Report No: ______________

Nigeria:
Opportunities for low carbon development
Volume 2, part A: Agriculture and Land Use

World Bank and Food and Agriculture Organization

Draft – May 2012

Currency Equivalents

(Exchange Rate Effective)

Currency Units = Naira

US$ 1.00 = 150 Naire in Jan 2012

All currency values are in constant 2009 US$ unless otherwise specified.

Weight and Measures

Systeme Internationale (SI Units)

Vice President:	Makhtar Diop
Country Director:	Marie-Francoise Mary-Nelly
Sector Director:	Jamal Saghir
Sector Manager:	Idah Pswarayi-Riddihough
Task Team Leader:	Raffaello Cervigni

Acknowledgments

The report was prepared by a Joint World Bank – FAO team. The World Bank was led by Raffaello Cervigni and included (in alphabetical order) Ademola Braimoh, Amos Abu, Abimbola Adubi, John Rogers, Shobha Shetty, Steve Danyo and Stephen Ling.

The FAO team was led by Louis Bockel and included Pierre-Luc Sutter, Ophelie Touchemoulin and Francis Bisong.

From the Government of Nigeria, policy guidance was provided by Hon. Mrs. Hadiza Ibrahim Mailafa (Minister of Environment) and Hon. Dr. Akinwunmi Ayo Adesina (Minister of Agriculture).

We wish to thank the following for their support and access to data for the study Mr. Tunde Lawal (Director, National Planning Commission), Prof. Adeola Adenikinju (University of Ibadan) Mr. Peter Papka (Director, Federal Ministry of Environment, Department of Forestry) and Eng. M.C.C Eneh (Director, Federal Department of Agriculture).

The team is grateful for the comments received from participants in the consultation workshop held in Abuja in November 2010. These include L. G. Ogundare (FME, Forestry) S.B. Akinsola (FME, Forestry), Shehu Ndama (FME, Forestry), Dr. J.E. Onyekuru (FME, Forestry), A.I. Njoku (FME, Forestry), Stephen Aluko (FME, Forestry), B.O. Falana (FME, Forestry), John Auta (FME, Forestry), T.F. Fameso (FME, Forestry), O.S. Adedoyin (FME, Forestry), Njere Emmanuel (FMARD) John Akubo Yakubo (FMARD) Mrs Nyazi Henrientta Alhassan (FMENV/SCCU), Damilola Eniayeju (FMARD), Dr Ibrahim G. Umaru Senior (Lecturer/ Researcher) Ikereve Akpehe (FMARD) Richard Nzekwu (FMARD) Micheal Idowu (National Programme for Food Security) Nnaemeka Chukwuone (University of Nigeria), T. Julius Odeyemi (FMARD), Amina Ahiba (FMARD), Dr John E. Onyekuru (FME Forestry) and C. Cordelia Ndukwe (FME).

Financial support from the TFESSD and TerrAfrica following Trust Funds is gratefully acknowledged

Acronyms

AFOLU	Agriculture, Forestry, Land Use
C	Carbon
CSA	Climate Smart Agriculture
CO_2-eq	CO2 equivalent
EX-ACT	EX-Ante Carbon balance Tool
FAO	Food and Agriculture Organization
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
LC	Low Carbon
MACC	Marginal Abatement Cost Curve
M ha	Million of hectares
NAIP	National Agriculture Investment Plan
NFSP	National Food Security Program
NPV	Net Present Value
NV	Nigeria Vision
SGM	Sustainable Grazing Management
SLM	Sustainable Land Management
SRI	Sustainable Rice Intensification
WB	World Bank

Table of contents

Acknowledgments 3

Acronyms 4

Executive summary 7

Chapter 1 Introduction 9

- 1.1 Background 9
- 1.2 Scope and limitations of the analysis 10
- 1.3 Overview of methodology & data sources 10

Chapter 2 The reference scenario 15

- 2.1 Agricultural growth model 15
- 2.2 GHG emissions model 16
  - 2.2.1 Land use changes 16
  - 2.2.2 Sector investments and technological change 20
  - 2.2.3 Climate and soils 20
- 2.3 Emissions baseline 20

Chapter 3 The Low Carbon scenarios 23

- 3.1 Introduction to mitigation options 23
- 3.2 Adjusted agricultural growth model 29
- 3.3 Emissions models under two low carbon scenarios 30
  - 3.3.1 Low carbon scenarios 30
  - 3.3.2 Land use and other mitigation factors 30
- 3.4 Results of the low carbon scenarios 33
  - 3.4.1 Mitigation potential 33
  - 3.4.2 Marginal abatement costs 37
  - 3.4.3 Incentivizing high mitigation through carbon payments 44

Chapter 4 Recommendations for an effective implementation of a low carbon strategy in the Nigerian AFOLU sector 47

- 4.1 Towards a network of Climate Smart Agriculture partners 48
- 4.2 Main Implementation mechanisms 48
  - 4.2.1 Supporting the agricultural research 48
  - 4.2.2 Capacity building and technology transfer platforms 49
  - 4.2.3 Field support platforms as small farmers aggregators 50
  - 4.2.4 Systematic review and carbon appraisal of sector project and program proposals 50
- 4.3 The necessity of a strong and coherent policy environment 51
  - 4.3.1 Ensuring a relative stability of the policy framework 51
  - 4.3.2 Strengthening capacity of decentralized institutions 51
  - 4.3.3 Strengthening the Climate Smart Agriculture policy and project planning 51

References 53

Annexes to the Agriculture and Land Use Sector 60

Executive summary

Through its Vision 20:2020, the Federal Government of Nigeria has laid out ambitious targets to increase the domestic agricultural production 6-fold by 2020. Output growth would be achieved through reduction in post-harvest losses, increased yields and expansion of crop land. The overall objectives of the program are to achieve food sovereignty and to fight poverty. The present study analyses the climate change mitigation potential of the agricultural sector within the constraint of meeting these growth targets. The Ex-Ante Carbon balance Tool (EX-ACT), developed by the Food and Agriculture Organization (FAO), was used for the analysis. The tool, which is based on the IPCC 2006 methodology, enables comparison of emissions between scenarios involving different land use and management choices. The analysis was conducted over a 25-year period from 2010 to 2035, with a 15-year *implementation* period for land management changes and a 10-year *capitalization* period during which no further land management changes are considered, but the emissions effects flowing from the earlier changes are assessed.

A reference scenario was constructed to provide a plausible pathway for achieving the Vision 20:2020 growth targets in 2025, based on government policies and expert opinion. Firstly a growth model was established to estimate expected contributions of cropland expansion and yield increases to meeting sector-wide output targets, and then more detailed land use and technology change projections were developed in line with the broad parameters set by the growth model. Net greenhouse gas (GHG) emissions were calculated from the detailed land use and technology models, which also incorporated a spatial analysis of land suitability and specific government policies (e.g. on afforestation, expansion of irrigation and rural roads, etc.).

The reference scenario produces emissions of about 2.7 billion t CO_2-eq for 2010-2035, at an average of 1.2 t CO_2-eq/ha/yr. Annual emissions are 6 times lower by 2035, reaching 25 Mt CO_2-eq from an initial 161 Mt CO_2-eq in 2010. The main reason is a reduction in emissions from land use change, as land use patterns stabilize and in particular deforestation is halted, although 50% of secondary forest area is still lost by the end of the model, leaving only 5% secondary forest coverage for country. By 2035, grassland (-16% compared to 2010), fallow (-67%) and other land classes (-30%) are also reduced to make room for cropland expansion (+45%). However, because croplands are better managed with less use of fire on perennial plantations, and improved seeds and water management on irrigated surfaces, they provide a net sink of -44 Mt CO_2-eq p.a. by 2035. The results show that by improving land management to meet the ambitious Vision 20:2020 growth targets, significant reductions in GHG emissions are already achieved, but further improvements are possible. Roughly 2/3 of the emissions are due to land use changes, and 1/3 come from livestock, and therefore these activities should be the focus for improvements under the low carbon scenarios.

A revised growth model demonstrated that the same sector output targets can be met with reduced expansion of cropland, if yield growth is accelerated by a realistic amount in response to increased adoption of improved and conservation agriculture techniques. Based on the reduced rate of cropland expansion (1.2% on average, rather than 1.6%) suggested by the revised growth model, two low carbon scenarios were explored. Both involve introduction of a range of additional sustainable land management (SLM) technologies, which promote increased agricultural productivity and/or increased retention of trees in the landscape. Within the confines of a technical constraint on the maximum average land area over which SLM technologies could be introduced each year (800,000 ha/yr), one scenario (A) selected SLM options so as to maximize the emissions reduction potential, whilst the other (B) maximized the net benefits experienced by farmers.

All SLM technology options have a positive cost to Government, who is assumed to provide technical support and subsidies for their implementation. The balance of costs to private farmers and land owners is very different, however, depending on the specific option selected. Scenario A focuses on those options which maximize emissions reductions potential per ha of land, namely avoided deforestation and agroforestry. Scenario B, however, focuses on the options which provide the highest private return, particularly conservation agriculture, which increases crop yields for a relatively low investment (note that agroforestry also provides significant yield increases, but requires more intense up-front investments from farmers, particularly in labor, and is therefore only marginally profitable for them). Overall, scenario A results in a mitigation potential of 1.0 billion t CO_2-eq (in comparison to the reference scenario) at a cost to government of US$ 3.2 billion (in NPV terms) and whilst generating a net return of US$ 5.7 billion to farmers (also NPV). Scenario B generates roughly half the emission reductions, at slightly more than 0.6 billion t CO_2-eq, at a similarly reduced public cost of about US$ 2.2 billion, whilst private returns are roughly increased by one third, reaching US$ 7.3 billion.

Finally, it is demonstrated that introduction of carbon payments to private farmers / land owners at a minimum price of $ 6.1 per t CO_2-eq would be sufficient to achieve the same overall private returns as scenario B, even when adopting the same mix of SLM options as scenario A (although some options, such as avoided deforestation remain unattractive to private farmers when assessed in isolation, even under this level of carbon finance).

The results outline the broad potential for sector growth targets to be achieved which a greatly reduced carbon footprint through the adoption of appropriate SLM technologies, some of which are directly profitable to farmers, and others of which are not so financially attractive, but involve even greater emission reductions (and other environmental) benefits. Despite their benefits, however, there are significant practical obstacles for the large-scale introduction of SLM technologies, mostly associated with the need to convince risk-averse farmers to adopt new practices, and providing a supportive environment for making up-front investments that will pay off over several years. Chapter 4 reviews some of the steps that may be necessary for SLM to take off, including development of the agricultural research and extension services, and providing a stable, conducive policy framework. Decentralization, reallocation of funding, and increased cooperation and interaction between diverse stakeholders are some of the institutional steps required.

Chapter 1 Introduction

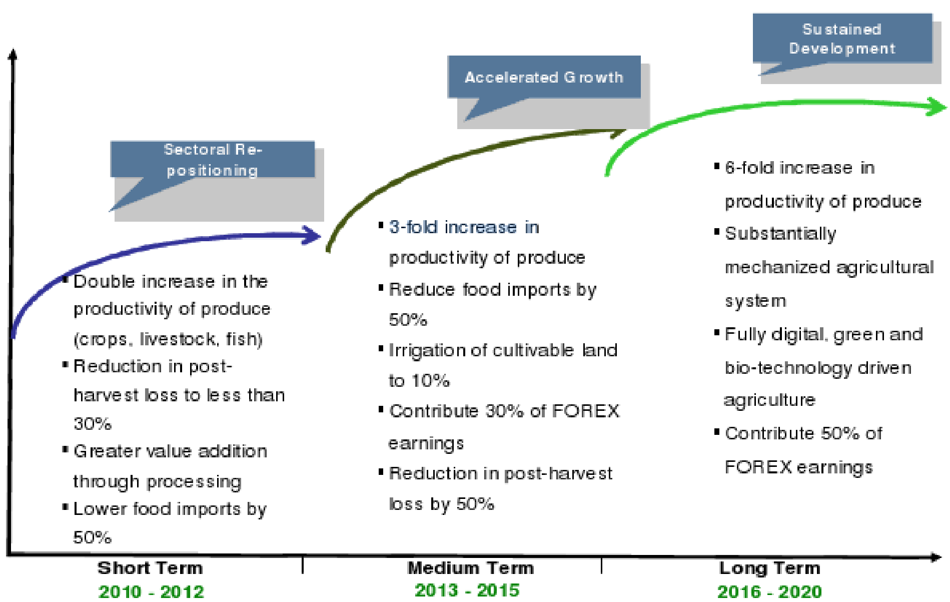
1.1 Background

The Federal Government of Nigeria (FGN) and the World Bank have agreed to carry out a Climate Change Assessment (CCA) within the framework of the Bank's Country Partnership Strategy (CPS) for Nigeria (2010-2013). The CCA includes an analysis of options for low carbon development in selected sectors, including power, oil/ gas, transport and, the subject of the present report, agriculture. The goal of the low-carbon analysis is to define likely trends in carbon emissions up to 2035, based on Government sector development plans, and to identify opportunities for achieving equivalent development objectives with a reduced carbon footprint. The sector-specific low carbon reports will be consolidated into a synthesis report covering all four sectors.

Agriculture (including land use change) is a major contributor to Nigeria's total emissions, accounting for emissions equivalent to an estimated 156 million tons of carbon dioxide, and 45% of the national total (UNCCS). At the same time, agriculture also offers various mitigation options, essentially through enhanced carbon storage in the soil and vegetation.

The sector currently contributes 33% of national income and 60% of employment (WB, 2007 and CBN, 2002), and is likely to remain a major economic sector, even if stagnant or declining sector output is not reversed. Agriculture features prominently in Vision 20:2020, the overall growth strategy adopted by the government in 2008, which aims for Nigeria to become one of the world's 20 leading economies by 2020. Vision 20:2020 establishes targets for 3-fold and 6-fold increases in domestic agricultural productivity by 2015 and 2020 respectively. This is to be achieved through: (i) reduction of post-harvest losses; (ii) increasing yields (expansion of irrigation and greater use of improved and disease-resistant crop varieties); and (iii) expansion of cropland. Figure 1 illustrates the phased approach to achieve these objectives.

Figure 1: Implementation of the Nigeria Vision 20:2020 Road Map



Source: Report of the Vision 20: 2020 National Technical Working Group on Agriculture & Food Security

More recently, the Federal Government has adopted the Agricultural Transformation Agenda (ATA) for transformation of the sector through processes including import substitution, export orientation, value-addition through processing and backward integration linkages. Emphasizing the role of the private sector, the ATA focuses on a selected number of value-chains (including rice, cassava, sorghum, cocoa, and cotton.), on complementary investments in infrastructure; and on providing improved access to credit and steps towards an enabling policy environment.

1.2 Scope and limitations of the analysis

The present report analyzes greenhouse emissions from Agriculture, Forestry and Land Use (AFOLU). Emissions from agro-industries are not included. The study consists of the following components:

- Elaboration of a reference scenario of GHG net emissions for the agriculture sector, consistent with Vision 20:2020 and other government plans.
- Identification of opportunities for reduced net emissions (reduced emissions and/or enhanced carbon sequestration) while achieving the same development objectives as in the reference scenario.
- Economic assessment of low carbon options in order to help the Nigerian government to prioritize policy options.

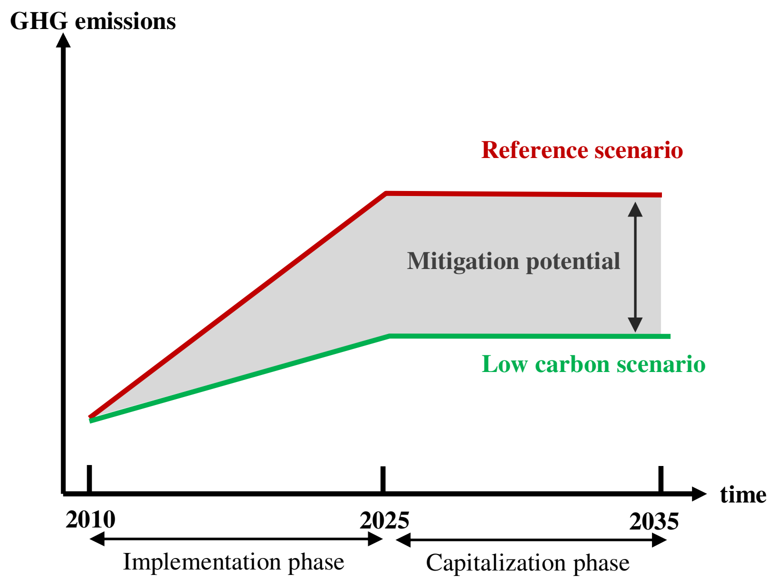
The analysis does not intend to evaluate the feasibility of government policy targets incorporated into the reference scenario, but rather to investigate whether, and at what cost (to farmers and to the government), those targets could be achieved with lower net carbon emissions. The agriculture targets under Vision 20:2020 are ambitious and there are many uncertain variables that will impact upon them. Hence the reference scenario is not necessarily the most likely to actually materialize, but does serve as a basis of comparison with the low carbon alternative.

The study evaluates costs and benefits in a partial equilibrium setting, with no attempt to capture the indirect, general equilibrium effects of adopting low carbon technologies or management practices. The results of this analysis (the first of its kind in Nigeria) should therefore be considered as a first approximation of the potential for low carbon development in the Nigerian agriculture sector. The study aims at providing policy makers with an order-of-magnitude estimate of mitigation potential, and an understanding of the value of dedicating further efforts (including through specific projects) at pursuing low carbon development in agriculture, but is not meant to inform the design of specific project level interventions.

1.3 Overview of methodology & data sources

GHG emissions under the reference and low carbon scenarios are estimated using EX-ACT (*Ex Ante* Appraisal Carbon-balance Tool), developed by the Food and Agriculture Organization (FAO) and aimed at providing *ex ante* estimates of the impact of agriculture and forestry projects or policies on net GHG emissions (EX-ACT 2010). The mitigation potential of the low carbon scenario is calculated as the difference in emissions resulting from the two scenarios (Figure 2).

Figure 2: Mitigation potential of the Nigerian agriculture sector with the implementation of low carbon practices



In consultation with government officials and other Nigerian experts, it was agreed to adopt a conservative assumption that the Vision 20:2020 targets (including a 6-fold increase in agricultural productivity) would be met by 2025 rather than 2020. Both scenarios therefore start in the year 2010, and span a 15-year implementation phase in which aggressive investments are made to achieve sector development targets, and a 10-year capitalization phase, in which benefits of those investments continue to accrue.

A simple growth model was used to estimate the magnitude of crop expansion, consistent with the Vision 20:2020 targets[1]. More detailed land use and technology change models were then constructed within the overall growth parameter in order to calculate emissions. The detailed models drew from discussions with experts from the Government, FAO and World Bank to determine distributions of secondary forests, grasslands, degraded lands and other lands, taking into account a spatial analysis of soil quality, slope and other suitability factors for cultivation. Experts' opinion was also used to select the most plausible low carbon options suited to the Nigerian context.

The data sources on agronomic practices and land use are listed in Table 1 and Table 2, with specific references to be found in the bibliography.

[1] Note that it is assumed that the 6–fold increase in the value of agricultural output envisioned under Vision 20:2020 is only partly met through increase in physical output, with the rest accounted for in terms of an increases in price / value of output at least partly due to increased value-added, etc. Hence the growth in physical output to 2025 used as the basis of the growth model is less than a 6-fold increase.

Table 1: Sources for the Nigerian agronomic practices

Practices	Data sources
Yield, Irrigation	• The Federal Government of Nigeria - National Implementation Plan (NIP) • Getting agriculture going in Nigeria (WB) • The Nigerian Federal Ministry of Agriculture and Rural Development - National Agricultural Investment Plan (NAIP) • The Nigerian Federal Ministry of Agriculture and Rural Development - Global Agriculture and Food Security Program (GAFSP)
Fertilizer use	• FAOSTAT • National Bureau of Statistic (NBS)
Rice planning	• National Rice Development Strategy (NRDS)
Livestock management, yield evolution, regional agriculture practices disparity	• Farming & Rural System Economics
SLM practices	• FADAMA study • Benefit Cost Analysis of SLMW in Nigeria (WB)

Table 2: Data sources for Land Uses

Practices	Data sources
Rice	• National Rice Development Strategy (NRDS)
Cropland and perennial crop	• FAOSTAT • National Bureau of Statistic (NBS)
Forest management	• Forest Resources Assessment 2010 (FAO) • UN-REDD
Cropland, grassland, forest, soil quality	• Global Administrative Areas Database • Land cover (ESA, Global Land Cover Network)
Climate and soil constraints for the cultivation of crops	• ASTER GDEM • CGIAR-CSI • IIASA Harmonized World Soil Database

Emissions factors and carbon storage coefficients are needed to convert land use changes and agronomic practices into GHG emissions. The EX-ACT tool includes default coefficients taken from the Intergovernmental Panel on Climate Change (IPCC) Guidelines 2006, but where possible and appropriate, local data were used to drive values more suited to the Nigerian context. Table **3** below summarizes the sources of the coefficients used in the analysis. More details are available in Annexes

Table 3: Sources of the coefficients used in the analysis

Type of vegetation	Type of coefficient	Tier 1 (IPCC 2006)	Tier 2 (data sources)
Forests	Carbon content in above and below ground biomass for secondary forests		Henry M., 2010, Carbon stocks and dynamics in Sub Saharan Africa, AgroParisTech/Engref, University of Tuscia
	Emissions factors of forest biomass burning	×	
	Afforestation/reforestation: carbon pool content	×	
Annuals, perennials, grasslands, degraded lands, other	Non forest land use changes (initial and final carbon pool in biomass and soil)	×	
Annuals	Carbon storage capacity of different agronomic practices	×	P.P. Chivenge, H.K. Murwira, K.E. Giller, P. Mapfumo, J. Six, 2007, Long-term impact of reduced tillage and residue management on soil carbon stabilization: Implications for conservation agriculture on contrasting soils, Soil & Tillage Research 94 (2007) 328–337 L.F.C. Leite and al. 2009, Modeling organic carbon dynamics under no-tillage and plowed systems in tropical soils of Brazil using CQESTR, Soil & Tillage Research 102 (2009) 118–125
Perennials	Above and below ground biomass growth rate	×	
	Emissions factors of biomass burning	×	
Rice	Methane emissions	×	
Grassland	Emissions factors of biomass burning	×	
Livestock	Methane emissions from enteric fermentation	×	
	Methane emissions from manure management	×	
	Nitrous oxide emissions from manure	×	

Type of vegetation	Type of coefficient	Tier 1 (IPCC 2006)	Tier 2 (data sources)
	management		
	Mitigation potential of better feeding practices	×	
Inputs	Carbon dioxide emissions from urea application	×	
Other investments	CO_2 emissions of gasoil	×	
	CO_2 emissions of biodiesel		R. Guo, K. Hanaki, 2010, Potential and life cycle assessment of biodiesel production in China, J. Renewable Sustainable Energy 2, 033107 (2010); doi: 10.1063/1.3449298
	CO_2 emissions of the installation of irrigation system	×	
	CO_2 emissions from the construction of buildings and roads	×	

Chapter 2 The reference scenario

2.1 Agricultural growth model

A simplified growth model was constructed to represent a feasible pathway to achieving the increase in total agricultural production envisaged by Vision 20:2020. The model, based on literature, consultation with stakeholders and expert judgment, accounts for growth via three factors:

- **Cropland expansion**: The annual rate of cropland expansion is assumed to decline from 2.33% to 0.79% linearly, resulting in a compounded mean annual surface growth rate of 1.56% for 2010-2025. Thereafter, the rate of expansion remains at 0.79% p.a.
- **Yield growth**: Average crop yields (per unit area of cropland) are estimated to grow by 3% per annum for the first two years and then by 5% for the next three through investments in improved agronomic practices, such as adoption of improved seeds and fertilization, and based on national yield responses to similar investments in Asian countries[2]. Thereafter, 4%[3] annual growth was estimated for the rest of the model period, since shorter fallow periods will decrease soil organic content, thus limiting the yield growth.
- **Annual growth due to the reduction of post harvest loss**: Post harvest loss is currently estimated at 33% of production. The Vision 20:2020 strategy aims to reduce it by 50% by 2015 and 90% by 2020. The growth model assumes more conservatively that the 90% target will be reached by 2025, via a linear 6% decrease per annum in the rate of post harvest loss. This is equivalent to an annualized compound growth rate due in the volume of agricultural production reaching market of 2.48% during 2010-2025. After 2025, reductions in post harvest losses are assumed to take place at a slower pace (1% per year).

