synopsis REPORT

SOUTH AFRICAN NATIONAL TERRESTRIAL CARBON SINK ASSESSMENT

environmental affairs

Department:
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Research Synopsis Report prepared by Cirrus Group Consortium

MAY 2015

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Foreword

Global change through land use and cover change, climate change and the increase in atmospheric carbon dioxide has modified the structure and function of many ecosystems throughout the world. Such changes across the globe have over the years altered the relationship between the natural sources and sinks of carbon dioxide. Similarly, in South Africa, land use change and land degradation as a result of conversion to croplands, urban areas, mines and roads has modified the original geographical extent of vegetation biomes. However, the impact and the magnitude of these changes are not well understood, prompting the current research.

The National Terrestrial Carbon Sinks Assessment (NTCSA) is a first of its kind for South Africa and was commissioned following a directive from the National Climate Change Response Policy (NCCRP). Given this, the aim was to assess the national carbon sinks in relation to afforestation, forest restoration, wetlands, agricultural practices and urban greening. Furthermore, to assess all significant land use change and quantify the potential future carbon stocks under varying climate change and land use scenarios. Taken together, these variables will assist in the understanding of emissions generated from land use and in identifying land based mitigation opportunities.

Although the independent research and findings contained in this report do not necessarily represent the views, opinions and/or position of Government, the department believes that this research is critical to enhance our understanding of the global change dynamics in South Africa's Agriculture, Forestry and Other Land Use (AFOLU) sector. Hence, the department is happy to make this work publicly available and accessible.

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Contents

Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
$[CO_2]$	Atmospheric carbon dioxide concentration
CSIR	Council for Scientific and Industrial Research
CGCM	Coupled Global Change Model
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DFID	Department for International Development
DRDLR	Department of Rural Development and Land Reform
EPWP	Expanded Public Works Programme
GHG	Greenhouse Gas
ha	Hectare
MRV	Monitoring, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NCCRP	National Climate Change Response White Paper
NGO	Non-Governmental Organization
REDD	Reduced emissions from deforestation and forest degradation (through planning and regulation)
REDD+	Reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
SIP	Strategic Infrastructure Project
tC	ton of carbon
tCO_2e	Ton of carbon dioxide equivalent
UNFCCC	United Nations Framework Convention on Climate Change
UNREDD	United Nations program aimed at REDD
VCS	Verified Carbon Standard

Rationale and approach

The South African National Carbon Sink Assessment provided an unprecedented opportunity to explore the nature of terrestrial carbon stocks and fluxes at a national scale and to evaluate all climate change mitigation opportunities within the land-use (AFOLU) sector. Work had previously been done on carbon stocks and fluxes, in particular biomes, as well as climate change mitigation activities at a project scale in certain locations, however a comprehensive analysis at a national scale had been lacking and certainly needed.

This need was clearly noted in the National Climate Change Response Policy which calls for an assessment of "… the current national carbon sinks related to afforestation, forest restoration, wetlands, agricultural practice, bio-fuels, urban greening and all significant changes in land use and to quantify the potential future carbon sinks under varying climate change scenarios and land use change."

To address this need, the Department of Environmental Affairs (DEA) commissioned the "South African National Carbon Sink Assessment" with the purpose of addressing a broad set of related objectives. In response, the Cirrus Group in partnership with the CSIR, GeoTerraImage and Beatus, proposed a three-phase process that encompassed the extensive multi-disciplinary scope of the required analysis (Fig. 1).

The intention of Section 1 was to provide an understanding of the scope and nature of terrestrial carbon stocks and fluxes across the country and how they may change over time. The Ecosystem Processes and Dynamics Group within the CSIR developed an innovative continuous variable approach to map the national distribution of carbon stocks at a resolution of 1 km^2. This continual surface approach is a significant improvement on previous traditional stratification methods in that it provides a far better understanding and measure of the variability in carbon stocks across landscapes and the entire country. Furthermore, due to the output being in the form of a 'wall to wall' map, it allows stakeholders (e.g. a District Municipality or Government Program), to easily extract a map of carbon stocks and fluxes for their particular area of interest.

Thereafter, two analyses were undertaken to assess how terrestrial carbon stocks and land-cover may change over time. The Cirrus Group modeled the effect of predicted changes in climate and atmospheric carbon dioxide on carbon stocks and accumulation rates in predominant South African vegetation types. This was accompanied by an assessment by Geo Terra Image of how land-use across South Africa changed in the period 2000-2010 and how land-use is likely to change over the next 10 year period. The outcomes of Section 1, not only provided a biophysical template on which to develop Sections 2 and 3, but a far better quantification of terrestrial carbon stocks that is useful to many other applications (e.g. required reporting of national GHG emissions to the UNFCCC).

Section 2 assessed the type and nature of land-use based climate change mitigation opportunities within the country. As per the Terms of Reference, a broad of land-use based mitigation activities was adopted as defined in the UNFCCC paper on Agriculture (2008) and in IPCC AR4 (2007). These definitions include biogas and biomass-to-energy opportunities in addition to activities that increase or maintain terrestrial carbon stocks (e.g. reforestation, reduced tillage and reducing deforestation). The explicit intention of the analysis was to move from – "*the general*" to the "*specific*", in terms of size and location of activities, potential implementing agencies, the structure of costs, employment opportunities, required institutional support, incentive mechanisms, and monitoring and reporting requirements.

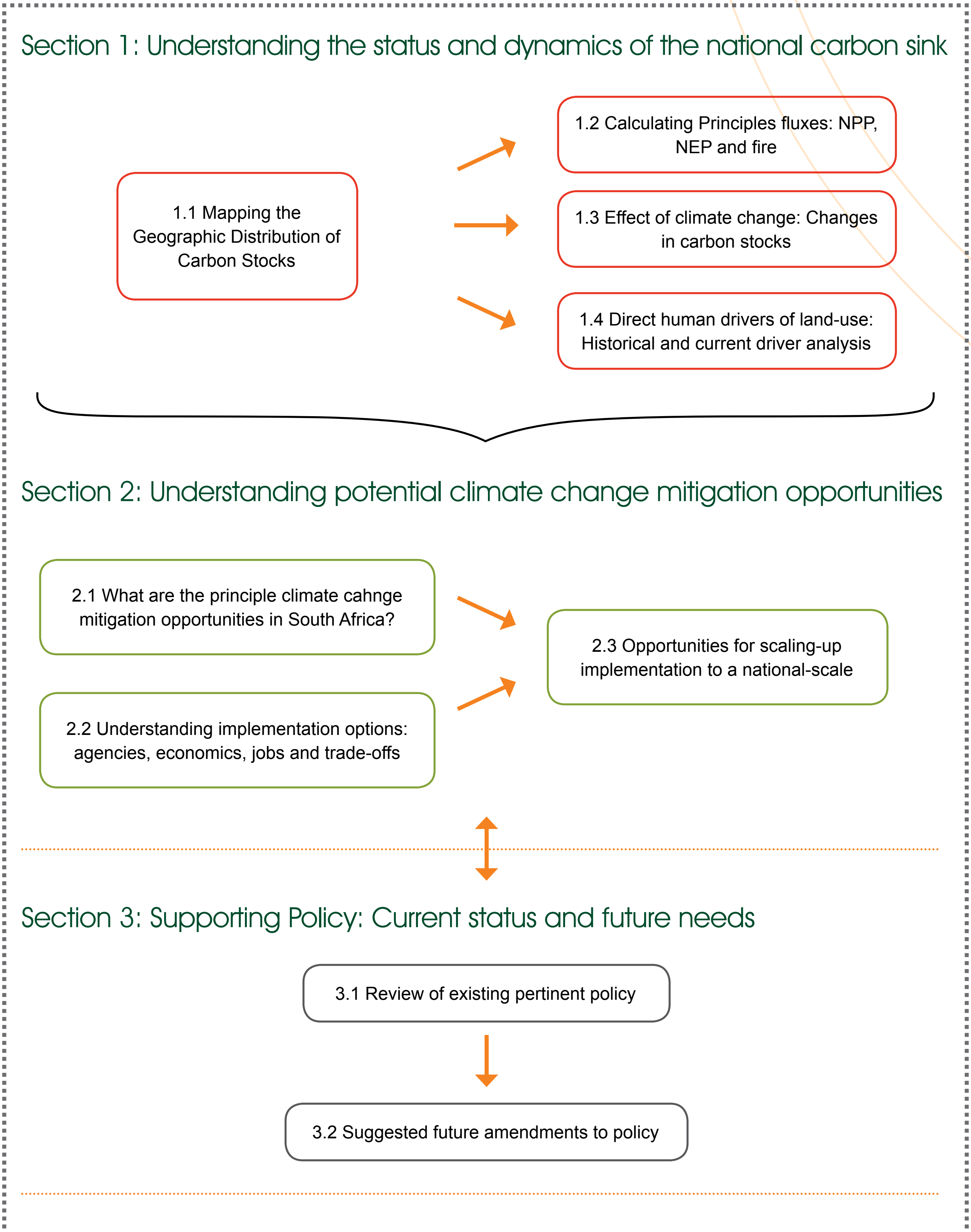


***Figure 1.** A flow diagram illustrating the different sections and elements of the National Carbon Sink Assessment*

Eight potential climate change mitigation activities were identified through a substantial stakeholder engagement process undertaken by members of the Cirrus Group, Beatus and the DEA. The process, that included meetings with entities located in Government, academia and private sectors, was used to understand the specific nature of climate change mitigation activities within the land-use sector, to learn from the substantial experience that has already been gained over the past 10 years (why have some worked and others have failed?), and to assess what is required to scale up existing successful interventions to their full potential within the country.

Section 3 focused on the relationship between policy and terrestrial carbon stocks and the associated climate change mitigation opportunities. An initial review was made of 109 existing policies that are pertinent to the land-use sector with the goal of understanding which key policies may have an effect on terrestrial carbon stocks or associated GHG emissions. The initial review was followed by an analysis of potential future amendments to policy that would lead to the maintenance of existing carbon stocks and encourage the climate change mitigation activities identified in Section 2.

Overall, the intention of the assessment was to shift our level of understanding of the sector from relatively unknown, to a good knowledge of the magnitude and nature of terrestrial carbon stocks, associated implementation options and pertinent policy. As such, this assessment provides a strong foundation on which to develop further programs and implementation options. These next steps are explored further below.

Methodology in brief

(*An introductory explanation of the analytical approach to each section follows below. For a more detailed description, please see the full report for each section*).

Section 1.1 and 1.2 – First estimate of terrestrial carbon stocks and fluxes

Approach

A continuous-variable, 'wall-to-wall' approach to mapping the stocks and fluxes in South Africa has been adopted for this study, rather than a more conventional stratified-random sampling approach. A stratified-random approach would proceed by first classifying the land area of South Africa into different vegetation- or land-use types (stratification), and then estimating of the average carbon stock in each, based on a large number of randomly-located field samples. Our approach uses geostatistical methods, models and remote sensing to extrapolate a large set (several thousand) of unevenly-distributed set field measurements to the whole country. From those continuous coverages, the mean stocks and fluxes for any area can be calculated, along with an uncertainty estimate. The reasons for this choice of approach were:

- South Africa is so large and ecologically diverse that using a stratified sampling approach would require a minimum of 20 strata. Based on the observed variability within strata, the number of samples needed to constrain the uncertainty to reasonable levels would be about 100. The cost and time required to undertake new, random sampling of about 2000 sites would be excessive.
- Existing data is too sparse and non-randomly distributed to adequately fulfill the needs of a stratification method. For instance, some land types have no existing data.
- Recent advances in remote sensing and geostatistics make it possible to estimate aboveground woody biomass stocks (i.e., trees and shrubs) for many thousands of locations, systematically distributed over large areas, at required levels of accuracy but at low cost. Similarly, new extrapolation approaches to soil profile data, and models of herbaceous and litter biomass, allow robust but inexpensive estimates over large areas.
- The emergence of these new approaches means that a continuous variable approach is both more feasible and more accurate, for a given cost, than a stratified approach.

Technical procedure

The national carbon stock consists of a set of linked and interacting sub-stocks (called 'pools') which change over time: slowly in the case of soil carbon, moderately quickly in the case of woody biomass, and rapidly in the case of herbaceous and litter carbon. The carbon flows between the pools, and between the land and the atmosphere, land and ocean, and land and human systems are called fluxes (Figure 2).

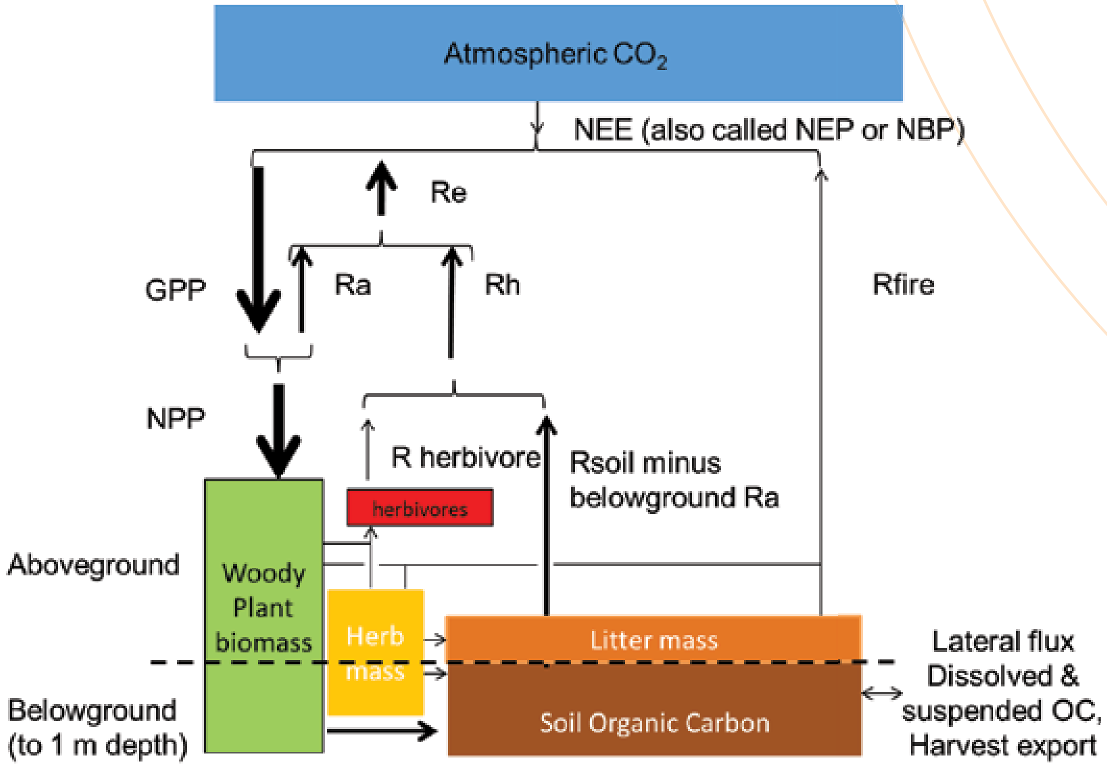


Figure 2. *Components of a generalized terrestrial carbon cycle: The size of the boxes and the arrows, which represent stocks and fluxes respectively, is only roughly indicative of their relative size. The herbivore stock is relatively small (<10^{12}gC nationally), and neither it nor the corresponding herbivory flux is directly evaluated in this study. Terminology: NEE – Net Ecosystem Exchange, NEP – Net Ecosystem Productivity, NBP – Net Biome Productivity, GPP – Gross Primary Production, NPP – Net Primary Production, Ra – autotrophic respiration (respiration by plants) , Rh – heterotrophic respiration (herbivores, carnivores and microbes), Re – ecosystem respiration (the combined respiration from all sources), Rfire – fire emissions.*

The size of each major carbon pool was estimated for every 1000 x 1000 m pixel across the range of different land-use and vegetation types in South Africa, and then summed to estimate the total carbon stock in the country (TEOC – total ecosystem organic carbon). The above-ground woody plant biomass was estimated using remotely-sensed tree height (from ICESAT-GLAS) and canopy cover (MODIS). The corresponding belowground biomass was estimated using published root:shoot ratios, scaled by environment. Above-ground herbaceous and litter biomass was calculated using published relationships between rainfall and annual grass and litter production and expanded to belowground herbaceous biomass using published root:shoot ratios. Soil organic carbon to 1 m depth, corrected for soil bulk density variation, was from the recently-released AfSIS Africa Soil Property map, based on over 3000 soil profiles in South Africa and a further 6000 elsewhere in Africa and a Bayesian statistical extrapolation technique taking into consideration the many factors relevant to soil carbon formation. The location and area of converted land-use types (cultivated lands, plantation forests and urban areas) were obtained from 30 m resolution land cover maps more recent than 2005. Soil and biomass stocks within the converted classes were calculated from forestry and agriculture sector databases, usually at municipal scale resolution.

