocks; cultivation; pastoralism; pastures; plantations

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Introduction

Sequestering C in vegetation or soils could mitigate the problem of a rising atmospheric CO_2 concentration (Lal, 2001). Change in land use can potentially release or sequester soil and biomass C (Mendham, O'Connell & Grove, 2003). The distribution of C within a landscape, the influence of land use on C and the relationship between climate and C need to be considered when developing plans for C sequestration at a national level (Post & Kwon, 2000; Post *et al.*, 2001). Such information will assist decision makers in deciding where carbon sequestration efforts are best expended. In an earlier paper, Mills and Fey (2004) examined soil C and N at five study sites in South Africa. The following paper examines the influence of climate and land use on ecosystem C storage (i.e. in soils and biomass) at four of these sites and ascertains whether the effect of land use on C storage is predictable.

Six factors affecting the accumulation of C within an ecosystem were identified *a priori*. Firstly, C storage is positively related to water availability, which is a function of mean annual precipitation and temperature. Soil C tends to increase with an increase in mean annual precipitation (Dalal & Mayer, 1987; Hontoria, Rodriguez-Murillo & Saa, 1999) probably because primary productivity tends to be a function of rainfall (Knapp & Smith, 2001), and organic matter inputs into the soil will tend to be greater in mesic than arid regions. Secondly, C storage will increase with an increase in woody biomass. Thirdly, frequent fire will lead to a decrease in C storage in both biomass (Tilman *et al.*, 2000) and soils (Birch, 1958; Knapp, Conrad & Blair, 1998; Bird *et al.*, 2000). Fourthly, tillage will reduce C storage in biomass and soils (Tiessen, Salcedo & Sampaio, 1992; Gregorich *et al.*, 1994; Aslam, Choudhary & Saggar, 2000; Francis, Tabley & White, 2001). Fifth, the establishment or maintenance of a permanent cover of vegetation (e.g. pasture, thicket) will maintain or increase soil C (Dalal & Chan, 2001; Dominy & Haynes, 2002). The effect of pasture establishment on biomass C depends on the natural vegetation structure. Pastures may accumulate more biomass C than natural grassland if a dense grass sward is established, but will have less biomass C than woody systems. Sixth, any of the above effects will be dependent on inherent chemical and physical properties of the soil as well as changes to such properties (Oades, 1993; Zech *et al.*, 1997; Percival, Parfitt & Scott, 2000). The establishment of plantations in grassland, for example, may be expected to reduce soil water content, improve soil aeration and therefore reduce soil C storage (Birch, 1958; Jaiyeoba, 1998).

Based on these expectations, it was predicted that the effects of land use on C storage in grassland, xeric shrubland and thicket vegetation types in the study sites would be as follows: (i) goat pastoralism in thicket, which results in a loss of the dense matrix of shrubs (Lechmere-Oertel, 2004; Lechmere-Oertel, Kerley & Cowling, 2004a; Lechmere-Oertel, Kerley & Cowling, 2004b), would reduce soil and biomass C; (ii) cultivation of wheat in xeric shrubland would reduce soil C; (iii) establishment of annual leguminous pastures on old

Figure A.13.7: Mills et al., 2005b. Ecosystem carbon storage under different land uses in three semi-arid shrublands and a mesic grassland in South Africa. *South African Journal of Plant and Soil* 22(3):183-190.

