Deliverable

1

Water Research Commission

Project Number: **K5/2719/4**

Project Title: Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems.

Deliverable No.1: Desktop review of Climate Smart Agriculture and Soil and Water Conservation

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Contract Summary

Project objectives

1. To evaluate and identify best practice options for CSA and Soil and Water Conservation (SWC) in smallholder farming systems, in two bioclimatic regions in South Africa. (Output 1)
2. To amplify collaborative knowledge creation of CSA practices with smallholder farmers in South Africa (Output 2)
3. To test and adapt existing CSA decision support systems (DSS) for the South African smallholder context (Outputs 2,3)
4. To evaluate the impact of CSA interventions identified through the DSS by piloting interventions in smallholder farmer systems, considering water productivity, social acceptability and farm-scale resilience (Outputs 3,4)
5. Visual and proxy indicators appropriate for a Payment for Ecosystems based model are tested at community level for local assessment of progress and tested against field and laboratory analysis of soil physical and chemical properties, and water productivity (Output 5)

Project rationale

Poverty, food insecurity and malnutrition levels in South Africa are still high and on the increase. About 53% of children under six live in poor households. The vast majority of these children are African and live in rural areas in Kwazulu Natal, Eastern Cape and Limpopo. The figures can be compared with just less than 33% of households and 45% of individuals categorised as poor in terms of South Africa's official upper-bound poverty line of R779 ($50) per month.

Agriculture remains vital to the economy in South Africa and its development has significant implications for food security and poverty reduction. Although improvement of food security and improved nutrition as well as the promotion of sustainable agriculture and sustainable water management strategies are national policy priorities, strategies and implementation processes for the millions of impoverished rural dwellers are sorely lacking.

Increase in agricultural productivity for the smallholder sector has mainly focussed on commercialisation strategies and conventional farming practices, with very little change in production techniques and limited improvement in yields.

Land tenure insecurity for millions of smallholder farmers, including women, declining soil fertility, severely restricted access to water, degraded ecosystems, poor market access, inadequate funding and inadequate infrastructure development continue to hinder agricultural development for smallholder farmers. These challenges are expected to be further exacerbated by climate change and developing adaptation mechanisms is a high priority.

Economic development and agricultural expansion are often achieved at the expense of environmentally sustainable practices. Ecosystem functions, including biodiversity and water services, are key to increasing resource efficiency and productivity and ensuring resilience. They are even more critical under the new realities of climate change. Ecosystem Based Adaptation (EBA)-driven agriculture linked to viable supply and demand side value chains, has an important role to play in developing an agricultural sector that is well integrated to the broader landscape, is climate resilient and environmentally and socially sustainable.

Climate Smart Agriculture (CSA) promotes increases in productivity and adaptation to climate change that encompass socially and environmentally responsible agriculture. Numerous approaches, technologies and practices to support CSA are already available. CSA includes both traditional and innovative agricultural practices and technologies that promote agricultural productivity and generate income, while boosting resilience to climate change.

The ideal combination of CSA actions varies from location to location. For this reason, site specific assessments are critical aspects of CSA implementation, identifying the most suitable actions for each agro-ecological and socioeconomic context. A number of decision support systems and tools have been developed, mainly by international and national research based organisations for this purpose, but similar systems and knowledge mediation processes appropriate to our smallholder context are however still lacking. These decision-support systems and prioritisation frameworks must characterise CSA practices, prioritize locally appropriate actions, assess costs and benefits, link national and local planning mechanisms and most importantly must be built on community based criteria, indicators and priorities Concrete actions must be taken to enhance the evidence base to underpin strategic choices, promote and facilitate wider adoption of appropriate technologies by smallholder farmers and develop institutional arrangements to support, apply and scale-out CSA in the smallholder farming systems. Actions are required from a broad range of stakeholders from government and the public sector, private sector, academia and research, NGOs and CBOs, among others.

The CSA decision-support system (DSS) aims to improve regional and local planning by providing a coherent process for directing climate change and agriculture adaptation investments and programmes. With transparency and participation at the heart of this process, local knowledge and scientific evidence can work together to establish realistic pathways for increasing CSA adoption. Sustainable soil, water and natural resource use options and practices effect increased productivity, food security and wellbeing for a range of smallholder farmers; from subsistence through to semi-commercial.

Outputs and Impacts

Outputs of the development phase of this research process include the decision-support framework, series of manuals, stakeholder platforms for continued support (post-project) and lessons learned from the pilot implementation processes. Each subsequent use of the platform will produce investment portfolios and linked outputs for scaling out CSA, which will both create real action on the ground and provide feedback for improving the platform and establishing further best practice options.

OUTPUTS

1. A locally relevant DSS for CSA and WSC in smallholder farming systems in South Africa
2. A choice of appropriate, tested practices and technologies for implementation at homestead and field level across a range of bioclimatic regions
3. Baskets of options for use at community based level for introduction of concepts, awareness raising and implementation, across a range of bioclimatic regions
4. Recommendations for appropriate knowledge mediation, learning and dissemination strategies for CSA in smallholder farming systems
5. A model for community based monitoring of CSA indicators

EXPECTED IMPACTS

1. Smallholder farmers across a range of bioclimatic regions have increased knowledge and awareness of climate change and are able to adapt to these stresses by implementing appropriate agricultural and water management practices.
2. Smallholder farmers are able to make informed decisions about and are able to implement a range of climate smart agricultural practices that are best bet options for their specific socio-economic and agro-ecological situations
3. Implementation of practices that include but are not limited to soil and water conservation practices (including conservation agriculture), rainwater harvesting and storage for productive activities, increased diversity in food production and inclusion of indigenous crops and plants in their farming systems, micro climate management strategies (such as drip irrigation and small greenhouses), integration of small livestock and agroforestry.
4. Smallholder farmers link with and are supported by local stakeholders and use the CSA decision support frameworks for implementation and increased awareness through scaling out of practices to other communities in and between localities
5. Smallholder farmers work together and build local platforms for joint activities related to their improved farming systems (including savings, local value chain development and joint resource management options)
6. Scaling out and scaling up of the CSA frameworks and implementation strategies lead to greater resilience and food security for smallholder farmers in their locality.

Deliverables

No	Deliverable	Description	Target date
FINANCIAL YEAR 2017/2018			
1	Report: Desktop review of CSA and WSC	Desktop review of current science, indigenous and traditional knowledge, and best practice in relation to CSA and WSC in the South African context	1 June 2017
2	Report on stakeholder engagement and case study development and site identification	Identifying and engaging with projects and stakeholders implementing CSA and WSC processes and capturing case studies applicable to prioritized bioclimatic regions Identification of pilot research sites	1 September 2017
3	Decision support system for CSA in smallholder farming developed (Report	Decision support system for prioritization of best bet CSA options in a particular locality; initial database and models. Review existing models, in conjunction with stakeholder discussions for initial criteria	1 February 2018
FINANCIAL YEAR: 2018/2019			
4	CoPs and demonstration sites established (report)	Establish communities of practice (CoP)s including stakeholders and smallholder farmers in each bioclimatic region.5. With each CoP, identify and select demonstration sites in each bioclimatic region and pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies in homestead farming systems (gardens and fields)	1 May 2018
5	Interim report: Refined decision support system for CSA in smallholder farming (report)	Refinement of criteria and practices, introduction of new ideas and innovations, updating of decision support system	1 September 2018
6	Interim report: Results of pilots, season 1	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies , working with the CoPs in each site and the decisions support system. Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation.	1 February 2019
FINANCIAL YEAR 2019/2020			
7	Report: Appropriate quantitative measurement procedures for verification of the visual indicators.	Set up farmer and researcher level experimentation	1 May 2019
8	Interim report: Development of indicators, proxies and benchmarks and knowledge mediation processes	Document and record appropriate visual indicators and proxies for community level assessment, work with CoPs to implement and refine indicators. Link proxies and benchmarks to quantitative research to verify and formalise. Explore potential incentive schemes and financing mechanisms. Analysis of contemporary approaches to collaborative knowledge creation within the agricultural sector. Conduct survey of present knowledge mediation processes in community and smallholder settings. Develop appropriate knowledge mediation processes for each CoP. Develop CoP decision support systems	1 August 2019
9	Interim report: results of pilots, season 2	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies, working with the CoPs in each site and the decisions support system. Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation.	1 February 2020
FINANCIAL YEAR 2020/2021			
10	Final report: Results of pilots, season	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies , working with the CoPs in each site and the decisons support system. Create knowledge mediation productions, mauals, handouts and other resoruces necessary for learning and implementation.	1 June 2020
11	Final Report: Consolidation and finalisation of decision support system	Finalisation of criteria and practices, introduction of new ideas and innovations, updating of decision support system	3 July 2020
12	Final report - Summarise and disseminate recommendations for best practice options.	Summarise and disseminate recommendations for best practice options for knowledge mediation and CSA and SWC techniques for prioritized bioclimatic regions	8 July 2020

Overview of Deliverable 1

This Deliverable is essentially intended to scope the context in which the Project will need to locate itself. This context includes the increasing global recognition of the realities of climate change and the potential impacts on agricultural production, and indeed the trends already observed in relation to this. The document identifies the key global responses to these potential impacts, and locates them within the South African situation. The context also includes the national policy framework within which agricultural developments take place in South Africa, and provides an initial analysis in relation to the support for agricultural approaches consistent with improving resilience to climate change, in particular in relation to smallholder farmers. The Deliverable then describes the various agricultural approaches that will be tested through the project in some detail, identifying the potentials and possible constraints on each of these.