The assumptions and results of the growth model are illustrated, respectively, in Table 4 and Figure 3.

Table 4: Agricultural growth model of the reference scenario

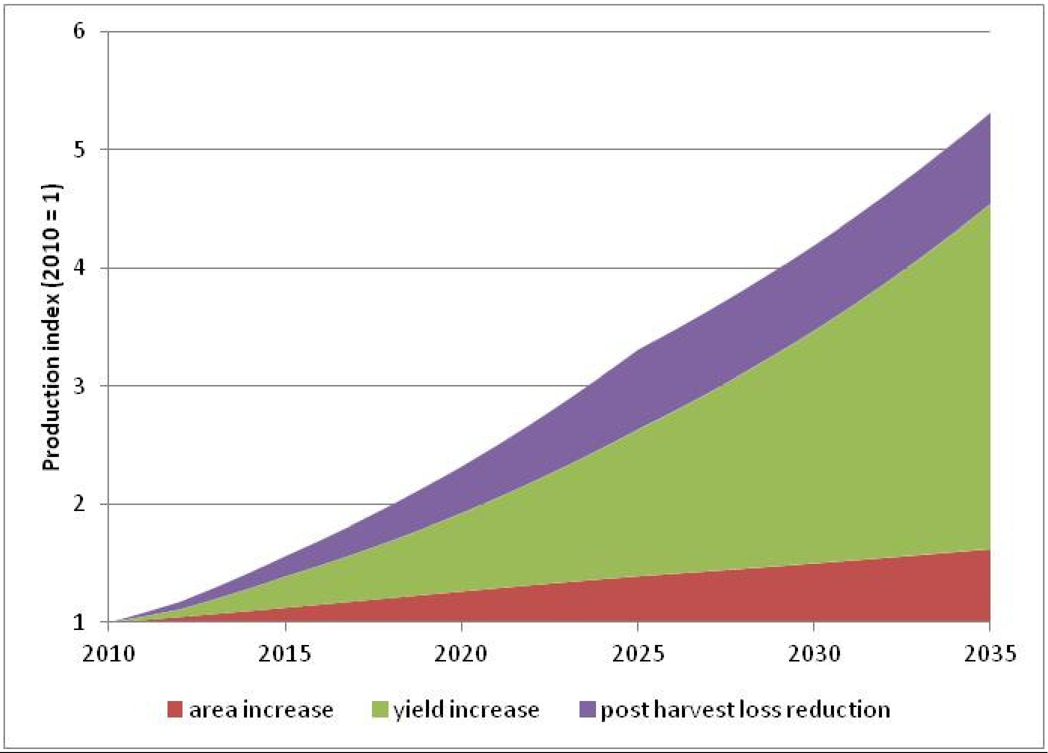
Type of growth	Average 2010-2025	Average 2026-2035
Annual cropland expansion	1.56%	0.79%
Annual yield growth	4.07%	4.00%
Annual growth due to post harvest loss reduction	2.48%	0.03%
Total supply growth	8.30%	4.86%

---

[2] Evenson R.E., Gollin D., 2003, Assessing the impact of the Green Revolution, 1960 to 2000, Science Vol. 300 no. 5620 p.758-762

[3] As no scientific data were available, this figure was estimated thanks to consultations with FAO experts

Figure 3: Reference scenario: total production increase and sources of growth over the model period



2.2 GHG emissions model

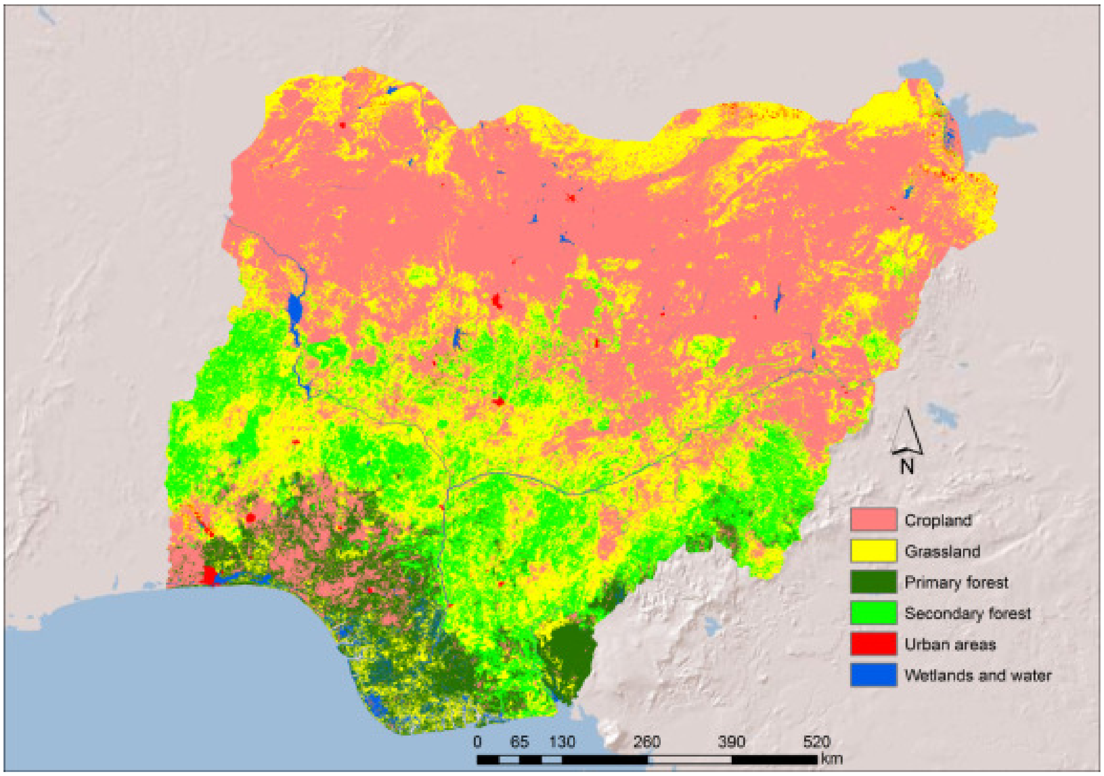
The growth model was then used as a basis for identifying a consistent set of land use and technological changes that could plausibly be expected to occur by 2025, and which would form the basis for estimating GHG emissions from the agriculture sector.

2.2.1 Land use changes

Despite a decreasing rate of cropland expansion during the model period, ongoing land use changes are expected to contribute to GHG emissions, particularly conversion of forests, grassland (i.e. pasturelands which also contribute to agriculture sector output), fallow and other lands to cropland. In accordance with government policies, land use changes are predominantly assumed to take place from 2010 to 2025. After 2025, land use patterns notionally follow the same trends as in the reference growth model, but only the land use changes until 2025 are counted in the calculation of emissions.

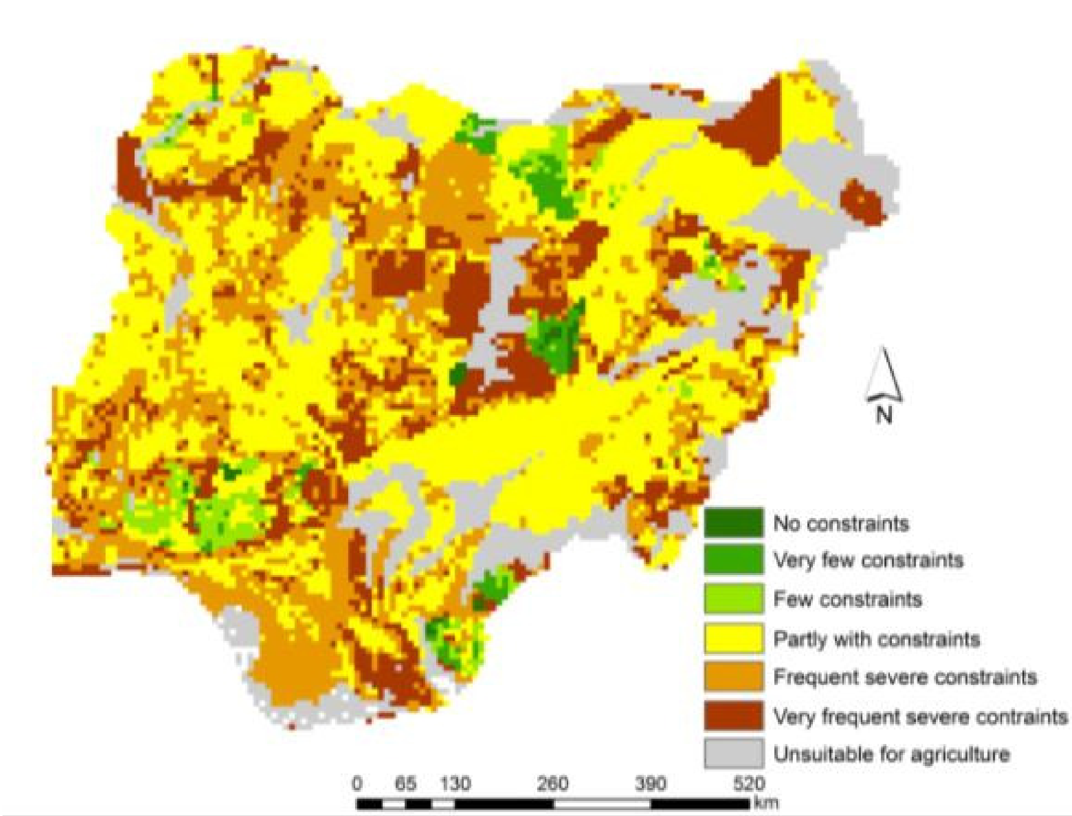
Conversion of forest to agricultural lands was assumed to affect only secondary forests. A GIS-based evaluation of the suitability of secondary forests for agricultural conversion was undertaken based on current land use (Figure 4), slope and soil quality. Secondary forest areas were considered suitable for conversion if categorized as “partly with constraints” or as a higher suitability class. The results of the exercise are shown in Figure 5, which indicates that over 3 million hectares of existing secondary forest could be converted to agriculture.

Figure 4: Land use map



Source: World Bank 2011 (A. Braimoh)

Figure 5: Land suitable for agricultural use



Source: World Bank 2011 (A. Braimoh)

The assumptions of the land use change model in the reference scenario, based on official policy, current trends, experts' opinion and consistency with the growth model to 2025, are as follows:

- Land conversions are based on linear processes between 2010 and 2025[4].
- The area of land under annual crops (cereals, tubers) increases by 1.56% p.a., and the area under perennial crops (palm tree, rubber tree, cocoa) by 3.22% p.a. following the trend for 1990-2010.
- 90% of secondary forest land suitable for agriculture is converted into annual crops, with the rest assigned to perennials and grasslands.
- Tropical secondary forest in the Southwest accounts for 75% of forest land converted to perennial crops, due to the wet preference of perennials. The remaining 25% of forest conversion to perennials takes place in moist secondary forest in the North.
- As the area of forest available for conversion is insufficient to meet the total increase in cropland, some grassland and fallow are also converted to cropland, since they offer a better soil quality for cultivation than degraded land or other land.
- The area of wet rice cultivation within annual cropland roughly doubles to 2.625 million ha by 2025 from 1.313 in 2010, meeting the Government's 2018 target from the National Rice Development Strategy.
- Based on consultation with the Department of Forests, afforestation will take place over 600,000 ha. Reforestation (dry and moist plantation forest) takes place on degraded land (50%), on fallow (30%) and pasturelands (20%).
- Half of the degraded lands are restored into perennial plantation, while the rest is restored into pasturelands or forest.
- The conversion of other land uses (grassland, degraded land, fallow, other land)[5] is calculated in ways that ensure overall consistency of the land use matrix reported in Annex 2 for 2025.

Figure 6 illustrates the change in land use over time. Overall, as for 2025, forest land shrinks by more than 50%, annuals and perennials increase by a factor of 1.3. Grassland and other land remain quite stable or are slightly reduced. In 2010, crops (annual, perennial, rice) account for 46% of the total country area, forests for 10%, pasturelands for 20% and the rest (degraded lad, fallow, other) for 23%. In 2025, crops are projected to account for 61% of total land area. Forests have shrunk to 5%. Pasturelands remain stable at about 19%. From 2025, the crops expansion slows down, and crops now account in 2035 for 68% of the total country area, forest for 3%, pasturelands for 17% and other lands for 12%. The land use change details are available in Annex 2.

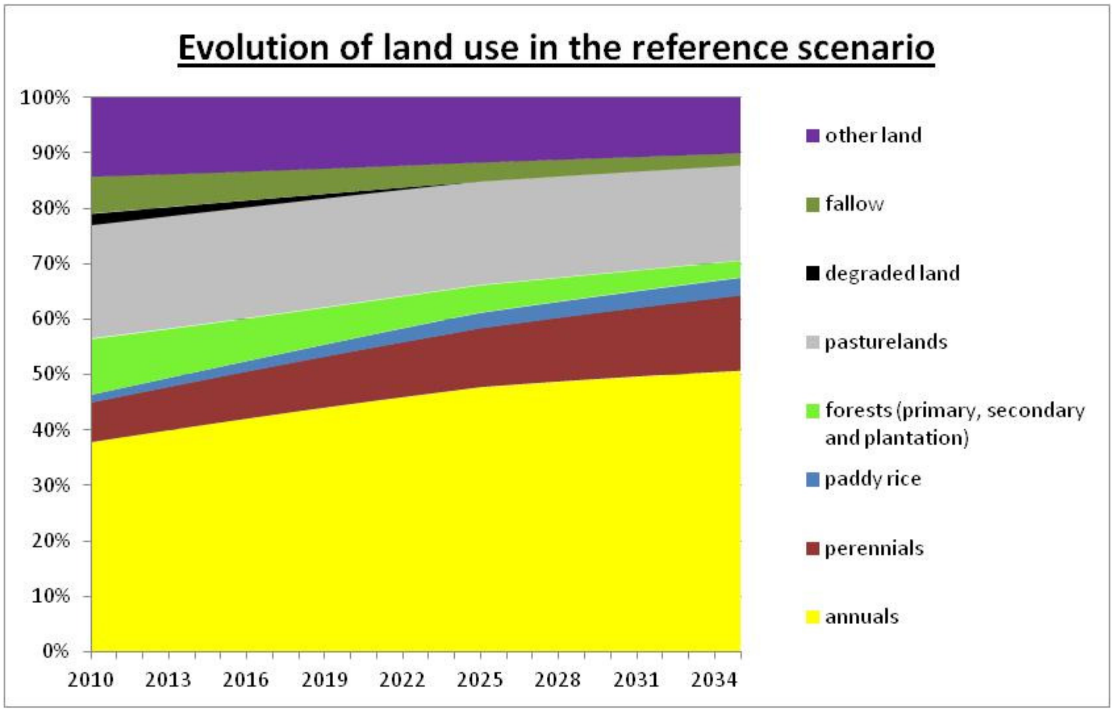
[4] Forest loss is actually a decelerating process, rather than being strictly linear, but the effect is too minor to be evident in Figure 6 below.

[5] Other lands include gullies, dominantly grasses, discontinuous grassland, shrub/sedge/graminoid freshwater marsh/swamp, natural waterbodies, urban, sand dunes, montane grassland, reservoir, rock outcrop, graminoid/sedge freshwater marsh, saltmarsh/tidal flat, alluvial, mining areas, canal.

Table 5: Land uses in 2010 and 2035 for the reference scenario (in 000 ha)

Land use	2010	2025	2035
Annuals	34,437	43,437	46,155
Perennials	6,552	9,712	12,419
Flooded rice	1,313	2,625	2,919
Forests	9,101	4,438	2,700
Secondary forests	*8,805*	*3,542*	*1,804*
Plantations	*296*	*896*	*896*
Live fencing/agroforestry	*0*	*0*	*0*
Pasturelands	18,629	16,974	15,669
Degraded lands	1,849	0	0
Fallows	6,234	3,257	2,076
Other lands	12,941	10,602	9,116
Total	**91,054**	**91,054**	**91,054**

Figure 6: Evolution of the land use from 2010 to 2035 in the reference scenario



2.2.2 Sector investments and technological change

The reference scenario assumes that the Vision 20:2020 goal for improved crop cultivars, and fish and livestock breeds to constitute 50% of stocks will be met by 2025 (via linear growth), and that where applied, these improved varieties will be accompanied by better management, namely use of suitable fertilizers and no residue burning for crops, and improved breeding and feeding practices for livestock. Livestock numbers increase continuously at the same rate as for 2000-2010.

The government target to expand irrigation, from 1% of cultivated area in 2010 to 25% in 2020, is assumed to be reached only in 2035. Hence in 2025, 15.8% of the crop land will be irrigated. All the irrigated area will be managed with improved water efficiency. Degraded lands converted to pasturelands will be improved with organic and inorganic fertilizers, and managed without fire, to allow recovery of soil fertility.

It is assumed that 6,000 km of roads will be constructed to improve market access to remote areas. The proportion of tractor-ploughed arable land will rise from about 8.5%[6] to 50% by 2025. Assumptions on the expansion of processing and storage infrastructure have been derived from Vision 20:2020 plans to strengthen agricultural export markets. These are summarized in Table 6

Table 6: Projected expansion of infrastructure for agriculture in 2025

Type of building	Quantity	000 m^2 Office	000 m^2 Concrete	000 m^2 Metal
Livestock Breeding and Multiplication Centres	12	12	23.76	0
Export Conditioning Centres	12	12	23.76	0
Agric Seeds Centres	36	36	71.28	0
Slaughterhouse	36	36	71.28	0
Large Scale Rice Processing	181	36.2	0	325.8
Cassava processing Factories	200 000	0	0	2 000
Storage capacity from 3 Mt to 44 Mt	41	2.05	40 795	

2.2.3 Climate and soils

Moist tropical climate and low active clay (LAC) soil classifications were used for the analysis as these were considered closest to the typical conditions in Nigeria. Although there is local variation in soil and climate conditions, a sensitivity analysis (see Sensitivity analysis) was conducted which indicated that these factors would have little effect on the final results in terms of the comparative emissions between the reference and low carbon scenarios.

2.3 Emissions baseline

GHG emissions were calculated from 2010 to 2035 for land use changes and other sector reforms that take place up to 2025 – i.e. the emissions consequences of agricultural development up to 2025 is being estimated, with allowance for a 10-year *capitalization* period thereafter, but further sectoral changes after 2025 are not represented in the calculation.

[6] K. C. Oni, Creating a competitive edge through agricultural mechanization, p.6

GHG emissions are expressed in CO_2-equivalent (CO_2-eq)[7]. The different emissions sources have been clustered into 4 main categories:

- Crops (including annuals, perennials and paddy rice), which provide a net carbon sink over time, due to an increase in soil carbon through the improved management practices introduced alongside new crop varieties in the reference model. Paddy cultivation on the other hand acts as a net source due to methane production from the flooded soil.
- Land use changes, which will emit or sequester CO_2 depending on whether the conversion is to a vegetation cover type with lower or higher carbon density. The greatest changes occur as a result of deforestation or afforestation. Land use change may result in GHG emissions / sequestration beyond the time at which it occurs, due to associated changes in soil carbon, which may some years to reach a new equilibrium.
- Livestock and pasturelands: emissions from the livestock are essentially methane and nitrous oxide produced by the digestion processes of ruminants and from manure, whilst improved pastureland management can store carbon through an increase in the soil organic matter.
- Agricultural inputs, which involve GHG emissions associated with fertilizer consumption and production, infrastructure construction and fuel consumption.

Whilst emissions decrease over time, agriculture remains a net source of GHG in the reference scenario, and emits about 2.7 billion t CO_2-eq during the whole period from 2010 to 2035 (i.e. an average of 1.2 t CO_2-eq /ha/yr). Table 7 shows total annual emissions at the beginning (2010) and end (2035) of the simulation period, and Figure 7 illustrates the evolution over time of the 4 main emissions categories, and the overall net emissions pathway.

Table 7: Comparison between the annual emissions of 2010 and 2035 in the reference scenario (in M t CO_2-eq/yr)

Activities	2010	2035	Difference
Land Use Changes	127.1	15.6	-88%
Crops	-9.4	-43.6	-364%
Livestock and Grassland	42,4	46.4	+10%
Inputs	0,6	6,7	+1068%
Total	**160.6**	**25.2**	**-84%**

Annual emissions due to land-use changes (representing 60% of cumulative emissions) decline by a factor of eight, as land use change (including net deforestation) is brought to a halt by 2025. Residual emissions from soil carbon changes related to land use change increase and then decrease after 2025 due to an interaction of ongoing soil carbon loss from deforestation of non-forest land use change, with more gradual and increasing accumulation of soil carbon from afforestation.

Conversion of degraded land, fallow and other lands into perennials accounts for 65% of gross sinks, followed by annual crops (22%) and afforestation (13%).

Emissions from livestock and grassland account for 30% of the cumulative total. They increase a little due to augmentation in the number of animals.

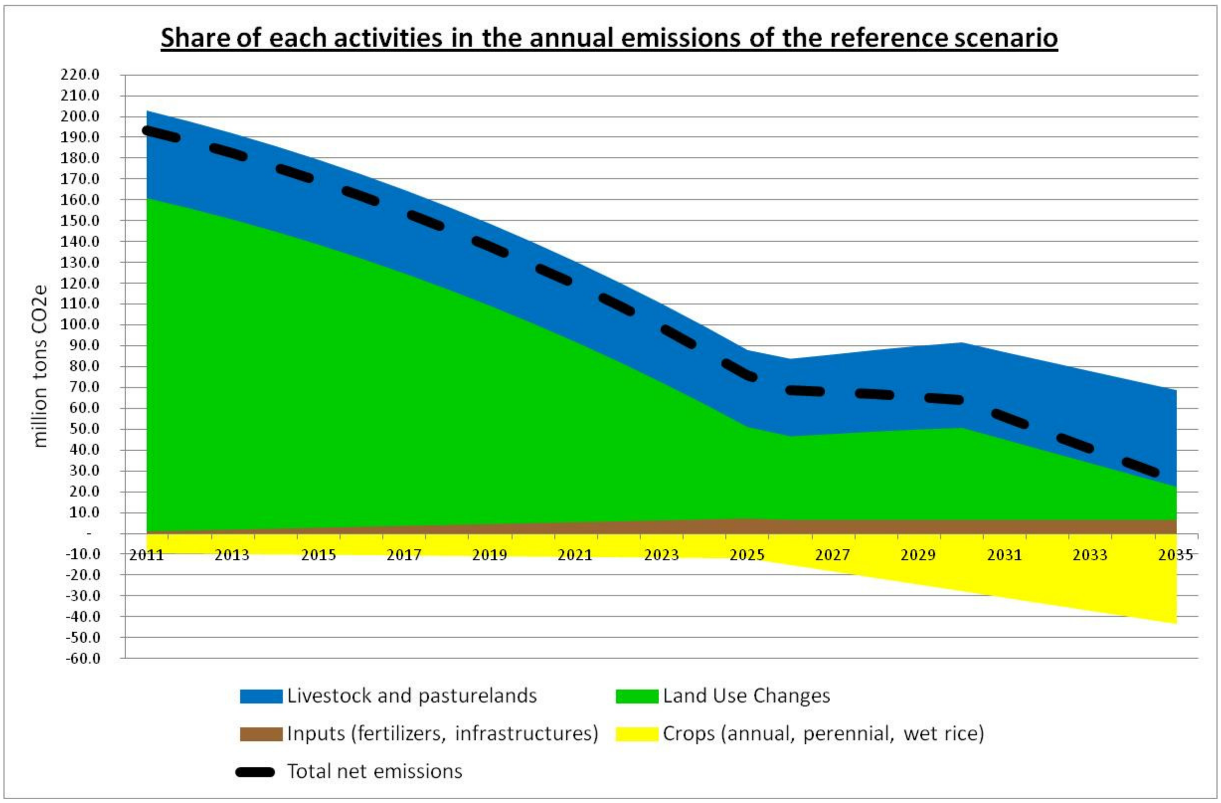
---

[7] Which standardizes the contribution of each GHG, according to its Global Warming Power (GWP) – 1 for the carbon dioxide, 21 for the methane and 310 for the nitrous oxide.

The net sink function of crops is enhanced over time as a result of both the increase in the area of perennials and of improvements in agronomic practices for annual crops (e.g. use of improved seeds and water management for the irrigated surfaces). Carbon storage increases after 2025 because residue burning in annual and perennial croplands is halted by that point. Wet rice remains a net GHG source, but its emissions are exceeded by the sink function of annuals and perennials.