Annex 14 R script for calculation of carbon sequestration

```
# Baseline for Degraded bare lands and degraded lands
setwd("C:/Documents and Settings/Jay/My
Documents/C4ES/Baviaanskloof/Calculations")
library(MASS)

########## Constants ###############################################

yn <- 70                    # crediting period (years)
T_B <- 1                    # time period between assessments (years)
Ver <- 5                    # time period between verification(years)
strata_num <- 3             # number of strata
strata_area<- c(10000,25530,33164)     # size of strata (ha)
percentage_restored <- 70 # percentage of total land restored
init_dia <-  3              # diameter of truncheon initially
final_C <- 49790            # Amount of carbon sequestered in
                            conversion from Non-forest to Forest (kg)
# Number of teams
Em_tot <-  300                          # total number of employees
Em_team <- 14                           # number of employees per
team

# Planting rate (ha yr-1)
Cont_mech_area <- 26        # size of mechanical planting area
Cont_man_area <- 7          # size of manual planting area
Cont_mech_yr <- 9           # number of mechanical contracts/year/team
Cont_man_yr <- 1            # number of manual contracts/year/team
Num_trees_ijk <- 2500       # number of trees planted per hectare

M_k <- 0.01                 # Average annual rate of natural mortality
                            for P. afra (estimate)
DC_k <-  0.8                # Decomposition factor for species k
                            (estimate) - decomposes fast
f_L <- 0.2043                # Average annual change in carbon stock
                             in litter (tC ha-1)[from field
                             measurements]
Rk <- 0.253                  # Root-shoot ratio for P. afra
                             (calculated from field measurements)
Cfrac_k <- 0.47              # Carbon fraction of P. afra (Used IPCC
                             default)

#SOC calculations
SOC_Non_Forest <- 59.125     # Average SOC for unforested/degraded
                             land (from literature review)
SOC_Ref <- 95.11             # Average SOC in intact/50yr reforested
                             land (from literature review)
f_ijk <- 1                   # Forest management function (all forest
                             managed the same, minimal impact)
T_Forest <- 50               # Time for transition from non-forest to
                             forest (years)
```

```
# Constants for project emissions
                          ########################################
C_degraded <- 5.658       # carbon stock of degraded field (t ha-1)
                          [from literature meta-analysis]
CE <- 0.5                                 # combustion efficiency (IPCC
                          default = 0.5)
GWP_CH4 <- 21             # global warming potential for CH4 (IPCC
                          default=21)
EF_CH4 <- 0.012           # emission factor for CH4 (IPCC default =
                          0.012)
CF_Ntree <-               # Carbon fraction of non-tree biomass

f_Burn <- 0.001           # fraction of landscape that burns
                          annually (ha ha-1) [Estimated]
Num_trees_ijk <- 2500     # number of trees planted per hectare
Plant_clear <- 0.1*0.1/10000          # area cleared per plant
                          [10cm x 10cm in ha)

# Base calculations
################################################

Teams <-  floor(Em_tot/Em_team)         # Number of teams

strata_area <- strata_area *            # actual areas given
restoration percentage
    (percentage_restored/100)

strata_sum<-0             # maximum planting area
for (i in 1:strata_num){