1 CONTEXT AND OVERVIEW OF CLIMATE SMART AGRICULTURE

For millennia farmers across the globe have adapted their farming practices, such as their choice of crops and livestock; sowing, planting and harvesting times; transhumance patterns and irrigation and other farming techniques, to the vagaries of season and climate in their part of the world. In many areas these adaptations evolved into fixed patterns where each year the timing of the farming activities could be predicted almost to the day, with some relatively minor variations. Farming practices in many areas were therefore predicated on a relatively high degree of climate predictability in terms of rainfall patterns and amounts and temperature variations. Inevitably some regions -- particularly the more marginal and drier regions -- were prone to periodic extremes, of drought or flood or extreme temperatures, which impacted negatively on the productivity of the farmers and on the food security and livelihoods of entire populations. Farmers' abilities to adapt under such conditions has, in some cases, been stretched to the limit.

In recent times, however, climate has become more difficult to predict as conditions have become more extreme. Farming adaptations developed over the millennia are proving inadequate in the face of these challenges. There is increasing evidence that a key driver of these shifts is global climate change caused, and/or accelerated, by human activities (anthropogenic influences). The Intergovernmental Panel on Climate Change (IPCC, 2014) reports that

> "*In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans.*"

With regard to agriculture, the IPCC comments that

> "*Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts,*"

and with regard to livelihoods it states that

> "*Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty (high confidence).*"

In response to these challenging new conditions faced by farmers across the globe, the United Nations Food and Agriculture Organisation (FAO) presented its response -- an approach it has termed Climate Smart Agriculture (CSA) -- at the 2010 Conference on Agriculture, Food Security and Climate Change in the Hague. In its definition the FAO states, in its CSA Sourcebook (Climate Smart Agriculture Sourcebook, FAO, 2013), that CSA

> *'…contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:*
>
> *1. sustainably increasing agricultural productivity and incomes;*
>
> *2. adapting and building resilience to climate change;*
>
> *3. reducing and/or removing greenhouse gases emissions, where possible.*

> *CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. The magnitude, immediacy and broad scope of the effects of climate change on agricultural systems create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments and programs. The CSA approach is designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change.'* (emphasis added)

The FAO explains the urgency for a new approach as follows:

> *Between now and 2050, the world's population will increase by one-third. Most of these additional 2 billion people will live in developing countries. At the same time, more people will be living in cities. If current income and consumption growth trends continue, FAO estimates that agricultural production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed. Agriculture must therefore transform itself if it is to feed a growing global population and provide the basis for economic growth and poverty reduction. Climate change will make this task more difficult under a business-as-usual scenario, due to adverse impacts on agriculture, requiring spiralling adaptation and related costs.*
>
> ***Developing countries and smallholder farmers and pastoralists in particular are being especially hard hit by these changes. Many of these small-scale producers are already coping with a degraded natural resource base. They often lack knowledge about potential options for adapting their production systems and have limited assets and risk-taking capacity to access and use technologies and financial services*** *(ibid).* (emphasis added)

The emphasised section has particular relevance for this WRC project in that the smallholder farmers intended as the main beneficiaries of the project activities are subject to the stresses and constraints outlined by the FAO here. Additionally the approach promoted by CSA, and which will inform the project activities, is particularly concerned with the notion of livelihoods and food security and the need to enhance these wherever possible, through the practices outlined by the FAO, and summarised here:

> *'This approach also aims to strengthen livelihoods and food security, especially of smallholders, by improving the management and use of natural resources and adopting appropriate methods and technologies for the production, processing and marketing of agricultural goods. To maximize the benefits and minimize the trade-offs, CSA takes into consideration the social, economic, and environmental context where it will be applied. Repercussions on energy and local resources are also assessed. A key component is the integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use.'*

This therefore provides a valuable summary of the approach to be adopted by the project. [More detail on the FAO approach to CSA is provided in Chapter 3 of this report.]

The following sections explore climate change, Climate Smart Agriculture, and the response of the South African government in terms of policy and initiatives addressing climate change and promoting CSA, in greater depth.

1.1 Predictions for climate change

One of the greatest challenges with regard to climate change is the near impossibility of making accurate predictions as to how it will impact different areas of the world. While current impacts can be identified with fairly high levels of confidence, the precise nature of the changes in climate and the effects of this on agricultural production in different areas are far less certain. However the IPCC have bitten the bullet and made some fairly strong predictions in relation to agriculture globally, and within different regions of the world.

Predicted global climate change

- All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability (high confidence).
- For the major crops (wheat, rice, and maize) in tropical and temperate regions, climate change without adaptation will negatively impact production for local temperature increases of 2°C or more above late-20th-century levels, although individual locations may benefit (medium confidence).
- Climate change will increase progressively the inter-annual variability of crop yields in many regions (medium confidence).

Predicted climate change in Africa

- African ecosystems are already being affected by climate change, and future impacts are expected to be substantial (high confidence).
- Climate change will amplify existing stress on water availability in Africa (high confidence).
- Climate change will interact with non-climate drivers and stressors to exacerbate vulnerability of agricultural systems, particularly in semi-arid areas (high confidence).
- Africa's food production systems are among the world's most vulnerable because of extensive reliance on rainfed crop production, high intra- and inter-seasonal climate variability, recurrent droughts and floods that affect both crops and livestock, and persistent poverty that limits the capacity to adapt
- Increased temperatures are expected to increase pests and disease and reduce yields – by as much as 28% in Africa over the next 50 years, in the absence of adaptations (Boko et al., 2007)

And of particular relevance to this project:

> Progress has been achieved on managing risks to food production from current climate variability and near-term climate change but these will not be sufficient to address long-term impacts of climate change (high confidence). Livelihood-based approaches for

managing risks to food production from multiple stressors, including rainfall variability, have increased substantially in Africa since the IPCC's Fourth Assessment Report (AR4). While these efforts can improve the resiliency of agricultural systems in Africa over the near term, current adaptations will be insufficient for managing risks from long-term climate change, which will be variable across regions and farming system types. Nonetheless, processes such as collaborative, participatory research that includes scientists and farmers, strengthening of communication systems for anticipating and responding to climate risks, and increased flexibility in livelihood options, which serve to strengthen coping strategies in agriculture for near-term risks from climate variability, provide potential pathways for strengthening adaptive capacities for climate change. (emphasis added) (ibid)

Predictions for South Africa

The IPCC makes these broad predictions relating to rainfall and temperature in South Africa:

> All of Africa is projected to warm during the 21st century, with the warming very likely to be greater than the global annual mean warming – throughout the continent and in all seasons. The drier, subtropical regions are projected to warm more than the moister tropics. This result is consistent with the strong observed temperature trends over subtropical South Africa (Kruger and Shongwe, 2004), which indicate that change is already occurring.
>
> The model projects an increase in the median temperature of more than 3°C over the central and northern interior regions of South Africa. Over the coastal regions of the country, a somewhat smaller increase (about 2°C) is projected. The largest increase in median temperature is projected to occur over the central interior of South Africa, exceeding a value of 4°C during autumn and winter. Generally, the largest temperature increases are projected for autumn and winter, with the summer and spring changes being somewhat smaller.
>
> The Coupled General Circulation Models (CGCM) projections described in AR4 indicate that rainfall is likely to decrease over the winter rainfall region of South Africa and the western margins of southern Africa (Christensen et al., 2007). Observed trends in rainfall over South Africa are not as well defined and spatially coherent as the observed trends in temperature.
> Most of the summer rainfall region of South Africa is projected to become drier in spring and autumn as a result of the more frequent formation of mid-level high-pressure systems over this region. More frequent cloud-band formation takes place over eastern South Africa, resulting in increased summer rainfall totals.
>
> Greater increases in dry spell duration is projected for the greater proportion of eastern and north-eastern South Africa for all seasons, indicating that dry spells of relatively long duration may be expected to occur more frequently. Similar patterns of change are projected for the late 21st century.

Potential Impact on Food Security

With regard to the impact of climate change on food security in Southern Africa, the IPPC makes the following predictions:

- Maize-based systems, particularly in southern Africa, are among the most vulnerable to climate change (Lobell et al., 2008). **Estimated yield losses at mid-century range from 18% for southern Africa** (Zinyengere et al., 2013) **to 22% aggregated across sub-Saharan Africa, with yield losses for South Africa and Zimbabwe in excess of 30%** (Schlenker and Lobell, 2010).
- Loss of livestock under prolonged drought conditions is a critical risk given the extensive rangeland in Africa that is prone to drought. **Regions that are projected to become drier with climate change, such as northern and southern Africa, are of particular concern** (Solomon et al., 2007; Masike and Urich, 2008; Dougill et al., 2010; Freier et al., 2012; Schilling et al., 2012).
- Groundwater recharge may also not be significantly affected by climate change in areas that receive more than 500 mm per year, where sufficient recharge would remain even if rainfall diminished, assuming current groundwater extraction rates. By contrast, **areas receiving between 200 and 500 mm per year, including the Sahel, the Horn of Africa, and Southern Africa, may experience a decline in groundwater recharge with climate change to the extent that prolonged drought and other precipitation anomalies become more frequent with climate change, particularly in shallow aquifers, which respond more quickly to seasonal and yearly changes in rainfall than do deep aquifers** (Bovolo et al., 2013).

Climate Trend Analysis and Predictions for South Africa

In 2012 the South African national Department of Environmental Affairs (DEA) in collaboration with the South African National Biodiversity Institute (SANBI) established the Long-Term Adaptation Scenario (LTAS) Flagship Research Programme in response to the South African National Climate Change Response White Paper White Paper (NCCRP).

The LTAS has produced a series of detailed technical reports covering different sectors. It reports the following climate trends observed in South Africa in the half century since 1960:

- Mean annual temperatures have increased by more than 1.5 times the observed global average of 0.65°C.
- Maximum and minimum temperatures have been increasing annually, and in almost all seasons.
- Hot and cold extremes have increased and decreased respectively in frequency, in most seasons across the country, particularly in the western and northern interior.
- In almost all hydrological zones there has been a marginal reduction in rainfall for the autumn months. Annual rainfall has not changed significantly, but an overall reduction in the number of rain days implies a tendency towards an increase in the intensity of rainfall events and increased dry spell duration.
- Extreme rainfall events show a tendency towards increasing in frequency annually, and especially in spring and summer, with a reduction in extremes in autumn.