The magnitude of the main fluxes from unconverted ('natural') systems, which dominate the South African landscape, were estimated using ecosystem-specific carbon cycle models, driven by 10-daily satellite observations of surface greenness (MERIS FAPAR) over the period 2001 to 2010 and constrained by monthly climate data. The fluxes in cultivated and plantation areas are estimated from crop and forest production data respectively, and the lateral fluxes in and out of the national territory from trade statistics and measurement-based models.

Section 1.3 – Modeling the effect of predicted climate change and elevated atmospheric CO_2 on terrestrial carbon stocks

The analysis aimed to answer two principle questions:

1. The need to understand the potential effect of projected climate change and elevated atmospheric carbon dioxide ([CO_2]) on terrestrial carbon stocks in important South African biomes
2. The need to understand the potential effect of projected climate change and elevated [CO_2] on the outcome of land-use based climate change mitigation activities located in South Africa

These elements were included in the National Carbon Sink Assessment due to a growing body of evidence that indicates that changes in climate and [CO_2] may lead to substantial changes in the rate of plant growth, litter decay rates and other ecological variables that determine observed above- and below- ground carbon stocks (Bond and Midgley 2000, Doherty et al. 2010, Kgope et al. 2010). In the context of the project, assessing this potential is important to first understand how the terrestrial carbon stocks and fluxes reported in Section 1.1 may change in the future, and second, to understand how the outcome of land-based climate change mitigation activities identified in Section 2 may be influenced by changes in climate and elevated [CO_2].

Due to pure time and cost practicalities, a modeling approach is typically used to assess the potential influence of changes in climate and elevated [CO_2] on carbon dynamics in terrestrial ecosystems. The Century Ecosystem Program was adopted for this analysis, as it has been successfully used in numerous past studies to model carbon, nitrogen and phosphorus dynamics. Guided by the results of Section 1 and 2 of the National Carbon Sink Assessment, the modeling exercise focused on vegetation types that are important in terms of their contribution to the national carbon stock and opportunities for mitigation activities - grassland, savanna, woodland, sub-tropical thicket and forest ecosystems (Table 1).

Table 1. *The principle set of input variables used to calibrate the Century Model for each location.*

Vegetation type	Location	Geog. co-ords decimal degrees		Elevation	Mean Annual Rainfall	Above-ground carbon stock
		South	East	meters	mm	tC.ha-1
Coastal Lowland Forest	eThekwini	29.825	31.016	74	800	75
Coastal Scarp Forest	eThekwini	29.804	30.337	380	800	65
Sub-tropical thicket	Baviaanskloof	33.639	24.455	450	413	41
Savanna - Combretum	Skukuza	24.992	31.598	264	572	9.5
Woodland - Mopane	Letaba	23.854	31.576	234	506	11.5
Dry grassland	Bloemfontein	29.100	26.950	1350	560	0.3
Moist temperate grassland	Cathedral Peak	28.927	29.127	2565	1324	2.3

Two principle scenarios were modeled:

- The effect of climate change and elevated [CO_2] on existing carbon stocks in each vegetation type
- And, the effect of climate change and elevated [CO_2] on the rate of carbon sequestration during the restoration of degraded ecosystems.

The first scenario will allow one to understand the potential impact of climate change on the national terrestrial carbon stock and activities that reduce emissions from deforestation and forest degradation (REDD). The second will provide an estimate of the influence of climate change on afforestation, reforestation and grassland management activities as well as the rate of biomass accumulation in the context of Biomass to Energy initiatives.

The projections of six coupled global circulation models (CGCMs) were used to estimate the potential effect of future climate change on each of the modelled vegetation types (Table 2). The six CGCMs contributed to the Coupled Model Intercomparison Project (CMIP3) and Assessment Report 4 (AR4) of the Intergovernmental Panel on Climate Change (IPCC). All six simulations are for the A2 scenario as described in the Special Report on Emission Scenarios (SRES, Nakicenovic et al. 2000) over the period 1961-2100. The data was obtained from the CSIR's Climate Studies and Modelling and Environmental Health Research Group that downscaled the CGCMs using a conformal-cubic atmospheric model (CCAM).

Table 2. *Coupled Global Change Models used to simulate the effect of projected climate change on terrestrial carbon stocks and associated sequestration rates.*

CGCM	Source
CSIRO Mark 3.5.	Ver 3.5. Commonwealth Scientific and Industrial Research Organisation
GFDL-CM2.0	Ver. 2.0 Geophysical Fluid Dynamics Laboratory, NOAA, United States
GFDL-CM2.1	Ver. 2.1 Geophysical Fluid Dynamics Laboratory, NOAA, United States
ECHAM/MPI-Ocean Model	Max Plank Institut, Germany
MIRO3.2-medres	Japanese Agency for Marine-Earth Science and Technology

Section 1.4 – Modeling of '2020' future South African land-cover

This analysis, together with other elements of Section 1, forms the required template from which to develop the implementation and policy aspects of the assessment. The Terms of Reference for the project initially required the service provider to assess both an analysis of historical, as well as potential future changes in land-use (i.e. from 2000 through to 2020). Fortunately, GTI was already in the process of undertaking an analysis of current land-cover and historic changes in land-use at a national scale on behalf of the DEA, which was completed in April 2013. This analysis therefore focuses only on a potential '2020' future South African land-cover landscape.

The 2020 SA Land-Cover Dataset

The modelled '2020' land-cover dataset is not strictly linked to that specific year, but is rather an interpretation of a likely scenario in approximately 10 – 15 years time. The future changes are based on potential landscape changes arising from either planned or highly likely land-use changes, associated developments, and resultant land-cover changes, linked (if possible) to current or proposed legislation. Geographical restrictions on land-cover and land-use changes have been included within the modelling process by using current and potentially protected, conserved and environmentally sensitive areas likely to be safeguarded from change through an EIA or similar legislated processes.

The data product is based on the same ± 500 x 500m raster cell framework used in the 2010 base land-cover dataset and contains the same 17 x land-cover classes. As per the 2010 dataset, only the dominant (modelled) land-cover (or land-use) class is shown in each pixel, although in reality it can be expected that a significantly greater range of cover classes will occur within each pixel extent. For this reason therefore, the reported areas of each land-cover cannot be seen as exact measurements, but rather as comparative modelled areas, which approximate to real-world land-cover area statistics.

Due to the modelling processes and data inputs used, it should be clearly understood and communicated to all end-users that the 2020 land-cover product, as with the 2001, 2005 and 2010 land-cover products, has been developed *specifically* in support of the DEA carbon stock reporting information needs and should *not* be considered a new national land-cover dataset for wider application without full knowledge and understanding of the manner and processes by which it has been generated.

The "2020" land-cover modelling is based on readily accessible reference information and spatial data, obtained from a wide range of sources, which in GTI's view encapsulate all major drivers and restrictors of landscape change that are generically applicable at the scale and detail contained in the land-cover dataset. Full disclosure of the data sources, data inputs, data modelling and final model outputs are provided in the Section 1.4 report to provide transparency on the overall methodology, in support of further modifications and improvements to this initial output.

Section 2 – Understanding potential climate change mitigation opportunities

Section 2, aimed at assessing the size and nature of climate change mitigation opportunities, had five objectives:

- To identify the principal land-use based climate change mitigation opportunities in South Africa
- To understand the nature of implementation in terms of required capacity and the institutional and financial context of potential implementing agents
- To better understand the magnitude and structure of implementation costs
- To understand the co-benefits and trade-offs and co-benefits implementation, particularly employment opportunities and the effect of implementation on ecosystem services
- To identify clear roadblocks to implementation that could be addressed by Government in the near term

The set of objectives stems from needs identified in the *National Climate Change Response White Paper*, particularly the identification of climate change mitigation activities that increase the size of the national terrestrial carbon sink and deliver sustainable benefits as captured in section six of the National Climate Change Response Policy (NCCRP).

The approach to the analysis

The study was designed to move beyond a broad general overview of implementation options, to a specific consideration of the magnitude and nature of all land-use based mitigation activities in South Africa. The rationale for this approach is driven by Government's mandate to implement appropriate mitigation activities, at scale, across the country. The first step towards meeting this mandate is an explicit exploration of each potential land-use based mitigation activity (beyond only afforestation and REDD+), including careful consideration of the nature of implementation – the context of implementing agents, required management, field and monitoring capacity, required institutional support, payment and incentive mechanisms, necessary supporting policy, and implication of different implementation models on job creation, permanence and sustainability over the long-term.

The concept of land-use based climate change mitigation is certainly not new in South Africa. Several parties located in the public and private sectors have extensive experience in implementing climate change mitigation and adaptation options. Moreover, substantial expertise exists in the development of related ecosystem service and ecological infrastructure activities. In addition to populating the analysis with data from published datasets, publications and established models, the team attempted to leverage the rich body of established expertise and experience in South Africa through a number of structure interviews with leading parties.

Eighteen interviews, typically lasting 3-4 hours, were held with the individuals listed in Table 3 below. Individuals were primarily chosen based on robust experience in implementing or designing climate change mitigation in South Africa. In addition to prominent field practitioners, members of Treasury and the national monitoring, reporting and verification (MRV) group where interviewed to better understand how to align suggested implementation measures and structures with existing Government programs.

The Cirrus Group, Beatus and Mr. Barney Kgope and Mr. Itchell Guiney of the Department of Environmental Affairs conducted the interviews. Where in-person meetings were not feasible, interviews were conducted telephonically.

Table 3. A list of interviewed stakeholders

Participant	Entity	Location
National Government		
Peter Lukey	Department of Environmental Affairs	Pretoria
Sebataolo Rahlao, Oscar Mokotedi	Department of Environmental Affairs	Pretoria
Peter Janoska	National Treasury	Pretoria
Guy Midgley, Mandy Barnett, Mandy Driver and Jeff Manual	SANBI	Cape Town
Field practitioners (in Government, private and NGO sectors)		
Mike Powell	Subtropical Thicket Restoration Research Group at Rhodes University	Grahamstown
Bruce Taplin	SANParks	Addo National Park
Sarshen Scorgie	Conservation South Africa	Cape Town
Andrew Venter, Andrew Whitley and the Wildlands team	Wildlands Conservation Trust	Hilton
Ian Rushworth and Steve McKean	KZN Wildlife	Howick
Marilyn Govender	South African Sugar Association	Pietermartizburg
David Everard, Nico Hattingh, and Dutliff Smith	SAPPI	Pietermartizburg
Alan Manson and Cobus Botha	CEDARA	Hilton
Riaz Jogiat	uMgungundlovu District Municipality	Pietermartizburg
Christo Marais and Ahmed Khan	Expanded Public Works Program	Cape Town
Errol Douwes, Sean O'Donoghue	eThekwini Municipality	eThekwini

Section 3 – Supporting policy: current status and future needs

Two analyses formed the third section of the National Carbon Sink Assessment:

1. A review of existing policy – the NCCRP noted that an audit and gap analysis of various sector policies must be undertaken to identify areas of weakness and to establish a firm foundation from which the development of policy responses can be designed. The review was guided by the White Paper as well as the outcomes of Section 1 and 2.
2. Suggested future amendments to policy – this component focused on two broad objectives, (i) addressing the gaps and issues identified in the initial review, and (ii) creating an enabling environment for the eight climate change mitigation opportunities identified in Section 2 of the National Carbon Sink Assessment.

A transparent, qualitative, framework approach was adopted to review 112 policies. This approach provided a structured process through which a substantial amount of primary data could be consolidated and analyzed in an orderly manner. Each considered policy was systematically catalogued using a set of predefined categories – the full catalogue is attached to the primary report in spreadsheet format. Table 4 below describes the thirteen categories by which the policies were assessed.

The transparent, structured nature of the process provides the DEA with a means of tracing findings back to each policy listed in the catalogue. In addition, it allows researchers to consider a substantial number of documents in a systematic manner. The broader set of over 100 policies provides a more robust foundation for the analysis and will be a particularly useful reference to members of DEA that may focus on particular areas of land-use based climate change mitigation at a later date.

Following the review of the 122 policy documents, the Top 30 policies were identified as having the most influential impacts on carbon stocks and GHG emissions in the AFOLU sector.

Policy support for each climate change mitigation activity was reviewed in three phases:

- An assessment of whether a mandate for undertaking the activity exists within the Top 30 policies identified in the initial policy review or other relevant policies as deemed appropriate.
- A review of particular barriers that may currently impede the national-scale rollout of the activity
- The development of suggested changes to policy that would strengthen the mandate for each activity.