Emissions from inputs and infrastructure increase, reflecting government plans to expand the use of fertilizers. However, they contribute to a limited part (4%) of total GHG emissions.

Figure 7: Evolution of the annual emissions in the reference scenario, from 2010 to 2035



Chapter 3 The Low Carbon scenarios

3.1 Introduction to mitigation options

The low carbon scenarios pursue the same development goals as the reference scenario, i.e. a roughly 6- fold increase in the overall productivity of the agricultural sector by the end of the model period, but include additional investments aimed specifically at reducing the net GHG emissions from the sector. These mitigation options are composed of available and proven sustainable land management (SLM) practices. According to TerrAfrica (2005), SLM is the "*adoption of land systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources*".

SLM options occur in agricultural, livestock and forestry, and may be interlinked:

- Conservation agriculture aims at increasing yields environmental benefits through improved management of soil and water resources. The key agronomic practices included are crop rotation / inter-cropping, minimal turning of the soil (minimum or no tillage) and maintaining soil cover through cover cropping and/or mulching. However, the availability of mulch material (from e.g. crop residues, cut vegetation, manure, compost, byproducts of agro-based industries) is typically lower in semi-arid regions (Kayombo and Lal, 1993), which cover a significant part of Nigeria.
- Conservation agriculture could facilitate another major mitigation option – avoiding deforestation – as increased yield should reduce the need to convert additional forest areas to crop land (for the same overall production targets[8]).
- Agroforestry refers to land use systems in which woody perennials are integrated with crops and/or animals on the same land management unit (SWCS, 2008), including agro-silvicultural systems (intercropping, alley cropping), silvo-pastoral systems (fodder banks, live fences, trees and shrubs on pasture), and inter-mixtures. Agroforestry may also contribute to conservation agriculture by providing mulch.
- Methane emissions from rice paddy can be reduced by adopting Sustainable Rice Intensification (SRI) practices, which involves modifying the growing environment so that the rice plants can grow better with more economical use of inputs. For instance, instead of flooding the rice, seedlings are planted in dry soils that are watered periodically. Seedlings are also spaced more widely, to allow for regular soil aeration and weeding as the plants develop.
- Livestock emissions from enteric fermentation and manure can be reduced by adopting better feeding and breeding practices, and can even be compensated by sequestering carbon in the biomass and soil of pasturelands. Improved rangeland management may involve rotational grazing, reduction of fire use, application of fertilizers and/or manure, irrigation, improved grass varieties, association with legumes, etc. Sustainable rangeland management should also result in lower stocking densities.

Implementation of different SLM options involves different public and private costs. Public costs are incurred through provision of government support for each option, in the form of e.g., provision of improved seed, subsidies for fertilizers or feed, extension services, and administrative / management costs. Farmers or private land owners incur costs for e.g. labor, and producing/purchasing fertilizer, feed and fuel, but also benefit from the incomes accruing from

[8] Conservation agriculture also tends to be more labor-intensive for a given area of cropping.

increased production. Table 8 summarizes different SLM technologies, appropriate for Nigeria, which have been used to formulate the low carbon scenario, including information on public costs and private costs/benefits that will be used in the models. Mitigation options included in the low carbon scenario presents the same technologies in more details, including information on the assumptions behind the calculation of costs in Table 20.

Table 8: List of the mitigation options adopted within the low carbon scenario

Description	Dynamic of adoption and year lag	Potential yield increase	Potential carbon benefits	Public Costs $/ha/yr	Private costs and benefits $/ha/yr (negative = benefit)	Key constraints
SLM practice: Protection of existing forests – avoiding deforestation						
The forest is preserved	Gradual adoption rate (geometric) No year lag, because it is vital to start right now taking actions to preserve the remaining forest and biodiversity it shelters.		Depends on the type of forest, its density and the use after conversion From 0.75 to 4.25 t C/ha/yr for a Brazilian tropical forest	1st year: 1481 Years 2 to 4: 600 Following years: 0 Cost to protect the forest (physical and policy/management protection), plus an opportunity cost the first year (non harvesting of timber)	During the whole period: 588 Opportunity cost for the non conversion of the forest into a more profitable land use Benefits: Non Timber Forest Product (NTPF), i.e. fauna and flora	Often the sole option to preserve forested area is to intensify agricultural production on other land Need to find and provide more affordable fuel efficient stoves or sustainable alternative fuels to decrease the pressure on wood resources Timber can be for some countries an important exports' revenue that they might not want to loose Sustainable forest management is effective if designed on a participatory basis.
SLM practice: Conservation agriculture						
Minimum or no-tillage **Mulching** **Crop rotation integrating leguminous and crop association**	Gradual adoption rate (geometric) Conservation agriculture is one of the most important LC option, and must therefore be implemented rapidly. Our suggestion is to begin 2 years after the actions on deforestation.	Yields can be more than 60% higher than under conventional tillage Conservation agriculture with fertilization increases the yield from 1.2 to 2 t/ha for maize and from 0.5–0.7 to 1.1 t/ha for tef in Ethiopia (an annual grass crop harvested for grain)	Conservation tillage can sequester between 0.1 and 1.3 t C/ha/yr globally	years 1 to 3: 71 Following years: 21 It includes the public subsidies for seeds and fertilizers, which stops after 3 years, as well as the cost of extension services and the transaction expenses	1st year: 71 Years 2 to 3: -234 Following years: -218 The cost for producing the manure and purchasing the fertilizers is compensated by the	Farmers need training and access to skilled advisory services Transition period (5- 7 yrs) before conservation agriculture reaches equilibrium Reduced tillage means having recourse to herbicides (farmers must be educated in correct use) or adopt integrated pest

Description	Dynamic of adoption and year lag	Potential yield increase	Potential carbon benefits	Public Costs $/ha/yr	Private costs and benefits $/ha/yr (negative = benefit)	Key constraints
					80% increase in yield.	management (crop rotation, cover crop, cultural practices)[9] Not successful in heavy clay soils, poorly drained sites, compacted soils, and arid areas
SLM practice: Agroforestry						
Establishing stands of trees on land not currently classified as forest **Includes shelterbelts, windbreaks and woodlots**	Gradual adoption rate (geometric) Agroforestry should begin at the same time as conservation agriculture, as they are linked and work in synergy. The year-lag is therefore 2 years.	Growth rate depends on the type of plantation, as well as its density The crop yield response is uncertain and variable due to competitive effects of the different cultures for light, water, nutrients. Different studies show an increase by 50 to 200%, others no significant effect	From 0.86 to 3.75 t C/ha/yr for a Brazilian tropical plantation	1st year: 166 Years 2 to 5: 300 Following years: 0 The government pays 25% of the plantation (livefencing, hedges, ...) cost, and the protection costs	1st year: 906 2sd year: 357 3rd year: 280 Following years: -318 The first years, the farmer has the bear 75% of the plantation cost. During the whole period, we take into account the maintenance cost of the livefences and the opportunity cost (because trees are planted on cropland and grassland surfaces). But the NTPF from the hedges (fodder,	In drylands, planting of trees is difficult due to lack of water for nurseries in the dry season and absence of labor for protecting the trees Uncertain land tenure situations Land availability, i.e. high population density and competition for land between agriculture and forestry Ongoing need for protection, as with natural forest Long period to grow industrial tree crops to merchantable size Risks of fungal or insect diseases

[9] World Bank, 2002, No-Till Farming for Sustainable Rural Development, p.30

Description	Dynamic of adoption and year lag	Potential yield increase	Potential carbon benefits	Public Costs $/ha/yr	Private costs and benefits $/ha/yr (negative = benefit)	Key constraints
					wood) and the 50% increase in the yield of adjacent crops largely compensate the expenses.	
SLM practice: Sustainable Rice Intensification (SRI) (flooded rice)						
Rotational and intermittent irrigation **Use of genetically improved seeds that are transplanted instead of broadcasted** **Application of organic fertilizers** **Integrated Pest Management**	Gradual adoption rate (geometric) SRI is another important mitigation option, but maybe less important than conservation agriculture and deforestation, since less surfaces are concerned. We would therefore recommend to start SRI just after conservation agriculture, so on year 3	Average yield increase by 10-25%	Emission rates ranged from less than 100 kg CH4 ha-1 to more than 400 kg CH4 ha-1 for intermittent irrigation and continuous flooding respectively	years 1 to 5: 42 Following years: 16 Subsidies for improved seeds, plus transaction and extension services costs	1st year: 296 2sd year: 36 Following years: -64 Takes into account time for coordination, manure production, and an increase by 25% in the yield	Due to great diversity in rice production systems, SRI will not be applicable invariably everywhere SRI requires excellent land preparation, timely availability of irrigation water during critical periods of growth, good irrigation infrastructure, and efficient methods of weed control SRI is mainly suitable for increasing rice yields in environments with acid, Fe-rich soils, high labor availability, and a generally low level of crop intensification
SLM practice: Sustainable grazing management (SGM) with inputs (gathered in the livestock and pastureland improvement category)						
Restoration of degraded pastures with inputs such as mineral fertilizers, manure application, irrigation **No use of fire**	Gradual adoption rate (geometric) Livestock and grassland management are linked, these three options should be implemented at the same time, after leaving about 3 years between the start of conservation agriculture and grassland	Increase varies depending on the type and quantity of improvements Herbage production can be increased by 1- to 4-fold through timing and intensity of grazing	Rates of carbon sequestration by type of improvement: 0.11 to 3.04 t C·ha−1 yr−1, with a mean of 0.54 t C·ha−1·yr−1 (highly influenced by biome type and climate)	years 1 to 3: 35 Year 4 to 5: 15 Following years: 2 Subsidies for fertilizers (during 3 years), for seeds (during 5 years), and	years 1 to 3: 80 Following years: 96 The small pastoralist gain does not cover the costs of fertilizers	Requires community organization for limiting overgrazing Investments the first years in fertilizers and irrigation systems

Description	Dynamic of adoption and year lag	Potential yield increase	Potential carbon benefits	Public Costs $/ha/yr	Private costs and benefits $/ha/yr (negative = benefit)	Key constraints
	improvements (so the farmers have time to integrate conservation agriculture practices and start having increased revenues before implementing other measures)			extension services and transaction costs		
SLM practice: Sustainable grazing management (SGM) without inputs (gathered in the livestock and pastureland improvement category)						
Restoration of degraded pastures without inputs, through the use of improved grass variety and rotational grassing **No use of fire**	Gradual adoption rate (geometric) 5 year-lag	Increase varies depending on the type and quantity of improvements	From 0.2 to 0.4 t C/ha/yr (improved species, controlled grazing, fire management)	whole period: 2 Transaction and extension service cost	whole period: 0.1 Small increase in the yield by the reduction of fire use (in the reference scenario, pastures are also improved without inputs, but fire is heavily used)	Need to develop grazing plans tailored to specific local conditions → participative approaches
SLM practice: Livestock management (cattle, sheep, goats) (gathered in the livestock and pastureland improvement category)						
Better feeding practices **Breeding management to select improved and more efficient animals** **Limitation of the number of livestock**	Gradual adoption rate (geometric) 5 year lag as for sustainable grazing	Increase in meat and milk production per animal	Possible decreases in GHG production per unit of livestock product about 1% per year Methane production can be reduced by 10% - 40%	year 1 to 3: 21 Following years: 0.2 Subsidies for prophylaxis and feed during 3 years, plus transaction and extension services costs	year 1 to 3: 26 Following years: 10 The costs of feed and prophylaxis are covered by the33% increase in animal yield	Techniques are often out of reach for smallholder livestock producers who lack the capital and often knowledge to implement such changes Less animals reduce the amount of manure available to fertilize the crops → may lead to the use of chemical fertilizers

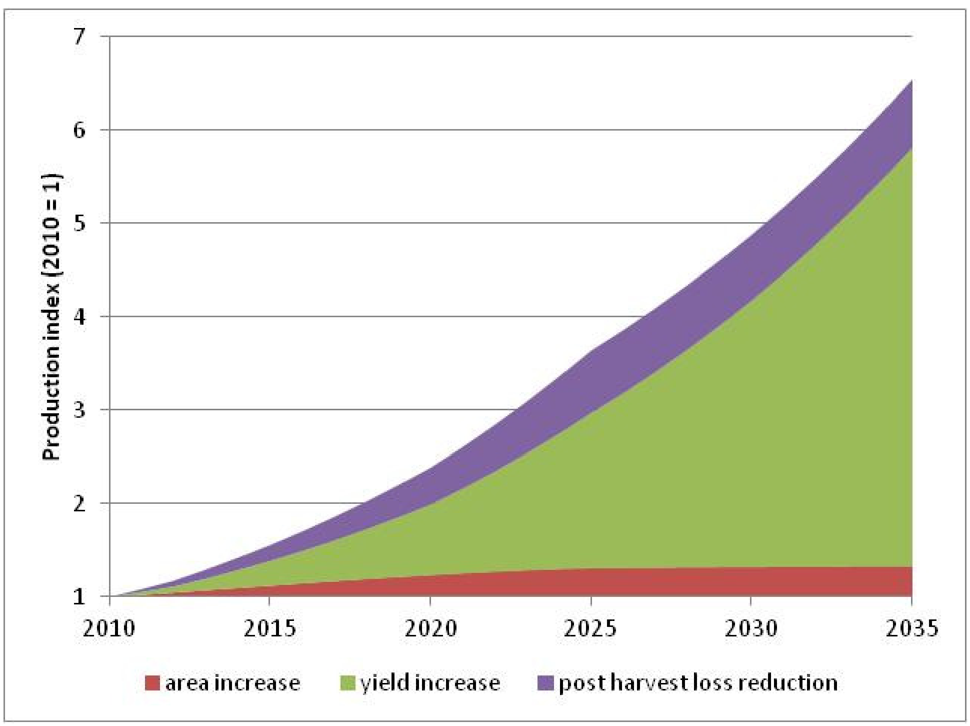
3.2 Adjusted agricultural growth model

The agricultural growth model was adjusted to assess whether it was feasible for crop expansion to decrease to 0% by 2025, whilst still reaching the same sector production targets, given the higher yields expected from the introduction of SLM technologies. Reduction of post harvest loss remains the same as in the reference scenario. Annual yield growth is expected be a little higher than in the reference scenario, but numerous studies indicate that the increase in yield from SLM may take a little time to become noticeable. Therefore, the increase in annual growth yield is estimated to be the same as in the reference scenario for the first 5 years, then one point higher than the reference scenario for the following 5 years and 2 points higher the next 5 years. This gives an annual compound growth rate close to 5.1%. After the implementation phase, 2025 and beyond, yield growth remains stable, at the same rate of 2025. This results in total production growth during the model period that is somewhat higher than that of the reference scenario.

Table 9: Agricultural growth model of the low carbon scenario in comparison to baseline

Source of growth	2010-2025		2026-2035	
	Reference	Low Carbon	Reference	Low Carbon
Area increase	1.56%	1.24%	0.79%	0.00%
Post harvest loss reduction	2.48%	2.48%	0.03%	0.03%
Yield increase	4.07%	5.07%	4.00%	6.00%
Total Production Growth	8.30%	9.00%	4.86%	6.04%

Figure 8: Low Carbon scenario: total production increase and sources of growth over time



3.3 Emissions models under two low carbon scenarios

3.3.1 Low carbon scenarios

Introduction of SLM technologies is assumed to be an accelerating process (due to some of the initial implementation lags discussed in table 8), but also subject to a technical constraint, whereby no more than 800 000 ha/year on average can be brought under new SLM technologies[10][11]. Subject to this constraint, two scenarios were explored:

A. Resources available to support the introduction of SLM technologies are targeted so as to maximize the total mitigation potential.
B. Resources available to support the introduction of SLM technologies are targeted so as to maximize profitability (i.e. net present value, NPV, of private investment) for farmers, according to the cost / benefit estimates given in Table 8.

In order to provide for a minimally balanced mix of mitigation options, additional constraints were added on the minimum rate of adoption for each SLM technology, in line with their anticipated intrinsic appeal to farmers. These minimum rates of uptake by 2025 are:

- conservation agriculture – 13% of annual cropland area;
- SRI – 3% of total rice area;
- avoided deforestation – 5% of secondary degraded forest partly with constraints;
- agro-forestry – 3% of annual cropland area[12];
- improved pasture management – 2% of existing pasturelands;
- improved livestock management – 51% (i.e. 1% more than the 50% already included under the reference scenario).

The two different scenarios impact choices between available mitigation measures, but not the total land area subject to introduction of SLM technologies.

3.3.2 Land use and other mitigation factors

In accordance with the revised growth model, the expansion of agricultural land is reduced under both low carbon scenarios in comparison with the reference scenario, as an increased proportion of the least suitable secondary forest is not converted to agriculture.

Under scenario B, SLM options selected favor profitability to the farmer over maximum GHG abatement potential. As conservation agriculture provides the largest private returns, it accounts for 82% of the 800,000 ha/yr area subject to new SLM technologies, resulting in 24% of the annual cropland being managed under conservation agriculture practices, compared to only 13% under scenario A (Figure 9). Other SLM technologies are only adopted at their minimum rates under scenario B.

Scenario A favors high mitigation land uses, but the available area of avoided deforestation is limited to no more than that also involved in scenario B. Hence SLM investments under scenario A focus on agroforestry, with a little SRI. Other SLM technologies are introduced according to their assumed minima, although that still involves a considerable are of conservation agriculture.

---

[10] At an average farm size of 2 ha, this is equivalent to roughly 400 000 rural families adopting SLM options annually. This is ambitious, but not in comparison with the scale of sector reforms already needed to address the Vision 20:2020productivity goals.

[11] Another scenario was also explored in which a realistic budget constraint was applied, but the technical constraint was still found to be limiting.

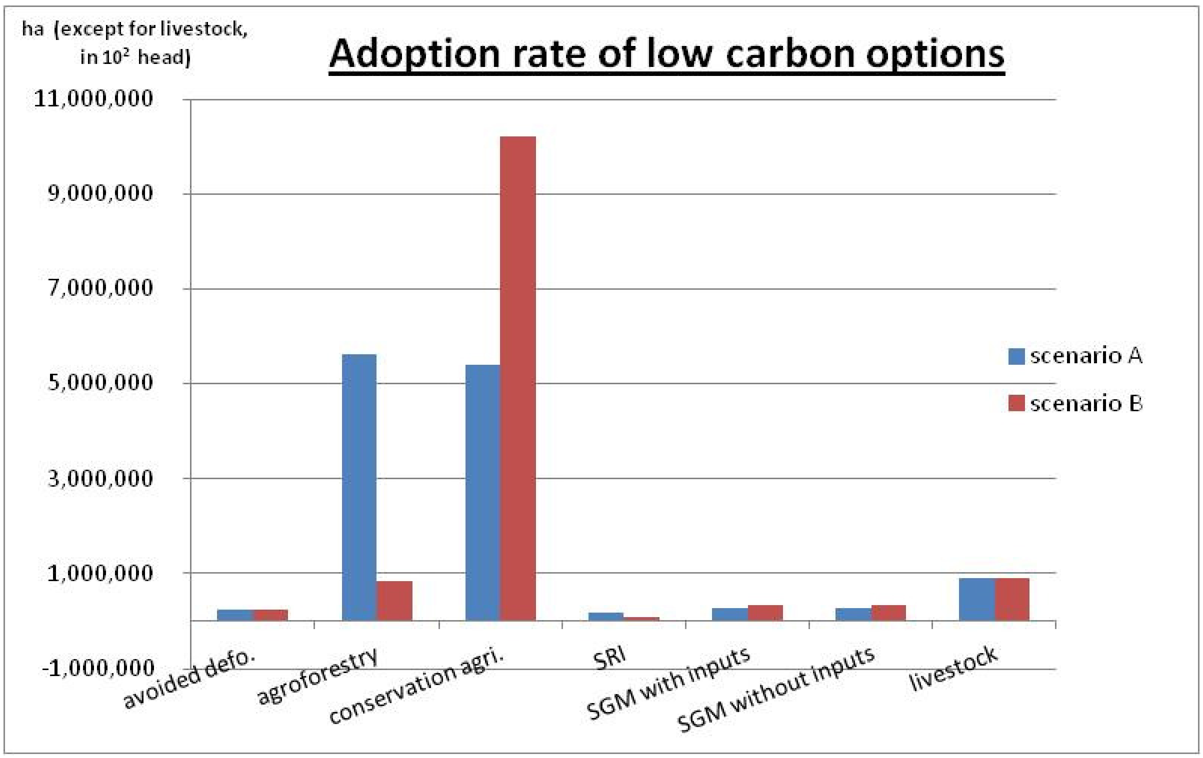
[12] A 3:1 ratio is also assumed for the introduction of live fences on annual cropland and pasturelands, respectively

The greater emphasis on agroforestry under scenario A, results in changes to the final ratio of agroforestry area to grassland area in comparison with scenario B. Largely due to the investment in agroforestry[13], scenario A ends with over 4 times the area of secondary forest and live fences than the reference scenario, and almost 2 times that of scenario B.

Table 10 below and

Figure 10 show the evolution of land use between 2010 and 2035, for the reference scenario and the two low carbon simulations. The cropland area remains the same under both scenarios. Further details **on the two low carbon scenarios A and B** presents the land use change matrix for the different low carbon scenarios.

Figure 9: Number of hectares managed under the designated SLM practice



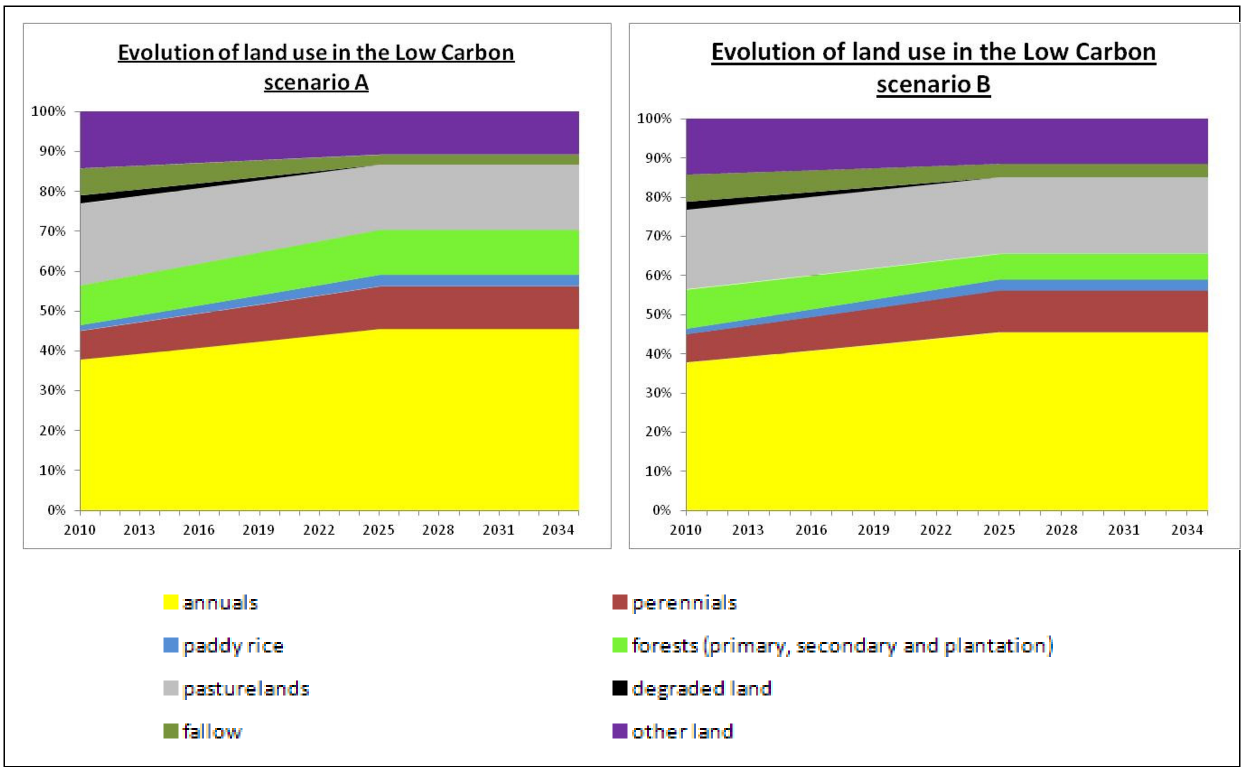
---

[13] Note also that agroforestry investments provide for significant increases in productivity of the surrounding agricultural land. This largely compensates for the foregone yield increases that could otherwise have been achieved through additional investment in conservation agriculture, such that the sector-wide agricultural yield increase for both scenarios A & B are roughly equivalent, and in line with the modified growth model for the low carbon options.