The LTAS's climate change projections for South Africa for 2050 and beyond, without mitigation, include significant warming, as high as 5–8°C over the South African interior; somewhat reduced over coastal zones and a general pattern of possible drier conditions to the west and south of the country and wetter conditions over the east of the country. In a cautionary note the LTAS emphasises the high degree of uncertainty that accompanies interpreting modeled and even observed trends: contradictions have been noted between some modeled and observed trends, while many of the projected changes are within the range of historical natural variability. However, despite these caveats it retains high levels of confidence in its predictions.

In a parallel process, the national Department of Science and Technology (DST) as part of its 10-year Global Change Grand Challenge commissioned the Council for Scientific and Industrial Research (CSIR) to develop the South African Risk and Vulnerability Atlas (SARVA), as an information portal through which to share analyses and predictions in relation to climate change in South Africa. SARVA makes the following predictions with regard to the impact of climate change on agriculture in South Africa (SARVA, 2013):

> In South Africa, a semi-arid country where the average evaporation rate exceeds its precipitation, water is a critical limiting factor for agricultural production. The agriculture sector accounts for about 60% of water utilisation in South Africa. Changes in water demand and availability will significantly affect farming activities, with western regions predicted to have 30% reduced water availability by 2050. Under these conditions irrigation demand will increase, especially in the affected drier western parts of the country, adding to the pressure on water resources.
>
> The profitability of maize and wheat production is highly climate dependent. With a 2°C increase in temperature and a 10% reduction in rainfall, profits are projected to be generally reduced by around R500/ha, which is equivalent to a yield reduction of 0.5 t/ha (Schulze, 2007). Wheat-producing regions in marginal areas of the winter rainfall region are expected to suffer losses of 15-60% by 2030- 2050, depending on the extent of warming and drying (Midgley et al., 2007).
>
> The greatest impact on production is expected to be in the most marginal areas, where low and irregular rainfall is already experienced. The implications of these projections are significant as many livelihoods depend upon these industries (Midgley et al., 2007).
>
> Extensive livestock farming comprises nearly 80% of agricultural land in South Africa. Dairy farming is practiced all over South Africa, whereas sheep farming and most of South Africa's rangelands are to be found in the semi-arid areas of the country. Any further decline in water availability in these water-stressed areas is likely to impact carrying capacity and may lead to severe livestock loss and a decline in overall productivity.
>
> Predicted changes in climate are expected to:
>
> - modify agricultural productivity across different farming regions;
> - alter the spatial distribution of climatically suitable growing areas, with certain areas benefiting, while others may find themselves at a disadvantage;

• impose new management practices or adjustment to existing operations;

• result in a shift in agricultural trade patterns; and

• identify new crop opportunities with certain crops having competitive advantages/ disadvantages over others (Schulze, 2007).

While SARVA has a strong commercial focus in terms of agriculture, it does offer some comments on the potential impacts of climate change on small-scale farmers:

> Emerging, small-scale and resource-poor farmers are particularly vulnerable to climate change and variability because they have fewer capital resources and management technologies at their disposal. Subsistence farmers often do not have the ability to adapt nor sufficient means to deal with and recover from extreme events such as floods and droughts (SARVA, 2013).

It is small-scale and emerging farmers, such as the participants in this research study, who stand to be most impacted by changes in climatic conditions.

1.2 Technical responses to climate change: CSA and related approaches

As discussed above, Climate Smart Agriculture (CSA) is the principal agricultural approach being promoted by the UN Food and Agriculture Organisation (FAO) in response to climate change. Climate Smart Agriculture aims to integrate the economic, social and environmental aspects of sustainable development by addressing food security and climate challenges in tandem (FAO, 2013). The FAO describes CSA as:

> *"…an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change.* ***The magnitude, immediacy and broad scope of the effects of climate change on agricultural systems create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments and programs****."* (emphasis added) (ibid)

The Climate Smart Agriculture approach is built on three key principles:

1. sustainably increasing agricultural productivity and incomes
2. adapting and building resilience to climate change
3. reducing and/or removing greenhouse gases emissions, where possible

Price Waterhouse and Cooper describe CSA as the second 'green revolution':

> The United Nations Environment Programme defines a 'green economy' as one that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities. The first green revolution in agriculture began in the mid-1960s with the advent of high yielding seed varieties and the increased use of pesticides and fertilisers. Climate change now necessitates a second green revolution as the world moves towards a green economy. This revolution will take the form of 'climate-smart agriculture' that sustainably increases productivity, resilience (adaptation) and reduces/ removes greenhouse gases (mitigation), while enhancing the achievement of national food security and development goals (Mammatt, 2016).

CSA is also concerned with the notion of livelihoods and food security and the need to enhance these wherever possible, particularly in the case of small holders:

> *This approach also aims to strengthen livelihoods and food security, especially of smallholders, by improving the management and use of natural resources and adopting appropriate methods and technologies for the production, processing and marketing of agricultural goods. To maximize the benefits and minimize the trade-offs, CSA takes into consideration the social, economic, and environmental context where it will be applied. Repercussions on energy and local resources are also assessed. A key component is the integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use (ibid).*

The FAO statement, above, also makes clear that appropriate technologies, developed under different agricultural regimes are entirely compatible with the broad concept of CSA. Within the project there will be particular emphasis on technologies developed under the headings of Conservation Agriculture (CA), Agro-ecology, and Water and Soil Conservation (WCS). These approaches are introduced below and will be discussed in greater detail in Chapters 3 and 4.

CSA is also a focus for research by the (former) Consultative Group for International Agricultural Research (CGIAR), through their Climate Change, Agriculture and Food Security (CCAFS) programme in partnership with other international agricultural research organisations. In particular CGIAR is concerned with developing a participatory climate change and food security vulnerability assessment toolkit, and a decision support system for identifying appropriate CSA practices. Both of these will inform the project's work with farmers.

1.2.1 Conservation Agriculture (CA)

Conservation agriculture (CA) has gained popularity across the world as an alternative to both conventional tillage and organic agriculture. It is founded on three principles:

- Continuous minimum mechanical soil disturbance
- Permanent organic soil cover
- Diversification of crop species grown in sequences and/or association

Dumanski et al. (2006) describe CA as a system aimed to *optimize* rather than *maximize* yields and profits and balance agricultural, economic and environmental benefits. The Africa Portal website (www.africaportal.org backgrounder no. 61 August 2013) under the heading "Conservation Agriculture: South Africa's new green revolution?" posits the following benefits for CA:

> *When practiced in a comprehensive way, improved crop yields have been noted over time while the required quantity of most inputs has reduced. Soil fertility and moisture and the system's resilience to environmental pressures improve dramatically in the absence of tillage, and in the presence of cover crops and residues which add organic matter and nutrients. Over time, sensitivity to weather variability and extremes is reduced by gains such as improved water-holding and drought performance (Thierfelder and Wall, 2010). Improved soil moisture retention creates more reliable conditions for*

> *planting, and single-pass tillage techniques enable planting to be completed within a much shorter timeframe. Planting under the CA approach therefore requires less rainfall and a smaller window of good weather, improving the farmer's ability to optimally time planting relative to the growing season. (Hobbs, 2007)* (emphasis added).

This holds particular significance for smallholder farmers, such as the participants in this project.

Conservation agriculture has been taken up on a large scale in some parts of the world, particularly by commercial grain (wheat, maize etc.) producers, and the practices are often combined with the use of genetically modified seeds, and quite intensive herbicide, pesticide and fertilizer applications. In South Africa, CA was first introduced around 40 years ago. While uptake was initially slow, the adoption of CA in the commercial agriculture sector in the major grain producing regions of South Africa has increased dramatically, especially over the past decade, as conventional methods have proven increasingly limiting, especially in terms of land degradation and input cost pressures, as the benefits of CA practices gained exposure. The most recent assessment indicates that 40% of commercial farmers across all grain producing areas of South Africa have adopted all CA principles and it is expected that adoption trends will increase sharply over the next decade (Smith et al, 2017).

Although no figures exist to indicate the extent to which CA has been adopted within the smallholder production sector in South Africa, it is believed to still be very low (below 5%). Promotion of CA to smallholders occurs mostly through projects funded by government or other agencies. Frequently adoption of practices peaks during the implementation of a project and declines after the project ends and funds are no longer available, although some participants in these projects do continue to implement CA without project support. The constraints facing smallholders, such as availability of resources such as land, production inputs, labour, information, funds, markets and access to infrastructure, all contribute to severely limit the adoption of CA (Smith et al, 2017).

1.2.2 Agroecology

The Scientific Society of Agroecology (SOCLA) defines agroecology as follows (Agroecology 2015):

> *Agroecology is a scientific discipline that uses ecological theory to study, design, manage and evaluate agricultural systems that are productive but also resource conserving. Agroecological research considers interactions of all important biophysical, technical and socioeconomic components of farming systems and regards these systems as the fundamental units of study, where mineral cycles, energy transformations, biological processes and socioeconomic relationships are analyzed as a whole in an interdisciplinary fashion.*
>
> *Agroecology is concerned with the maintenance of a productive agriculture that sustains yields and optimizes the use of local resources while minimizing the negative environmental and socio-economic impacts of modern technologies. In industrial countries, modern agriculture with its yield maximizing high-input technologies generates environmental and health problems that often do not serve the needs of producers and consumers. In developing countries, in addition to promoting environmental degradation, modern agricultural technologies have bypassed the circumstances and socio-economic needs of large numbers of resource-poor farmers.*

In industrial countries, modern agriculture with its yield-maximizing, high-input technologies generates environmental and health problems that often do not serve the interests of producers and consumers. In developing countries, modern agricultural technologies -- in addition to promoting environmental degradation – often do not speak to the circumstances and socio-economic needs of large numbers of resource-poor farmers.