Table 4. Categories against which each policy was assessed in the catalog

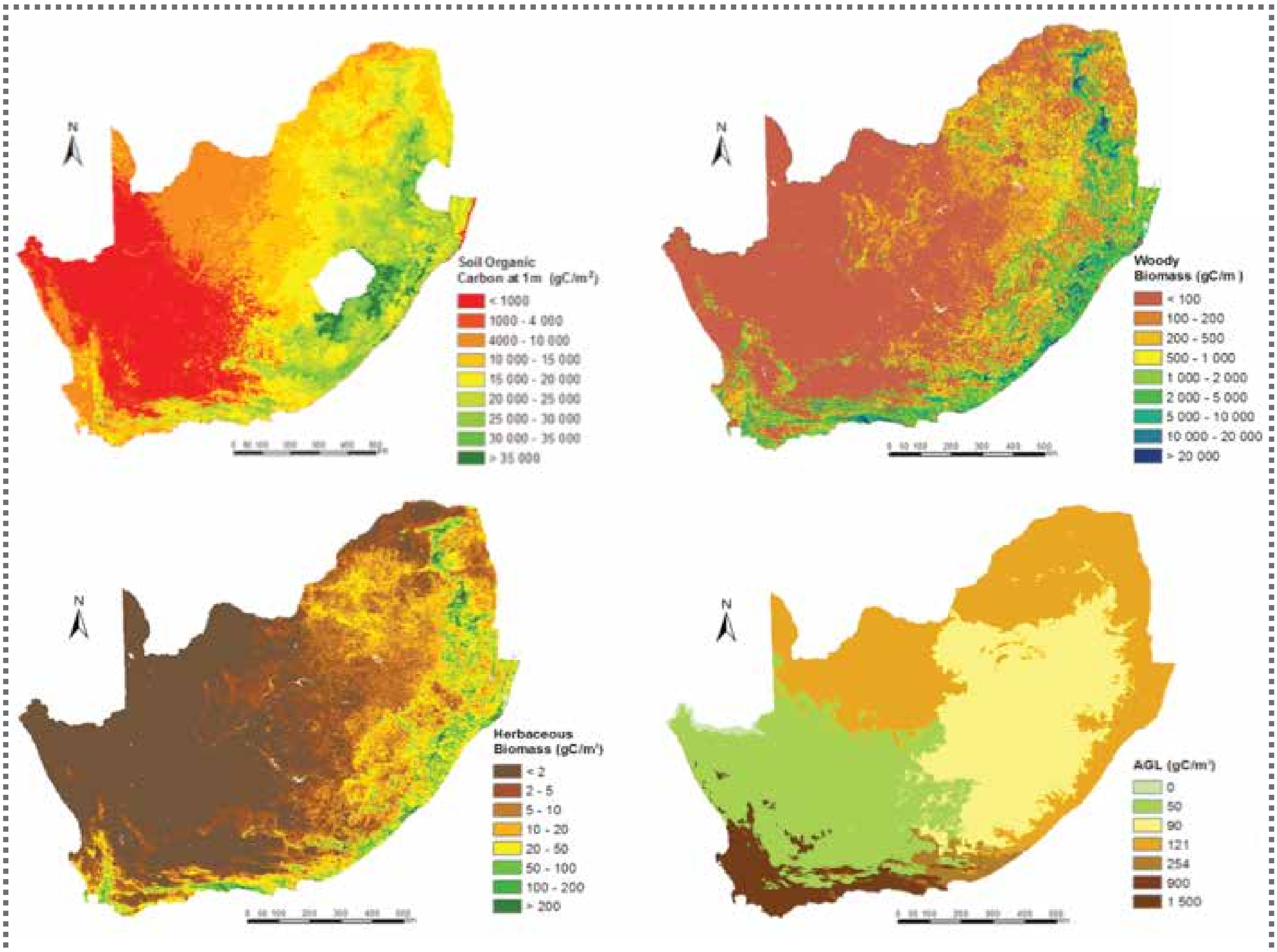
Category	Details
Principle AFOLU sector influenced by the policy	Based on the nature of carbon stocks and GHG emission in each land-use type, the AFOLU sector was divided into a) Coastal, berg and scarp forests b) grasslands c) woodlands / savanna / thicket d) mosaic small scale farming e) commercial crop agriculture f) plantation forestry g) commercial livestock agriculture, and h) urban / peri-urban development. First, the potential influence of a policy on carbon stocks and GHG emissions in each of these land-use types was noted, followed by a broad, general indication of the influence: P (for preservation of the existing area covered by the land-use type), C (for conversion to an alternative land-use type) or E (for expansion of the land-use type).
Land-Use Activity	Potential land-use activities promoted by the policy are noted. These range from woodland conservation to ploughing, and fire management.
Policy type	The policy type describes broad policy categories: Acts, Regulations, Strategic Plans, Frameworks, and so forth
Purpose of the document	Many policies, notably Acts, explicitly state their purpose. This was either quoted directly, or a summary of the purpose provided in instances when it was less clearly presented.
Key dependencies	Policies may depend on the delivery of future regulations, frameworks, or plans to be effectively realized. Their success may rely on the cooperation of particular departments, the establishment of committees or forums, or the delivery of new research. This category seeks to contextualize each policy, demonstrating the ways in which policies may rely on further interventions to be fully realized.
Direct emissions	Practically no policy made provision for an accurate calculation of the GHG emissions or removals. Instead, this is a descriptive review of the types of emissions and removals that could be expected if the policy was implemented. The potential types of GHG emissions or removals as well as the activities that would lead to them are described.
Indirect emissions	Most policies, if implemented, will result in “leakage” or unintended, indirect emissions. This might be for example, the displacement of fuel wood collection sites from one area to another following the institution of new conservation practices. This category will allow the DEA to consider the full range of potential emissions and reductions associated with a given policy.
Direct effect	The primary intention(s) of the document that impact on terrestrial carbon stocks is discussed. This includes a summary of the types of activities and interventions proposed by the policy. It covers “what can be expected” if the policy is implemented.
Indirect consequences	The indirect consequences of a policy are reviewed, detailing the potential unexpected or unplanned outcomes that may stem from policy implementation. As it is not feasible to assess every potential outcome of a policy, this provides a broad view of the potential indirect effects of policy adoption.
Reference to climate change	This provides insight into the extent to which a given policy clearly refers to “climate change”.
Reference to GHG emissions	Here, it is noted if the document makes clear reference to GHG emissions and associated reductions.
Are there clear policy targets?	The provision of clear targets, notably in departmental strategic plans, helps to assess the potential impact of a policy; it is also a sound indication of the amount of planning that may accompany certain commitments. In many instances, Act and Regulations will not be accompanied by targets; this category is more relevant to strategic plans that seek to align with Acts, Regulations and White Papers, and to assess the extent to which adequate planning has been undertaken.
Description of the potential magnitude of the impact on carbon stocks and GHG emissions	The magnitude of a policy is a broad categorization of its potential impact on terrestrial carbon stocks and fluxes. The magnitude is assigned a certain qualitative designation: limited, moderate, substantial, or a range of these (moderate to substantial, for example). The category focused on the magnitude of the impact is discussed in more depth in Module 8 of the primary report.

Key results in brief

Section 1.1 and 1.2 – First estimate of terrestrial carbon stocks and fluxes

Terrestrial Carbon Stocks in South Africa

The main determinants of terrestrial carbon stocks are plant-available moisture, temperature, soil conditions and vegetation cover. Soil, woody-plant and herbaceous biomass carbon stocks increase from the arid areas in the western part of the country, to the moister eastern seaboard of South Africa. Carbon stocks in the Karoo and desert biomes are very low, while the highest carbon stocks per hectare are found in the coastal and montane forests. The spatial extent of these forests (and plantation forests) is small compared to the extensive grassland and savanna biomes, which have intermediate per-hectare carbon stocks, and thus dominate the national stock accounts (Map 1, Tables 5 and 6). The grassland biome contains many planted trees, which add to their carbon stocks. Carbon stocks in the fynbos are quite low, due to frequent fires. Stocks in intact thickets are quite high, given the dry environments in which they occur in the southern and eastern Cape, but their spatial extent is small.



***Map 1.** The components of the terrestrial carbon stock of South Africa. Top left: soil organic carbon to 1m in depth. Top right: the above- and below-ground woody-plant biomass pool Lower left: above- and below-ground herbaceous biomass pool. Lower right: above-ground litter*

The biomass estimates have been validated against a database of over three hundred plots nationally, collected completely independently of this study. Overall they are in fair agreement. It is not possible to say which is 'right', since both contain uncertainty. The soil carbon estimates have been independently validated against a database of nearly 200 very detailed soil carbon studies in three biomes: savannas, grasslands and thicket, and found to be in fair agreement. Croplands are mostly in former grasslands. Their soil carbon in the top 30 cm is approximately halved as a result, while the crop biomass is similar to the original grass biomass.

Table 5. Terrestrial total ecosystem carbon stocks in South Africa by land cover class. SD stands for standard deviation, which is a measure of the spatial variability of the stock. A continuous, total coverage approach as applied in this project has no sampling error, only an estimation error due to uncertainties in the models used. This estimation error is reflected as a lower (10%) and upper (90%) confidence limit in the totals for the entire class, on the right hand side of the table. These limits have been calculated using a rigorous error accumulation approach. Note that stratified sampling approaches also contain estimation errors of the same magnitude (in addition to sampling errors), but these are almost never accounted for.

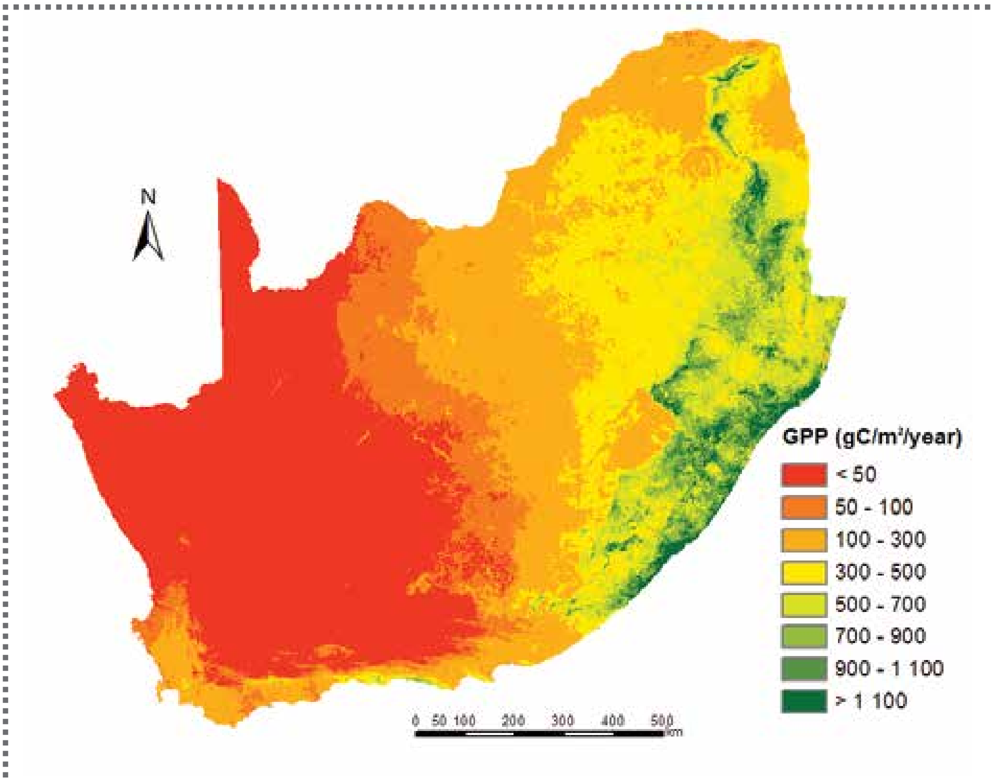
Land cover class	Mean	SD (spatial)	Area	Best estimate	Lower confidence limit	Upper confidence limit
	gC/m²		km²	Tg C		
Savanna	5 834	3 513	358 473	2 091	1 961	5 214
Grassland	10 660	4 725	224 377	2 392	2 213	5 736
Nama and succulent karoo	1 769	1 799	334 812	593	587	862
Fynbos	6 773	4 100	61 490	416	372	1 140
Thicket	10 101	5 347	27 402	277	236	785
Indigenous forest	18 198	6 172	857	16	12	42
Desert	799	113	7 017	6	6	6
Cultivated	5 980	1 731	143 948	860	840	1 788
Plantation forestry	17 559	4 320	16 952	298	252	769
Settlement, mines, industry	6 793	2 448	23 119	157	152	276
Other, waterbodies etc	3 167	1 536	19 967	64	62	97
Total South Africa			**1 218 414**	**7 170**	**6 693**	**16 715**

Table 6. Soil organic carbon stocks in South Africa to a depth of 1 m, by land cover class. Soil organic carbon is the largest part of the ecosystem stock in all South African ecosystems, and the most stable. The AfSIS data extrapolation procedure did not extend into the driest, hottest third of the country, which have relatively low carbon stocks. We assumed a total soil carbon content to 1 m of 700 g/m² for these areas. The notes regarding the measures of spatial variability (standard deviation, SD) and estimation uncertainty (lower and higher confidence limits) apply to this table as well.

Land cover class	Mean	SD (spatial)	Area	Best estimate	Lower confidence limit	Upper confidence limit
	gC/m²		km²	Tg C		
Savanna	5 422	3 078	358 473	1 943	1 779	7 138
Grassland	10 149	4 427	224 377	2 277	2 008	7 671
Nama and succulent karoo	1 700	1 744	334 812	569	339	1 872
Fynbos	5 658	3 854	61 490	348	305	1 301
Thicket	7 737	3 298	27 402	212	189	772
Indigenous forest	11 057	3 497	857	9	8	30
Desert	833	112	7 017	6	1	12
Cultivated	5 785	1 704	143 948	835	774	2 547
Plantation forestry	12 961	3 553	16 952	220	193	663
Settlement, mines, industry	6 375	2 379	23 119	148	136	414
Other, waterbodies etc	2 819	1 375	19 967	57	50	135
Total South Africa			**1 218 414**	**6 624**	**5 781**	**22 555**

Terrestrial Ecosystem Carbon Fluxes in South Africa

In the undisturbed 'equilibrium' state, Gross Primary Production approximately equals ecosystem respiration (Reco + Fire) over the long-term and at large scales. Simply put - for all the additional carbon that is accumulated in biomass through plant growth each year, an equal amount is released back into the atmosphere through respiration and fire. Although South Africa is not 'undisturbed' and the global carbon cycle is currently not at equilibrium, the balance between production and respiration remains quite close to zero. For instance, regional atmospheric CO_2 inversion analyses, completely independent of this study, suggest that the net southern African flux is small to zero. With rising atmospheric CO_2 and a changing climate, the *global* terrestrial land surface is currently a sink of about 1 PgC/y (Pg = Petagram or 10^{15} grams). A small part of this sink is probably in South Africa, due to processes such as bush encroachment. It would be somewhat less than the South Africa fraction of the global land area (1%) because South Africa is both more arid and hotter than the global average. A rough estimate would be 1-10 TgC/y (Tg – Teragrams or 10^{12} grams), which translates to around 1-10 gC/m^2/y. This would be very hard to detect over a short accumulation period, but should be detectable of a period of decades.