  strata_sum <- strata_sum + strata_area[i]
}

strata_ratio <- rep(0,strata_num)# ratio of plantings in each area
for (i in 1:strata_num){
  strata_ratio[i] <- strata_area[i]/strata_sum
}

Pl_rate_team <- (Cont_mech_area *       # Planting rate (ha/yr/team)
                 Cont_mech_yr) +
                 (Cont_man_area *
                 Cont_man_yr)
Pl_rate <- Pl_rate_team * Teams     # Total planting rate (ha/yr)
Pl_yrs <- floor(strata_sum/Pl_rate) # Years of planting (at max
rate)

f_Clear <- Num_trees_ijk *          # fraction of site cleared
        Plant_clear                 # for planting (ha ha-1)

# Growth equations
################################################

plant_C <- final_C/Num_trees_ijk        # C sequestered per plant
CBSA_final <- 10^((log10(plant_C)-      # CBSA of plants at peak
growth
```

```
         2.4464)/1.1043)

CBSA_start <- ((init_dia/200)^2)* pi   # Initial CBSA (msq.)

strata_CBSA <-c(CBSA_final,            # max CBSA by strata
         CBSA_final,       # by default, set to the same value
         CBSA_final)       # change if more data available

remainder <- strata_sum %%(Pl_yrs * Pl_rate)
quotient <- strata_sum - remainder
total_area <- c(seq(Pl_rate,quotient,Pl_rate),rep(strata_sum,yn-
Pl_yrs))

gr_line <- matrix(0,strata_num,yn)
# Growth curve replaced with a straight line:
for (i in 1:strata_num){
  increment_a <- (CBSA_final - CBSA_start)/(T_Forest-1)
  gr_line[i,] <- c(seq(CBSA_start, CBSA_final,
increment_a),rep(CBSA_final,yn-T_Forest))
}

# Equation AL.1 (allometric equation from Powell, 2009)
allometric <- function(CC.B){
       log10Cmass <- (1.1043 * log10(CC.B)) + 2.4464
       Cmass <- (10^log10Cmass)
     # convert mass to kg C
       return(Cmass)
}

 C_AB_t1 <- matrix(0,strata_num,yn)

# Tracking tools
ann_C <- rep(0,yn)
ann_AB <- rep(0,yn)
ann_BB <- rep(0,yn)
ann_DW <- rep(0,yn)
ann_L <- rep(0,yn)
ann_SOC <- rep(0,yn)
ann_deltaC <- rep(0,yn)
GHGe <- rep (0,yn)
for (y in 1:yn){ #,T_B
  subtotal <- 0;
  deltaC_ijk_t <- matrix(0,strata_num,y)
  GHGe_i <- rep (0,strata_num)
  # stratify by growing year
  for (i in 1:strata_num){
    #gr_curve_i <- gr_curve[i,]
  # growth curve for stratum i
    gr_curve_i <- gr_line[i,]
    # Using straight lines for growth rates
    Area_ijk <- Pl_rate * strata_ratio[i]                          #
default stratum area

    yearcount <- 0
```

```
    # Iterate for planting year (sub stratum)
    for (j in y:1){
      CBSA <- gr_curve_i[j]

      yearcount <- yearcount +1
  # change stratum area depending
      if (yearcount > Pl_yrs){
  #  on the sub stratum
        if (yearcount == (Pl_yrs+1) ) {
            Area_ijk <- strata_area[i]%%
            (Pl_yrs*Pl_rate *
            strata_ratio[i])
        }
        else
        {
            Area_ijk <- 0
        }
      }

      # Equation AL.1 (allometric equation from Powell, 2009)
      Allometric_k <- allometric(CBSA)/Cfrac_k
    # convert to kg biomass
      # Equation B.21
      C_AB_Tree_ijk <- Area_ijk * Num_trees_ijk *
                        Allometric_k * Cfrac_k * .001

      #Conservative estimate: shrub biomass does not increase
      C_AB_Ntree_ijk <- 0

      # Equation B.19
      C_AB_ijk <- (C_AB_Tree_ijk + C_AB_Ntree_ijk)

      # Equation B.18
      deltaC_AB <- (C_AB_ijk - C_AB_t1[i,j] )/T_B

      # NB: Since  C_AB_Ntree_ijk = 0:
      deltaC_AB_Tree <- deltaC_AB

      C_AB_t1[i,j] <- C_AB_ijk
    # make this the old carbon stock

# Below-ground
biomass################################################
      # No Equation quoted; from a2 Step 1.
      # NB: deltaC_AB_ijk = deltaC_AB_Tree
      deltaC_BB_Tree  <- deltaC_AB_Tree * Rk

      #Conservative estimate: shrub biomass does not increase
      deltaC_BB_Ntree <- 0

      # Equation B.30