Agroecology is concerned with sustaining yields and optimising the use of local resources while minimizing the negative environmental and socio-economic impacts of modern technologies. Applying agroecological technologies requires:

> *Technological innovations, agriculture policy changes, socio-economic changes, but mostly a deeper understanding of the complex long-term interactions among resources, people and their environment. To attain this understanding agriculture must be conceived of as an ecological system as well as a human dominated socio-economic system. A new interdisciplinary framework to integrate the biophysical sciences, ecology and other social sciences is indispensable.* (www.agroeco.org, 2017)

Interdisciplinarity -- where the natural and social sciences come together – is key, and presents perhaps the biggest challenge. The approaches used in natural science, with their preference for modelling systems behaviour, struggle to deal with the immense range of variables affecting human behaviour, making them ill-suited to simple modelling approaches, while natural scientists may be averse to approaches used in social sciences, which they see as lacking technical rigour. Over the past 10 years, however, there has been increasing recognition of the need for genuinely interdisciplinary approaches and more convergence between the natural and social science approaches.

1.2.3 Soil and Water Conservation (SWC)

Soil and Water Conservation is more an umbrella term than a specific approach, and incorporates a wide range of practices focussed on making effective use of available water, improving soil health and quality and minimising soil loss through erosion. Many practices, such as mulching, cover-cropping, integration of organic matter into the soil, and minimum tillage are effective for both water and soil conservation and it is practices such as these (many of which are derived from organic or permaculture approaches) which best further the aims of Climate Smart Agriculture

1.3 Policy responses to climate change in South Africa

The challenges facing smallholder farmers and the agricultural sector as a whole as a result of climate change require transformation through institutional and policy support. On the international level, international agricultural research organisations have begun to partner to achieve this and realise the objectives of CSA. One example is the Climate Change, Agriculture and Food Security (CCAFS) programme initiated by the (former) Consultative Group for International Agricultural Research (CGIAR) in partnership with other international agricultural research organisations.

The FAO stresses that national policies in agriculture, environment, finance and other sectors will have to be aligned effectively to support farmers if any significant change is to be realised (FAO, 2010).

In South Africa, a number of key policy documents address climate change and the impacts and required adaptations in different sectors, particularly agriculture. The overarching policy document on South Africa's response to climate change is the National Climate Change Response White Paper, which outlines climate responses for different sectors of the SA economy (South Africa, 2011). Its objective is that:

> *South Africa will build the climate resilience of the country, its economy and its people and manage the transition to a climate-resilient, equitable and internationally competitive lower-carbon economy and society in a manner that simultaneously addresses South Africa's over-riding national priorities for sustainable development, job creation, improved public and environmental health, poverty eradication, and social equality (South Africa, 2011).*

A considerable amount of research has been conducted into the potential impacts of climate change on South Africa, including on agriculture across the country. One of the key research programmes is the Long Term Adaptation Scenarios Flagship Research Programme (LTAS), introduced in the previous section. The LTAS is part of the International Climate Initiative (ICI) supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. This programme draws on global climate research models to develop a range of possible scenarios emerging from different climate change impacts, and suggests mitigation and adaptation measures in relation to these.

The LTAS is one of eight Near Term Priority Climate Change Flagship Programmes identified by the White Paper, and while they all have some relevance for the agricultural sector, the LTAS and the Water Conservation and Water Demand Management Flagship Programme (WCWDM) are perhaps most directly applicable.

Several South African policy documents mention and promote Climate Smart Agriculture specifically. The Agricultural Policy Action Plan mentions that CSA includes numerous well-developed approaches to agriculture and the Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries recommends a number of CSA measures for implementation (DAFF, 2014).

The National Department of Agriculture, Forestry and Fisheries (DAFF), in its Strategic Plan 2015/16 to 2019/20 highlights an interesting economic argument in favour of CSA:

> *It is important to note that the competitiveness of agriculture is being eroded by high and rising input costs. For example, the value of imported fertilisers, diesel and machinery, has for many years, exceeded the value of agricultural exports, meaning that even though agriculture may appear to make a positive contribution to the trade balance, this is not necessarily the case. An argument is currently emerging that the key is to promote a shift from conventional agriculture to "climate-smart agriculture" such as conservation agriculture. Whereas climate-smart agriculture has long been argued on grounds of environmental sustainability and reducing production risk, another advantage is that it can achieve the same or greater productivity, but with greatly reduced production inputs. This will have the effect of making producers more competitive by lowering input costs, while reversing the trend of agriculture`s negative contribution to the trade balance (DAFF, 2015).*

Conservation agriculture is cited here as an example of CSA and it is with CA which DAFF is most directly involved. A CA policy is in the process of development, although its status is unclear at present.

In the Department's Integrated Growth and Development Plan (DAFF, 2012) a section (3.3) is devoted to ecological sustainability, where the importance of protecting the natural resources is highlighted --in particular the need for an optimal regulatory framework that is adequately enforced:

The plan explains that:

> *"…it is postulated that optimising ecosystems services within the agricultural, forestry and fisheries sectors will require a holistic approach that includes, among others:*
>
> - *Control to prevent losses through rezoning and neglect of productive land;*
> - *Adoption of improved technologies, particularly input cost-reducing eco-technologies such as conservation agriculture, in especially sensitive areas;*
> - *Re-building of capacity for appropriate R&D; and*
> - *Creation of an enabling environment (DAFF, 2012)". (ibid)*

There is also recognition of the importance of ecosystem services and the introduction of the notion of 'dis-services' provided by inappropriate agricultural practices and approaches:

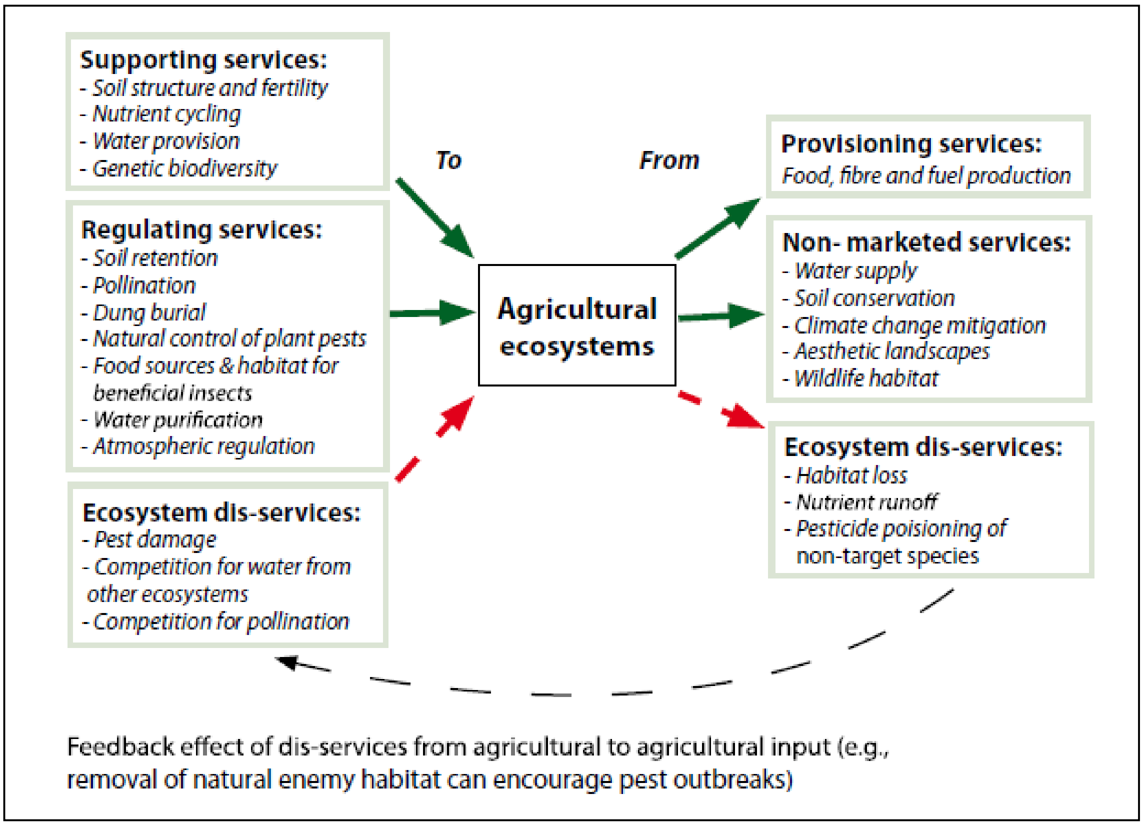


Figure 1 Ecosystem services and dis-services (DAFF, 2012)

The plan goes on to discuss the impacts of climate change on agriculture generally and raises the issue of the sector's own contribution to climate change:

The IGDP goes on to discuss the impacts of agriculture generally and raises the issue of the sectors own contribution to climate change:

> *Agricultural practices can have direct impacts on productive lands and biodiversity, as well as indirect impacts on downstream water quality and flows and aquatic ecosystem health. The continued pressure on agriculture to increase output per unit of land intensifies the challenge to ensure the natural resource base is protected. Programmes initiated by the former Department of Agriculture to protect the resource base are successful, but insufficient. Agriculture also contributes to global climate change through the release into the atmosphere of greenhouse gases such as carbon dioxide, methane and nitrous oxide. Livestock contribute 18% of global greenhouse gas emissions (FAO, 2006). Industrial meat production contributes to global warming through deforestation for ranching – this industry is the largest contributor to deforestation – and gas production. Commercial, export-oriented and input-intensive agriculture contributes to climate change through carbon emissions from petrol and diesel, in the production and sourcing of inputs, in primary production, in processing, and in transport and international trade. Smallholder farming is less environmentally damaging, in terms of climate impact (ibid).*

There is clearly considerable understanding of the relationship between agriculture and climate change in the department, however this has not as yet translated into active promotion and support of CSA, beyond the existing relatively small-scale LandCare programmes and some moves towards conservation agriculture among commercial grain producers. The department itself, with some justification, ascribes the continuing environmental degradation caused by farming to a lack of compliance with existing legislation (such as the Conservation of Agricultural Resources Act, CARA, 43 of 1983, the National Environmental Management Act, NEMA, 107 of 1998 and related legislation) and associated regulations (DAFF, 2015) .