Table 10: Land uses in 2010 and 2025/2035 for the low carbon scenarios in comparison to the baseline (in 000 ha)

Land use	2010	2025/2035		
		Baseline	Low carbon scenario A	Low carbon scenario B
Annuals	34,437	46,155	41,432	41,432
Perennials	6,552	12,419	9,721	9,721
Wet rice	1,313	2,919	2,625	2,625
Forests	9,101	2,700	10,301	5,929
Secondary forests	*8,805*	*1,804*	*3,790*	*3,790*
Plantations	*296*	*896*	*896*	*896*
Live fencing/agroforestry	*0*	*0*	*5,615*	*1,243*
Pasturelands	18,629	15,669	14,882	17,779
Degraded lands	1,849	0	0	0
Fallows	6,234	2,076	2,290	3,110
Other lands	12,941	9,116	9,803	10,459
TOTAL	91,054	91,054	91,054	91,054

Figure 10: Evolution of the land use from 2010 to 2035 in the low carbon scenarios



Other land use changes (such as expansion of perennial crops and paddy, and restoration of degraded land) remain the same as the reference scenario, as do other emissions model parameters (such as soil and climate characteristics, construction of new infrastructure, and introduction of technologies and improvements already included under the reference scenario). However, it is assumed that 75% of the existing perennial cropland will stop burning practices by 2025, as opposed to 50% in the reference scenario. Also there are some differences in the amounts of inputs and energy used in line with changes in cropland areas and extent of application of improved agronomic techniques.

3.4 Results of the low carbon scenarios

3.4.1 Mitigation potential

Total emissions accumulated over the model period remain positive under both low carbon scenarios. Total mitigation potentials in comparison to the reference scenario are summarized in Table 11. Further details **on the two low carbon scenarios A and B** presents the gross GHG emissions for the different low carbon simulations.

Both low carbon scenarios present a significant mitigation potential, respectively of 1.0 and 0.6 billion t CO2-e during the 25 years of appraisal.

In scenario A, various land use changes, including reduced net deforestation, agroforestry and non forest land use change, accounts for 77% of emissions reduction. In scenario B, the total mitigation potential is a little over half that of A, and contributions are more evenly spread across emissions classes, particularly from a much greater contribution from croplands to carbon sinks as conservation agriculture techniques increase soil and above-ground carbon level. In both LC scenarios, the increase use of fertilizers emits more GHG than in the reference scenario, but it is really negligible compare to the reduction of other emissions. Energy and fuel consumption decreases a little compared to the reference scenario since less areas are tilled (less annuals surfaces and more surfaces under conservation agriculture).

Table 12 and Figure 11 below illustrate the contribution of each sub-sector to the mitigation potential of the different LC scenarios. A negative figure indicates higher emissions compare to the reference scenario.

Table 11: Main results for the four low carbon simulations

Scenario	A	B
Emissions for the whole 25 year-period, in Mt CO_2-eq	1687	2017
Total mitigation potential, in t CO_2-eq	976	646
Average mitigation potential, in t CO_2-eq/ha/year	0.4	0.3
Public expenses during 20 years (gross / NPV), in M$	10 211 / 3 207	6 983 / 2 228
Private revenues during 25 years (gross / NPV), in M$	41 024 / 5 699	44 278 / 7 277

Table 12: Mitigation potential of various activities

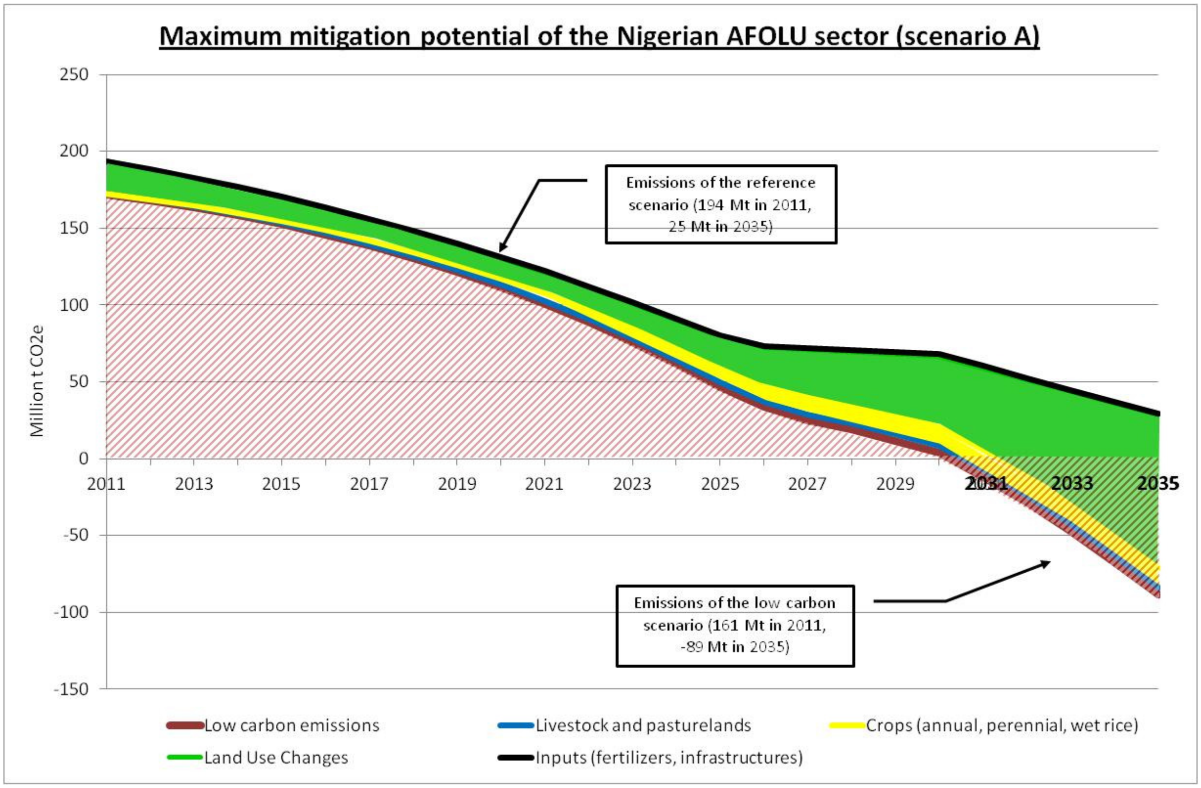
Activities	Scenario A mitigation			Scenario B mitigation		
	in Mt CO_2-eq	in Mt CO_2-eq/ha		in Mt CO_2-eq	in Mt CO_2-eq/ha	
Avoided Deforestation	207	833[14]	18%	207	830	30%
Afforestation and agroforestry (livefences)	712	126[15]	61%	158	126	22%
Non Forest Land Use Change	-142	-11[16]	/	-13	-1	/
Annual Crops	124	3[17]	11%	222	5	32%
Perennial Crops	46	6 [11]	4%	46	6	7%
Wet Rice	7	3[11]	1%	3	1	0%
Grassland	34	2[11]	3%	34	2	5%
Livestock	28	0.[18]	2%	28	0	4%
Inputs	-39	-1[19]	/	-39	-1	/
Other Investment	2	0[20]	0%	2	0	0%
TOTAL	**976**	**6.8[21]**		**646**	**4.6**	

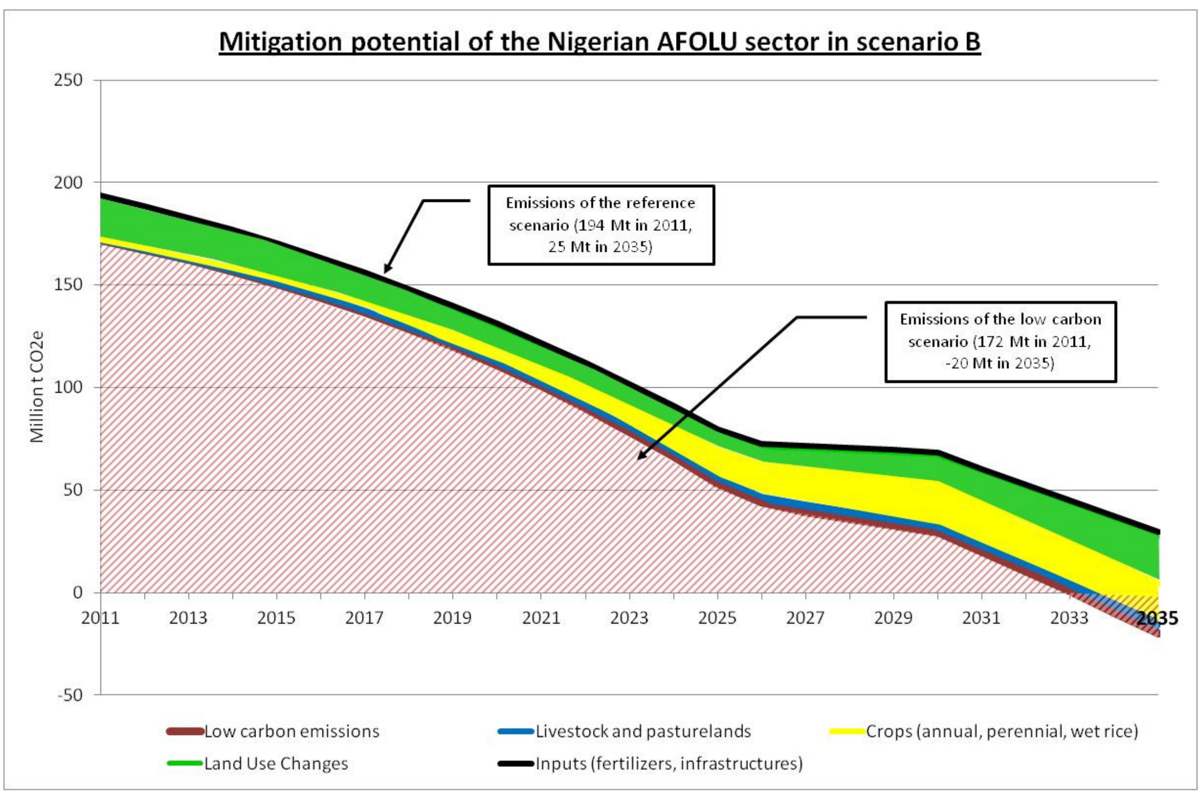
On a per hectare basis, there are some differences in mitigation potential from different activities between two scenarios:

- Annual crops sequester more C per ha under scenario B, because a higher proportion is subject to conservation agriculture.
- Grasslands sequester more C per ha under scenario A because the total extent of grasslands is lower, and therefore a higher proportion is subject to sustainable rangeland management.

[14] Calculated based on the surface non deforested
[15] Calculated based on the hectares planted
[16] Calculated based on the hectares changing land use
[17] Calculated based on the total annual/ perennial/rice/grassland surface
[18] Calculated based on the total number of heads
[19] Calculated based on the surface fertilized
[20] Calculated based on the tilled surface; even if there are more areas under conservation agriculture (no-tillage), the assumption is that 50% of the total annuals surfaces will be tilled, as in the reference scenario. Or the adoption rate of conservation agriculture in lower than 50%, so this activity emits the same amount of GHG for scenarios A/B/D and C
[21] Calculated based on the total hectares effectively concerned by a change, and not on the whole area of Nigeria

Figure 11: Agricultural mitigation potential by sub-sector for the different low carbon scenarios





3.4.2 Marginal abatement costs

The marginal abatement cost (MAC) is the net present value (calculated at a 10% discount rate) of cost of each mitigation option per unit of emissions reduction[22]. These were calculated separately for public and private costs in order to construct marginal abatement cost curves (MACCs) to visualize the cost-effectiveness of various mitigation options for government and for farmers. A MACC is a histogram that displays both the MAC (height of each bar), and the total mitigation potential (width of the bar) for each mitigation option. The bars are arranged in order of increasing unit cost along the x axis, so that the cheapest mitigation options intuitively considered first, and the total emissions abatement cost increase with the area under the curve as additional mitigation activities are undertaken.

Note, however, that:

i. Only monetary costs and revenues were included in the analysis – no account was taken of externalities, such as positive or negative environmental or social effects.
ii. Negative costs imply that a mitigation option is profitable in its own right – i.e. it would make financial sense to adopt it, even if there were no interest in reducing GHG emissions.
iii. The MACC should not be used to compare mitigation costs directly to current or projected carbon prices. For a valid comparison to be made, expected future carbon finance income would have to be discounted to its net present value.

The unit public costs to the federal Government of Nigeria for the various mitigation options are always positive and do not vary between the two low carbon scenarios, since government does not receive any direct revenue from agricultural production and there are no economies of scale included in the cost models for SLM support. However, the total mitigation available from each option varies with the adoption rate. Results are presented in Figure 12 and

[22] I.e.

$$MAC^{i} = \frac{NPV_{LC}^{i} - NPV_{ref}^{i}}{E_{ref}^{i} - E_{LC}^{i}}$$

Where

- MAC_i is the marginal abatement cost of the option i, expressed in \$/t CO2e
- NPV_{LC} is the Net Present Value of the technology i in the low carbon scenario, expressed in \$
- NPV_{ref} is the Net Present Value of the technology in the reference scenario, expressed in \$
- E_{ref} is the total GHG emissions with the technology in the reference scenario, expressed in tCO_2-eq
- E_{LC} is the total GHG emissions with the technology in the low carbon scenario, expressed in tCO_2-eq

Table 13.

Some specific SLM measure, such as conservation agriculture or agroforestry for example, have been included into a broader category to take into account the whole mitigation potential of the sub-category. Therefore, the following categories include:

- Annuals: conservation agriculture, no residue burning, higher fertilization on annual crops (in total, not per ha), reduced fuel consumption (in total, not per ha)
- Perennials: no residue burning, higher fertilization on perennial crops (in total, not per ha)
- Livestock and pasturelands improvement: pastures improved with and without inputs, reduced fire, livestock improvements
- Avoided deforestation: only the surfaces of forest not converted into another land use
- SRI: only rice
- Agroforestry and NFLUC: agroforestry and non forest land use changes, since the plantation of trees on grass and crops will have an impact on other lands (e.g. fallows have to be converted into crop to satisfy cropland expansion)

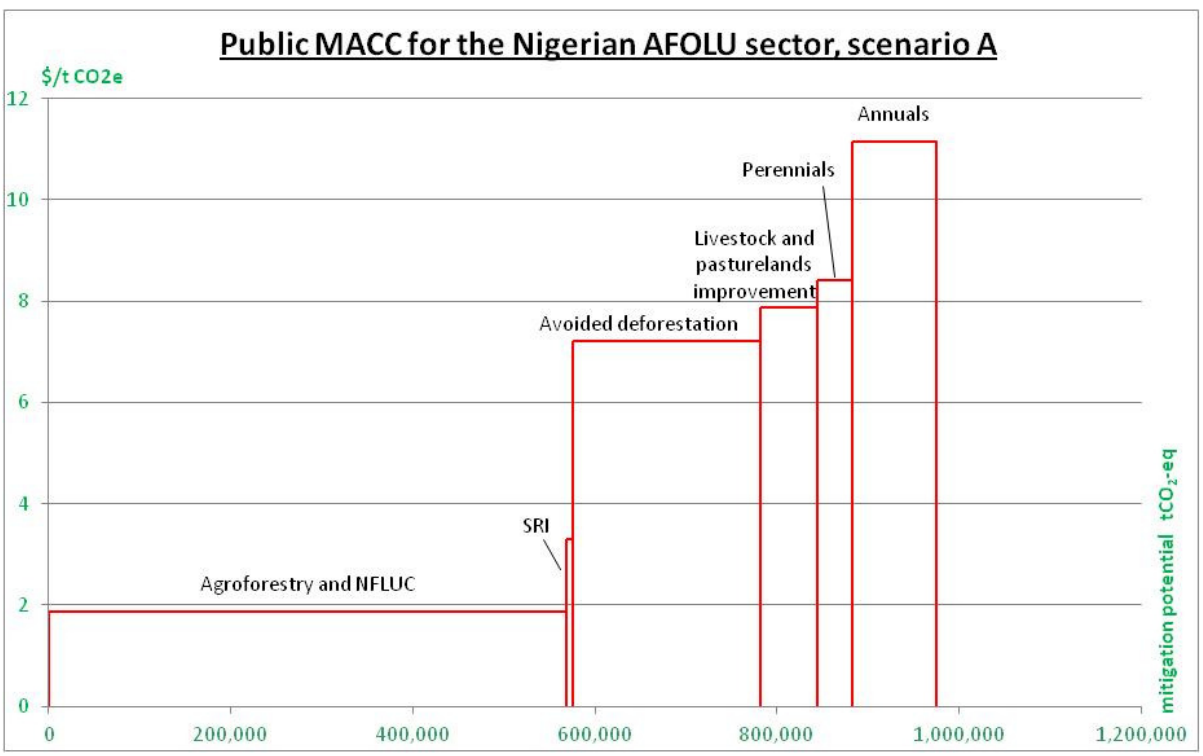
Between scenario A and B, the average hectare of perennial, rice, agroforestry, pastureland and protected forest is the same (or very slightly different), so the MAC are also identical. However, for annuals, the composition of an average hectare of annual differs: in scenario B, there is a higher proportion of conservation agriculture than in scenario A.

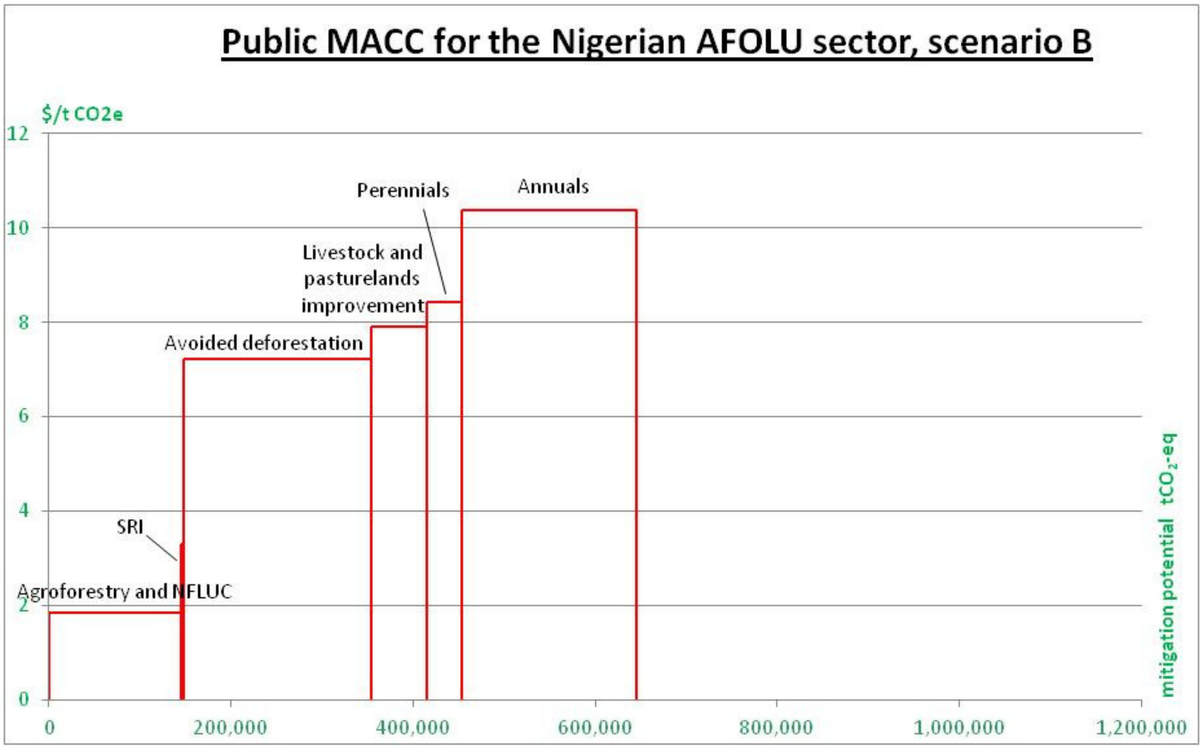
Table 13: Public cost per ton of CO_2-eq and mitigation potential of each SLM measure

Mitigation option	Mitigation potential in Mt CO2e for scenario A	Mitigation potential in Mt CO2e for scenario B	MAC in$/t CO2e Scenario A	MAC in$/t CO2e Scenario B
Agroforestry and NFLUC	569.4	144.7	1,86	
SRI	6.7	2.8	3,31	
Avoided deforestation	206.6	206.6	7,21	
Livestock and pasturelands improvement	61.6	61.5	7.87	7.91
Perennials	38.5	38.5	8.42	
Annuals	**93.2**	191.7	11.15	10.38
TOTAL	**975.9**	**645.8**		

Agroforestry and Sustainable Rice Intensification (SRI) are the most cost-effective mitigation options for government, whilst livestock/ pasturelands improvement, perennials as well as annuals are expensive to support. If Government were to support all mitigation options, the total cost (in cash flow terms) would be about US$10 billion in scenario A and US$ 7 billion in scenario B, at an average cost of 10 $/t CO_2-eq (in cash flow terms).

Figure 12: Marginal Abatement Cost of the different SLM practices for the government





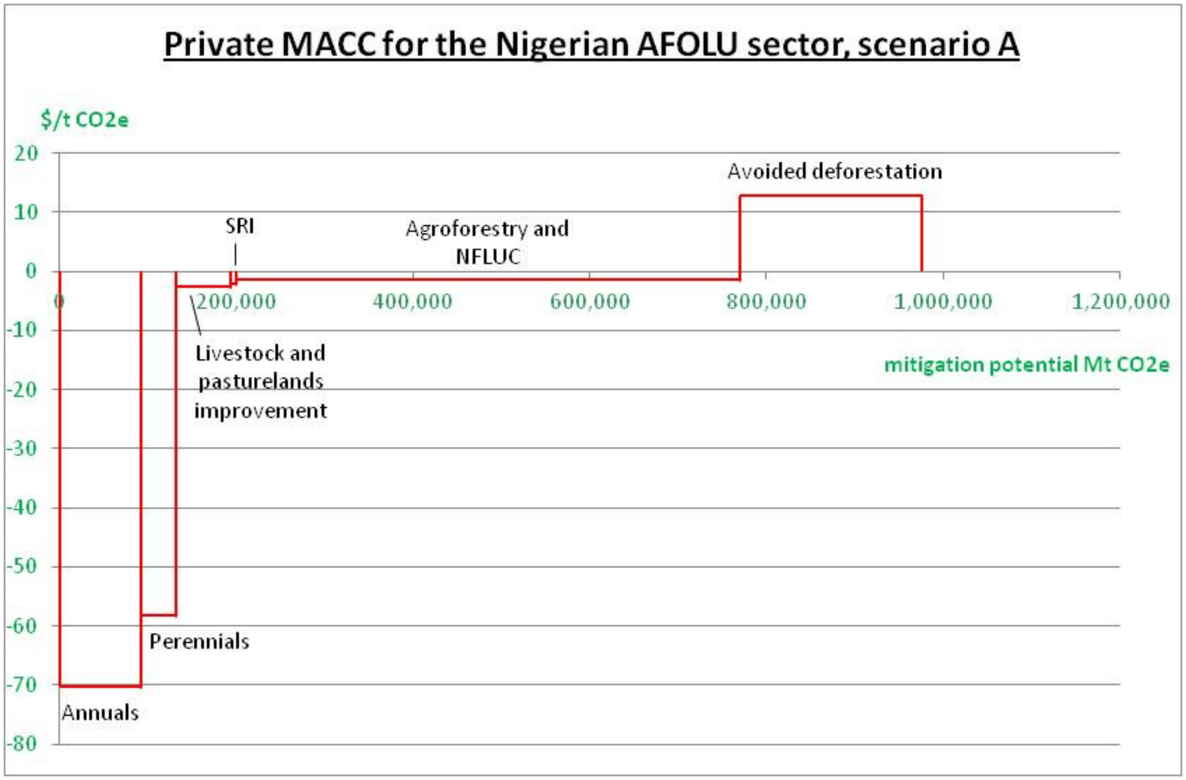
Farmers' net costs depend on the expenses on additional inputs (fertilizer, feed, fuel, labor, etc.) in comparison to the gain from higher yields. Negative costs shown in Table 14 and Figure 13 indicate that several mitigation options are intrinsically beneficial to farmers. There are significant differences in the likely attractiveness of the various options to Government and farmers. Avoiding deforestation is not financially rewarding for farmers, because they would benefit from converting the forest into more productive lands, and agroforestry is only marginally profitable (due to high implementation costs, which offset the significant downstream yield increases), despite these options offering the greatest mitigation potential per hectare and being most cost-effective for Government. Conservation agriculture (part of the annuals' category) is highly attractive to farmers, whilst offering relatively little mitigation potential per hectare, and being comparatively costly for Government to support. The same observation can be made for the perennial crops.