Map 2. *Distribution of Gross Primary Productivity (GPP) in terrestrial ecosystems in South Africa. GPP is the carbon which is taken out of the atmosphere into plant biomass through the process of photosynthesis. About half of this returns to the atmosphere within hours to months through respiration by the plant. What remains is Net Primary Production (NPP), which is the basis of production-based ecosystem services such as timber and crop yield, firewood and grazing. NPP is not equivalent to carbon storage, since most of the NPP is also ultimately respired, burned or exported. NPP does establish an upper limit to the short-term carbon sequestration rate in carbon storage projects. It is clear from this map that the potential for such projects is greatest in the wetter parts of the country, where they also come into conflict with land needs for agriculture, settlement and water provision.*

Implications of this study for policy and implementation

This assessment is the first to generate a map of terrestrial carbon stocks and fluxes at national scale, with fine resolution. It results in a better understanding of how carbon stocks and fluxes vary across the country, and thus which particular biomes or areas are most and least important in terms of developing land-use based Greenhouse Gas (GHG) emission reduction activities. For example, whereas the forest biome has significant carbon stocks per hectare, due to its limited spatial extent, the total carbon stock located in forests is amongst the lowest when comparing vegetation classes (Table 5). In comparison, the grassland and savanna biomes together contain approximately three-quarters of South Africa's terrestrial carbon stock and account for over 90% of Gross Primary Production occurring within the country (Table 7). If land-use based climate change mitigation activities are to be created that contribute significantly to the national greenhouse gas budget, the emphasis should therefore be on developing implementation models that work within these biomes. Projects in smaller, but nevertheless high-stock potential and high-sequestration rate vegetation types, such as forests and thickets, may be viable at project scale, but can only make a limited national contribution. The potential in the arid biomes for projects that are both viable and nationally meaningful is very small.

The bulk of carbon is stored in the soil, which currently does not count towards many carbon storage projects. Woody biomass is the next largest store. The stores in herbaceous biomass and litter are too small, and too ephemeral, to matter very much. The lateral fluxes such as forestry and agricultural exports, carbon in rivers and smoke from fires are small relative to the gross vertical fluxes and the national anthropogenic inventory, but these are however significant relative to the net natural fluxes and would need to be considered.

The annual flux in and out of natural ecosystems, at about 1100 $TgCO_2$/y, is over twice the emissions from South Africa from anthropogenic sources. Only about one hundredth of this is the 'net ecosystem production' retained in ecosystems as a carbon store. This will be very hard to measure and prove at national scale on a year-by-year basis, but may be detectable on a decadal basis.

Table 7. *Gross Primary Production (GPP) of terrestrial natural ecosystems in South Africa. GPP is the carbon taken up by the vegetated surface from the atmosphere. It is about twice the Net Primary Production, which is what is retained as biomass growth after the plant has respired part of the uptake to support its own metabolism. Estimation error calculations are in progress. Validation of these fluxes using direct measurement is only possible for a few sites in the country. They are consistent with global-scale model-based estimates.*

Land cover class	Mean	SD spatial	Area	Best estimate	Lower confidence limit	Upper confidence limit
	gC/m²/y		km²		TgC/y	
Savanna	415	320	358473	149	54	351
Grassland	645	304	224377	145	72	361
Karoo	44	46	334812	15	5	34
Fynbos	142	134	61490	9	2	19
Thicket	381	264	27402	10	2	23
Desert	977	281	857	1	0	2
Forests	1	0	7017	0	0	0
Total, natural ecosystems			**1014428**	**329**	**135**	**790**

Further application of the results and the underlying model

National greenhouse gas inventories are periodically required from South Africa as a party to the UN Framework Convention on Climate Change (UNFCCC). One category of emissions (or uptakes) is from the Agriculture, Forestry and Other Land Use (AFOLU) sector. The AFOLU sector estimates thus far have had the highest uncertainty associated with them, partly because there was no reliable map of the distribution of soil or biomass carbon in the country, with the fine resolution required to calculate the impacts of land use change. This project satisfies that need.

In addition, the models have been set up in a VisTrails environment (an open-source software for organizing complex calculations). The models can therefore be readily updated as improved algorithms or datasets become available. This may be especially useful to Government for future national reporting. Starting from 2016, South Africa is expected to submit a national communication to the UNFCCC once every 4 years. The developed models and associated base datasets provide a valuable tool that can be readily updated.

Further to reporting on GHG emissions at a national scale, several stakeholders within provisional and local government noted that for planning and governance purposes, they have been seeking access to basic land-use, vegetation type and biomass and terrestrial carbon maps for their derestriction for some time. In a similar manner, project developers within Government and the private sector noted that such map would greatly assist the planning and development of land-use based climate change mitigation activities. Access to the basic product in a manner where users can extract (cookie-cut) their particular area of interest, may therefore open the deliverable to a broad scope of uses beyond national GHG emission accounting.

Section 1.3 – The effect of predicted climate change and elevated CO_2 on terrestrial carbon stocks

The results of the modelling exercise indicate that the impact of projected climate change and elevated [CO_2] is likely to vary between vegetation types and locations, both in terms of the direction and the magnitude of the effect. Whereas both carbon stocks and sequestration rates are likely to increase in the modelled woodland, savanna and grasslands ecosystems, the change in coastal lowland and scarp forest is anticipated to be neutral to negative in direction (Fig. 3). A 30 year period was principally modeled as this is the typical project period adopted for land-use based climate change mitigation activities as well as time-frame often used by Government and commercial entities for land-use planning activities. *The full report also reports the effect over 20 years and we encourage interested readers to access the initial document.*

An important observation is the range of outcomes predicted by different CGCMs in particular locations (Fig 3). For example, the modelled percentage change in aboveground carbon stocks in coastal lowland forest systems ranges from -1 to -4 percent (depending on the particular CGCM used), whereas the results for Combretum savanna site range from 9 to 40 percent. This range of responses is both due to the particular CGCM modelled as well as factors governing, and especially limiting, plant growth and litter and nutrient turnover in particular locations. The changes in carbon stocks and sequestration rates observed in Fig 3 are broadly related to the changes in minimum and maximum temperature and especially rainfall predicted by each CGCM. However, the response is also substantially influenced by limiting constraints to plant growth in certain systems. For example, plant available moisture may be a clear constraint to carbon sequestration in dry woodland and savanna ecosystems. In this context, an increase in rainfall leads to a clear increase in biomass accumulation. Yet in other ecosystems, for example coastal lowland and scarp forest, a similar change in rainfall leads to a negligible change in carbon stocks. In these ecosystems, plant growth may be more limited by soil nutrient availability rather than climatic factors.

Elevated atmospheric CO_2 alone (modelled with a continuation of historical climate) is predicted to lead to a positive change in carbon sequestration rates ranging from 1-8 percent, depending on the particular vegetation type modelled (Fig 3). The effect of [CO_2] on standing carbon stocks is less consistent. In certain systems, for example, coastal lowland forest, the effect may be negligible to marginally negative (<1%). However, for most of the ecosystems modelled, elevated [CO_2] is anticipated to lead to a 2-10% increase in aboveground carbon stocks over period of 20-30 years.

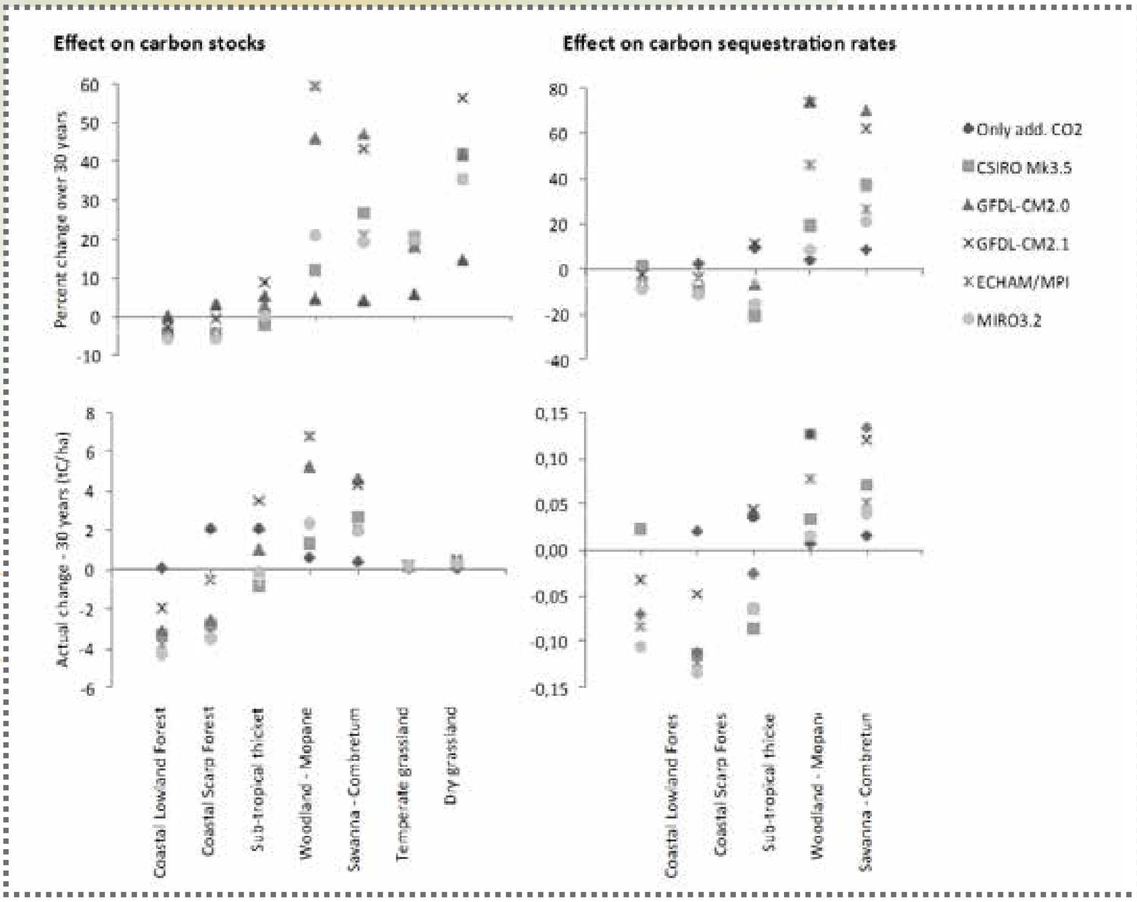


__Figure 3.__ The modeled effect of predicted climate change and elevated [CO_2] on aboveground carbon stocks and carbon sequestration rates (during restoration or reforestation activities) over the next 30 years.

Relative compared to actual changes

The relative changes in carbon stocks and sequestration rates reported in Figure 3 should also be viewed in terms of the actual change in carbon stocks and sequestration rates. This is especially true when seeking to understand the impact of climate change on the outcome of land-use based mitigation activities and magnitude of the national terrestrial carbon stock. For example, although the relative change in carbon stocks in grassland systems is predicted to be considerable (up to 40%), the actual change equates to less than 0.2tC.ha^{-1} over 30 years. In comparison, a similar relative change in woodland and savanna systems results in an increase of 3-5tC.ha^{-1} over the same period.

This is particularly pertinent when considering predicted changes in carbon sequestration rates. Although the relative change is considerable (over 40% in woodland and savanna systems), the actual change equates to an increase of less than 0.1tC.ha^{-1}.yr^{-1}.

Section 1.4 – Modeling of '2020' future South African land-cover

Overall, the comparison of all modelled land-cover results show an expected general increase in the area of transformed land-cover classes (i.e. mines, settlements, plantations, and cultivation), and a comparable loss in natural / semi-natural vegetation types between 2001 and 2020. The rate and extent of change however varies significantly with cover type (Figure 4 & 5).

During the period 2001 – 2010 the expansion of all cultivated lands, especially semi-commercial subsistence-level activity and sugarcane represent the main drivers of landscape change in terms of percent change in area. Furthermore, there is a substantial increase in the area of 'bare ground' on private, communal and Government land. The increase in 'bare ground' may be both due to the degradation of indigenous vegetation classes (forests, thickets, savannas and grasslands) as well as short-term decreases in primary productivity in rangelands.

During the modelled period from 2010 – 2020, this pattern changes with both sugarcane and subsistence cultivation decreasing in spatial extent, while commercial agriculture continues to expand (note that this excludes pivot irrigated cultivation since this was not a modelled class for 2020 as it was impossible to predict where an individual farmer would place new structures). Mines, settlements and plantation areas all show potential expansion with a corresponding decrease in indigenous thicket, savannas and grasslands.

The greatest potential percentage area losses in natural vegetation are associated with thickets and indigenous forest, mainly as a result of the cell-based modelled agricultural expansion in the Eastern Cape and the creation of new dams.

Potential terrestrial carbon stock and flux implications

To fully understand the impact of historical and predicted future land-cover changes on the size of the national terrestrial carbon stock and associated fluxes, the GIS surfaces generated in this analysis need to be integrated into a spatially explicit carbon stock and flux model (for example, the model created by the CSIR in Section 1.1 and 1.2 of the Assessment). Such a model would allow the carbon stock and flux implications of changes in land-use to be assessed in detail and would provide valuable data for Government planning and UNFCCC reporting purposes.

In the interim, it is reasonable to assume that the observed historical change in land-use (the general conversion of indigenous landscapes into built environments and commercial and subsistence agriculture) has led to a net decrease in the size of the national terrestrial carbon stock. As indigenous ecosystems are cleared and ploughed (in the case of cultivation), the carbon sequestered in above-ground biomass and soils is released into the atmosphere.

The predicted expansion of exotic plantations over the next 10 years may lead to an increase in woody carbon stocks in particular forestry areas, but overall, the size of the national terrestrial carbon stock is expected to decrease in size due to the anticipated expansion of settlements, mines and areas under commercial cultivation.