Despite the currently limited support for CSA, as discussed above, the plan does include some clear directives for future interventions in relation to climate change:

> *With regard to climate change, there is the need to develop both adaptation and mitigation strategies for the sector. In agriculture, the most important adaptation strategies identified in major research studies on African farmers and climate change are diversification in crop and livestock production (varieties and breeds), income diversification, and migration (Dinar et al., 2008). However, opportunities to adapt in these ways are not equally available to all; as one major study concludes, "<u>too often it will be poor people whose adaptive capacities are the most constrained</u>" (Mortimer et al., 2009, emphasis added). This forms the basis for a strong argument in favour of public policies to support adaptation by poor producers, on the grounds of human rights, economic development and environmental sustainability. The most effective adaptations will require substantial public and private investments in irrigation and to support "crop varieties and animal breeds that are tolerant to heat, water and low fertility stresses", and to build roads and marketing infrastructure to improve small farmers' access to critical inputs as well as to output markets (Dinar et al., 2008). For both crop production and animal husbandry, diversification (of crops and varieties, and of breeds) is a centrally important adaptation strategy that may be pursued autonomously ('private adaptation') by farmers but needs to be accompanied and anticipated by 'public adaptation' – these shifts in production should be planned for, researched, and supported through government policies. Planting different varieties of the same crop – and maintaining seed varieties – is also a key adaptation strategy, to limit possibilities of total harvest failure. There is an important role therefore for research on robustness of seed varieties, and extension services to advise on crop choice and planting times, as precipitation and temperature changes are felt. Similarly, "adaptation by livestock farmers includes changing seasonal grazing migrations to take advantage of alternative forage when their usual grazing is damaged by drought. More water-efficient production technologies will be essential in South Africa, as will rainwater harvesting for smallholder production" (Dinar et al., 2008). (ibid)*

While it can be argued that not all of these suggestions may be entirely relevant to smallholder producers, the underlying principle of the need to embed local adaptations into a macro-adaptation framework is sound. There also needs to be recognition that different adaptations are appropriate in different circumstances, and need to be contextually located.

In contrast to much of the literature that emphasises the need for greater investment in irrigation, a major study by three respected institutions – IIED, IUCN and UNDP – shows how drylands can be resilient ecosystems and, in the face of climate change, people living and producing in drylands are themselves already resilient. IIED promotes a 'resilience paradigm' to responding to climate change in drylands, in which the priority is development that can promote sustainability – rather than degrading resources. More production is needed in drylands, not less, and producers in marginal areas should have stronger, more secure rights to natural resources. Enabling policy should focus on valuing dryland ecosystems, restoring investment, linking up with effective (and equitable) markets, and rebuilding institutions (Mortimer et al., 2009).

The DAFF Agricultural Policy Action Plan (DAFF, APAP, 2015) 2015-2019 takes things further with a section entirely devoted to CSA. This shows a broadening understanding of and commitment to CSA, which is worth quoting here:

> *The Department of Agriculture, Forestry and Fisheries supports the development and implementation of climate-smart agriculture as a means of adaptation and mitigation against the adverse impacts of climate change. Climate-smart agriculture in South Africa would be based on the following production systems, namely organic farming, agro-ecology and conservation agriculture*.
>
> *Aspiration*
>
> *1. The development of CSA framework / strategy - AFF sector should mobilise stakeholders to discuss and develop the concept document on CSA within the MTSF period and identify/appoint suitable service provider to finalise the CSA framework.*
>
> *2. Up-scaling of the CSA concept and practices by/among all farmers in all the nine (9) provinces – there is a need for tailored and locally driven capacity building programmes on CSA among farmers. This requires a sustained and ground-truthed intervention based on local needs and the prevailing circumstances.*
>
> *3. The provision of incentives for CSA practices with special focus on small holder farmers – attempts should be made to provide incentives to farmers in the form of tax benefits for farmers implementing CSA through measures such as, but not limited to, reduced tax on fuel.*
>
> *4. To produce more with the same amount of water - by using more efficient irrigation methods & water demand management*
>
> *Policy levers*
>
> *1. The up-scaling of the LandCare programme under the Conservation of Agricultural Resources Act (CARA), 1983 (Act 43 of 1983), by improved alignment, coordination and policy implementation*
>
> *2. Between and among national, provincial and local spheres of government - Align CSA policy framework and programme with sector departments and provinces*

3. Between state, state entities, academia and private sector entities - Improve collaboration between government and private sector entities including academic and research institutions

4. Approval of the irrigation strategy – adopt irrigation strategy to guide water demand management and water use efficiency.

In the Action Plan it is encouraging to see the reference to the development of a CSA capacity building programme (scheduled for 2016/17) for extension officers and large-scale commercial farmers, with demonstrations in all 9 provinces. Unfortunately, there is no evidence that this target has been reached, or even attempted with any rigour. Also, there seems nothing planned in terms of capacity building at the smallholder level, although as it is with the smaller-scale emerging farming sector with which the extension services are most involved; perhaps this is seen as being covered by the capacity building of the extension officers. This may not, though, be a realistic assumption or an adequate response to the needs for capacity building. The final reference to a 'platform for knowledge sharing' (scheduled for 2015/16) is also encouraging, but there is little evidence of the existence of such a platform, and if it is intended to be a web-based platform it may well be inaccessible to many farmers.

Further research is now required to see how the department is meeting these output targets. With regard to the National CSA Research and Development programme, scheduled for 2015/2016 for action by the Agricultural Research Council (ARC), nothing yet appears available in the terms of research outputs or policy recommendations. However, on Earth Day, 22 April 2016 the ARC made the following commitment:

"The Agricultural Research Council (ARC), South Africa, is committed towards research focusing on climate smart and sustainable agriculture for South Africa and Africa. Many of the ARC projects focus on conducting research that is environmentally sustainable and economically viable for the end user. Some of these key research projects fall under Conservation Agriculture (CA), which is fairly new in South Africa but increasing in popularity because of its low input and environmentally sustainable agronomical practices. ARC-GCI has several projects investigating aspects such as insect and weed dynamics in CA systems as well as how crop yields are affected when these principles are applied. Dr Nel reports that the outcomes of CA projects are positive at this stage and have shown promise under adverse drought conditions."(ARC, 2016)

> *"CA is definitely the way forward for climate smart agriculture in SA as the use of fossil fuels and the release of carbon from the soil is reduced."*
>
> \- Dr Andre Nel, Agricultural Research Council (ARC) of South Africa

From the interest expressed by both DAFF and the ARC in CSA – and CA, in particular -- it would seem that now is an opportune time for research into farmer innovation around CSA and related agricultural practices. However there may be one note of caution in that the approach to CA being adopted by the ARC involves the development of modified 'transgenic' seeds as promoted by the Water Efficient Maize for Africa (WEMA) partnership programme with which the ARC is involved:

The Water Efficient Maize for Africa has created a large following with the positive results it has had to offer since its inception in 2008. The WEMA project is public-private partnership and aimed to produce low-cost drought tolerant conventional and transgenic (GM) hybrids that give at least 25% yield advantage under moderate drought conditions.

> *The first WEMA Drought TEGOTM hybrid WE3127 was launched in December 2014. The variety received positive feedback from the various representatives of farmers and extension officers that received 10 000 promotional seed packs during the launch. To date, the ARC has released and registered ten Drought TEGOTM hybrids with predominant characteristics of drought tolerance and high yield potential under optimal moisture. (ibid)*

While the overall approach adopted by the ARC can be considered in some ways compatible with a more agroecological approach to CSA, the promotion of such seeds is certainly not consistent with strengthening food sovereignty. Understandings of CSA are therefore likely to vary according to the agendas being pursued by various stakeholders.

The policy context for CSA in South Africa would appear at first glance to be fairly robust, and well informed by global research and trends. However, the proof will be in the implementation of the various policies, strategies and plans, and to date there is little evidence of this happening at any scale. It may be that the work of the Project will have some influence in increasing the focus on CSA for smallholder famer across the country.

2 APPLYING CSA IN THE CONTEXT OF SMALLHOLDER FARMING IN SOUTH AFRICA

2.1 Issues shaping the context of smallholder farming in South Africa

Development in South Africa is inextricably tied to massive challenges rooted in both the past and in the future. In the past, colonial appropriation and control of access to resources was taken to disastrous extremes through the policies of apartheid; twenty-three years into democracy poverty and dispossession still plague us. At the same time, problems anticipated in the future already loom large: South Africa as a water stressed country can expect to face particularly difficult challenges in terms of food security due to the increased temperatures and pests and decreased water access anticipated to result from climate change. In 2011 the government reported that climate change was already impacting South Africa, with greater variations in temperature and rainfall and rising sea levels (South Africa, 2011). The issues of who should have land and why are increasingly linked not only to redressing historical injustices but also to achieving resilience, sustainable livelihoods and food security under the challenging conditions of the future.

South Africa's vision in 1994:
"No political democracy can survive and flourish if the mass of our people remain in poverty, without land, without tangible prospects for a better life. Attacking poverty and deprivation must therefore be the first priority of a democratic government."
- The Reconstruction and Development Programme (SA, 1994)

South Africa's vision for the present:
"Unless emissions are checked soon, development will be reversed in many parts of the world, bringing major economic decline …
The political challenge in the next two decades will be to develop policies and regulatory initiatives that prompt improved resource management and deliver substantial clean-technology industries. This will include policies that help people cope with new risks during the transition, adapting land and water management to protect livelihoods and threatened natural environments, while transforming energy systems."
- National Development Plan for 2030 (SA, 2011).