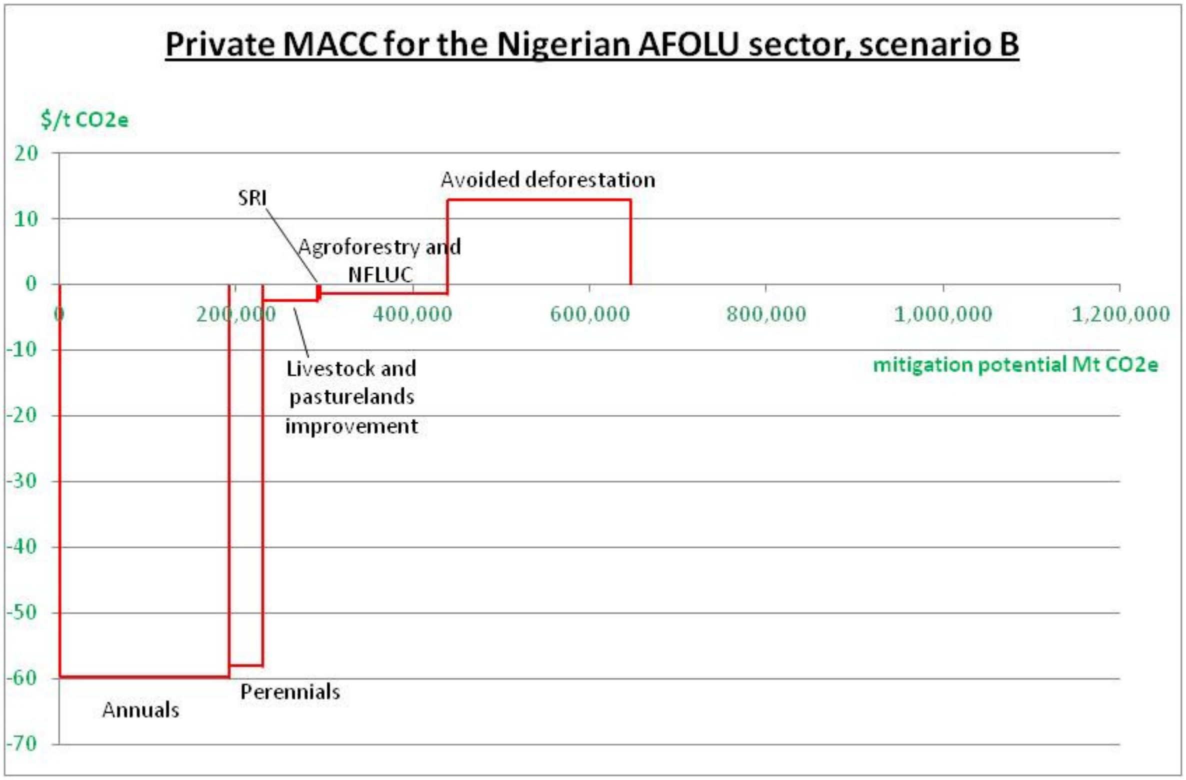
Table 14: Private cost per ton of CO_2-eq and mitigation potential of each SLM measure

Mitigation option	Mitigation potential in Mt CO2e for scenario A	Mitigation potential in Mt CO2e for scenario B	MAC in $/t CO2e Scenario A	MAC in $/t CO2e Scenario B
Annuals	93.2	191.7	-70.33	-56.76
Perennials	38.5	38.5	-58.18	
Livestock and pasturelands improvement	61.6	61.5	-2.49	-2.50
SRI	6.7	2.8	-2.04	

Agroforestry and NFLUC	569.4	144.7	-1.32
Avoided deforestation	206.6	206.6	12.82
TOTAL	**975.9**	**645.8**	

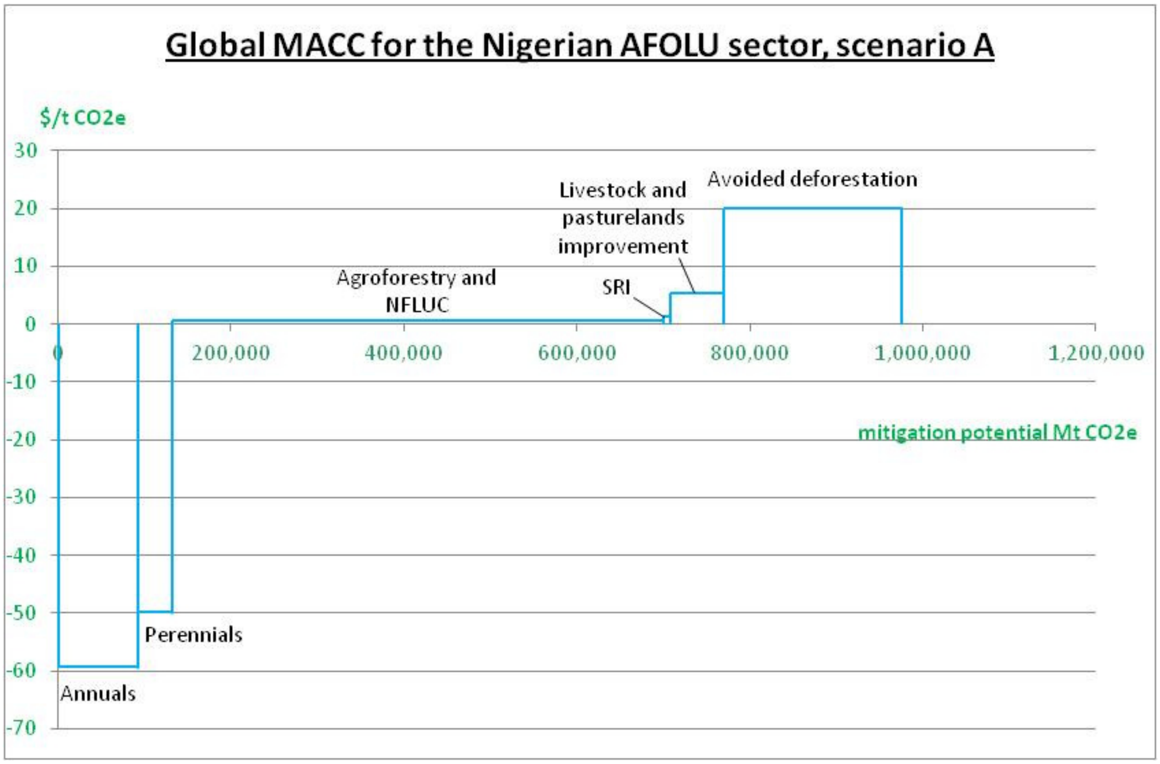
Figure 13: Marginal Abatement Cost of the different SLM practices for the farmers

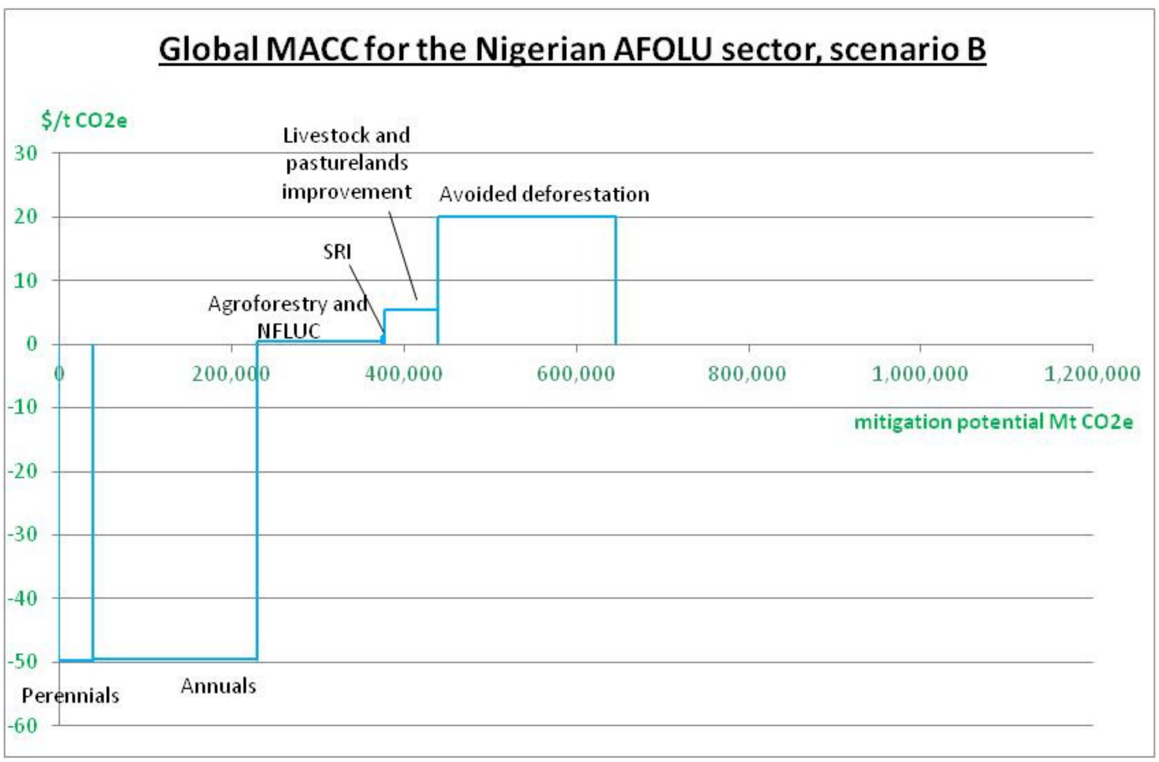




When public and private costs are combined, only two SLM measures, annuals (i.e. mainly conservation agriculture) and perennials (no residue burning), are profitable without any additional carbon revenues. Agroforestry presents a small cost of 0.5 $/t CO_2-eq, while avoiding deforestation is the most expensive option for the whole nation (20 $/t CO_2-eq).

Figure 14: Marginal Abatement Cost of the different SLM practices for the whole nation (public + private costs and benefits)





3.4.3 Incentivizing high mitigation through carbon payments

The NPV of the financial benefit to farmers from all the SLM measures introduced in scenario A is just over US$ 5 billion (see Table 11). Under scenario B, where private benefits are maximized, this increases to almost US$ 7 billion. However, the additional GHG emissions reductions generated under scenario A offer the possibility to use carbon payments to incentivize land owners / farmers to adopt more carbon-intensive land uses. In fact, a minimum carbon price of 6.1 \$/t CO_2-eq[23] paid to farmers would be sufficient to increase the private financial benefit of the land use choices under scenario A to the same level as that enjoyed under scenario B, effectively compensating farmers as whole for adopting SLM options with higher mitigation potential.

Figure 15 represents the private and global MACCs for scenario A with carbon payments to farmers of 6.1 \$/t CO_2-eq (the public MACC is the same as for the standard scenario A shown in Figure 12above). With carbon payments, annuals/conservation agriculture is still the most profitable option, but SRI and livestock/pasturelands improvement are significantly more attractive, and avoided deforestation is relatively more attractive, although still not financial rewarding in isolation. Hence carbon payments at this level are not sufficient to incentivize private decisions to take up all SLM option in accordance with scenario A, but could be used to compensate to the foregone income at the macro level. Therefore, if governments were able to control the distribution of carbon incomes, then they could potentially be used to selectively incentivize the most carbon intensive options, such as avoided deforestation and agroforestry, as a strategy to provide for a more balanced mix of SLM technologies, that would exploit the synergies between them[24], as well as the additional positive environmental externalities from maintaining increased forest cover[25].

It is worth noticing that at a global level, i.e. from a public and private point of view, only two options have a positive MAC; namely livestock/pasturelands and avoided deforestation, compare to four options without the addition of a carbon price.

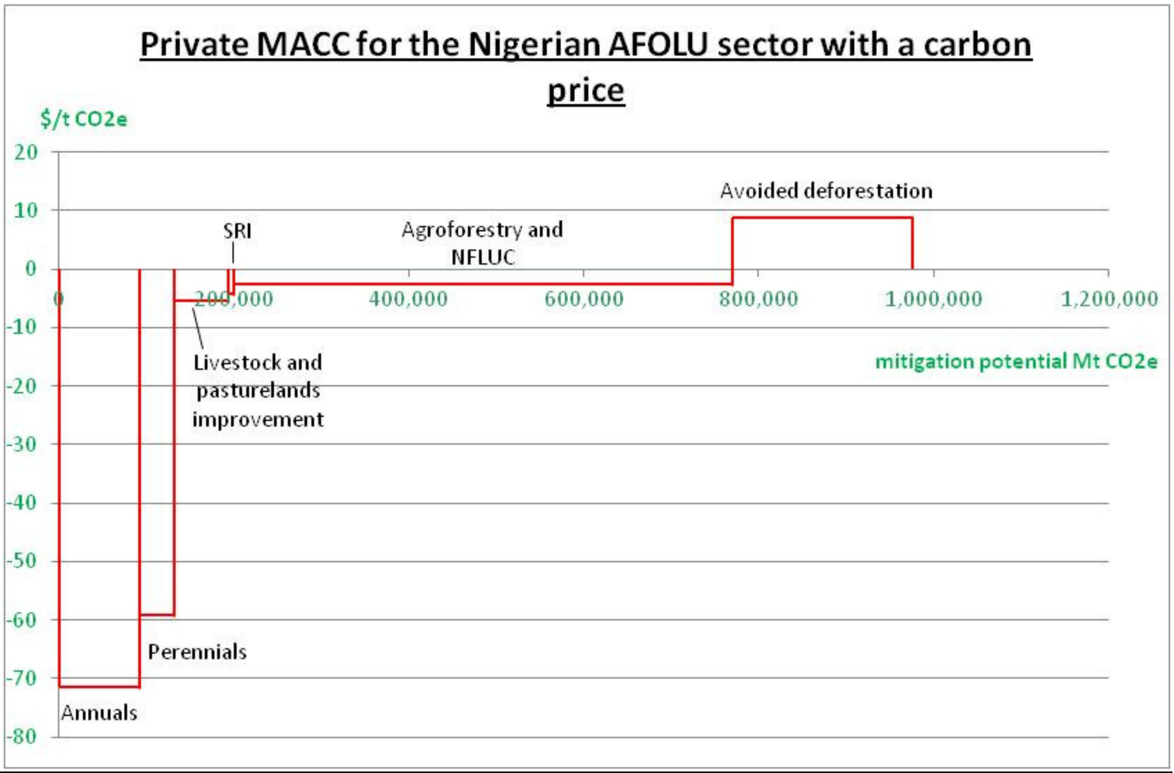
Table 15 summarizes the public and private MACs for each SLM option under various conditions.

[23] Note by contrast, that as of 2010, the average carbon price on the voluntary market was at a relatively low level of 6.0 \$/t CO_2-eq – data from Ecosystem Marketplace & Bloomberg New Energy Finance, 2011, Back to the future: state of the voluntary carbon markets 2011, http://www.forest-trends.org/documents/files/doc_2828.pdf. Future carbon prices will depend in part on the establishment of a post-Kyoto framework.

[24] E.g. agroforestry can facilitate conservation agriculture and improved livestock management through the provision of mulch materials and fodder.

[25] I.e. public goods such as maintenance of hydrological functions, which benefit local farmers and downstream water users, and provision of forest products.

Figure 15: Marginal Abatement Cost of the different SLM practices with the addition of a carbon revenue for the farmers



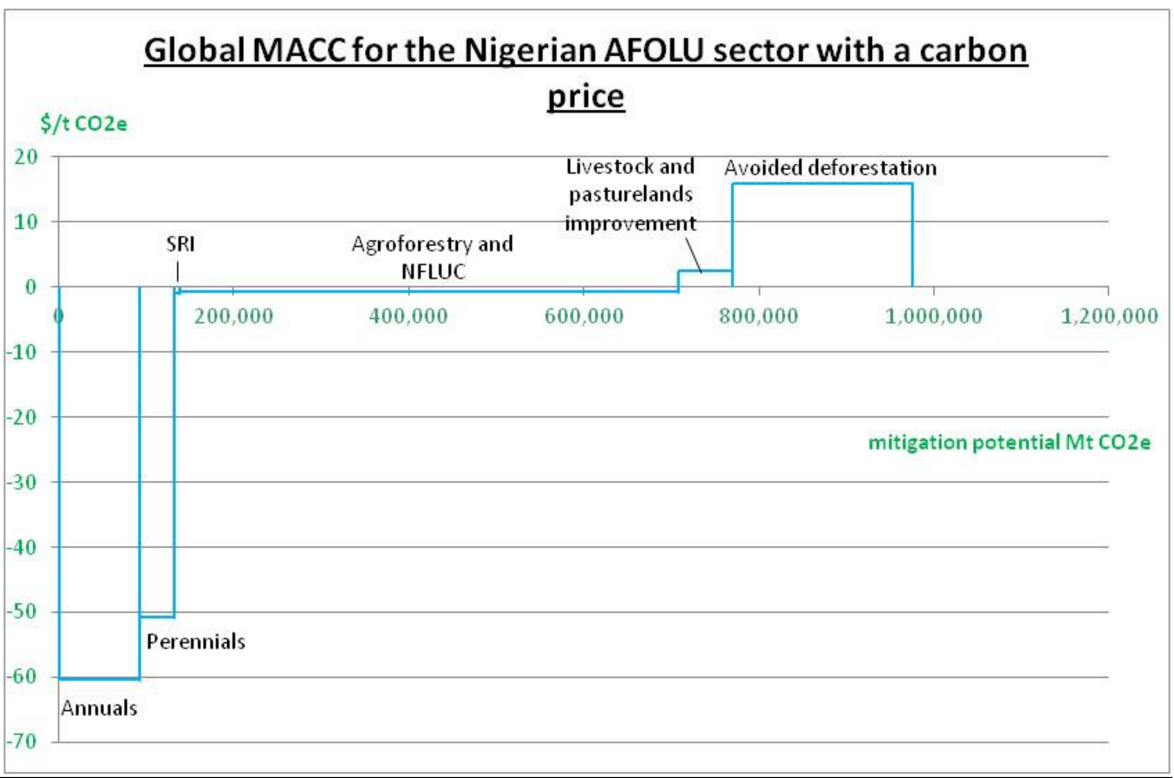


Table 15: Summary of the Marginal Abatement Cost of SLM measures, depending on the low carbon scenarios

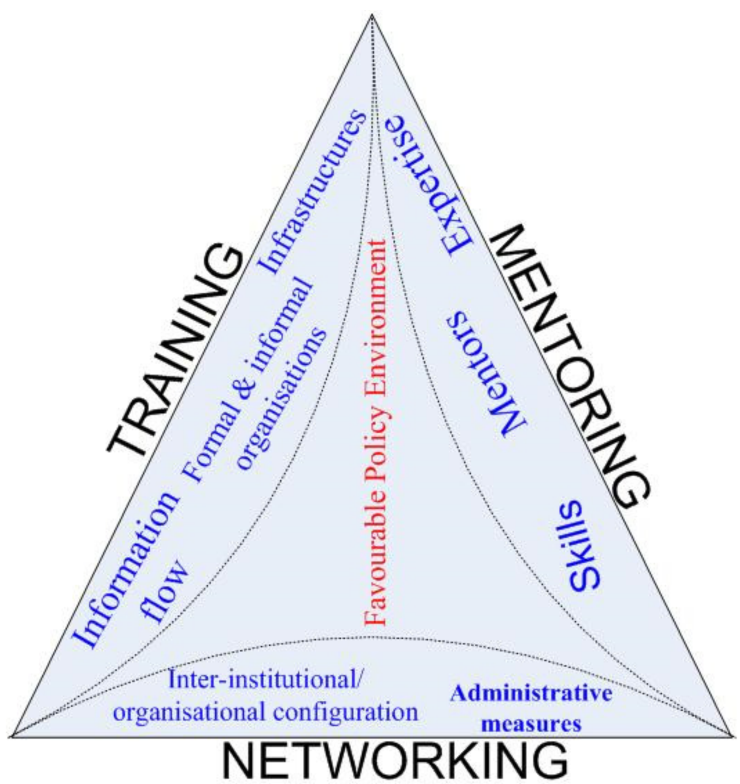
MAC, in \$/t CO_2-eq	Public MAC	Private MAC	
	Public	**Private**	**Private with carbon payment**
Annuals	For scenario A: 11.2 For scenario B: 10.4	For scenario A: -70.3 For scenario B: -56.8	-71.5
Perennials	8.4	-58.2	-59.2
Livestock and pasturelands improvement	7.9	-2.5	-5.3
SRI	3.3	-2.0	-4.2
Agroforestry and NFLUC	1.9	-1.3	-2.6
Avoided deforestation	7.2	12.8	8.7

Chapter 4 Recommendations for an effective implementation of a low carbon strategy in the Nigerian AFOLU sector

Despite the demonstrated benefits of SLM technologies, uptake is still often slow, even for those options which involve significant private financial returns. According to the FADAMA project, only 30% of farmers currently use manure, 4.6% compost and 3.4% mulching practices. Several practical obstacles hinder rapid adoption, including the need to convince and train risk-averse farmers in new ways of farming, and the frequent need for up-front investment that pay off over a number of years. Financial support, training and demonstrations are all necessary to encourage farmers to undergo the radical change in working and thinking needed to adopt new SLM techniques. A further practical issue with the low carbon scenarios is that they assume that higher productivity will offset expansion of cropland, whereas in reality increasing yields may increase the private incentives to convert more land to agriculture (with the risk that over-exploitation of land may eventually lead to declining output). Hence, agricultural intensification is unlikely to result in avoided deforestation unless it occurs within a strong policy framework. This chapter discusses some of the policy and institutional steps needed to realize the potential of SLM.

Building the capacities and the political framework to mainstream climate change in agriculture and forestry strategies is a complex and dynamic process, involving numerous stakeholders, from central to field level. Figure 16 provides a schematic of minimum necessary elements in Nigeria: (i) mentoring, i.e. research institutions identifying problems and solutions, (ii) training, which will bring to the field scientific knowledge and (iii) networking, i.e. creating a conductive policy environment with interactions between experts and actors.

Figure 16: A triadic model of capacity building



Source: Sanni et. al. 2010

4.1 Towards a network of Climate Smart Agriculture partners

Implementation of a low carbon policy within the agriculture and forestry sector will require mobilization of major public institutions, development partners, and federal, state and local level stakeholders, including banks, the private sector, legislators, nongovernmental organizations and other actors.

- Key institutions to be mobilized include: (i) Federal Ministry of Environment as the National designated Authority for Climate Change and Sustainable Development; (ii) the Federal Ministry of Agriculture and Water Resources (FMAWR) as the main coordinator; (iii) the River Basin Development Authorities (watershed management–reforestation); (iv) the Nigerian Agricultural Insurance Corporation (NAIC) on risk managements–weather based insurance; and (v) the Nigeria Agricultural Cooperative and Rural Development Bank (NACRDB) (fertilizer, input-investment credits).
- Existing programs that should be oriented towards low carbon development are: the National Food Security Program (NFSP); the strategic framework for the National Agriculture Investment Plan (NAIP); and the Agricultural Development Projects (ADPs), which have been the main vehicle for public investment in agriculture in Nigeria during the past 25 years and which provide technical support through extension services to smallholder farmers as a means of promoting the adoption of improved farming practices.
- Producer Organizations (farmer organizations) form one of the most important pillars of policy and institutional capability for agricultural development because of their ability to engage in dialogue with the government and to widely mobilize farmers The participation of farmer associations in policy formulation, monitoring and evaluation increases ownership and sustainability of policy measures. The All Farmers Association of Nigeria (AFAN), an umbrella body for Nigerian farmers, is seen as the national platform for corporate and professional bodies, cooperatives and commodity associations. Currently, there are 43 major farmers' associations in Nigeria and these associations are formed along commodity lines (The Federal Republic of Nigeria, 2011). The AFAN could act as a field support platform to promote climate smart agriculture practices and gather smallholders to channel carbon funding and payment of environment services.