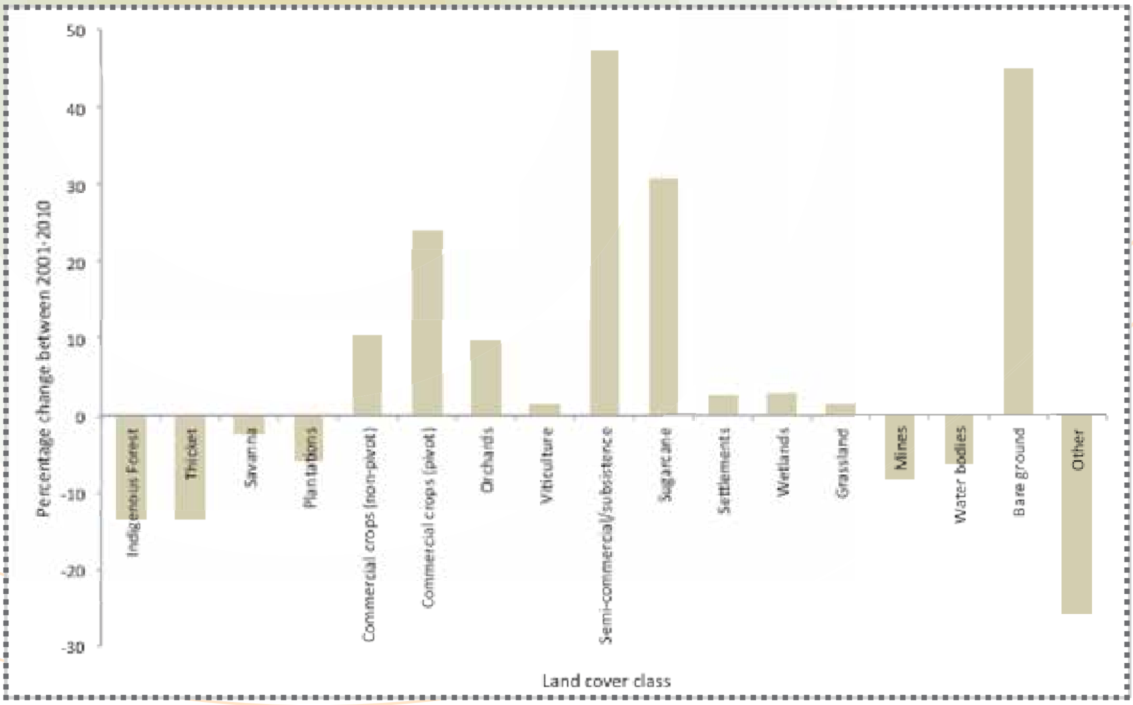


Figure 4. *Percentage change in each land-cover class between 2001 and 2010*

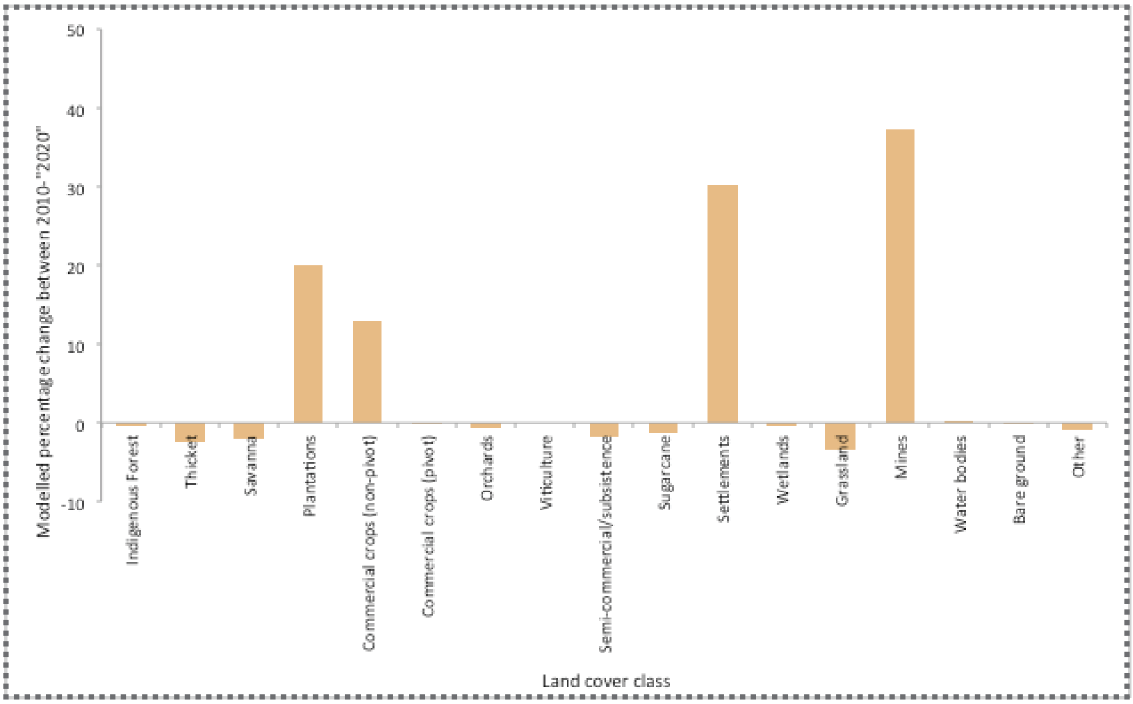


Figure 5. *Modelled percentage change in each land-cover class between 2010 and "2020"*

Section 2 – What are the principle land-use based opportunities in South Africa?

The type and magnitude of climate change mitigation opportunities

Eight prominent land-use based climate change mitigation activities were identified (Table 8, Fig. 6). These include both activities that increase and sustain the size of the national terrestrial carbon stock (reducing tillage, applying biochar, and the restoration and management of grasslands, subtropical thicket, woodlands and forests) as well as activities that lead to a net decrease in GHG emissions (biomass to energy and anaerobic biogas digesters). *Each is described in brief in Appendix A.*

Two estimations of each activity's contribution to reducing atmospheric GHGs are provided. The first "minimum" estimate is a robust, conservative estimate of the potential scope of the activity. However, certain stakeholders thought that these estimates may be too low and therefore an additional 20% has been added to this initial estimate in separate column to provide a range for planning purposes.

A total mitigation potential of between 14,1 and 16,9 million tCO_2e can be expected from the activities combined. Biogas has the largest potential (considering farm manure only, i.e. excluding household biogas digesters), followed by sub-tropical thicket and forest restoration, and then the restoration and management of grassland systems. In addition, the generation of energy through the combustion of bagasse and wood sourced from invasive alien species can also form a significant contribution. The activities' contribution in both absolute and relative terms is indicated in Figure 6.

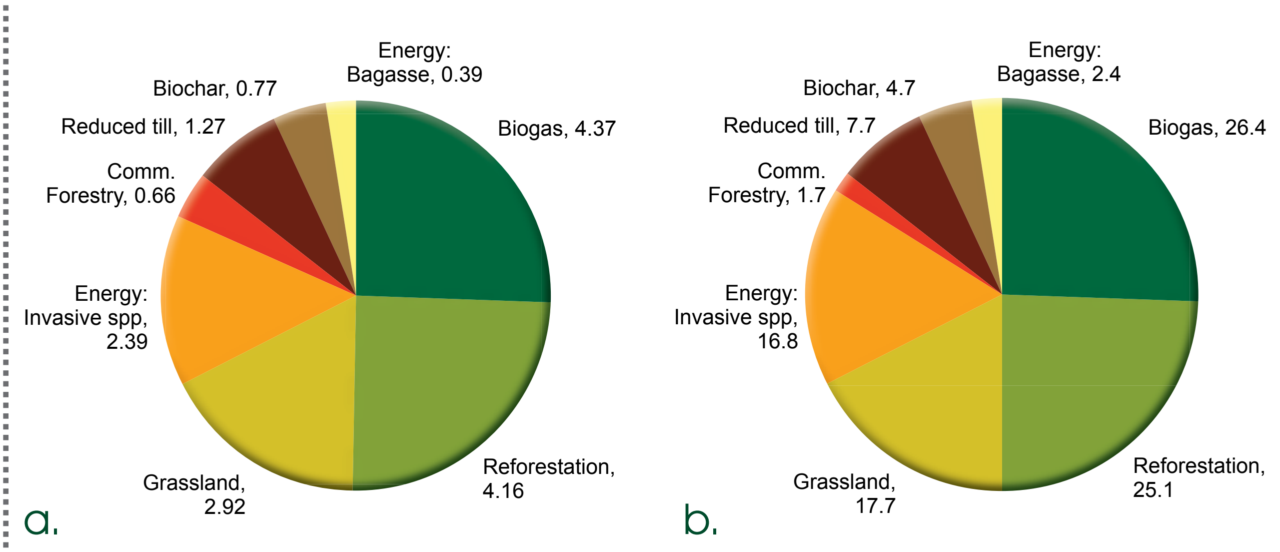


Figure 6. *Individual contribution of the various terrestrial activities towards carbon sequestration and mitigation in (a) million tonnes of CO_2e and (b) in percentage contribution*

Table 8. Contribution of terrestrial carbon sequestration and mitigation activities

Activity	Sub-class	Spatial extent (ha)1	Reduction per unit area per yr (tC)	Emission reduction per yr (tCO2e) (min)	Emission reduction per yr (tCO2e) (+20%)	Reduction in emissions over 20yr (tCO2e) (min)	Percent contribution %
Restoration of sub-tropical thicket, forests and woodlands	Sub-tropical thicket[2]	500 000	1,2	2 200 000	2 640 000	44 000 000	25,1
	Coastal and scarp forests[3]	8 570	1,8	56 562	67 874	1 131 240	
	Broadleaf woodland[4]	300 000	1,1	1 210 000	1 452 000	24 200 000	
Restoration and management of grasslands	Restoration - Erosion Mesic[5,6]	270 000	0,7	693 000	831 600	13 860 000	17,7
	Restoration - Erosion Dry[7]	320 000	0,5	586 667	704 000	11 733 333	
	Restoration - Grasslands Mesic[8]	600 000	0,5	1 100 000	1 320 000	22 000 000	
	Avoided degradation mesic[9]	15 000	1,0	55 000	66 000	1 100 000	
Commercial small-grower afforestation	Eastern Cape[10]	60 000	1,5	330 000	396 000	2 750 000	1,7
	KwaZulu-Natal[11]	40 000	1,5	220 000	264 000	1 833 333	
Biomass energy (IAPs & bush encroachment)	Country-wide[12]			1 990 316	2 388 379	39 806 316	14,4
Biomass energy (bagasse)	Country-wide[13]			328 955	394 746	6 579 099	2,4
Anaerobic biogas digesters	Country-wide[14]			3 642 408	4 370 890	72 848 160	26,4
Biochar*****	Country-wide[15]	700 000	0,3	641 667	770 000	12 833 333	4,7
Reduced tillage******	Country-wide[16]	2 878 960	0,1	1 055 619	1 266 742	21 112 373	7,7
Reducing deforestation and degradation	Through planning[17]						
	Through regulation[17]						
Total				**14 110 193**	**16 932 231**	**275 787 189**	**100,0**

Notes and references associated with the table above:

1. The spatial extent estimate should be viewed as a conservative estimate based on existing publications and expert opinion. A dedicated assessment of the potential spatial extent of each activity is still required that should not only assesses the ecological potential but economic constraints and social acceptance as well.
2. **Spatial extent:** Powell pers comm (based on Lloyd *et al.* 2002). Range depending on land-owner participation; **Reduction per unit area per year (tC):** Mills and Cowling 2004 (Great Fish River Reserve site) Ramp-up or roll-out period: 10 years
3. **Spatial extent:** Conservative est. of 10% of total forest area; **Reduction per unit area per year (tC):** Glenday 2007; Ramp-up or roll-out period: 10 years
4. **Spatial extent:** Conservative est. of 10% of savanna area, 10% of which is assumed to be degraded; **Reduction per unit area per year (tC)** Glenday 2007 and Knowles 2011; Ramp-up or roll-out period: 10 years
5. The national-scale assessment of gully erosion undertaken by Mararakanye and Le Roux (2011) provides an initial (conservative) estimate of degraded bare land that could be restored. It is reasonable to assume that the majority of soil carbon pool has been lost through the degradation process. In addition, the assessment is useful for identifying the location of 'degradation hotspots' across the country. It is however not a comprehensive assessment of grassland degradation. This analysis remains to be done.
6. **Spatial extent:** Mararakanye and Le Roux 2011; **Reduction per unit area per year (tC):** Watson *et al.* 2000, Conant and Paustian, 2002; Ramp-up or roll-out period: 15 years
7. **Spatial extent:** Mararakanye and Le Roux 2011; **Reduction per unit area per year (tC):** Watson *et al.* 2000, Conant and Paustian, 2002; Ramp-up or roll-out period: 15 years
8. **Spatial extent:** The mesic grasslands occupy a total extent of about 6 000 000 ha. It is conservatively estimated that 10% of this area is degraded; **Reduction per unit area per year (tC)** Watson *et al.* 2000, Conant and Paustian, 2002, Ramp-up or roll-out period: 15 years
9. **Spatial extent:** Conservatively, 5% of the mesic grasslands is at risk of degradation over the next two decades; **Reduction per unit area per year (tC)** Inferred from Knowles *et al.* 2008 (average over 20 yrs) Ramp-up or roll-out period: 15 years
10. **Spatial extent:** SAPPI pers comm (2013); **Reduction per unit area per year (tC):** SA Forestry Annual Statistics (E. grandis pulp on 8 yr cycle, 50t dry matter at end of cycle), Ramp-up or roll-out period: 5 years
11. **Spatial extent:** SAPPI pers comm (2013); **Reduction per unit area per year (tC):** SA Forestry Annual Statistics (E. grandis pulp on 8 yr cycle, 50t dry matter at end of cycle), Ramp-up or roll-out period: 5 years
12. Potential: Blignaut (2009); Emission reduction based on: Load factor = 75%; Emission factor = 85% of Eskom grid factor; Ramp-up or roll-out period: 20 years. It should be noted that at least three estimates of the potential of invasive alien plants and bush encroachment exist, all with different assumptions and constructed for different purposes. In this study we used the mid-estimate of Blignaut (2009). The estimates are:

IRP2010(rev2)				Blignaut et al. (2008)				Blignaut (2009)			
MW	MWh	tCO_2/MWh	tCO_2	MW	MWh	tCO_2/MWh	tCO_2	MW	MWh	tCO_2/MWh	tCO_2
25	164 250	0.8415	138 216	720	4 730 400	0.8415	3 980 632	360	2 365 200	0.8415	1 990 316

13. Potential: IRP2010(rev2); Emission reduction based on: Load factor = 85%; Emission factor = 85% of Eskom grid factor Ramp-up or implementation period: 20 years
14. Potential: 75% of the potential estimated in Blignaut (2009), supported by a conservative estimate by Burton et al. (2009); Emission reduction based on: Load factor = 75%; Emission factor = 70% of Eskom grid factor; Ramp-up or implementation period: 20 years
15. **Spatial extent:** The cultivated area is 14,394,800 ha and penetration rate is assumed to be 5%. **Reduction per unit area per year** 0.25 tC/y for 20 years.; Ramp-up or implementation period: 10 years
16. **Spatial extent:** Adoption is assumed to be 20% of the potential cultivated area. **Reduction per unit area per year** 0.1tC.$ha^{-1}.yr^{-1}$ following the adoption of no-tillage practices based on study by Farage et al. (2007). Ramp-up or roll-out: 10 years
17. Although numerous stakeholders noted this opportunity, the spatial extent thereof is currently unknown. Please see a discussion focused on this activity in Chapter 3 of this report.