Development is a double-edged sword: economic development and population growth are the main drivers of increased $C0_2$ emissions (Sims and Kienzle, 2015). We cannot afford for development agendas to be preoccupied with problems inherited from the past without considering the impact of the strategies used on the future. While agriculture is a main contributor to greenhouse gases, it also offers powerful options for combating climate change. Climate Smart Agriculture engages both the historical and future challenges that must be addressed within development programmes by working for sustainable increases in productivity, increased resilience and food security and reduction of greenhouse gases.

This section explores the issues of access to and use of land, livelihood and food security.

2.1.1 Land and livelihood

In 1994, South Africa's first democratically elected government undertook to transfer 30% of the 86 million hectares of white-owned agricultural land to black South Africans by 1999; by 2016 only 9% had been transferred, however (Cousins, 2016). Only about half of the land reform projects have brought improvements – which are often limited - to the livelihoods of beneficiaries (ibid).

The 2015 General Household Survey found that 58% of households reported salaries/wages/commission as their main sources of income, while 21,7% listed social grants as their main source of income. The dependence on grants was greatest in the Eastern Cape, (37,6%), Limpopo (33,2%), Northern Cape (32,1%) and KwaZulu-Natal (28,0%) (StatsSA, 2016). The percentage of householders involved in agricultural production varied widely by province, with the highest percentages in Limpopo (43,8%), Eastern Cape (33,4%), Mpumalanga (28,7%) and KwaZulu-Natal (20,3%) as shown in the table below:

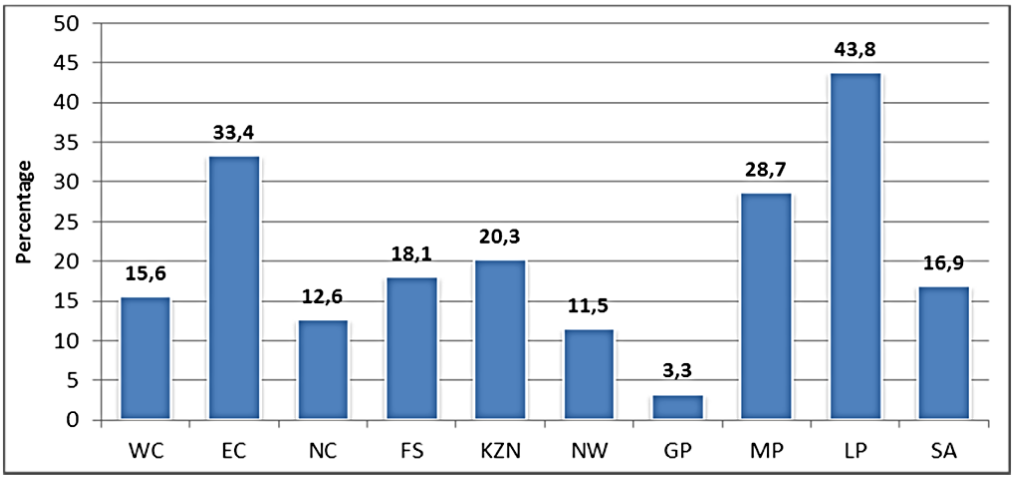
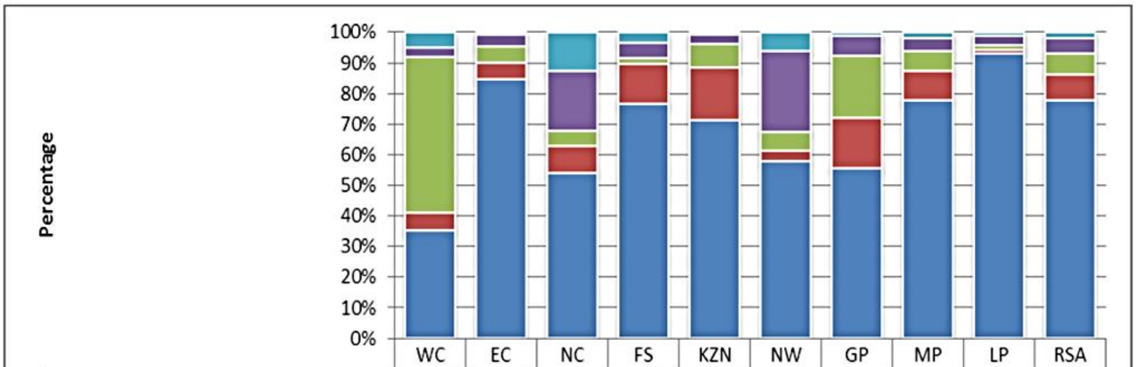


Figure 2 Percentage of households involved in agricultural activities by province in 2015 (StatsSA, 2016)

Over three-quarters (77,9%) of those households involved in agriculture did so to secure additional food; this was most prevalent in Limpopo (93,2%), Eastern Cape (84,5%) and Mpumalanga (77,6%) as shown in the table below. In KwaZulu-Natal, 17,2% of households involved in agriculture indicated that they did so to create their *main source of food*. Almost a fifth (19,5%) of households involved in agriculture in the Northern Cape attempted to create an *additional source of income*.



	WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
Main source of income	4,9	0,8	12,7	3,6	0,7	6,3	1,1	2,0	1,2	1,8
Extra source of income	3,2	3,9	19,5	4,9	3,1	26,4	6,5	4,2	3,1	5,1
Leisure activity	50,8	5,3	5,1	1,8	7,6	6,0	20,3	6,5	1,5	6,8
Main source of food for the household	5,9	5,5	8,9	13,3	17,2	3,4	16,5	9,7	0,9	8,3
Extra source of food	35,2	84,5	54,0	76,5	71,4	58,0	55,5	77,6	93,2	77,9

Figure 3 Percentage distribution of the main reasons for agricultural involvement by practice in 2015 (StatsSA, 2016).

2.1.2 Food security

Food security is a function of the **availability** of food (is enough food produced?), **access** to food (can people get it, and afford it?), **utilisation** of food (how local conditions bear on people's nutritional uptake from food) and the **stability** of the food supply (is the supply and access ensured?). Strong consensus exists that climate change will have a significantly negative impact on all these aspects of food security in Africa.

Food availability could be threatened through the direct impact of climate change on crops and livestock -- such as increased flooding, drought, shifts in the timing and amount of rainfall and high temperatures -- or indirectly through increased soil erosion from more frequent, heavy storms or through increased pest and disease pressure on crops and livestock caused by warmer temperatures and other changes in climatic conditions. Food access could be threatened by climate change impacts on productivity in important cereal-producing regions of the world, which, along with other factors, could raise food prices and erode the ability of the poor in Africa to afford purchased food. Access is also threatened by extreme events that impair food transport and other food system infrastructure. Climate change could impact food utilisation through increased disease burden that reduces the ability of the human body to absorb nutrients from food. Warmer and more humid conditions caused by climate change could impact food availability and utilisation through increased risk of spoilage of fresh food and pest and pathogen damage to stored foods (cereals, pulses, tubers) that reduces both food availability and quality. Stability could be affected by changes in availability and access that are linked to climatic and other factors.

The percentage of respondents to the South African General Household Survey who reported that adult or child members of the household went hungry decreased from 29,3% in 2002 to 13,7% in 2007; since then it has dropped only slightly to 13,1% in 2011 and has remained static until 2015 (StatsSA, 2016). In 2009, a set of questions based on Household Food Insecurity Access Scale (HFIAS) was added to the General Household Survey to determine households' access to food with greater sensitivity.

These questions explored modifications made to diet or eating patterns due to limited sources of food. The index showed that the percentage of households that had limited access to food decreased only slightly from 23,9% in 2010 to 22,6% in 2015. Inadequate or severely inadequate food access was most common in North West (39%), Mpumalanga (31,7%), Northern Cape (31,3%) and Eastern Cape (28,4%) (StatsSA, 2016).

The Pietermaritzburg Agency for Community Social Action (PACSA) calculates on a monthly basis the typical expenditure of a low-income household on food – the "Food Basket". Figure 4 shows how under the conditions of drought and high temperatures during 2015 the cost of a Food Basket (nutritionally inadequate) rose from around R1 110 in July 2015 to R2 095 in January 2016, while PACSA's calculation for the Minimum Nutritional Food Basket (which provides complete nutrition) rose to R4 453 (PACSA, 2017).

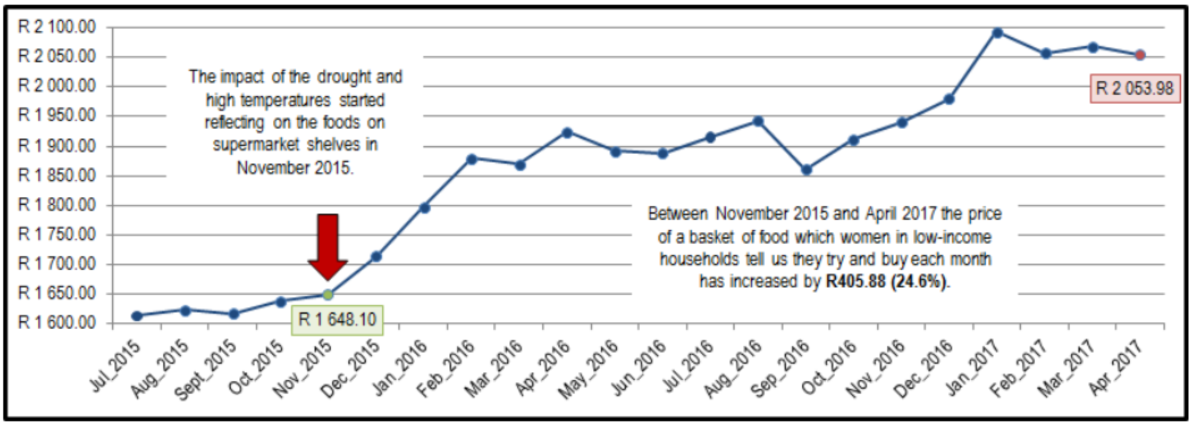


Figure 4 The impact of the 2015 drought on the price of the PACSA Food Basket from November 2015 to April 2017 (PACSA, 2017)

As the price of the core foods (maize meal, rice, cake flour, cooking oil, sugar and sugar beans) prioritised by women in these households rose by 25% over their price before the drought, the ability of women to secure additional foods to ensure a balanced nutrient intake was compromised, with expected negative impacts on health, immunity and development of children (ibid). PACSA also reports that while real inflation on food prices has increased by about 16% over 2015/2016, old age pensions – which in the South African context is typically used to take care of households, not individuals – were increased by only 6% (Mgabadeli, 2017).