      deltaC_BB <- deltaC_BB_Tree + deltaC_BB_Ntree
```

```
# Deadwood
############################################################
      # Equation B.34
      # NB: deltaC_AB_ijk = deltaC_AB_Tree
      deltaC_DW <-  deltaC_AB_Tree * M_k * (1-DC_k)

# Litter
############################################################
      # Estimated from literature
      if ((y-yearcount)<=T_Forest){
        deltaC_L <- Area_ijk * f_L
      }

# Soil Organic Carbon
################################################
      # Equation B.36
      SOC_Forest <- SOC_Ref * f_ijk

      # Equation B.35 (modified to ensure that crediting
      # stops 50 years after planting)
      if ((y-yearcount)<=T_Forest){
        deltaC_SOC <- ((SOC_Forest - SOC_Non_Forest) *
                                                  Area_ijk) /
T_Forest
      }

# TOTAL CARBON STOCK CHANGE
########################################
      # Equation B.17
      deltaC_ijk_t[i,j] <- (deltaC_AB + deltaC_BB +
                            deltaC_DW + deltaC_L +
                            deltaC_SOC) *(44/12)

# TRACKING##########
  ann_L[y] <- ann_L[y] + (deltaC_L * (44/12))
      ann_AB[y] <- ann_AB[y] + (deltaC_AB * (44/12))
      ann_BB[y] <- ann_BB[y] + (deltaC_BB * (44/12))
      ann_DW[y] <- ann_DW[y] + (deltaC_DW * (44/12))
      ann_SOC[y] <- ann_SOC[y] + (deltaC_SOC * (44/12))
      ann_deltaC[y] <- ann_deltaC[y] + deltaC_ijk_t[i,j]
    }

##### EMISSIONS
############################################################
    Area_Cleared <- 0
    if (y < Pl_yrs)
    {
      Area_Cleared <- (Pl_rate * strata_ratio[i]) * f_Clear
    }
    if (y == Pl_yrs)
    {
      Area_Cleared <- (remainder * strata_ratio[i]) * f_Clear
    }
```

```
# b.1 Emissions from the decline in the carbon stock of non-tree
vegetation
     # Area lost to site preparation
     # Equation B.39
     # E_Cleared <- Area_Cleared * Bio_NTree * CF_Ntree *44/12
     # BUT field measures of carbon stock of degraded land was
assessed
     # so the term [Bio_NTree * CF_Ntree] is replaced with field-
measured
     # carbon stock [C_degraded]:
     E_Cleared <- Area_Cleared * C_degraded *44/12

# b.2. Greenhouse gas emissions from biomass burn
     Area_Burn <- (total_area[y] * strata_ratio[i]) * f_Burn

# Carbon dioxide emissions from biomass burn
     # Equation B.40
     # E_Burn_CO2 <- Area_Burn * Bio_NTree * CF_Ntree * CE *44/12
     # BUT field measures of carbon stock of degraded land was
assessed
     # so the term [Bio_NTree * CF_Ntree] is replaced with field-
measured
     # carbon stock [C_degraded]:
     E_Burn_CO2 <- Area_Burn * C_degraded  * CE *44/12

# Methane emissions from biomass burn
     # Equation B.41
     E_Burn_CH4 <- E_Burn_CO2 * GWP_CH4 * EF_CH4 * (12/44) * (16/12)

     # Equation B.38
     GHGe_i[i] <- E_Burn_CH4 + E_Burn_CO2 + E_Cleared
     # TRACKING ###################################
     GHGe[y] <- GHGe[y] + GHGe_i[i]
   }

# Sum all strata for the year
# Equation B.43
# This equation as written in the methodology is incorrect.
Currently it
# subtracts GHG emissions per stratum from each change in carbon
stock for
# stratum, substratum and species (ie: it is equivalent to:
# sum for i( change in carbon stock - ( n(j) * n(k) * GHGe) )
# Revised equation:
#ann_C[y] <- sum for i (sum for j,k(deltaC_ijk_t) - GHGe[i])

   sum_i <- function (d, g) {
     sumi <- 0
     for (i in 1:length(g)){
       sumi <- sumi + sum(d[i,]) - g[i]
     }
     return(sumi)
   }
   ann_C[y] <- sum_i(deltaC_ijk_t, GHGe_i)
```

```
}

cumulative <- rep(0,yn)
for (i in 1:yn) {
  if (i ==1){
    cumulative[i] <- ann_C[i] #deltaC_Actual[i]
  }
  else
  {
  cumulative[i] <- cumulative[i-1] + ann_C[i] # deltaC_Actual[i]
  }
}
```

Annex 15 Aerial imagery of planting sites in the project areas (separate annex)