Section 3 – Supporting policy: current status and future needs

The full report provides a detailed analysis of over 100 policies that may affect each sub-sector of the greater AFOLU domain. Here, we highlight 30 pertinent policies that are assumed to be most likely to effect terrestrial carbon stocks, and land-use based climate change mitigation activities in future. Interested readers are encouraged to review the full report and associated catalogue as each contains a substantial amount of pertinent information, including an analysis of gaps, trade-offs and so forth.

30 Key Policies that may have a substantial impact on terrestrial carbon stocks

The realization of the 30 policies listed in the table below may either lead to a significant increase or decrease in terrestrial carbon stocks or fluxes. They are noted to have a "significant" effect on a per hectare or farm scale – few policies will substantially change the total size of the national terrestrial carbon stock reported in Section 1.

Table 9. *30 Key Policies that may have a substantial impact on terrestrial carbon stocks and fluxes*

Policy Type	Policy
White Papers	• White Paper on Disaster Management
	• National Climate Change Response White Paper
Acts	• Conservation of Agricultural Resources Act, 1983
	• National Forests Act, 1998
	• National Environmental Management Act, 1998
	• National Environmental Management: Protected Areas Act, 2003
	• National Environmental Management: Air Quality Act, 2004
	• National Environmental Management: Biodiversity Act, 2004
Regulations	• National Environmental Management: EIA Regulations
	• National Environmental Management: Environmental Management Framework Regulations
Bills	• Spatial Planning and Land-Use Management Bill
Strategies, Plans and Frameworks	• National Development Plan
	• Medium Term Strategic Framework
	• New Growth Path
	• Strategic Plan for Smallholder Producers
	• The Strategic Plan for South African Agriculture
	• Strategic Plan 2012/13-2016/17 for the Dept. of Agriculture, Forestry and Fisheries
	• Integrated Growth and Development Plan: Agriculture, Forestry and Fisheries
	• National Strategy for Sustainable Development and Action Plan (NSSD1) - 2011 -2014
	• Strategic Plan for Environment Sector: 2009 - 2014
	• National Biodiversity Framework
	• National Air Quality Management Framework
	• National Protected Areas Expansion Strategy for South Africa 2008
	• Integrated Resource Plan
	• Industrial Policy Action Plan: 2012/2013 - 2014/15
	• Dept. of Rural Dev. and Land Reform, Strategic Plan 2011-2014 (amended 2013)
	• Carbon Tax Policy Paper
	• National Disaster Management Framework
	• A Woodland Strategy Framework for the Dept. of Water Affairs and Forestry 10
Other	• Guidelines Regarding the Determination of Bioregions and the Preparation of and Publication of Bioregional Plans

Broadly, these policies fit into several categories:

- **Policies focused on environmental management:** Acts and Regulations originating from the NEMA cluster, or related Acts that aim to reduce negative impacts on ecosystems, such as the *National Forests Act* and the *Conservation of Agricultural Resources Act*. These are complemented by the *Disaster Management* family of policies – the *White Paper, Act* and *Framework* – which provide for undertaking prevention and mitigation actions for single disaster events or longer-term trends that could lead to a disaster.
- **Presidential policies focused on economic growth:** These include the NDP, NGP and MTSF, supported by IPAP – that promote infrastructure development, expansion of the built environment and that view agriculture as a key means to reducing poverty.
- **Departmental strategic plans:** Those from DAFF, which tend to align with mandates from Presidential policies, but that make references to the adoption of improved agricultural techniques, restoration or afforestation. In general, DAFF's plans propose agricultural expansion, notably at the smallholder level.
- **Planning policies:** These policies are focused on providing planning guidelines for land-use change, namely through the use of mapping, land functionality, spatial equity, sustainability and other considerations. This suite of policies is required to mediate between competing land-use objectives.
- **Outlier documents:** These include documents such as the *Strategic Plan for the Environmental Sector* or the *National Sustainable Development Strategy* that originate from the office of the Minister of Water and Environmental Affairs. These policies are intended to impact a broad range of sectors and activities through streamlining sustainability and environmental management.

Several broad observations can be made about this set of policies. The first is that there is a strong legislative framework favoring the sustainable long-term management of ecological infrastructure, ecosystem services and biodiversity. The legal precedent is strong, rooted in Acts and Regulations.

However, policies that promote rapid job growth in the agricultural sector and support significant infrastructure build appear to have been more widely adopted in current departmental and ministerial strategies, particularly that of DRDL and DAFF. These two departments have considerable influence on the land-use sector, and their alignment with *rapid* agricultural expansion could lead to the conversion of grassland and savanna ecosystems, leading to a net increase in GHG emissions.

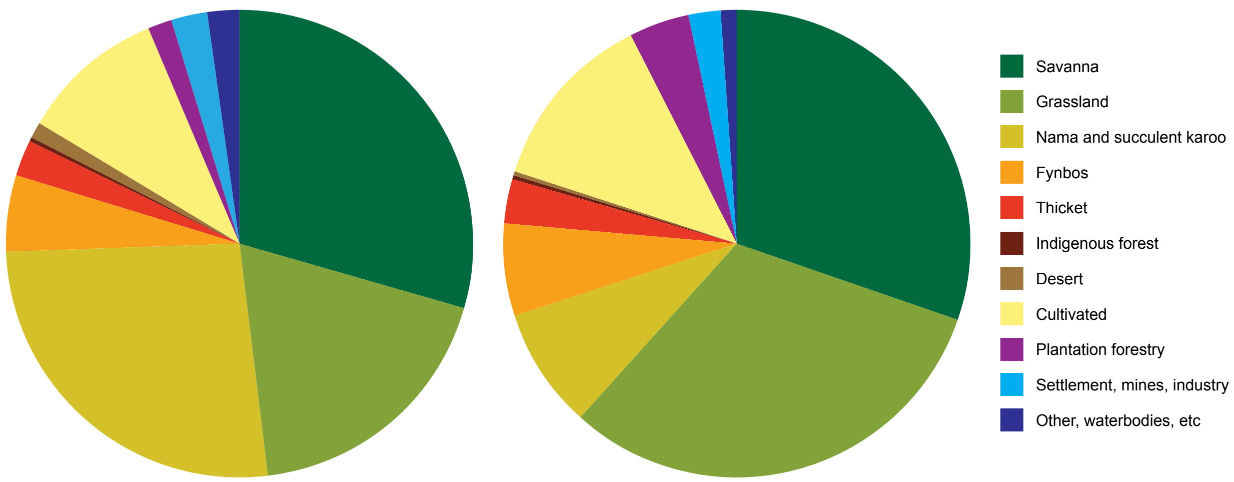
The need to strike a reasonable balance between these two sets of differing objectives may certainly lead to trade-offs, but it may also provide the opportunity to expand emerging mechanisms that decrease the impact of planned land-use change on carbon stocks. For example, the adoption of the reduced tillage, biochar, erosion management and sustainable grassland management practices listed in Section 2, may reduce the impact of land-use change on carbon stocks while providing emerging farmers with an additional source of revenue.

Synthesis: key emerging outcomes

Here we highlight five key outcomes that we believe are important to members of Government that focus on climate change matters and sustainable resource management more broadly. However, we strongly encourage the reader to further explore the reports that focus on their particular area of interest as they include substantial information on the nuance details of each issue.

Section 1 – The majority of South Africa's terrestrial carbon stock is located belowground in grassland and savanna ecosystems

- Over 60% of the national terrestrial carbon stock is located in grassland and savanna ecosystems. Within these two ecosystems, more than 90% of the total carbon pool is located belowground mainly in the form of soil organic carbon (Fig 7).
- Historical international focus on afforestation and avoiding deforestation (REDD+) has lead to the recent strong emphasis on the development of climate change mitigation activities in forest and woodlands ecosystems. Whereas there is good opportunity restore and sustainably manage forests and subtropical thicket in South Africa, in future there needs be a better balance of effort with greater focus on restoring and sustainably managing grassland and savanna ecosystems.



a. The relative spatial area of each land-cover type

b. The relative percentage of the national terrestrial carbon stock within each land-cover type.

Figure 7. *The relative contribution of each of the principle land-cover types in South Africa in terms of (a) spatial area and (b) terrestrial carbon stocks*

Section 2 – Climate change itself may not present a considerable risk to land-use based mitigation activities

The results of the modeling exercise in Section 1.3 indicate that while predicted climate change and elevated [CO_2] may have an effect on terrestrial carbon stocks and associated sequestration rates over the next 20-30 years, the actual effect on the outcome of climate change mitigation activities, in terms of the amount of carbon sequestered due to the project, is likely to negligible. The results suggest that there is likely to be a slight increase in carbon stocks and sequestration rates for the majority of South African vegetation types. A concern may be the predicted decrease in carbon stocks and sequestration rates in coastal forest, but it is important to note that the magnitude of the predicted change is anticipated to be less than 5 percent over 30 years.

Our intention here is not to completely discount the potential effect of climate change and elevated [CO_2] on terrestrial carbon stocks, but to rather place the effect over the next 30 years in perspective. At present, prominent carbon-market standards such the Verified Carbon Standard (VCS) and Gold Standard, stipulate a default 20-30 percent discount ("buffer") on the volume of issued emission reduction units to the developers of land-use based activities due to perceived risk within the land-use sector (e.g. fire or pests). Considering the risk that climate change presents in this context, the results of the modelling exercise indicate that changes in climate and elevated [CO_2] are generally likely to lead to an increase in carbon stocks – which can be seen as 'upside risk'. Where a decrease in carbon stocks is predicted (in the case of coastal forests), the magnitude of the potential change is less than five percent and well within the 20-30 percent discount typically applied to land-use based mitigation projects in a near compulsory manner.

Section 3 – Eight principle mitigation opportunities were identified but they differ in terms of "readiness' and their additional social and environmental benefits

"Readiness" is a term that recently emerged during the development of national-scale REDD+ programs internationally. It refers to how ready a country is to rollout implementation in terms of required scoping assessments, institutional capacity, methodologies, incentive mechanisms, monitoring frameworks, supporting policy and other important elements.

The concept was used in the context of the National Carbon Sink Assessment to understand the level of existing development of each identified mitigation opportunity and what is still required on the potential path to implementation at scale. As the outcome of the comparison is aimed at providing direction to future strategy in South Africa, the analysis was extended beyond typical carbon market, governance and implementation measures to include the relative social and environmental benefits of each opportunity as well - interviewed members of Government noted that future prioritization of particular opportunities will most likely not solely be driven by the climatic benefit of an opportunity but a more balanced, holistic assessment of benefits that includes social and ecosystem service elements.

Eight sub-criteria were used to compare each option:

Carbon market, governance and implementation measures

1. *Market acceptance:* Market acceptance is assessed according to several criteria, namely the presence of a recognized legal counterparty, the ability to raise traditional forms of finance, the application of known and successful technologies, the ability to generate revenues, and the probability of receiving early government support.
2. *Readiness to implement*: A number of activities have a well-documented track record of success in South Africa – examples include small-scale commercial forestry and restoration of sub-topical thicket. Several other activities have already been subject to pre-feasibility, feasibility and costing assessments. These types of activities are deemed more favorable due to their readiness for implementation compared to those that lack this preparatory work, especially where further extensive primary research is required.
3. *Capital intensity:* The extent to which large sums of capital will have to be deployed, notably at project inception. For example, biomass–to-energy and anaerobic biogas digesters, require intensive injections of capital for upfront construction and early operational costs. In comparison, grassland rehabilitation and reforestation demand less upfront capital.
4. *Government support:* It is believed that government support is more likely for projects that are self-sufficient over time, and which adopt proven, known technologies. In addition, activities that can raise external sources of finance and deliver local jobs and potential equity opportunities for previously disadvantaged persons are likely to be prioritized.

Ecological and social characteristics

5. *Ecological risk:* The extent to which a project might be exposed to forms of ecological risk, for example, fire, pests and changes in climate.

6. *Ecological infrastructure:* The extent to which a project is expected to contribute to ecosystem services at landscape or catchment spatial scales.
7. *Contribution to social welfare and quality of life:* This rating aligns with the World Bank's Environment Strategy, where improving the quality of life is assessed by the contribution to: a) enhancing livelihoods b) reducing health risks and c) reducing vulnerability to natural hazards.

Contribution to carbon sequestration potential

8. *Potential to store carbon:* The potential to store carbon or reduce GHG emissions based on the results listed in Table 8.

Each of the eight identified climate change mitigation opportunities in Section 2 have been assessed according to the set of criteria in Figure 8 below. A quintile ranking system, from *unfavorable* to *favorable*, is used to illustrate how implementation options compare. It should be noted that this is a relative rank and not an absolute measure.