In addition to climactic pressures which have already begun to impact vulnerable households, population growth is likely to place increasing strain on resources. The global population is expected to exceed 9 billion by 2050; in South Africa the population is anticipated to increase by 10.2% from 2015 to 60 million in 2030, with the urban population growing twice as fast as the general rate and less than 30% in rural areas by 2030 (Euromonitor International, 2016). Globally food production will need to have increased by up to 70% from 2007 levels; rates of growth in the yield of major crops however, have begun to fall due, in part, to the degradation of agricultural land (Sims and Kienzle, 2015). Climate change is expected to cause the number of malnourished children to increase by 8.5-10.3% across developing countries (Nelson et al, 2014).

These factors, combined with the systematic decreased in the number of smallholders who are farming, demonstrate the extreme vulnerability of rural, poor South African households in terms of food security.

2.2 South Africa's smallholder agricultural producers

2.2.1 Access to agricultural land

While across developing countries smallholder farms produce about 80% of food (Sims and Kienzle, 2015), the situation in South Africa is atypical. The agricultural sector comprises approximately 350,000 white farmers producing around 95% of agricultural output on 87% of the nation's agricultural land, and 4 million low-producing black smallholder farmers employing 13% of agricultural land – primarily in the former homelands (Aliber and Hart, 2009).

There was a 19% drop in the number of households engaged in agriculture from 2011 (2,88 million households) to 2016 (2,33 million households) (Stats SA, 2016b). The bulk of households engaged in agriculture in 2016 were in KwaZulu-Natal (23%), Eastern Cape (21%) and Limpopo (17%) (ibid). In these three provinces, the percentage of households which were engaged in agriculture ranged from to 28% in Eastern Cape (down from 35% in 2011) to 17% in KZN (down from 28% in 2011) and 24% in Limpopo (down from 33% in 2011) (ibid).

The table below, showing South African householders' access to agricultural land in 2006, illustrates the very difficult conditions smallholders may farm under, with 64,5% of the 1.3 million households represented having access to less than 0.5ha of agricultural land.

Table 1 South African Households' Access to Agricultural Land (StatsSA 2006)

South African Households' Access to Agricultural Land (StatsSA 2006)		
Hectares	**No (weighted)**	**Percentage (%)**
<0.5	831 871	64.5
0.5-1	235 454	18.3
1-5	138 196	10.7
5-10	38 146	3
10-20	11 940	0.9
20+	34 546	2.7
unkown	17 556	-
TOTAL	**1 307 710**	**100**

While this means on the one hand that there is enormous potential for South Africa's smallholders to increase productivity to both better secure their own livelihoods and food security and to contribute to increased national demands for agricultural products, it also means that agricultural resources and support and distribution systems are heavily focussed on large-scale, commercialised agriculture.

2.2.2 Characterisation of smallholder farmers

As described earlier, the agricultural sector in South Africa is dualistic, with a well-developed commercial sector, comprising about 35,000 units which are mostly white-owned, and a small-scale farming sector comprising about 3 million units which are mostly black-owned (Cousins, 2015 in Smith et al, 2017). The situation of smallholders is worlds apart from that of the large-scale commercial farmers and within this group there are vast differences. Broad distinction within this structure are show in Table 2.

Table 2 The agrarian structure of South Africa in 2014 (from Cousins, 2015 in Smith et al, 2017)

Farmers	Numbers	Key features
Top 20% of large-scale commercial farmers on private land; almost all are white	7 000	Sophisticated, specialized, capital-intensive farmers, producing for export or for agro-processing and large retailers; produce bulk of produce, perhaps as much as 80%
Medium- to large-scale commercial farmers on private land; almost all are white	9,000	Some farmers succeed, some struggle, some are unable to earn a living from farming alone
Small- to medium-scale commercial farmers on private land; mostly white, some black	19,000	Many cannot survive from farming alone; includes hobby farmers
Small-scale black capitalist farmers in communal areas and in land reform contexts	5,000 – 10,000	Many farmers earn income from off-farm incomes and businesses in addition to farming
Market-oriented black smallholder farmers in communal areas and land reform contexts, supplying tight value chains (e.g. under contract)	5,000 - 10,000	Many grow fresh produce under irrigation, others are livestock producers, and a few engage in dryland cropping
Market-oriented black smallholder farmers in communal areas and land reform contexts, supplying loose value chains	200,000 - 250,000	Many grow fresh produce under irrigation, and others are livestock producers. Few depend wholly on farming
Subsistence-oriented smallholder farmers growing food for themselves, and selling occasionally	2 million - 2.5 million	Most crop production takes place in homestead gardens, some of which are quite large. Occasional livestock sales by some

Pienaar and Traub (2015) note that farming households in South Africa's rural areas typically pursue a variety of livelihood strategies on the basis of the available natural, physical, human and financial capital and these are also to a large extent dependent on biophysical and socio-economic conditions. In 2014 the government stated that half of all smallholder households live below the poverty line (DAFF, 2014). Apart from the land reform issues discussed above, the proportion of South Africans living in rural areas has declined from 50% to 40% since 1994; by 2030 it is expected to have dropped to 30% (South Africa, 2011). The trend is for men to go to urban areas, leaving women, the elderly and children as the "farm power" in rural areas (Sims and Kienzle, 2015).

In the context of a Smallholder Farmer Innovation Programme (SFIP) implemented by Grain SA in Bergville, KwaZulu-Natal among smallholders in the community that has been targeted for this study, smallholder farming systems and farmer categories were differentiated as shown in Table 3**Error! Reference source not found.** below (Smith et al, 2017).

Table 3 Farmer segmentation in the Bergville smallholder farming system (Smith et al, 2017)

Category	Non-commercial smallholders	Semi-commercial smallholders	Commercial smallholders in loose value chains	Commercial smallholders in tight value chains
% of people in each category	72	23	5	-
Farmer priorities	Most production consumed by the	Production is intensified. Selling becomes more	Consumption and sale in various percentage mixes	Primarily for sale-working within existing

	household and additional food is bought in	significant and supplements household income.	but moving to more sales.	well defined commodity value chains
Gender	Mostly women (89%)	Mostly women (96%)	Women, men (40% ♀ 60%♂)	Mostly men
Resources	Low external input systems are used with a minimum of bought inputs	Mixed (low and external) input systems are used with a minimum of bought inputs	Mixed (low and external) input systems are used with greater reliance bought inputs	Mostly high external input systems
Traction	Hand cultivation	Hand cultivation, animal traction	Animal traction, tractors	Tractors
Land size	≤ 0.1ha	0.1-1ha.	1-2.5ha	>2ha
Farm productivity, including labour access	Extremely low	Low to high	Low to high	Low to high
Access to improved agricultural tech and information	Very limited	Limited	Limited	Good
Access to financial services	Very limited if at all	Very limited if at all	Very limited	Informal and some formal through buyers
Local organisation	Almost non existent	Almost non existent	Informal farmers groups	Farmers associations and cooperatives
Agribusiness support	Very limited.	Very limited.	Informal but growing	Reasonable
Engagements with markets	Very little; entirely informal	Limited and still informal for the most part	Both informal and formal	Can be good due to value chain farming bundles
Environmental performance	Generally not considered	Generally not considered, some adoption of conservation and sustainable practices	Generally not considered, some adoption of conservation and sustainable practices	Some adoption of conservation and sustainable practices
Crop mix	Staple crops Crop livestock mixes focussing on 4-5 commodities	Staple crops, some cash crops, crop livestock mixes – focussing on 3-4 commodities	Staple crops, some cash crops, crop livestock mixes – focussing on 2-3 commodities	Mostly cash crops – focusing on 1, maybe 2 commodities
Livelihood (Food Security, Total monthly income, assets, poverty likelihood, perceived well being)	Food Security: low Monthly Income: R0-R2000 Assets: minimal Poverty Likelihood; High	Food Security: low-medium Monthly Income:R2001-R4000 Assets: minimal- starting to build Poverty Likelihood: medium	Food Security: medium-high Monthly Income:>R4000 Assets: reasonable Poverty Likelihood: low	Food Security: high Income: Assets Poverty Likelihood

Table 4 illustrates the types of agricultural production activities in which households were engaged in 2015, by province. About half cultivated grains (52%) and fruits and vegetables (51%); 34% produced livestock. Only 12% reported getting agriculture-related support from the government.