4.2 Main Implementation mechanisms

4.2.1 Supporting the agricultural research

Agricultural research has been shown to be one of the most effective forms of public investment (IFPRI, Hazell and Haddad 2001; IFPRI, Fan and Rao, 2003). In Nigeria, compared to the recommendations that agricultural research spending should not be less than 2% of agricultural GDP, Nigerian government's funding of agricultural research has been well below the average for Africa as a whole (0.85% of GDP) (Enete and Amusa, 2010). Moreover, private sector agricultural research in Nigeria is also negligible, as is the case throughout most of Sub-Saharan Africa (IFPRI, 2008). The Department of Agricultural Sciences (DAS) of the Federal Ministry of Agriculture is responsible for all aspects of agricultural research in Nigeria. DAS oversees the funding and management of 15 national agricultural research institutes located throughout the country. Those institutes are tasked with generating improved agricultural technologies for use by farmers and agro-allied industries. However, DAS funding of agricultural science research and technology have been generally stagnant and has even decreased since the collapse of oil prices in the early 1980s. The agricultural research capacity in Nigeria is highly dispersed and the country does not have a well-defined national strategy. Nonetheless, research is necessary to develop crop and livestock management practices aimed at enhancing resilience and mitigation potential of smallholder farming systems, through adapting SLM approaches to local circumstances, as well as for meeting the overall growth targets under Vision 20:2020. Another key challenge involves extending the existing capacity in agro-meteorological disciplines to include agro-climatic competency. Local climate change adaptation platforms have been proposed by a number of development agencies, as a means of promoting collaboration between scientists and practitioners, and enhancing local adaptation capacity. Such platforms enable collaborative action, mutual learning and the exchange of a range of material, for example from mailing lists, e-conferences, academic papers, policy briefs or information sheets. It is essential that these institutions design their activities around local needs and not the funding or reporting requirements of the international climate change community (SEI, 2008).

A recent report prepared by IFPRI in 2010 assesses the level of innovation capacity of Nigerian agricultural research system, and discusses options for strengthening it:

- *Improve collaboration between researchers and promote communication on innovations.* Although research productivity seems high, the overall level of collaboration is low and there is a lack of monitoring and evaluating the use, influence, and impact of technologies and publications being produced by organizations and individual researchers.
- *Increase interactions with farmers, the private sector, extension agents, and other actors within the innovation system.* Greater awareness and sensitization, as well as exposure to practical knowledge, good practices, and experiences on innovation systems in other countries, are urgently needed. The Agricultural Research Council of Nigeria can play a role in facilitating a platform or forum for greater interaction and collaboration.
- *Strengthen the abilities for fundraising and diversifying fund sources.* Substantive capacity and incentive gaps are present at the agricultural research organizations. Among research institutes, the timely release of funds is the top motivating factor identified by researchers in order for them to produce more and be more innovative.
- *Improve governance of research organization*: good performance and innovation capacity are associated with the presence of fair and transparent hiring procedures; effective performance evaluation and reward systems; systems of career development and job security; systems of information sharing and knowledge management; clearly defined and communicated division of roles and responsibilities; systems of feedback from stakeholders; and provision of flexibility, freedom to do work, and mobility among researchers.
- *Establish a mechanism of continuous training and skill development*

4.2.2 Capacity building and technology transfer platforms

Diffusion of scientific and technical knowledge to farmers is a prerequisite to the adoption of SLM and climate-smart agriculture (CSA) practices. Agriculture needs to become professionalized with better incentives for educational training and development of technical capacity in crop and livestock production.

Agricultural Development Projects (ADPs) are the main vehicle for the delivery of public extension services in Nigeria. Despite their name, ADPs are not “projects” in the conventional sense. Instead, they are state-level parastatals working in the agricultural sector. The first generation ADPs were created during the mid-1970s and supported largely with donor funds. Their extension activities include establishing demonstration farms, identifying lead farmers, providing them with information about good farming practices, facilitating access to improved technology and inputs (e.g. seeds of improved varieties, fertilizer, machinery services), and helping the lead farmers teaching other farmers.

ADP could serve as capacity building CSA platforms to promote new policy recommendations and improved techniques. They can network with decentralized training institutions and colleges at provincial level to provide an adequate level of training for both extension officers and regional /

local planners for promoting Climate Smart Agriculture both at planning and project design level and at extension level with improved field techniques for sustainable agriculture, water and land management.

4.2.3 Field support platforms as small farmers aggregators

A key issue in exploiting carbon finance potentials in the agriculture sector is that whilst the overall GHG emissions potential may be highly significant, the contribution of each individual farm is often small, and therefore a highly efficient approach to aggregating the contributions of individual farmers is required, to avoid excessive transaction costs. Farmers' federations with support from Agricultural Development Projects (ADPs) could be strengthened to become field platforms and to channel both carbon funds and payment of environment services. Their dominant position within a value chain and their capacity to gather small farmers give them a comparative advantage as farmer's aggregator[26]. In this perspective, it is therefore important to

- build the capacity of these organizations to effectively and sustainably play a role in the promotion of improved practices and in the control and monitoring of applications programs and projects
- to provide technical assistance to farmer organizations to enable the trade of carbon credits on the voluntary markets (and possibly on the compliance market as well). These carbon assets (including soil carbon) would result from the implementation of climate-smart agriculture activities
- to develop effective and scalable tools to support partnerships and alliances between governments, private sector operators and leading local Farmers Organizations and Trade Associations in order to broaden the access of smallholder farmers to commercial and technical services.
- to provide a platform to scale out participatory farmer-to-farmer learning and farmer champions. It is often difficult to identify well-connected and credible farmer champions upon which to hold on-farm demonstrations and learning events that are critical for scaling out, but this is typically an important part of any strategy to scale up specific technologies.

4.2.4 Systematic review and carbon appraisal of sector project and program proposals

A reform that would have the potential to provide rapid results would be to request a systematic review of any new investment project or program, in term of impact on climate mitigation and of resilience. It automatically raises these criteria within the choice of technical options by project designers.

The FAO Guidance to Best Practices (FAO 2007, FAO 2009, and FAO September 2009) and on carbon balance appraisal of projects and policies[27] could be used by the country to develop its climate change response and adaptation strategies down to project and strategy design and appraisal.

---

[26] The high number of small farmers and their scattering in rural areas are a main constraint to reach small farmers with both incentives and adequate extension support within manageable transaction costs. A key issue is to find an entry point which allows reaching a wide number of small farmers. It can be either farmers' unions, farmers' cooperatives, value chains or an existing project –program which covers a whole region/ district with adequate services. The role of the aggregator is to deliver the whole range of services and support to a wide number of small farmers including the possibility of channeling of payment of environment services.

[27] EX-ACT (Ex Ante Carbon-balance Tool) http://www.fao.org/tc/exact/en/

The development of country specific planning tools (e.g. a Climate Smart Agriculture Atlas) to identify and prioritize opportunities for adopting a triple-win agriculture management options (higher yields, higher climate resilience, reduced carbon emissions) should also be considered.

4.3 The necessity of a strong and coherent policy environment

4.3.1 Ensuring a relative stability of the policy framework

A stable policy environment is a key requirement for the effective development of the agriculture sector and its contribution to mitigating climate change. Unfortunately, this has generally been lacking in Nigeria as successive governments have often reversed policies put in place by predecessors. Inconsistent agricultural policies have resulted in apathy on the part of the farmers regarding anything from government because nobody knows how long such may last, erratic import policies characterized by frequent changes in both import tariffs and quantitative import restrictions, creating much uncertainty for producers, and failure to set up a satisfactory credit system for farming. However, Nigeria has recently developed its Agricultural Transformation Agenda, which has the potential to act as a key, long-term vehicle to champion sustainable and climate-smart sector policies. The 2012 Agricultural Transformation Agenda (ATA) is a comprehensive plan that aims to restore Nigeria's old glory as an agriculture powerhouse. To this effect, the Agenda seeks to achieve dramatic increases in agricultural productivity, massive job creation in the agriculture sector, significant expansion of value-addition in processing, drastic reductions in agricultural imports, and improved penetration of international markets.

The Agenda is an important point of departure for transforming Nigeria's agriculture sector by providing: (i) an in-depth analysis of root causes of poor performance of the agriculture sector along with quantification of lost opportunities caused by this poor performance; (ii) a clear vision for transformation of the sector as a process, including import substitution, export orientation, value-addition through processing and backward integration linkages; (iii) an explicit focus on agriculture as a business, putting the private sector in the drivers' seat and recognizing the critical role of women; (iv) a comprehensive approach to change by focusing on value-chains; (v) a concrete and specific program of sector policy reforms, including revamping of the fertilizer subsidy program which has been a major drain on sector expenditures; and (vi) specific and quantified targets for expected outcomes in terms of jobs, income, food security and productivity improvements.

4.3.2 Strengthening capacity of decentralized institutions

With its federal system of government, Nigeria faces a challenge to define the roles and responsibilities of each tier of government. All the agricultural research institutes are owned and managed by the federal government while the State and Local governments, which provide extension services, have no research institutes. This means that all decisions on the funding, direction and implementation of research activities are taken from Abuja (Agbamu, 2000), resulting in a discrepancy between local needs and current research and development programs. An effort should be made by government to decentralize research funding and activities to reduce concentration at the federal level, and strengthen the linkage to extension services and farmer organizations.

4.3.3 Strengthening the Climate Smart Agriculture policy and project planning

Policies and institutions also need coordination with initiatives in other sectors that could help to strength the climate resilience in agriculture. For example:

- Technical assistance is required to consolidate and harmonize policies and legislations related to water resources management, as a pre-requisite for organic and effective integration of climate change considerations into sector planning and development.

- Guidelines should be prepared to enhance climate resilience of water resource development projects in the irrigation and hydro-power sub-sectors (including design criteria to enhance the reliability of water storage infrastructure under wider precipitation swings).
- Further attention should be paid to develop small-scale finance provision such as micro insurance, savings and transfer of money building on the innovation practices introduced by IT development.
- The National Food Security Program (NFSP) could be more closely coordinated with the National Agriculture Investment Plan (NAIP) to ensure comprehensive programs for food security and value addition to water systems, storage systems, value chain development and increased production so as to maximize the benefits of these growth elements and address some of the fundamental elements of vulnerability and food insecurity linked with climate adaptation.
- If safety nets are to be part of the risk-reduction strategy in Nigeria, these need to be elaborated and carefully designed to ensure they contribute to growth rather than competing for resources. There are many elements of the NAIP and NFSP that can provide social protection elements. For examples, public works programs on building dams; food for work programs; food for school programs; conditional transfers of farm inputs for stimulating agriculture; asset transfers through livestock or vouchers; etc.

References

Agbamu, J. U, 2000, Agricultural Research – Extension Linkage Systems: An International Perspective, *Agricultural Research & Extension Network (AgREN) Network Paper No.106. pp 1-24*

Ajayi R., 2012, Are Nigerian banks now ready for climate projects? http://www.vanguardngr.com/2012/02/are-nigerian-banks-now-ready-for-climate-projects-2/

Alberts, H., C. Moreira, et al., 1997, Firewood substitution by kerosene stoves in rural and urban areas of Nicaragua, social acceptance, energy policies, greenhouse effect and financial implications. *Energy for Sustainable Development, 3*(5), 26-39.

Albrecht A. and Kandji S., 2003, Carbon sequestration in tropical agroforestry systems, *Agriculture, Ecosystems and Environment 99 (2003) 15–27*

Ani Madu I., July 2007, The environmental impacts of regional disparity in population and wealth distribution in Nigeria, *Environment, Development and Sustainability, Volume 11, Number 2, 265-276*, DOI: 10.1007/s10668-007-9109-0

Aronson J., Floret C., Le Floc'H E., Ovalle C., Pontanier R., 1993, Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands - A view from the South, *Restoration Ecology Volume 1, Issue 1, pages 8–17, March 1993*

ASTER GDEM http://www.gdem.aster.ersdac.or.jp/

Batjes NH., 2010, *IPCC default soil classes derived from the Harmonized World Soil Data Base (Ver. 1.1), report 2009/02b*, Carbon benefits Project (CBP) and ISRIC – World Soil Information, Wageningen

Banful A.B., Nkonya E., Oboh V., IFPRI, 2009, *Constraints to Fertilizer Use in Nigeria: Perspectives and Insights from the Agricultural Extension Service*, NIGERIA STRATEGY SUPPORT PROGRAM.

Bationo A., Waswa B., Kihara J., Kimetu J., 2007, *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*

Bell R., 2005, Land restoration; principles, *Encyclopedia of Soil Science, Second Edition, Rattan Lal, CRC Press 2005*

Benchaar C., Pomar C., and Chiquette J., 2001, Evaluation of dietary strategies to reduce methane production in ruminants: A modelling approach, *Canadian Journal of Animal Science*

Bisong F.E., 2010, *Nigeria Strategic Investment Framework for strategic Land Management (NSIF-SLM)*, National Fadama Development Office, Abuja

Boli Z. et Roose E., 1996. Degradation & restoration of a sandy alfisol under cotton/maize intensive rotation in the sudano savannah of northern Cameroun, *In "Towards sustainable land use: furthering cooperation between people and institutions", 9th ISCO Conference, Bonn, Germany, 281-282*.

Briant L.D, 1985, *Livestock Management in the Riparian Ecosystem*, paper presented at the North American Conference of the University of Arizona, April 16-18, 1985

Bricas N., Veillard P. et Coopman P., 2010. Une influence déterminante dans le domaine agricole, *Défis Sud n°95 juin-juillet 2010*

Bronson, K.F., Neue, H.U., Singh, U., Abao Jr., E.B., 1997, Automated chamber measurements of methane and nitrous oxide flux in a flooded rice soil: residue, nitrogen, and water management, *Soil Sci. Soc. Am. J. 61, 981–987.*

Caroline C, *Fertilizer Use and Management Practices for Crops in Nigeria,* MBA, University of Nigeria

CBN, 2002, *Annual Report and Statement of Account,* Abuja: CBN

Chivengea P.P., Murwiraa H.K., Gillerc K.E., Mapfumod P., Sixb J., 2007, Long-term impact of reduced tillage and residue management on soil carbonhttp://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC6-4M04DV4-1&_user=6718006&_coverDate=06%2F30%2F2007&_alid=1690263228&_rdoc=1&_fmt=high&_orig=search&_origin=search&_zone=rslt_list_item&_cdi=5162&_sort=r&_st=13&_docanchor=&view=c&_ct=13068&_acct=C000055286&_version=1&_urlVersion=0&_userid=6718006&md5=02568278c16adb598eadf1823f7e6b81&searchtype=a - hit2 stabilization: Implications for conservation agriculture on contrasting soils, *Soil & Tillage Research 94 (2007) 328–337*

Chomitz K. ,2007, At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests, *World Bank Policy Research Report 308*

CGIAR-CSI (Consultative Group on International Agricultural Research - Consortium for Spatial Information) http://srtm.csi.cgiar.org/

CIA, 2010, The World Fact Book, https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html#Econ

Ciaian P., d'Artis Kancs, Swinnen J., Van Herck K. and Vranken L., 2012, Institutional Factors Affecting Agricultural Land Markets, *Factor market, working paper no.16, February 2012*

Conant R.T., Paustian K., and Elliott E.T., 2001, Grassland management and conversion into grassland: effects on soil carbon, *Ecological Applications 11:343–355.*

Corsi1 M. et al., *Impact of grazing management on productivity of tropical grasslands*

Dobermann A., 2003, A critical assessment of the system of rice intensification (SRI), *Agricultural Systems 79 (2004) 261–281*

Dumas-Johansen M.K., *Effect of the System of Rice Intensification (SRI) on livelihood strategies for Cambodian farmers and possible carbon storage and mitigation possibilities for greenhouse gas emissions*, Master Thesis

Eric C. Eboh Kalu O. Oji Okey G. Oji Uzochukwu S. Amakom Oliver C. Ujah, AFRICAN INSTITUTE FOR APPLIED ECONOMICS, August 2004, *Towards the ECOWAS Common Agricultural Policy Framework: Nigeria Case Study and Regional Analysis*

Enete Anselm A. and Amusa Taofeeq A., 2010, Challenges of Agricultural Adaptation to Climate Change in Nigeria: a Synthesis from the Literature, *Field Actions Science Reports [Online], Vol. 4*

Environquest Nigeria Limited, *Review of Policies and Regulations at the Federal Level on Watershed Management in Nigeria*

Evenson R.E., Golli D., 2003, Assessing the impact of the Green Revolution, 1960 to 2000, *Science Vol. 300 no. 5620, p.758-762*

Fadama III impact assessment study (2010)

FAO, 2007, *The State of Food and Agriculture 2007. Part I: Paying farmers for environmental services*

FAO 2008, Lipper L., *Paying farmers for environmental services: Identifying the links with Sustainable Land Management*

FAO, 2008, *Conservation Agriculture: Conserving Resources Above and Below the Ground*

FAO, 2009, Branca G., Medeiros K., *Ex-Act Software for Carbon-Balance Analysis of Investment Projects An application to the Santa Catarina Rural Competitiveness Project in Brazil*

FAO, September 2009, *Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies*

FAO, 2010, Mette Løyche Wilkie, *Global Forest Resources Assessment 2010*

FAO, 2010, Bockel L., Tinlot M., *First results of carbon balance appraisal on Agriculture Rehabilitation and Recovery Support project (ARRS) in DRC*

FAO, 2011, Country Profiles, http://www.fao.org/countries/55528/en/nga/

FAO Stat, http://faostat.fao.org/

Farming and Rural System Economics, edited by Doppler W. and Bauer S., Margraf Verlag Weikersheim

Feder, Gershon & Just, Richard E & Zilberman, David, January 1985, Adoption of Agricultural Innovations in Developing Countries: A Survey, *Economic Development and Cultural Change, University of Chicago Press, vol. 33(2), pages 255-98*

Genesis-Faraday Partnership 2008, *A study of the scope for the application of research in animal genomics and breeding to reduce nitrogen and methane emissions from livestock based food chains*. Final Report of Project AC0204 to the Department for Environment, Food and Rural Affairs, April 2008

Global Administrative Areas database, http://www.gadm.org/

Global Land Cover Network http://www.glcn.org/dat_0_en.jsp and http://www.fao.org/geonetwork/srv/en/metadata.show?id=37204&currTab=simple

Guo R., Hanaki K., 2010, Potential and life cycle assessment of biodiesel production in China, *J. Renewable Sustainable Energy 2, 033107 (2010); doi: 10.1063/1.3449298*

Henry M., 2010, *Carbon stocks and dynamics in Sub Saharan Africa*, AgroParisTech/Engref, University of Tuscia

IFPRI, Hazell, P and Haddad, L, 2001, *Agricultural research and poverty reduction.* IFPRI 2020 Discussion Paper

IFPRI, Fan, S and Rao, N, 2003, *Public spending in developing countries: Trends, determination, and impact,* EPTD Discussion Paper no. 99

IFPRI, Nkonya, E. and J. Pender, 2007, *Policies for scaling up sustainable land management in selected African countries*

IFPRI, Mogues et al., 2008, *Agricultural Public Spending in Nigeria*, Discussion Paper 00789

IFPRI (International Food Policy Research Institute), 2009, *SLM advisory services: key institutional, financing, and economic elements for scaling up sustainable land management in Nigeria*, IFPRI mimeo

IFPRI, 2009, *Constraints to Fertilizer Use in Nigeria: Perspectives and Insights from the Agricultural Extension Service*

IFPRI, Nkonya, E. and al., 2010, Options for Enhancing Agricultural Productivity in Nigeria, *Nigeria Strategy Support Program (NSSP) Background Paper No. NSSP 011*

IFPRI, 2010, *Agricultural Investment for Growth and Poverty Reduction in Nigeria*, Brief n. 13

IFPRI, 2010, Strengthening Innovation Capacity of Nigerian Agricultural Research Organizations, *IFPRI Discussion Paper 0105. Washington, DC*

IFPRI, April 2010, *A 2006 Social Accounting Matrix for Nigeria: Methodology and Results*

IIASA (International Institute for Applied Systems Analysis), Harmonized World Soil Database, http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/SoilQuality.html?sb=10

IIED (International Institute for Environment and Development), 2008, *The Cost of Avoiding Deforestation* - Update of the Report prepared for the Stern Review of the Economics of Climate Change

ILCA (International Livestock Center for Africa) and IITA (International Institute for Tropical Agriculture), 1986, *Alley Farming Network for Tropical Africa*

Ismaila U., Gana A. S., Tswanya N. M. and Dogara D., 2010. Cereals production in Nigeria: Problems, constraints and opportunities for betterment, *African Journal of Agricultural Research Vol. 5(12), pp. 1341-1350, 18 June 2010*

Jarecki, M.K and Lal, R., 2003. Crop management for Soil Carbon Sequestration, *Plant Sciences 22 (5): 471-502.*

Jones HE, Warkup CC, Williams A and Audsley E, 2008. The effect of genetic improvement on emissions from livestock systems, *Conference of the 59th Annual Meeting of the European Association of Animal Production, 24–27 August 2008, Vilnius, Lithuania, Session 05, no. 6, p. 28*

Jullien, F., 2006, Nomadisme et transhumance, chronique d'une mort annoncée ou voie d'un développement porteur ? , *Afrique contemporaine n° 217*, p. 55-75

Kang, B.T., Caveness, F.E., Tian, G., Kolawole, G.O., 1999, Long-term alley cropping with four species on an Alfisol in southwest Nigeria—effect on crop performance, soil chemical properties and nematode population. *Nutr. Cycl. Agroecosyst. 54, 145–155*

Kayombo B. and Lal R., 1993, tillage systems and soil compaction in Africa, *Soil and Tillage Research 27:35-72*

Koch J. and al., 2000, Inventory of emissions of greenhouse gases in Israel, *Water, Air, and Soil Pollution 123: 259–271, 2000.*

Lal R., 1990, *Soil erosion in the tropics, principles and management*, New York, McGraw-Hill

Lal R., 2004, Agricultural activities and the global carbon cycle, *Nutrient Cycling in Agroecosystems 70: 103–116, 2004*

Leite, L.F.C., et al., 2008, Modeling organic carbon dynamics under no-tillage and plowed systems in tropical soils of Brazil using CQESTR. *Soil Tillage Res. (2008), doi:10.1016/j.still.2008.08.003*

Lescuyer, G., 2005, *Evaluation économique et gestion viable de la forêt tropicale Réflexion sur un mode de coordination des usages d'une forêt de l'est-Cameroun*, THESE E.H.E.S.S

Lugo A., Sanchez M., Brown S., 1986, Land use and organic carbon content of some subtropical soils, *Plant and Soil Volume 96, Number 2, 185-196, DOI: 10.1007/BF02374763*

MacLeod and al., February 2010, Developing greenhouse gas marginal abatement cost curves for agricultural emissions from crops and soils in the UK, *Agricultural Systems 103 (2010) 198–209*

Masera O.R., 1995, Carbon mitigation scenarios for Mexican forests: methodological considerations and results, *Interciencia 20(6): 388-395.*

Mbwambo L., 2004, *Status of arid and semi-arid lands of Tanzania*, Paper to be presented at the Drylands Agroforestry Workshop 1st-3rd September 2004. ICRAF Headquarters, Nairobi- Kenya

Meyn, K. and Wilkins J. V., 1973, National cattle breeding programmes in Kenya. *11 World Conf. Anim. Prod., Pre-Conf. 3: (5e) 1-10*

National Food Reserve Agency (NFRA) and Japan International Cooperation (JICA), 2009, *National Rice Development Strategy – Federal Republic of Nigeria*, prepared for the Coalition for African Rice Development (CARD)

National Bureau of Statistic (NBS), 2009. *Filling Data Gap*

National Bureau of Statistic (NBS) *http://www.nigerianstat.gov.ng/index.php/*

Oyekale A.S., 2007. Determinants of Agricultural Land Expansion in Nigeria: an application of error correction modeling (ECM), *Journal of Central European Agriculture Vol 8 (2007) No 3*

Oni K. C., *Creating a competitive edge through agricultural mechanization*

Ramasamy et al., 1997, Yield formation in rice in response to drainage and nitrogen application, *Field Crops Research, 51* (1997), pp. 65–82

REDD+ in Nigeria, http://www.slideshare.net/theREDDdesk/nigeria-redd-programme-pb-6-mar-20111

Ringius L., 2002, Soil carbon sequestration and the CDM: opportunities and challenges for Africa, *Climatic Change 54: 471–495, 2002*

Rockström J. and al., 2008, Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research, *Soil & Tillage Research 103 (2009) 23–32*

Roose E., Ndayizigiye F., 1997, Agroforestry, water and soil fertility management to fight erosion in tropical mountains of Rwanda, *Soil Technology ll(1997) 109-l 19*

Roose E., 1996, Land husbandry - Components and strategy, *70 FAO SOILS BULLETIN*