	Relative rating:	Unfavorable	→			Favorable
C. market, implementation and governance measures	**Market Acceptance** Low → High	Biochar Grassland	REDD-plan Agric		Reforestation CommForest	Biomass – Energy Biogas
	Readiness to implement Long-term option → immediate	REDD-plan	Biochar Agric	Grassland	Biogas	Reforestation Biomass-Energy CommForest
	Capital intensity High → Low	Biomass-Energy Biogas Biochar	Agric	CommForest	Reforestation Grasslands	REDD-plan
	Required Government support High → Low	Reforestation Grassland REDD-plan	Agric		CommForest	Biomass-Energy Biogas Biochar
Social and ecological infrastructure measures	**Ecological delivery risk** High → Low		Reforestation	CommForest Biochar Agric	Grassland REDD-plan	Biomass-Energy Biogas
	Contribution to social welfare and quality of life Low → High	Biochar	Biomass-Energy* Biogas* Agric		Reforestation CommForest	REDD-plan Grassland
	Ecological infrastructure Low → High	Biomass-Energy	CommForest Biogas		Biochar Agric	Reforestation Grassland REDD-plan
Climate change	**Impact on national scale sink** Low → High	CommForest	Agric** Biochar**		Grassland Biomass REDD-plan	Reforestation Biogas

*Both biomass to energy and anaerobic biogas digesters have the potential to improve in terms of social benefits if generated electricity serves rural communities and economies directly
**As carbon accumulation rates remain inconclusive for low-tillage systems and biochar use, this estimate is based on the opinion of experts interviewed during the engagement process

KEY

Reforestation: Reforestation of thicket and forests
Grassland: Restoration and management of grasslands
CommForest: Commercial small-grower forestry
Biomass-Energy: Electricity generation using biomass
Biogas: Anaerobic biogas digesters
Biochar: Biochar production and distribution
REDD-plan: REDD+ through planning and regulation
Agric: Improved agricultural practices (principally low till)

Figure 8. *Ranking of principal opportunities: broken down by sub-criteria and ranked from unfavorable to favorable*

In terms of readiness, the list of eight implementation options can be grouped into four classes:

Ready in the short-term

- **Biomass to energy** – Several South African companies are already generating electricity for internal use through the combustion of sugar and forestry biomass waste, with considerable scope to scale-up generation for supply into the national grid.
- Interviewed companies noted that the full extent of the opportunity is well understood and that several entities have gone as far as developing the required documentation and methodologies to register projects through the Clean Development Mechanism (CDM). The main limiting factors to implementation are the establishment of long-term offtake agreements with the national electricity supplier and demand for generated emission reduction units (carbon offsets).
- **Commercial small-grower afforestation** – Full feasibility assessments by the forestry industry indicated that there is approximately 60,000ha in the Eastern Cape and 40,000ha in the KwaZulu-Natal that is suitable for afforestation. The 'technology' is well known and applicable CDM and VCS methodologies are available. **The key inhibitory factor is the influence of high retail interest rates on the financial viability of the opportunity.** Either favorable loans will need to be provided or an additional carbon-related income stream would need to be created.

In the short-medium term:

- **Restoration of sub-tropical thicket and forests** - Particularly the restoration of sub-tropical thicket in the Eastern Cape is at an advanced state of readiness. A significant body of supporting research has been undertaken over the past 10-15 years and parties have already started implementing pilot initiatives. Good knowledge exists of the 'technology', methodologies and scope for implementation.
- Implementation at scale is however limited by clear incentives, as well as awareness of the opportunity and high transactions costs associated with monitoring and verification through international carbon-market standards. The creation of clear demand for generated carbon offsets (or another form of incentive mechanism), together with institutional support that reduces high transaction cost and awareness issues, could unlock substantial rollout in the short- to medium term.

In the medium term:

- **Restoration and management of grasslands –** A substantial body of research exists on opportunities to sequester additional carbon and avoid further degradation in grassland ecosystems that supports the activity's prominent inclusion in Section 2. It may be one of the largest opportunities in the country and is especially noteworthy due to the substantial rural livelihood and ecological infrastructure benefits that would be generated through implementation. However, prior to implementation, the full scope of the opportunity needs to be assessed including dedicated mapping of degraded areas, the calibration of methodologies, the creation of a cost-effective monitoring framework, and the development of implementation- and associated business models. None of these issues presents a complete block to implementation, but addressing them may take 2-3 years to achieve.

In the long-term:

- **The implementation of biochar, reduced tillage, and REDD+ through planning –** Although each of these options presents a real potential opportunity to reduce GHG emissions and sequester atmospheric carbon, a significant amount of further research and methodology development is required prior to implementation at scale. These opportunities should not be completely discounted, rather they are merely at a lower level of readiness *relative* to the other five activities. In terms of strategic investment by Government, it may be appropriate to prioritize actual implementation of the first five options, while initiating the required research to support realization of biochar**, reduced tillage** and **REDD+ at scale**.

Section 4 – There are two predominant barriers to implementation: a lack of clear incentives and institutional support

During the stakeholder engagement process, participants were asked what they perceive as the key barriers to implementation. The first is the lack of incentives for implementation, particularly the absence of clear long-term sustainable demand for generated carbon offsets. A surprising number of entities located within government and the private and NGO sectors, have undertaken full feasibility assessments (at a project scale) and even gone as so far as to compile Project Design Documents (PDDs) and initiate implementation, to then be forced to stop further development due to lack of demand for carbon offsets. The creation of a sustainable incentive mechanism is required, be it in the form of local demand for carbon offsets or an alternative form of direct payment for implementation.

The second prominent barrier is the need for institutional support to facilitate implementation. Landowners and especially emerging farmers and rural communities are generally unaware of the opportunity and if they are, they generally do not have the required excess capacity to, for example, undertake feasibility assessments, required monitoring and reporting, contact international auditors and investors, and so forth.

Functions that may need to be provided to realize the full opportunity at a national scale include:

- ***Awareness and support services****:* A pervasive issue continually raised by almost all practitioners, is that there is currently very little awareness of the opportunity on the ground, especially among emerging farmers who may greatly benefit from an addition income stream.
- ***A cost efficient national MRV system:*** One of the main obstacles to the roll-out of projects to date has been the high transaction costs incurred associated with MRV through international standards.
- ***Research development:*** Practitioners noted that despite early successes, there is a crucial need for further research into the ecological, operational and monitoring aspects of implementation.
- ***Strategy development:*** A strategy is required that will focus on the long-term vision of the program and roll-out, and strategic alignment with other government programs, ecological infrastructure and development efforts, as well as government policies and priorities.
- ***Income creation and management:*** An entity is required to manage the trade of generated emissions reductions that are generated from the entire program, as well as to secure additional, alternative sources of revenue, for example payment for other ecosystem services (water), bilateral funding, and disbursements from the national fiscus.
- ***Incentive mechanisms and disbursements:*** Once income is secured, an effective, cost-efficient, yet flexible disbursement and incentive mechanism is required. An entity is required to manage the effective disbursement of generated income to implementation agents on the ground.
- ***Integration with policy and regional planning:*** The program needs to be aligned with national policies and planning, to ensure that envisioned activities do not conflict with national land-use priorities in particular areas, and so that implementation can support broader national development goals.

Section 5 – The close alignment between land-use based climate change mitigation and adaptation and restoration of ecological infrastructure needs to be formally acknowledged and leveraged

Although the eight activities listed above were principally identified from a climate change mitigation perspective, the implementation of each activity is likely to lead to substantial additional ecological infrastructure, ecosystem service and rural development benefits. For example, the realization of the proposed activities located in grassland, subtropical thicket and coastal forest ecosystems, will not only lead to the sequestration of atmospheric carbon but the long-term sustainable management of crucial water services as well. Independently from this assessment, the restoration and management of grassland and savanna systems has been identified as one of the principle ecosystem-based climate change adaptation opportunities in the country (e.g. the uThukela Initiative) and is the focus on SIP 19 that focuses on ecological infrastructure for water services. Furthermore, implementation, either through the EPWP, community-orientated NGOs or the private sector, is likely to increase employment and skill development in remote rural areas, which is a high priority of Government.

In a similar manner, the expansion of biochar production and reduced tillage is likely to have substantial water, soil erosion and associated climate change adaptation benefits. The implementation of biogas digesters that process livestock manure and municipal waste, not only leads to a reduction in GHG emissions but has substantial water services benefits as well. The principal reason for uMgungundlovu District Municipality implementing a suite of biogas digesters is not for the climate regulation benefit, but the urgent need to address water pollution in the greater area.

To improve the attractiveness and efficiency of climate change mitigation opportunities, such alignment and co-benefits need to be acknowledged and leveraged. First, co-benefits need to be recognized when evaluating the net benefit of proposed ventures and association levels of compensation or payment for implementation. Secondly, alignment in terms of implementation, monitoring and incentive mechanisms needs to be leveraged to reduce inefficiencies and barriers to entry.

Synthesis: potential next steps

Taking direction from national policy and the outcomes of this National Carbon Sink Assessment, we assume that the overall long-term goal is broadly three-fold:

1. To improve our understanding of carbon stocks and fluxes to fulfill South Africa's national GHG reporting requirements and to allow Government to direct policy and implementation from a position of knowledge.
2. To realize all climate change mitigation activities that are reasonably possible in terms of social, economic and environmental implications
3. To create alignment with existing programs and policy to ensure a cohesive approach to natural resource management that is effective and efficient.

To achieve this set of goals, a multi-disciplinary approach is required in a similar manner to this initial national carbon sink assessment that combines systems ecology, economics, policy and an understanding of the nature of implementation and required financial, institutional and monitoring support. Each goal is further expanded below, based on input received from stakeholders within government and the private sector.

Section 1 – To improve our understanding and reporting of carbon stocks and fluxes

The models developed in a VisTrails environment, not only significantly improve our understanding of current carbon stocks and fluxes, but provide a valuable tool for future national reporting and assessing the potential influence of particular drivers on national terrestrial carbon stocks.

As noted, the models have been created in such a way that algorithms and datasets can be readily changed, either purely for update purposes or for other analysis. For example, the 2000, 2010 and 2020 South African Land-Cover created by GeoTerraImage in Section 1.4 could readily be used as an alternative base land-cover layer to assess the impact of predicted land-use change on national terrestrial carbon stocks over time.

In addition, the development of a spatial form of the Century model, would improve our ability to understand the potential effect of climate change, elevated [CO_2] and changes in management practices on terrestrial carbon stocks. The basic input for variables for Century are now available in a spatial form for most of the country (AfSIS soil data base, the aboveground biomass surface developed in this study, and several climate data sets are available).

Section 2 – To realize all mitigation activities that are reasonably possible

Here, we recommend addressing three principle elements that are required to unlock the rollout of activities:

The creation of long-term incentives for climate change mitigation activities

The realization of a national program as well as private and NGO sector activities relies on the creation of secure, long-term financial incentives for implementation. This is especially pertinent following the collapse of international carbon offset markets. The creation of a dependable, incentive mechanism within South Africa, for example, related to the National Carbon Tax, is vital to a national program and to encourage implementation within the private and NGO sectors.

It is suggested that a focused scoping analysis is undertaken that explores all potential sources of revenue for climate change mitigation activities in South Africa, including broader payment for ecological infrastructure, ecosystem services and climate change adaptation.

The development of initial institutional capacity to support implementation

As noted, stakeholders nearly unanimously identified a lack of institutional support as one of the key barriers to implementation. Especially emerging farmers and local communities are generally unaware of potential opportunities and do not have the required capacity to undertake scoping assessments, required monitoring and so forth. Furthermore, the development of efficient, low-risk national MRV and incentive mechanisms would most likely lead to substantial implementation, especially in the sub-tropical thicket and grassland ecosystems.

However, a rationale balance does need to be achieved between addressing the required functions listed above and investment by Government in a new institution. It would be inappropriate to commit to substantial funds over the long-term without a comprehensive understanding of the opportunity.

It is therefore suggested that first, a full feasibility assessment of eight mitigation opportunities is undertaken (see point 3 below), and second, that an initial conservative team is established that could be expanded in future in response to justified needs. A small focused team (possible 3-4 individuals in an existing department) is could address many of the key roadblocks inhibiting the rollout of the first

3-5 activities listed in Table 8. The team could be increased over time as each of the implementation options are developed.

A comprehensive analysis of each climate change mitigation opportunity

The Section 2 report includes an initial exploration of the eight principle climate change mitigation activities located in South Africa. The analysis provides a good foundation but a dedicated, comprehensive analysis of each opportunity is required as a next step. In terms of prioritization, it is suggested that Government focus on the first five activities in Table 8:

- Restoration of sub-tropical thicket and forests
- Restoration and management of grasslands
- Commercial small-grower afforestation
- Biomass energy
- Anaerobic biogas digesters

A substantial amount of work has been undertaken on each of these activities to date, with field practitioners ready to start implementation in the short to medium term (1-3 years). In certain cases, initial implementation has already begun.

The remaining three activities provide good opportunity but may require further research prior to their realization. One should not discount their potential value and especially over time, REDD through planning may form one of the leading mitigation opportunities in the country. At present, however, they are not as well known or as developed as the five activities listed above.

Section 3 – To create alignment with existing programs and policy to ensure a cohesive national approach

A project key outcome listed above is the need to formally acknowledge and leverage the close alignment between land-use based climate change mitigation activities and similar ventures aimed at ecosystem-based adaptation and the restoration and sustainable management of ecological infrastructure. At numerous points during the extended engagement with members of government and the private sector, stakeholders noted close alignment between initiatives, but also repetition and inefficiencies that already exists in program mandates, implementation, monitoring and reporting, mapping of land-cover and degradation, and so forth. A joint, inter-departmental but cohesive approach is required to address such repetition and to reduce inefficiencies.

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Appendix A: considering each potential mitigation opportunity

1. Restoring sub-tropical thicket and forests

The opportunity to sequester carbon through the restoration of sub-tropical thicket and coastal forests is relatively well known and understood. To date, a considerable amount of work has been done on the science, implementation and financial aspects of sub-tropical thicket and forest restoration. Several entities are in the process of attempting to register projects through the VCS or CCBA. The carbon accounting, legislation and methodological issues are therefore relatively well understood. Due to the substantial amount of groundwork that has been done, the restoring of sub-tropical thicket and forests may be one of easiest mitigation activities to rollout in the near term.

Baseline without-activity scenario -

Approximately 4 million hectares of sub-tropical thicket located in the Eastern and Western Cape has been degraded to a certain degree through unsustainable pastoralism over the past century (Lloyd et al 2002). Of this degraded area, approximately 500,000-1,000,000 ha has been identified as suitable for restoration in the near term (Powell *pers comm*).

Additional with-activity scenario -

As sub-tropical thicket does not generally rehabilitate naturally, dedicated planting and long-term management programs are required to re-establish indigenous vegetation. The restoration process and accumulation of biomass and soil organic matter result in carbon sequestration rates of between 1.2-2.4 $tC.ha^{-1}.yr^{-1}$ (Powell 2009). If 500,000-1,000,000ha is suitable for restoration in the near term, assuming a conservative 1.2 $tC.ha^{-1}.yr^{-1}$, restoration would result in an average sequestration rate of 2,200,000-4,400,000tCO_{2e} per year.

Further social and environmental benefits

The restoration of ecological infrastructure is proven to be an efficient vehicle through which to create job opportunities in remote rural areas. The EPWP, internal municipal programs and NGOs within the sector employ a significant number of previously unemployed people. In addition to rural employment and skill-development opportunities, local benefits include the restoration of livestock forage and farming industries, nature-based tourism, and the supply of wood, fruit and medicines to local communities for consumption and sale. One of the key benefits is the effect of thicket restoration on water services. Initial research indicates that degraded land results in nearly double the amount of runoff and almost a six-fold increase in sediment load compared to intact thicket.