Sanni et al, 2010, Path to the Future for Climate Change Education: A University Project Approach, *W.L. Filho (ed.), Universities and Climate Change, DOI 10.1007/978-3-642-10751-1_2, # Springer-Verlag Berlin Heidelberg 2010*

Schwilch, G., F. Bachmann and H.P. Liniger, 2009. Appraising and selecting conservation measures to mitigate desertification and land degradation based on stakeholder participation and global best practices, *Land Degradation & Development, Volume 20, Issue 3, pages 308–326, May/June 2009*

SEI (Stockholm Environment Institute), 2008, *Using science to improve adaptation in Africa*

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007, *Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Soil and Water Conservation Society (SAWCS), 2008, *Soil Conservation in Nigeria, Past and present on-station and on-farm initiatives*

Spears J.S., 1983, Replenishing the world's forests: tropical reforestation: an achievable goal?, *Comnionw. For. Rev. 62(3), 1983*

Steinfeld et al, 2006, *Livestock's Long Shadow: Environmental Issues and options*, LEAD (Livestock and Environment Development Initiative) and FAO, Rome, Italy

Stoop et al., 2000, Twenty years of systems research in Southern Mali, M.P. Collinson, Editor, *A History of Farming Systems Research, FAO, Rome (2000)*, pp. 184–191

Stoop W.A., Uphoff N., Kassam A., 2001, A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers, *Agricultural Systems 71 (2002) 249–274*

Styger E., Aboubacrine G., Ag Attaher M., Uphoff N., 2011, The system of rice intensification as a sustainable agricultural innovation: introducing, adapting and scaling up a system of rice intensification practices in the Timbuktu region of Mali, *International Journal of Agricultural Sustainability 9(1) 2011, p.67–75, doi:10.3763/ijas.2010.0549*

TerrAfrica, 2009, *Using Sustainable land Management practices to adapt and to mitigate climate change in Sub-Saharan Africa, resource Guide version 1*

Tewari S.K., 2008, *Farm forestry, Agro-forestry*, p.51

The Federal Government of Nigeria, *The New Nigerian Agricultural Policy*

The Federal Government of Nigeria, December 2010, *Nigeria Vision 20: 2020, Abridged version*

The Federal Government of Nigeria, May 2010, *Nigeria Vision 20: 2020, The First National Implementation Plan, (2010 – 2013), Volume II: Sectoral Plans and Programmes*,

The Federal Government of Nigeria, May 2010. *Nigeria Vision 20: 2020 The 1st NV20:2020 Medium Term Implementation Plan (2010 – 2013)*

The Federal Government of Nigeria, 2009, *Report of the Vision 2020 National Technical Working Group On Urban and Rural Development*

The Federal Republic of Nigeria, 2011, *Review of ongoing agricultural development efforts*, Federal Ministry of Agriculture and Water Resources- NEPAD Nigeria

The Nigerian Federal Ministry of Agriculture and Rural Development, 2010, *ECOWAP/CAADP Process, National Agricultural Investment Plan (NAIP) 2011-2014*

The Nigerian Federal Ministry of Agriculture and Rural Development, 2010, *Nigeria: global agriculture and food security program (gafsp) - A Proposal to Global Agriculture and Food Security Program (GAFSP) Trust Fund*

The Nigerian Federal Ministry of Agriculture and Rural Development, 2005, National FADAMA Development Office

The Nigerian Federal Ministry of Agriculture and Water Resources, *National Program for Food Security*

Tomich, T.P., A. Cattaneo, S. Chater, H.J. Geist, J. Gockowski, D. Kaimowitz, E. Lambin, J. Lewis, O. Ndoye, and C. Palm, 2005, Balancing agricultural development and environmental objectives: Assessing tradeoffs in the humid tropics, *Slash and burn: The search for alternatives, p.415-440,*New York, NY: Columbia University Press.

UNCCS (United Nations Climate Change Secretariat), Emissions Summary for Nigeria, http://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/nga_ghg_profile.pdf

University of Calabar, *Agricultural Development Project*

USAID, January 1989, Agroforestry project for small farmers: a project managers' reference, A.*I.D. Evaluation special study no. 59* (Document Order No. PN-AAX-212)

Valeix, J., 1999, *What frame to the wet tropical forest management*

Wassmann R.and al., 2000. Characterization of methane emissions from rice fields in Asia - Comparison among field sites in five countries, *Nutrient Cycling in Agroecosystems 58: 1-12.*

West T.O. and Post W.M., 2002, Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis, *Soil Science Soc. Am. J., volume 66, November-December 2002*

World Bank (WB), 2006, *Getting Agriculture going in Nigeria: Framework For A National Growth Strategy,* Report no. 346180NG

World Bank, 2007, database http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

World Bank, 2008, Nigeria Agriculture Public Expenditure Review

World Bank. 2010, *Managing land in a changing climate: An operational perspective for sub-Saharan Africa*

Word Bank, November 2010. *NIGERIA Simulation of Sustainable Land Management Practices*

World Bank, November 2010, *Benefit-cost analysis of sustainable land and water management in Nigeria*

WB, 2010, Data for Nigeria, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/NIGERIAEXTN/0,,menuPK:368922~pagePK:141132~piPK:141109~theSitePK:368896,00.html

Yaron, G. 2001. Forest, plantation crops or small-scale agriculture? An economic analysis of alternative land use options in the Mount Cameroun area, *Journal of Environmental Planning and Management, 44 (1), 85-108*

Yue J. and al., 2005, Methane and Nitrous Oxide emissions from rice field and related microorganism in black soil, northeastern China, *Nutrient Cycling in Agroecosystems 73: 293-301*.

Annexes to the Agriculture and Land Use Sector

Annex 1. **Details of the emissions factor and coefficients used in the model**

Table 16: List of coefficients used in the model

Type of vegetation concerned	Type of coefficient	Data sources	Value of the coefficients	
Forests	Carbon content in above and below ground biomass for secondary forests	Henry M., 2010	Secondary moist forest ---------------- Secondary rain forest	AGB = 32.2 t C/ha/yr BGB = 7.7 t C/ha/yr ------------------ AGB = 89.3 t C/ha/yr BGB = 33.0 t C/ha/yr
	Emissions factors of forest biomass burning	IPCC 2006	2sd moist forest --------------- 2sd rain forest	% of biomass burned = 36% GHG emissions: 6.8 g CH4/kg DM burned 0.2 g N2O/kg DM burned --------------- % of biomass burned = 32% GHG emissions: 6.8 g CH4/kg DM burned 0.2 g N2O/kg DM burned
	Aforestation/reforestation : carbon pool content	IPCC 2006	Plantation of 2sd moist forest --------------- Plantation of 2sd dry forest	AGB = 4.70 t C/ha/yr BGB = 0.94 t C/ha/yr --------------- AGB = 3.76 t C/ha/yr BGB = 2.11 t C/ha/yr
Annuals, perennials, grasslands, degraded lands, other	Non forest land use changes (initial and final C pool in biomass and soil)	IPCC 2006	Annual --------------- Perennial ---------------	Biomass = 5 t C/ha Soil = 22.6 t C/ha --------------- Biomass = 2.6 t C/ha Soil = 47 t C/ha ---------------

Type of vegetation concerned	Type of coefficient	Data sources	Value of the coefficients	
			Wet rice --------------- Grassland --------------- Degraded land --------------- Other --------------- Fallow	Biomass = 5 t C/ha Soil = 51.7 t C/ha --------------- Biomass = 6.4 t C/ha Soil = 47 t C/ha --------------- Biomass = 1 t C/ha Soil = 15.5 t C/ha --------------- Biomass = 0 t C/ha Soil = 47 t C/ha --------------- Biomass = 5 t C/ha Soil = 38.5 t C/ha
Annuals	Carbon storage capacity of different agronomic practices	IPCC 2006 and	Moist tropical climate, improved varieties --------------- Moist tropical climate, water management	0.24 t C/ha/year --------------- 0.31 t C/ha/year
		Chivengea and al., 2007 Leitea and al., 2009,	Moist tropical climate, conservation agriculture	1.27-1.32 t CO2e/ha/year We have taken the average, i.e. 1.3 t CO2e/ha/year, which is equivalent to 0.35 t C/ha/year
Perennials	Above and below ground biomass growth rate (biomass accumulation rate)	IPCC 2006	Tropical moist climate	AGB: 2.6 t C/ha/year BGB: 0 t C/ha/year
	Emissions factors of biomass burning	IPCC 2006		% of biomass burned = 80% GHG emissions: 2.3 g CH4/kg DM burned 0.21 g N2O/kg DM burned
Rice	Methane emissions	IPCC 2006	Continuously flooded, non	1.3 kg CH4/ha/day

Type of vegetation concerned	Type of coefficient	Data sources	Value of the coefficients	
			flooded preseason <180 days --------------- Intermittently flooded, non flooded preseason >180 days	--------------- 0.69 kg CH4/ha/day
Grassland	Soil carbon content after 20 years (in 02-30cm depth)	IPCC 2006	Non degraded --------------- Severely degraded --------------- Moderately degraded --------------- Improved without inputs --------------- Improved with inputs	47.0 t C/ha --------------- 32.9 t C/ha --------------- 45.1 t C/ha --------------- 54.5 t C/ha --------------- 60.5 t C/ha
	Above Ground Biomass	IPCC 2006	Tropical moist, LAC soil	AGB = 6.2 t DM/ha
	Emissions factors of biomass burning	IPCC 2006		% of biomass burned = 77% GHG emissions: 2.3 g CH4/kg DM burned 0.21 g N2O/kg DM burned
Livestock	Methane emissions from enteric fermentation	IPCC 2006	Cattle --------------- Sheep --------------- Swine --------------- Goat --------------- Camel --------------- Horse --------------- Donkey ---------------	31 kg CH4/head/year --------------- 8 --------------- 1 --------------- 5 --------------- 46 --------------- 18 --------------- 10 ---------------

Type of vegetation concerned	Type of coefficient	Data sources	Value of the coefficients	
			Poultry	0
Livestock	Methane emissions from manure management	IPCC 2006	Cattle --------------- Sheep --------------- Swine --------------- Goat --------------- Camel --------------- Horse --------------- Donkey --------------- Poultry	1 kg CH4/head/year --------------- 0.37 --------------- 2 --------------- 0.26 --------------- 3.17 --------------- 3.13 --------------- 0.9 --------------- 0.02
	Nitrous oxide emissions from manure management	IPCC 2006	Cattle --------------- Sheep --------------- Swine --------------- Goat --------------- Camel --------------- Horse --------------- Donkey --------------- Poultry	39.8 kg N2O/head/year --------------- 20.7 --------------- 16.8 --------------- 19.3 --------------- 36.4 --------------- 63.3 --------------- 21.8 --------------- 0.6

Type of vegetation concerned	Type of coefficient	Data sources	Value of the coefficients	
	Mitigation potential of better feeding practices	IPCC 2006	Reduction in enteric fermentation from feeding practices (for cattle and sheep/goat) --------------- Reduction in enteric fermentation from breeding practices (for cattle and sheep/goat)	-1% --------------- -0.6%
Inputs	Carbon dioxide emissions from urea application	IPCC 2006		0.2 kg CO_{2e}/t urea
	Nitrous oxide emissions from N application	IPCC 2006		0.01 kg N2O/t N
Other Investments	CO2 emissions of gasoil	IPCC 2006		2.63 t CO_{2e}/m^3
	CO2 emissions of the installation of irrigation system	IPCC 2006	Hand moved sprinkle	60 kg CO_{2e}/ha
	CO2 emissions from the construction of buildings and roads	IPCC 2006	Office (concrete) --------------- Industrial building (concrete) --------------- Industrial building (metal) --------------- Agricultural building (concrete) --------------- Agricultural building (metal) --------------- Road	0.469 kg CO_{2e}/m^2 --------------- 0.825 --------------- 0.275 --------------- 0.656 --------------- 0.220 --------------- 0.073

Annex 2. **Land use changes in the reference scenario**

Table 17: Land use change matrix for the reference scenario in 1000 ha

		INITIAL 2010								
FINAL 2025		Annuals	Wet Rice	Perennials	Forests	Grasslands	Degraded lands	Fallow	Other lands	**Total Final**
	Annuals	33 124			4 641	2 063		2 063	1 547	**43 437**
	Wet Rice	1 312	1 313							**2 625**
	Perennials			6 552	475	317	951	634	792	**9 721**
	Forests				3 838	120	300	180		**4 438**
	Grasslands				147	16 129	598	100		**16 974**
	Degraded lands						0			**0**
	Fallow							3 257		**3 257**
	Other lands								10 602	**10 602**
	Total initial	**34 437**	**1 313**	**6 552**	**9 101**	**18 629**	**1 849**	**6 234**	**12 941**	**91 054**

Annex 3. **Mitigation options included in the low carbon scenario**

Table 18: Description of the SLM measure and limits of implementation

SLM practice	Justification	Description	Impacts	Main constraints of implementation
Conservation agriculture	In the reference scenario, there were already some improved agronomic practices such as the use of improved varieties, but Nigeria needs to go further if it wants to reduce crop expansion (and thus deforestation) while in the meantime increasing productivity to achieve food security and limit food imports	Land use concerned: Cropland • Minimum or no-tillage • Mulching (30% minimum of the crops residue remain on the soil surface after planting) • Crop rotation integrating leguminous and crop association	The no-tillage increases the soil organic content and soil properties (physical, chemical and biological), thus leading to a more efficient use of precipitation, soil moisture and plant nutrients, limiting erosion and storing carbon in soils The surface mulch that develops protects the soil surface from the impact of heavy raindrops, reducing the erosive power of the water (Derpsch *et al*, 1991) and wind while protecting the surface from excessive heat Increase yield within a single year and reduce inter-year variation in yields (FAO, 2008)[28]	Farmers need extensive training and access to skilled advisory services. Compared to conventional farming, a fundamental change in approach is required Typically there is a transition period of 5 to 7 years before a conservation agriculture system reaches equilibrium. Yields may be lower in the early years One of the biggest issues with no-tillage is weed control: reduced tillage means having recourse to herbicides. Farmers must be educated in the correct use of these herbicides, to avoid the harmful effects to the environment of improper use or they have to adopt integrated pest management (crop rotation, cover crop, cultural practices)[29] Farmers need to make an initial investment in specialized machinery, with an initially increased labor (weeding) [Laikipia District in Kenya maintenance - $93/ha/yr; Morocco maintenance - $600/ha/yr] Conservation agriculture has not been successful in heavy clay soils, poorly drained sites, compacted soils, and arid areas (insufficient carbon)
Sustainable Rice	Rice is an important crop for Nigeria which seeks to increase its production (in	Land use concerned: Irrigated rice	Transplantation reduces the number of plants and therefore of seeds (economical	In view of the great diversity in rice production systems that operate under varied local biophysical and socio-economic conditions, SRI methods will not

[28] FAO, 2008, Conservation Agriculture: Conserving Resources Above and Below the Ground.
[29] World Bank, 2002, No-Till Farming for Sustainable Rural Development, p.30

SLM practice	Justification	Description	Impacts	Main constraints of implementation
Intensification (SRI)[30]	yield and in surface), but it also highly contribute to climate change through methane emissions; therefore adopting better water management practices is vital	• Rotational and intermittent irrigation (keeping a saturated condition, non flooded) • Use of genetically improved seeds that are transplanted instead of broadcasted • Application of organic fertilizers • Integrated Pest Management (use less pesticide)	benefit) Organic fertilizers improve soil structure, organic matter content and fertility Reduce health hazards due to the use of pesticides Increase in yields Irrigation management reduces methane emissions	be applicable invariably everywhere. Each situation will require research and validation of the various SRI components. (Dobermann, 2003) Higher labor requirements, especially for weed control, initial investments in machinery for direct seeding and weeding operations. SRI requires excellent land preparation, timely availability of irrigation water during critical periods of growth, good irrigation infrastructure, and efficient methods of weed control. If land leveling and water management are poor, the risk for yield reduction due to temporary drought stress, weeds, or nutrient losses increases. (Dobermann, 2003) Other potential uncertainties include increases in soil greenhouse gas emissions (N2O) in systems with alternate wet-dry conditions (Bronson et al., 1997). It appears that SRI is mainly a suitable technology for increasing rice yields in environments with acid, Fe-rich soils, high labor availability, and a generally low level of crop intensification. Benefits of SRI over conventional rice management are likely to be small on fertile rice soils with no constraints such as potential Fe-toxicity, provided that management follows known best practices. (Dobermann, 2003)
Livestock management	One of Nigeria Vision 20: 2020 target is to expand dairy production and milk yield from less than 2 t to 5 t per cow per lactation by 2015[31]. It will require a switch	• Better feeding practices (less forage, more concentrates and additives) • Breeding management to select	Improving animal nutrition will increase the productivity of the livestock Selecting more productive animals enable to limit the number of livestock and therefore the emissions from enteric fermentation (ruminants) and manure	Such techniques are often out of reach for smallholder livestock producers who lack the capital and often knowledge to implement such changes (Steinfeld et al, 2006). By limiting the number of animals, it also reduces the amount of manure available to fertilize the crops, and

[30] E. Styger, G. Aboubacrine, M. Ag Attaher, N. Uphoff, 2011, The system of rice intensification as a sustainable agricultural innovation: introducing, adapting and scaling up a system of rice intensification practices in the Timbuktu region of Mali, International Journal of Agricultural Sustainability 9(1) 2011, p.67–75, doi:10.3763/ijas.2010.0549

[31] The Federal Government of Nigeria, May 2010, Nigeria Vision 20: 2020, The First National Implementation Plan, (2010 – 2013), Volume II: Sectoral Plans and Programmes, p.58

SLM practice	Justification	Description	Impacts	Main constraints of implementation
	towards more productive animals but also better livestock management such as feeding and breeding	improved and more efficient animals	management Dietary improvement reduce methane emission due to the enteric fermentation and through the increase in production efficiency, leads to a reduction of methane emitted per unit of production	it may lead to the use of chemical fertilizers Regular extension services is not easy for mobile pastoralists
Sustainable grazing management with inputs	In line with the increase in livestock productivity targeted by the NV 2020 strategy, improving grassland management and restoring degraded grassland will support livestock productivity	Land use concerned: Grassland • Restoration of degraded pastures with inputs such as mineral fertilizers, manure application, irrigation • Less or no use of fire	Maximize the capture, infiltration and storage of rainwater into soils, thus promoting conditions that increase vegetation cover, soil organic content and conserve above and below ground biodiversity Improved grazing conditions will increase livestock productivity in rangelands, in turn increasing food security. Fires reduce SOC content (thus releasing carbon) and nutrients level, lead to erosion and kill surface micro-organisms, limiting the soil capacity to reform. Limiting the use of fire limits all these drawbacks	Requires community organization for limiting overgrazing Investments the first years in fertilizers and irrigation systems
Sustainable grazing management without inputs	The Federal Government wants to establish at least 50 gazetted grazing reserves (NV 2020 document p.64); a sustainable grazing management is needed to support this goal	Land use concerned: Grassland • Restoration of degraded pastures without inputs, through the use of improved grass variety and rotational grassing • Less or no use of fire	Maximize the capture, infiltration and storage of rainwater into soils, thus promoting conditions that increase vegetation cover, soil organic content and conserve above and below ground biodiversity Improved grazing conditions will increase livestock productivity in rangelands, in turn increasing food security Fires reduce SOC content (thus releasing carbon) and nutrients level, lead to erosion and kill surface micro-organisms, limiting the soil capacity to reform.	Need to develop grazing plans tailored to specific local conditions (inter alia the pattern of local rainfall, area of land available, location of water supplies, numbers and types of livestock) by using participative approaches with entire communities developing, for example, new systems and regulations involving communities gathering their livestock into a group, then moving from one portion of their grazing lands to another during the year Costs in Ethiopia – improved grazing land management - \$1035/yr establishment and \$126/yr maintenance; Range closure for rehabilitation \$390/ha establishment and \$90/yr maintenance (TerrAfrica

SLM practice	Justification	Description	Impacts	Main constraints of implementation
			Limiting the use of fire limits all these drawbacks	2009)
Avoided deforestation	Deforestation is the biggest GHG emissions source in the reference scenario; therefore, it is an important improvement point	Land use concerned: Forest • The forest is preserved	Avoiding deforestation prevent the important release of CO_2 in the atmosphere (from clearing and burning) Keeping the forest will preserve biodiversity Deforestation can affect the flux of moisture to the atmosphere, regional convection and regional rainfall	In many instances the sole option to preserve forested area is to intensify agricultural production on other land. This raises complexities as where intensification involves increased fertilizer inputs, there will be increased emissions related to the fertilizer (TerrAfrica, 2009) Need to find and provide more affordable fuel efficient stoves or sustainable alternative fuels to decrease the pressure on wood resources Timber can be for some countries an important exports' revenue that they might not want to loose
Reforestation/ Afforestation and Agroforestry (livefences, alley cropping)	Nigeria objective is a proactive policy of afforestation, reforestation and erosion control programs[32]	Land use concerned: Forest • Reforestation is planting new trees in previously forested areas (where old tress have been recently cut or burned) • Afforestation involves planting stands of trees on land that is not currently classified as forest • Both reforestation and afforestation can include shelterbelts,	Tree planting sequesters carbon in the biomass and the soil, while conserving soil and water quality and quantity Increased tree cover will improve the functioning of the hydrological system and protect wild biodiversity Reforestation and afforestation will increase the amount of sustainably sourced wood for fuel and timber and non-woody forest products (medicinal plants, wild food, fodder etc), which would bring economic benefits to local people. The hedges are heavily pruned throughout the crop season to prevent them from shading the crops. The prunings and crop residues are used as mulch to conserve	In dryland areas, purposeful planting of trees is difficult due to lack of water for nurseries in the dry season and absence of labor for protecting the trees (TerrAfrica, 2009) Uncertain land tenure situations certainly had an adverse impact on farmers' attitudes towards tree planting in several countries (Spears, 1983) A commonly constraint is land availability, particularly where there is high population density and competition for land between agriculture and forestry and especially in those countries where a high proportion of the land suitable for forest is under fragmented private ownership (Spears, 1983) Given the fact that it takes 20 to 25 years in many countries to grow industrial tree crops to merchantable size, this long time period before any income is obtained can act a disincentive to small farmers

[32] The Federal Government of Nigeria, May 2010, Nigeria Vision 20: 2020, The First National Implementation Plan, (2010 – 2013), Volume II: Sectoral Plans and Programmes, p.62

SLM practice	Justification	Description	Impacts	Main constraints of implementation
		windbreaks and woodlots • The alley-cropping technique involves growing annual crops in spaces (4- to 6-meter-wide "alleys") between rows of leguminous trees or shrubs maintained as hedges.	moisture and enrich the soil in the cultivated alleys. Soil nutrients and nitrogen fixed by the tree roots similarly enrich the soil in the alleys. The technique allows for continuous cultivation of food crops because soil productivity is restored throughout the cropping cycle, thus eliminating the need for a fallow period. (USAID, 1989) For agroforestry, benefits are numerous: erosion control, runoff barrier, improvement of soil fertility and moisture content, control of drought and desertification	participating in industrial forestry. (Spears, 1983) The risks of fungal or insect diseases which are associated with large scale plantation monocultures, have created problems in some countries (e.g. Dothistroma pinii ii Kenya and the ravages of the Pine Shoot moth in Philippines). (Spears, 1983) Regarding agroforestry, the demand for labor is high (pruning)

Table 19: Impact of each SLM measures on GHG emissions and yield

SLM practice	Potential yield augmentation	Potential impact on GHG emissions and carbon sequestration
Conservation agriculture	As for the carbon storage in soil, changes in yield due to conservation agriculture will vary depending on the site characteristics. Researches shows that yields often decreased in the first years, before increasing Yields can be more than 60% higher than under conventional tillage (FAO, 2007) Studies in East and Southern Africa shows that conservation agriculture with fertilization increases the yield from 1.2 to 2 t/ha for maize and from 0.5–0.7 to 1.1 t/ha for tef in Ethiopia, a annual grass crop (Rockström, 2008)	It is difficult to make definitive quantitative statements on the effects of reducing tillage on Soil Organic Content (SOC), because the effects are highly dependent on the individual site (*inter alia* soil type, climate, crops grown, previous intensity of tillage, new regime) A change from conventional tillage to no-till can sequester 0.57 ± 0.14 t C/ha/yr (West and Post, 2002). The IPCC (2000) estimated that conservation tillage can sequester between 0.1 and 1.3 t C/ha/yr globally A field monitoring site in western Nigeria recorded that no-tillage combined with mulch application increased SOC from 15 to 32.3 t/ha in four years (Ringius, 2002) Levels can be expected to peak after 5 to 10 years, with SOC reaching a new equilibrium in 15 to 20 years. Overall, rates of SOC are lower in hotter climates
Sustainable Rice Intensification	Average yield increase by 10-25% (Ramasamy, 1997): • From 2.5t/h to 5-7.5t/ha in Gambia and Serra Leone ((USAID, 2004; Ceesay et al., 2006) • up to 15 t/ha in Madagascar(Stoop et al., 2002) • Maximum SRI yields in the range of about 8–12 t/ha appear to be more common in other studies (Dobermann, 2003)	Emission rates ranged from less than 100 kg CH4 ha-1 to more than 400 kg CH4 ha-1 for intermittent irrigation and continuous flooding respectively (Wassmann et al., 2000) Yue et al. (2005) compared continuous flooding with intermittent flooding and their role on CH4 and N2O emissions in Southern China and found that intermittent flooding showed a 17% lower GWP compared to continuous flooding while there was no significant differences between yields The soil C pool can be enriched with 401 kg C ha-1 annually, with a rice yield of 3.96 t ha-1 and input of crop residues amounting to 2.67 t ha-1 (Jarecki & Lal, 2003)
Livestock management	Increase in meat and milk production Example: in Kenya, genetic improvement program: the average lactation milk yield in the stud has gone up from 1,042 kg in 1965 to 1,527 kg in 1971 With the present selection procedure, annual genetic gain is projected to be 0.12 genetic standard deviations or 43.4 kg (Meyn 1973)	Recent modelling studies in the UK by Genesis-Faraday (Genesis-Faraday Partnership, 2008; Jones et al., 2008) have indicated that past selection for production traits such as growth rate, milk production, fertility and efficiency of feed conversion has resulted in decreases in GHG production per unit of livestock product of about 1% per annum Depending on the nature of the intervention, methane production can be reduced by 10 to 40%. Increasing DMI (dry matter intake) and the proportion of concentrate in the diet reduced methane production (–7 and –40%).

SLM practice	Potential yield augmentation	Potential impact on GHG emissions and carbon sequestration
		Methane production was also decreased with the replacement of fibrous concentrate with starchy concentrate (–22%) and with the utilization of less ruminally degradable starch (–17%). The use of more digestible forage (less mature and processed forage) resulted in a reduction of methane production (–15 and –21%). Methane production was lower with legume than with grass forage (–28%), and with silage compared to hay (–20%) Supplementation or ammoniation of straw did not reduce methane losses, but had a positive impact on the efficiency of rumen metabolism. (Benchaar et al., 2001)
Sustainable grazing management with inputs	Increase in yield will vary depending on the type and quantity of improvements (level of fertilization, amount of water, presence of leguminous, species, level of plants diversity …) Herbage production can be increased by 1-to 4fold through timing and intensity of grazing (Bryant, 1985)	Rates of C sequestration by type of improvement ranged from 0.11 to 3.04 t C·ha–1 yr–1, with a mean of 0.54 t C·ha–1·yr–1, and were highly influenced by biome type and climate (Conant, 2001) Stocking rates increased by 50% (from 0,8 to 1,2 AU/ha/year) in Brazil, mainly due to the better grazing efficiency associated with rotational grazing (Corsi et al)
Sustainable grazing management without inputs	Increase in yield will vary depending on the type and quantity of improvements (level of fertilization, amount of water, presence of leguminous, species, level of plants diversity etc.)	From 0.2 to 0.4 t C/ha/yr (improved species, controlled grazing, fire management) (Lal, 2004)
Avoided deforestation		It depends on the type of forest, its density and the use after conversion (emissions will be higher if the forest is converted into annul crops versus perennial crops or grassland) From 0.75 to 4.25 t C/ha/yr (Masera,1995) for a Brazilian tropical forest
Reforestation/afforestation and agroforestry (livefences, alley cropping)	Growth rate depends on the type of plantation, as well as its density. • Broad leaves plantation: 1 t DM/ha/yr (Koch, 2000) • Conifer plantation: 4 t DM/ha/yr • Eucalyptus plantation : 7 t DM/ha/yr • Fodder (tree + shrubland): up to 6.9 t DM/ha/yr in	From 0.86 to 3.75 t C/ha/yr (Masera, 1995) for a Brazilian tropical plantation The C sequestration potential of agroforestry systems is estimated between 12 and 228 Mg ha^{-1} with a median value of 95 Mg ha^{-1} (Albrecht and Kandji, 2003)

SLM practice	Potential yield augmentation	Potential impact on GHG emissions and carbon sequestration
	Tanzania (Mbwambo, 2004) Agroforestry (alley cropping, contour hedge-row farming) increase the yield of millet, maize ...by 45% to 200% according to some studies (Kang et al., 1999 - ILCA-IITA 1986). Other researches suggest that alley cropping has no significant effect on crop yields in most cases (SAWCS, 2008). The crop yield response is uncertain and variable due to competitive effects of the different cultures for light, water, nutrients.	

Table 20: Sources of data and assumptions taken to calculate costs for each SLM option

Required Investment	Mitigation option concerned	Assumptions	References
Fertilizer need	• Conservation agriculture and annuals • Sustainable grazing management with inputs • Perennials	The Federal Government of Nigeria (FGN) supports farmers in using fertilizers with subsidies. Subsidies represent 17% of the total cost of buying fertilizers. Farmers pay 83% of the total cost to buy these fertilizers.	Federal Fertilizer Department Federal Ministry of Agriculture and Rural Development ADP Report, University of Calabar International Food Policy Research Institute (IFRI) 2009 and 2010 World Bank, Nigeria Agriculture Public Expenditure Review
Organic Fertilizer	• Conservation agriculture • Sustainable Rice Intensification	Prices (USD 23)/bag and quantities obtained from records of the Soil Science Department, Organic Fertilizer Unit, University of Calabar Cost born at 100% by farmers	Bisong, 2010
Agric. Extension Agent	• Conservation agriculture and annuals	Number of visits / production rotation = 20	ADP report, Labour Records, University of Calabar

	• Perennials • Sustainable Rice Intensification • Sustainable grazing management with and without inputs • Livestock management	Cost born at 100% by FGN	
Seed development cost	• Conservation agriculture • Sustainable Rice Intensification • Sustainable grazing management with and without inputs	Cost based on market prices for matured seedlings Cost born at 100% by FGN	ADP Report, University of Calabar National Programme for Food Security: Federal Ministry of Agriculture and Water Resources
Administrative cost	• For all measures	Assumed to be 20% of all other costs, based on qualitative feedback from the FADAMA project, born at 100% by FGN	
Higher yield	• Sustainable grazing management with and without inputs • Livestock management • Sustainable Rice Intensification • Conservation agriculture and annuals • Perennials • Agroforestry	Assumed to be 80% times the traditional yield for conservation agriculture, 50% for agroforestry, 25% for SRI, 33% for livestock,10 to 66% for grassland and for inputs, 1/3 of the increased yield of conservation agriculture	Federal Fertilizer Department, Federal Ministry of Agriculture, ADP Report, University of Calabar SAWCS, 2008 Kang et al., 1999 Ramasamy, 1997 http://www.infonet-biovision.org/default/ct/268/livestockSpecies
Feed and management (prophylaxis and breeding)	• Livestock management	The Federal Government of Nigeria (FGN) gives subsidies to farmers to help them improving feeding and breeding practices. Subsidies represent 17% of the total cost, therefore farmers still have to pay 83%	No specific data was found in the scientific literature, so the figures used are based on the scheme for fertilizers subsidies

Planting cost	• Reforestation/afforestation and agroforestry	Cost born at 100% by FGN for afforestation, and at 25% for agroforestry. Thus farmers need to pay 75% of the cost of planting livefences and hedges	Federal Department of Forestry, Nigeria ILCA bulletin no 28, sept. 87 Tewari, 2008
Protection cost (against animals, during growing time, and forest management and enforcement)	• Reforestation/afforestation	Cost born at 100% by FGN	Federal Department of Forestry, Nigeria
Opportunity cost	• Reforestation/afforestation and agroforestry • Avoided deforestation	The cost of non converting the forested area into a more productive crop is born by the farmers, while the cost of non harvesting is supported by the government It is the value of the next-highest-valued alternative use of that resource (the benefits that could have been received by taking an alternative action, e.g. deforestation)	IIED, 2008
Non Forest Timber Product (NTFP)	• Reforestation/afforestation and agroforestry • Avoided deforestation	NFTP benefit the farmers. It includes the economical value of flora and fauna (picking, hunt) for the forest plantation, and the value of grass, fodder and wood for the agroforestry / live fencing.	Yaron, 2001 (Data are for Cameroon) Tewari, 2008 (Cost and benefits of agroforestry)
Fuel costs	• Annuals	0.77$/L in 2010	WB 2010, http://www.tradingeconomics.com/nigeria/pump-price-for-diesel-fuel-us-dollar-per-liter-wb-data.html

Annex 4. **Further details on the two low carbon scenarios A and B**

Table 21: Land Use Change matrix for scenario A in 1000 ha

		INITIAL 2010								
FINAL 2025		Annuals	Wet Rice	Perennials	Forests	Grasslands	Degraded lands	Fallow	Other lands	**Total Final**
	Annuals	28 913			4 381	2 504		3 130	2 504	**41 432**
	Wet Rice	1 312	1 313							**2 625**
	Perennials			6 552	634	475	792	634	634	**9 721**
	Forests + livefences/agroforestry	4 211			4 086	1 524	300	180		**10 301**
	Grasslands					14 126	757			**14 882**
	Degraded lands						0			**0**
	Fallow							2 290		**2 290**
	Other lands								9 803	**9 803**
	Total initial	**34 437**	**1 313**	**6 552**	**9 101**	**18 629**	**1 849**	**6 234**	**12 941**	**91 054**

Table 22: Land Use Change matrix for scenario B in 1000 ha

FINAL 2025	INITIAL 2010								
	Annuals	Wet Rice	Perennials	Forests	Grasslands	Degraded lands	Fallow	Other lands	**Total Final**
Annuals	32 192			3 234	1 848		2 310	1 848	**41 432**
Wet Rice	1 312	1 313							**2 625**
Perennials			6 552	634	475	792	634	634	**9 721**
Forests + livefences/agroforestry	932			4 086	431	300	180		**5 929**
Grasslands				1 148	15 875	757			**17 779**
Degraded lands						0			**0**
Fallow							3 110		**3 110**
Other lands								10 459	**10 459**
Total initial	**34 437**	**1 313**	**6 552**	**9 101**	**18 629**	**1 849**	**6 234**	**12 941**	**91 054**

GHG emissions for scenario A

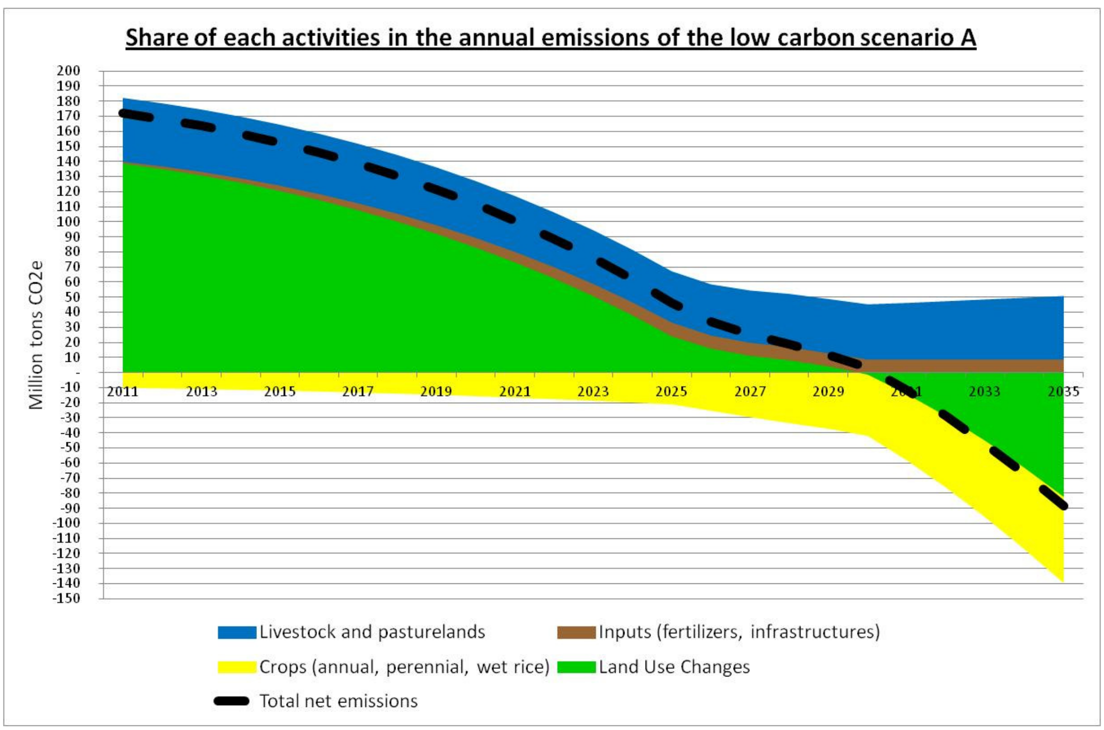
The total emissions of scenarios A/B/D for the whole 25 year-period go up to 1 687 Mt CO_2-eq, i.e. 0.74 t CO_2-eq/ha/yr, i.e. 1.6 times less than the reference scenario However, from 2030, the AFOLU sector begins to be a net sink, thanks to GHG abatement and carbon storage from the land use change component. Indeed, emissions from deforestation and other LUC are offset by the sequestration of carbon in tree plantations.

Gross emissions come from LUC for until 2029 (56% of total), from livestock and pasturelands (37%) and from inputs (7%). Gross sinks are divided between crops and LUC with a ratio of almost 4:1 (73% and 27%, from 2030 for LUC). It is especially perennials and agroforestry/afforestation that account for the carbon sequestration, respectively 33% and 47%. Even if reduced, deforestation still contributes strongly to gross emissions (53%), followed by livestock (29%).

Table 23: Comparison between the annual emissions of 2010 and 2035, in Mt CO_2-eq/yr

Activities	2010	2035		Difference	
		Baseline	LC	Baseline	LC
Land Use Changes	127.1	15.6	-82.6	-88%	-165%
Crops	-9.4	-43.6	-56.8	-364%	-504%
Livestock and grassland	42.4	46.4	42.0	+10%	-1%
Other	0.6	6.7	8.9	+1068%	+1439%
Total	**160.6**	**25.2**	**-88.5**	**-84%**	**-155%**

Figure 17: Evolution of the annual emissions in the LC scenario A, from 2010 to 2035



GHG emissions for scenario B

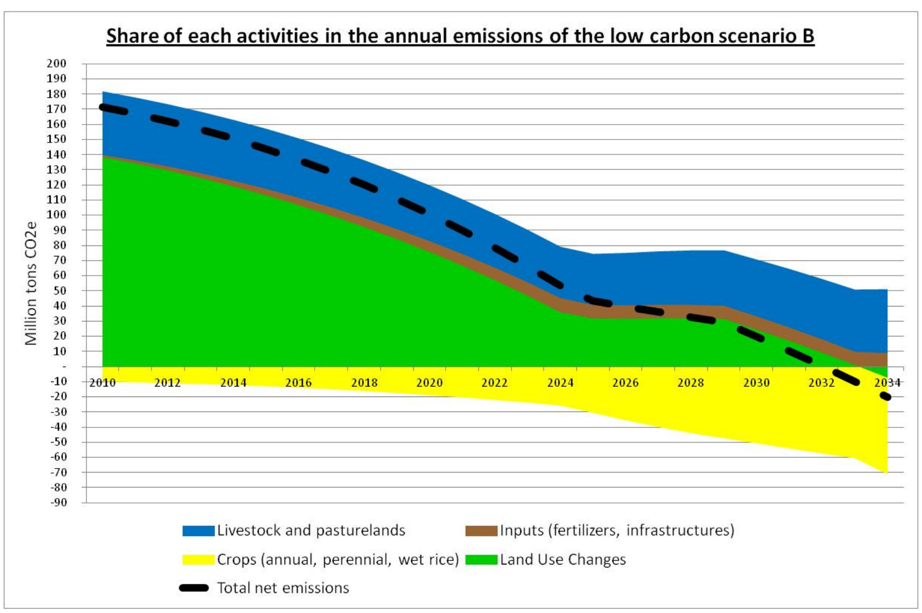
Total emissions for the whole period reach 2017 Mt CO_2-eq, which is equivalent to an average of 0.89 t CO_2-eq/ha/yr. Net emissions are positive until 2033, 2034 and 2035 are the first years where the agricultural and forestry sector becomes a sink. The main sources of gross emissions are LUC with 59%, followed by livestock and grass (35%). Again, this is essentially due to deforestation and enteric/manure management emissions. Crops provide the great majority of abatement, through annuals and conservation agriculture (31%) as well as perennials (45%). Since in this low carbon scenario agroforestry is not as important as in the previous ones, the contribution of this mitigation option is more limited (21% instead of 47%).

Total emissions for the whole period reach 2017 Mt CO_2-eq, which is equivalent to an average of 0.89 t CO_2-eq/ha/yr. Net emissions are positive until 2033; 2034 and 2035 are the first years where the agricultural and forestry sector becomes a sink. The main sources of gross emissions are LUC (59% of total), followed by livestock and grass (35%) due to deforestation and enteric/manure management emissions. Crops provide the great majority of sequestration, through annuals and conservation agriculture (31%) as well as perennials (45%). Since in this low carbon scenario agroforestry is not as important as in the previous ones, the contribution of this mitigation option is more limited (21% instead of 47%).

Table 24: Comparison between the annual emissions of 2010 and 2035, in Mt CO_2-eq/yr

Activities	2010	2035		Difference	
		Baseline	LC	Baseline	LC
Land Use Changes	127.1	15.6	-7.5	-88%	-106%
Crops	-9.4	-43.6	-63.7	-364%	-577%
Livestock and grassland	42.4	46.4	42.1	+10%	0%
Other	0.6	6.7	8.9	+1068%	+1439%
Total	**160.6**	**25.2**	**-20.2**	**-84%**	**-113%**

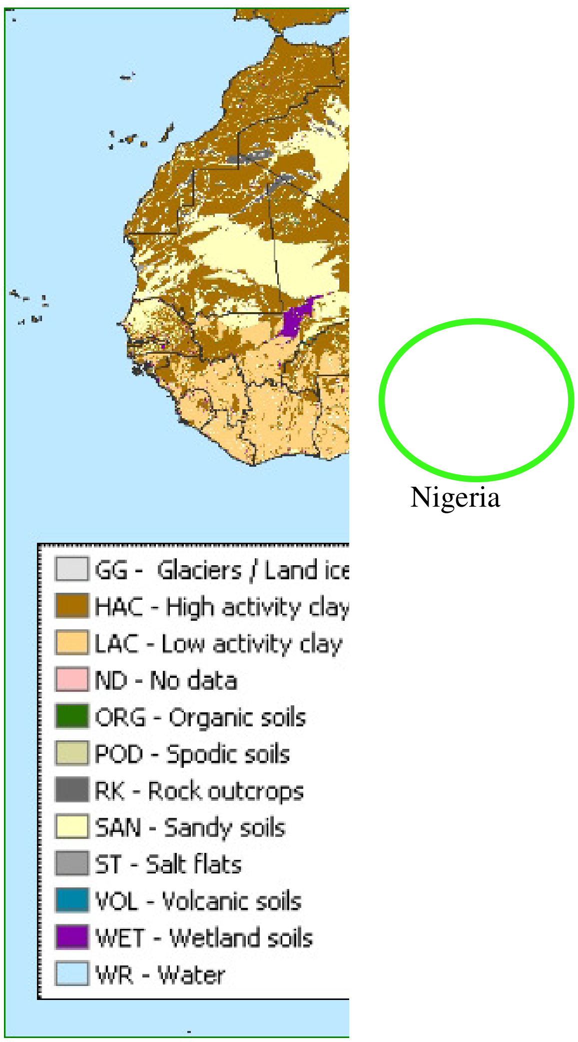
Figure 18: Evolution of the annual emissions in the LC scenario C, from 2010 to 2035



Annex 5. **Sensitivity analysis**

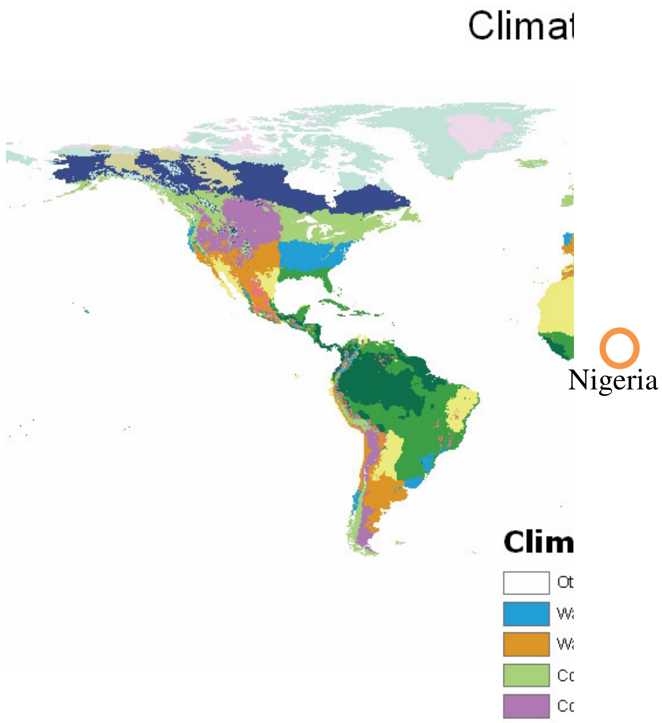
The results presented in this study depend, among others, on assumptions made on climate and soils. Given the study's limited timeframe, climate and soil parameters variables have been selected at a coarse scale of aggregation, selecting a single value for the country as a whole from the options defined by the IPCC (Figure 19 and Figure 20) at the global scale. Specifically, a tropical moist climate and Low Activity Clay (LAC) soil have been chosen since they best represent the bulk, but not all, of Nigeria's territory. To gauge the bias due to selection of single value for these parameters, a sensitivity analyses has been undertaken using different combinations of climate and soil parameters (tropical wet/moist climate and LAC/HAC soil).

Figure 19: Distribution of spatially dominant IPCC soil class for Africa



Source: Batjes, 2010, p.9

Figure 20: IPCC (2006) Climatic Zones



Source: http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/

Table 25: Discrepancy in GHG emissions depending on climate and soil types

Case	Climate	Soil
1[33]	Tropical moist	LAC (Low Activity Clay)
2	Tropical moist	HAC (High Activity Clay)
3	Tropical wet	HAC (High Activity Clay)
4	Tropical wet	LAC (Low Activity Clay)

	Reference scenario		**Low carbon scenario A**		**Low carbon scenario B**	
Case	GHG emissions for the whole 35 year-period in Mt CO_{2e}	Difference (relative to case 1)	GHG emissions for the whole 35 year-period in Mt CO_{2e}	Difference (relative to case 1)	GHG emissions for the whole 35 year-period in Mt CO_{2e}	Difference (relative to case 1)
1	2663		1687		2017	
2	2682	0.7%	1696	0.5%	2019	0.1%
3	1112	-58.3%	138	-91.8%	469	-76.8%
4	1128	-57.6%	146	-91.3%	471	-76.7%

[33] As used in the main analysis.

Changing only the type of soil (from LAC in the initial analysis to HAC) does not significantly affect the emission estimates; the difference is only 0 to 1%. However, the type of climate has an important impact on the emissions: the tropical wet climate gives figures that are 2 to 12 times lower than the tropical moist climate.

Table 26: Discrepancy in the mitigation potential depending on climate and soil types

	Mitigation potential from scenario A		Mitigation potential from scenario B	
Case	GHG avoided for the whole 35 year-period in Mt CO_{2e}	Difference (relative to case 1)	GHG avoided for the whole 35 year-period in Mt CO_{2e}	Difference (relative to case 1)
1	976		646	
2	986	1.07%	662	2.5%
3	973	-0.3%	643	-0.5%
4	982	0.6%	657	1.8%

Differences in mitigation potential, however, are low (less than 3%). This is not considered significant in comparison to uncertainty surrounding emissions factors for a single set of soil and climatic conditions (generally at least 30%). Therefore, the selection of soil and climate parameters is not considered to have significantly affected the results in terms of the sector mitigation potentials.