ACTIVITY SUMMARY	
Key Positives	• High annual carbon sequestration potential per hectare • Combats soil erosion through improved root systems • Substantial rural employment and livelihood benefits • A relatively low risk carbon sequestration option • Availability of approved methodologies to support early roll-out
Key Trade-Offs and Concerns	• Implementation in communal areas may require a new, progressive approach to incentives and disbursements

2. Restoration and management of grasslands

Due to the international focus on REDD+ and forests, the opportunity for climate change mitigation within the grassland biome is often underestimated. In South Africa, appropriate grassland management may be one of the principle climate change mitigation and adaptation activities within the land-use sector. Two primary mitigation activities are considered within the grassland biome:

- Carbon sequestration through grassland restoration and long-term management
- Reducing the degradation of grasslands and release of soil carbon into the atmosphere

Baseline without-activity scenario

- *Grassland restoration and long-term management:* The ploughing and turnover of soil leads to the release of soil organic carbon into the atmosphere. Overgrazing and the degradation of the herbaceous layer can also lead to a substantial loss of carbon, but over a longer period of time.
- *Reducing the degradation of grasslands:* Interviewed experts noted a clear increase in the spatial extent of degraded grassland and erosion gullies in their focus areas. It was further noted that unless new measures are introduced, the trend would continue over time.

Additional with-activity scenario

- *Grassland restoration and long-term management:* The restoration of grassland requires a comprehensive set of complimentary measures that may include a reduction in grazing pressure, physical replanting and rehabilitation. In dry grasslands, a conservative carbon sequestration rate of 0.5tC.ha^{-1}.yr^{-1} can be assumed. Sequestration in moister, mesic grasslands is more rapid (0.7-1.0tC.ha^{-1}.yr). If restoration were to be rolled out across the 1.2 Million hectares, it would lead to the sequestration of approximately 2.3 Million tC per year.
- *Reducing the degradation of grasslands:* Depending on the driver of degradation, the rate of release can either be rapid or a gradual decrease through leaching over a much longer period. For planning purposes a conservative release rate of 1.0tC.ha^{-1}.yr^{-1} can be assumed.

Further social and environmental benefits

The restoration of ecological infrastructure is an efficient vehicle through which to create employment and skill development opportunities in rural areas. This is particularly important in the remote areas of the Eastern Cape, KwaZulu-Natal, Free State and Northern Cape where additional grassland management measures are urgently required. Grasslands provide a wealth of ecosystem services to both local communities as well as regional urban and industrial centers. For this reason, the restoration and long-term appropriate management of grasslands is highlighted as a key intervention in the proposed 19th Strategic Integrated Project (SIP 19) focused on ecological infrastructure for water security.

ACTIVITY SUMMARY	
Key Positives	• The opportunity to restore 1.2 Million hectares of potentially productive grazing land • The provision of water services to key economic hubs in a cost-effective manner • Cost-effective adaptation to predicted climate change • Substantial rural employment and livelihood benefits • A relatively low risk carbon sequestration option
Key Trade-Offs and Concerns	• Implementation in communal areas may require substantial time to develop • A new form of monitoring, reporting and verification system will need to be pioneered.

3. Commercial small-grower afforestation

In the interests of creating rural jobs and economic activity, Government has proposed the expansion of small-grower forestry in areas of the Eastern Cape and KwaZulu-Natal, where there is sufficient water within catchments to accommodate plantations without significantly affecting base flows. Furthermore, if this is undertaken in areas that have been previously degraded, ploughed or have limited biodiversity, commercial small-grower forestry can be a long-term viable vehicle for providing rural jobs and income streams.

Implementation model: form and agencies

A review of existing literature and interviews with industry, have indicated that there is approximately 60,000ha in the Eastern Cape and 40,000ha in KwaZulu-Natal that is suitable for afforestation activities. Since much of the proposed expansion of forestry in South Africa is on communal land under local tribal authority or on private farms that have recently been redistributed to emerging farmers, commercial forestry companies have proposed a community partnership model.

Extent and potential to scale-up

The availability of suitable land that meets required water and biodiversity regulations is a clear constraint on the potential to expand this activity. Although government policy has proposed expansion across 100,000 ha in the Eastern Cape, forestry companies engaged during the stakeholder engagement process objected that this goal might be too optimistic. The amount of land that meets required water regulation, biodiversity, and EIA requirements may only amount to 60,000 ha in the Eastern Cape and 40,000 ha in KwaZulu-Natal

Employment and skill development

The implementation of a community-based pulp production model provides employment and revenue streams not only to rural communities and emerging farmers who have recently acquired land, but to other individuals within the logistics, milling and delivery functions of the value chain.

Ecological infrastructure and ecosystem services

There are well-founded concerns regarding the water, biodiversity and soil impacts of commercial plantations, including the spread of exotic trees from the initial site of the plantation. For this reason, forestry companies must clearly document the net effect of a plantation on base water flow (in order to obtain a water license) and are required to undertake a full EIA for each plantation.

ACTIVITY SUMMARY	
Key Positives	• A tested model that allows communities and emerging farmers to leverage the capacity and expertise of the commercial forestry industry, while fundamentally owning the project • Provision of a fairly low-risk income stream to communities and emerging farmers • Provision of jobs and skill development opportunities in remote areas of South Africa,
Key Trade-Offs and Concerns	• The impact of commercial forestry on water and biodiversity is a well-founded concern and it needs to be ensured that established guidelines are adhered to throughout the implementation process. • There is clear concern that exotic trees may spread from the initial plantation sites. • High retail interest rates will have an inhibitory impact on the financial viability of the plantation opportunity. A key catalytic intervention would be the provision of favorable loans to the smallholder industry.

4. Anaerobic biogas digesters

Anaerobic biogas digesters are fermentation tanks or sealed ponds in which biodegradable material ferments anaerobically, generating a composite gas of which methane is the most abundant. Methane is a greenhouse gas with a global warming potential 23 times that of CO_2. There are thus considerable benefits in reducing the release of gasses from biodegradable fermentation processes into the atmosphere.

Implementation model

Biogas digesters can be installed by:

- Virtually anybody as it is a relatively simple, do-it-yourself- type technology, or
- By small contractors who specializes in the construction of digesters, or
- By large engineering firms/outlets.

The level of technical capacity required is determined by the scale or size of the digester. Household-level units can be constructed either by the owners themselves or by small contractors. Large industrial and/or agriculture applications require special design features that makes engineering firms or the like better suited for the task.

Extent and potential to scale-up

In 2008, a national feasibility assessment of biogas in South Africa estimated that 310,000 rural households are eligible for biogas digesters by virtue of not having access to grid-based electricity, but having access to grey water and manure. Austin and Blignaut (2008) estimated the potential of agriculture-based biogas digesters based on the published number of cattle, sheep, pigs and poultry in the country, producing more than 156,000 tons of manure a day. The total power generation capacity of the methane gas, if between 25% and 50% of this manure is captured, is 280MW (for communal areas), and about 1,100MW for all animal-based agriculture operations.

Further social and environmental benefits

There is significant scope for the development of an entirely new economic activity in the construction sector as this technology is in its infancy and there are only a few applications of it to date in South Africa. In addition to the obvious carbon mitigation benefits, the introduction of biogas digesters will assist greatly in the management of waste. If designed appropriately, digesters will improve water quality by reducing the pollutants from dispersed sources into water bodies as digesters reduce the biological oxygen demand loads in effluent by up to 90%.

ACTIVITY SUMMARY	
Key Positives	• Easy to implement and to maintain with direct benefits to people and the environment • Easy to monitor and well-established and relatively simple CO_2-baseline methodologies • Significant employment creation potential
Key Trade-Offs and Concerns	• Capital intensive • Potential skepticism of the use and/or introduction of a new technology

5. Biochar production and application

Biochar is a partially combusted form of charcoal, produced through the process of pyrolysis using organic materials such as vegetation waste, crop residues and woody biomass such as timber harvest wastes or alien invasive species. It is a carbon-rich material that can be mixed into the soils of agricultural or other lands for the purpose of increasing soil-carbon; it may also improve crop yields in previously degraded or sandy soils.

Baseline compared to with-project scenarios

Under a "without project scenario" it is assumed that the rate of carbon loss from soils will continue unabated. Under the "additional, with project scenario" it is possible that the rate of soil carbon loss would be reduced, abated or reversed with biochar amendment to soils. Added to this is the "avoided decomposition" of biomass stocks used in the pyrolysis process, which are assumed to otherwise release emissions as they break down through normal organic processes.

Implementation model: form and agencies

Stakeholders identified two potential approaches. In the first approach, independent, commercial producers would manufacture biochar and oversee its delivery to interested end-users, such as commercial and small-scale farmers, or persons responsible for mine rehabilitation. In a second model, the EPWP would establish teams to remove alien invasives. The vegetation waste could either be transported to a central depot for biochar production, or combusted through the use of a mobile technology.

Employment and skill development

Employment could be generated from the harvesting of alien invasive species or the collection of other biomass waste resources required for pyrolysis (could be linked to the EPWP programme). Moreover, jobs at kiln production sites to manage the sorting and drying of biomass materials, to oversee the pyrolysis process, to maintain inventory and prepare shipments, and to oversee sales would be required. The biochar production and distribution network would likely lend itself to the establishment of small and medium enterprises (SMEs), many of which could be based in rural areas.

Ecological Infrastructure and Ecosystem Services

The removal of alien invasive species to supply biochar production will provide a significant ecological infrastructure benefit, notably in protecting important water catchments. The application of biochar, if proven effective in improving carbon absorption rates, should lead to improved soil nutrient density, water retention capacity, and limits to fertilizer run-off.

ACTIVITY SUMMARY	
Key Positives	• Potential to contribute to climate change adaptation and mitigation through improved soil water retention, fertility and carbon sequestration • Potential improvements to subsistence farmer crop yields and rural food security • Means for adding further value to the alien invasives removal programme
Key Trade-Offs and Concerns	• Limited understanding of the carbon mitigation benefits under South African conditions • Potentially prohibitive costs structure, which would have to be subsidized by government • Unclear level of potential uptake by commercial, emerging and subsistence farmers • Expensive, sophisticated biochar production technologies deliver the best health and greenhouse gas reduction outcomes, but require greater upfront capital cost

6. Reduced Emissions from Degradation and Deforestation (REDD) through planning and regulation

Conventionally, activities aimed at Reducing Emissions from Degradation and Deforestation (REDD) are primarily limited to forest ecosystems. In a South African context, there is limited opportunity for this classical interpretation of REDD since most deforestation happened decades ago. In the context of the National Carbon Sinks Assessment, we have adopted a broader approach to REDD by including the reduction in degradation of all terrestrial ecosystems, be it grasslands, savannas, woodlands, fynbos, thicket and so forth.

Under the "**without project scenario**" it is expected that unchecked degradation of natural landscapes will continue. For the purpose of describing the baseline, it is assumed that degradation is taking place, and that this degradation is not officially mandated but is rather the consequence of limited enforcement and local government oversight of the use of natural resources. Under the "**additional with-project scenario**", the degradation of critical above and below-ground carbon stocks would be avoided through rigorous application of environmental planning and regulations.

Implementation model: form and agencies

The planning and regulatory function needs to originate from government. At the local level, municipalities have a significant role to play in land-use planning functions through the annual release of an IDP. IDPs are to align with national level, binding policies, such as NEMA, and require that an environmental analysis be undertaken. This represents an important opportunity for assessing current natural resource use at the municipal level, identifying thresholds for exploitation, and capacitating staff to enforce planning principles and objectives.

Further social and environmental benefits

It is anticipated that capacity within local and rural municipalities would need to be increased marginally. This will provide long-term job opportunities for skilled individuals in government. REDD Planning and Regulation could form the broad planning foundation for ecological infrastructure management at a national scale, with the potential to deliver a substantial set of ecosystem goods and services over the long-term. This set would include: climate regulation, soil erosion prevention, habitat protection, medicinal plant protection, water catchment improvements and maintenance, stream flow improvements, soil nutrient and health improvements, biodiversity conservation, pollination services, and feedstock and fodder provision.

ACTIVITY SUMMARY	
Key Positives	• Relatively cost-effective implementation with substantial ecosystem benefits and alignment with climate change adaptation priorities. • Potential to be one of the principle land-based climate change mitigation activities in the country. • Opportunity to create a framework for national ecological infrastructure planning across the entire country.
Key Trade-Offs and Concerns	• Improved planning and application of regulations for the protection of ecosystems is not currently compatible with CDM / VCS standards. • While potentially the most significant activity, it is a longer-term option, which requires new investment. I

7. Reduced tillage

Over 95% of the terrestrial carbon stock in grassland and savanna systems is located belowground, in the form of soil organic carbon. It can, however, be rapidly released into the atmosphere through the process of ploughing, as soils are turned over and the carbon is exposed to the atmosphere. Together with this substantial release of carbon from the top 30 centimeters, there is also the loss of additional benefits that organic matter provides, in terms of soil nutrient, water retention and so forth.

Conservation or reduced tillage can generally be defined as any tillage technique (no-tillage, direct drilling, minimum tillage and/or ridge tillage) that leaves sufficient biomass residue in place to cover a minimum of 30% of the soil surface after planting. The net carbon sequestration benefit of reduced tillage may have initially been overestimated, and several recent studies suggest that the net effect throughout the soil profile, down to 1 meter, may be lower than first anticipated. For this study, we have therefore taken a conservative approach, and estimated the net sequestration rate to be 0.1 $tC.ha^{-1}.yr^{-1}$.

Implementation model: form and agencies

The concept is relatively well-known in South Africa, to the extent that there are no-till "clubs" in certain provinces. The majority of the winter wheat area in the South Western Cape has also already adopted reduced tillage practices. A National Facilitation Unit could expand such measures, providing additional outreach and awareness services to farmers.

Employment and skill development

Reduced/no tillage improves farming skills as farmers need to adopt various new pest and weed management strategies, including biological, physical and chemical measures to reduce the use of herbicides. The net impact on employment is unlikely to change.

Ecological infrastructure and ecosystem service implications

Reduced/no tillage systems can improve water infiltration, increase soil moisture and reduce runoff and water contamination as well as improve soil quality, reduce erosion and compaction, and increase surface soil organic matter. The water and soil quality and erosion benefits are often the primary reason for the adoption of reduced tillage systems, with carbon sequestration viewed as a marginal side benefit.

ACTIVITY SUMMARY	
Key Positives	· A climate change adaptation measure; · Energy and labour across the total production process can be reduced; · Less amounts of fertilisers used and lower production costs; · Increases crop productivity; · Maintenance or increase in soil organic matter content (enhanced soil quality); · Reduction in wind and water erosion; · Increased water infiltration into the soil and increased soil moisture.
Key Trade-Offs and Concerns	· Herbicides may be used more often, but risks being overexploited and used in excessive volumes. Application of herbicides is critical in cases where the farmer does not plough or till to control weeds and grasses.

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