Table 4 Nature of agricultural activities per province in 2015 (SAStats, 2016)

Production activity	Statistic (Numbers in thousands)	Province									
		WC	EC	NC	FS	KZN	NW	GP	MP	LP	SA
Livestock production	Number	5	315	20	20	257	87	3	71	151	**929**
	Percentage	7,2	54,9	49,6	12,3	46,3	62,3	1,7	20,8	22,5	**34,3**
Poultry production	Number	5	354	6	21	236	72	9	93	116	**912**
	Percentage	6,5	61,7	15,7	13,2	42,5	52,1	5,7	27,0	17,3	**33,7**
Grains and food crops	Number	3	331	2	15	329	8	15	188	507	**1 399**
	Percentage	3,6	57,6	3,8	9,3	59,3	6,0	10,1	54,9	75,8	**51,6**
Industrial crops	Number	0	3	0	1	4	0	2	1	4	**14**
	Percentage	0,0	0,5	0,0	0,4	0,8	0,0	1,0	0,2	0,7	**0,5**
Fruit and vegetable crops	Number	63	269	17	141	170	28	131	226	331	**1 377**
	Percentage	86,2	46,9	42,9	86,7	30,7	20,1	85,8	65,9	49,5	**50,8**
Fodder grazing/ pasture grass of animals	Number	4	6	1	4	8	1	5	5	7	**40**
	Percentage	4,9	1,0	3,3	2,6	1,4	0,4	3,5	1,5	1,0	**1,5**
Forestry	Number	0	1	0	0	1	0	1	1	0	**3**
	Percentage	0,0	0,1	0,0	0,0	0,1	0,0	0,8	0,2	0,0	**0,1**
Fish farming/aquaculture	Number	0	1	0	1	0	0	0	1	0	**2**
	Percentage	0,0	0,1	0,0	0,4	0,0	0,0	0,0	0,2	0,0	**0,1**
Game farming	Number	0	1	0	0	0	1	0	1	0	**3**
	Percentage	0,0	0,1	0,0	0,0	0,0	0,6	0,0	0,4	0,0	**0,1**
Other	Number	0	6	0	0	0	0	2	1	0	**9**
	Percentage	0,0	1,1	0,0	0,0	0,0	0,0	1,1	0,2	0,1	**0,3**

A particular household can be involved in more than one activity and percentages therefore do not add up to 100%.

In its National Development Plan (NDP) 2030, the South African government positions "smallholder agriculture" as the driver of rural development (South Africa, 2011) and in 2014 the Department of Agriculture, Forestry and Fisheries increased its budget to smallholder support programmes to R2.38 billion (DAFF, 2014). While the Agricultural Policy Action Plan (DAFF, 2015) reviews how the number of commercial farming units and the employment opportunities in the agricultural sector has steadily declined since 1950, it undertakes to increase the small holder sector by 300,000 and expand the number of smallholders selling their produce from 200,000 to 500,000 by 2020 (DAFF, 2014). The Department of Agriculture, Forestry and Fisheries (South Africa, 2012) proposes that small-scale producers be differentiated into the roughly 200,000 "emerging farmers" who sell their produce and "smallholder farmers" – the remainder who produce for household consumption.

Cousins (2010) argues that using terms such as "smallholder" presume a homogeneity and a set of common interests within this group that is misleading. This hinders an accurate understanding of the processes which contribute to inequalities and the tensions within households over the use of land, labour and capital. Policies and initiatives which do not work with divergent interests and differences are likely to fail. He argues for the use of a class-analytic differentiation between smallholders who are engaged in "accumulation from below" -- who generate a surplus resulting in potential for profit and capital accumulation and those who are engaged in "petty commodity production" – where farming represents one aspect of their livelihood scheme and advocates that differentiated policies should be developed for these differentiated producers. He suggests initiatives targeted at different producers as follows:

> *"A large-scale commercial farm model informs assessments of "viability" and shackles thinking about how to support smallholders."*
>
> - Cousins, 2016

Improving access to and productivity on irrigated land by accumulators from below should be a key focus for agrarian reform. Subdivision of large farms into smaller, privately-owned and self-contained units is suggested as the tenure option for small-scale capitalist farmers, but not for petty commodity producers and worker-peasants, who can be highly productive within communal tenure systems. Worker-peasants who engage in agricultural production in a significant scale could be key beneficiaries of a livestock improvement programme, which needs to take account of the fact that members of this category are often at home in rural areas at weekends or on holidays. Pension payment days, on which large numbers of local residents regularly gather at a designated site, provide a key opportunity for inputs supply, marketing and extension programmes aimed at supplementary food producers in communal areas (Cousins, 2010).

2.2.3 Smallholder farming systems

Within smallholder farming systems people practice a mixed farming approach and use available natural resources in the commonages. Access to resources (land, water and natural resources) depends to an extent on what and how much is available and on the local arrangements that are in place, ie. which are managed through the traditional and local authorities. In theory, everyone has access; in practice this translates to those who can leverage resources through individual influence and resourcefulness.

Mixed farming in communal tenure areas consists of homestead plots, fields and communal grazing for livestock.

Homestead plots, as the word indicates, are situated around the farmers' homes and range in size from around 500m^2 to around 0,5ha. These plots may or may not be fenced and in the more formally planned villages will have some access to a municipal supply of water. Water supply however is severely restricted in most cases to the municipal allocation of 20 litres per person per day – and only if that water is available. Shared, communal standpipes outside people's yards are the most common form of access to water. This means that for around 90% of smallholders they only have access to as much water as they can carry to their homes on any given day. This water is used primarily for household needs. This means that dryland cropping is still common even within homestead plots and that more intensive productive activities such as vegetable and fruit production and rearing of small livestock usually is done only if additional sources of water can be accessed, either through the municipal systems -- which is not common -- or through access to springs and streams nearby. A very limited number of individuals have their own boreholes.

Fields are generally allocated to individuals and are often not in direct proximity to the homesteads. Sizes range from 0,1ha - 5ha, averaging around 1ha in size. Historically these have been used primarily for field cropping grains (maize, sorghum, millet), pumpkin species and legumes (sugar beans). Fields may be fenced or unfenced and are worked by hand or by paying for private or government-based mechanisation services. At this scale, a number of group projects exist in the communal tenure areas and in some cases projects run by government and non-government organisations have included irrigation options. A very small percentage (around 1-5%) of individuals have set up their own irrigation systems.

Communal grazing is managed on a village level and livestock are allowed to graze in and around the villages and fields in winter months and adjacent veld, bush and hillsides during summer. Individual smallholders often have kraals for their livestock and pay towards herding and dipping systems for their livestock. Mostly these systems apply to cattle and sheep. In the past goats were not herded, but due to increasing pressure on grazing areas and conflicts related to livestock destroying crops and gardens this is becoming more common. Rangeland management is notoriously difficult in these communal tenure areas and the quality and quantity of grazing appears to be in an almost continual decline. Systems for fodder production, supplementary feeding and rotational grazing are not widespread.

Natural resources are harvested extensively for firewood, thatch, reed and grass crafts, food (eg. wild leafy greens) and medicinal purposes. Very few systems for control, management and regeneration of natural resources are currently in place and in addition wide scale poverty and population pressure in the communal tenure areas have led to overuse of resources and denuding of the commons.

Figure 5 below outlines the typical average monthly water demand of a household. On average, most households receive around one fifth of this allocation of water.

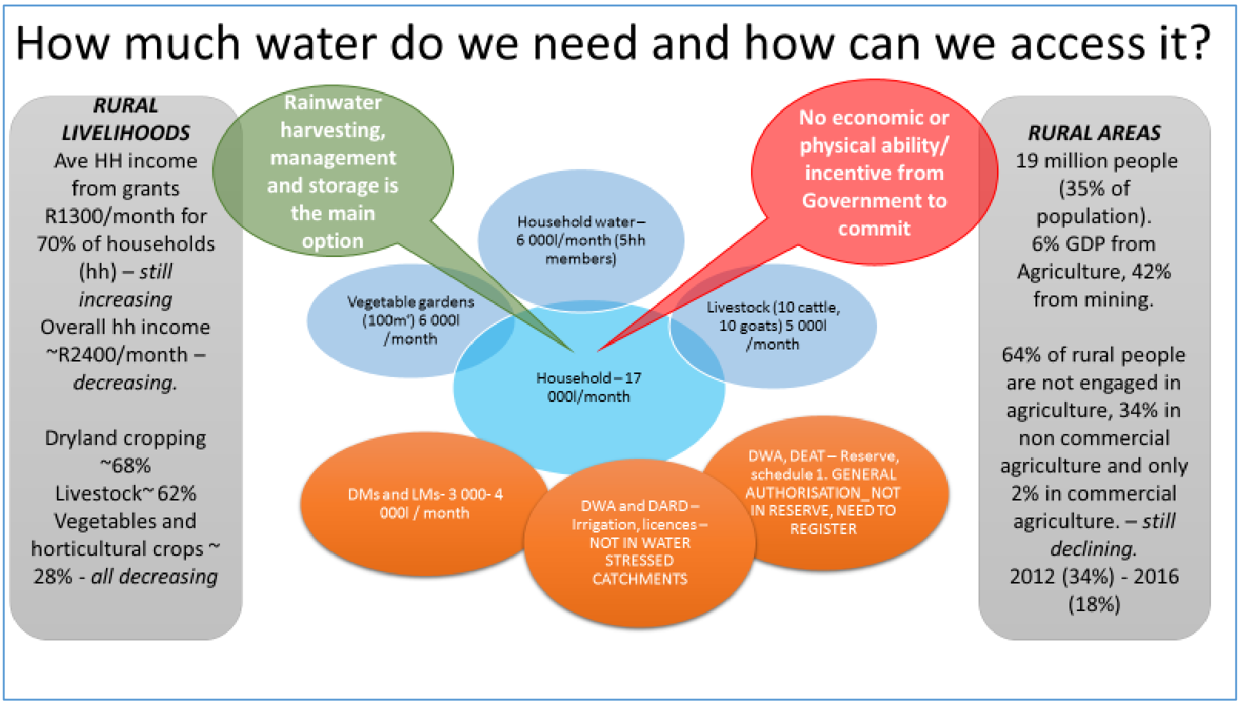


Figure 5 Household water requirements and access (Kruger, 2016)

2.2.1 Climate change impacts on smallholder farming systems

The more extreme weather patterns with increased heat, decreased precipitation and more extreme rainfall events; increase of natural hazards such as floods, droughts, hailstorms and high winds that characterise climate change place additional pressure on smallholder farming systems and has already led to severe losses in crop and vegetable production and mortality in livestock (Madondo and Kruger, 2016, pers comm). A significant proportion of smallholders have abandoned agricultural activities and this number is still on the increase (NIDS, 2012). Smallholders are generally not well prepared for these more extreme weather conditions and experience high levels of increased vulnerability as a consequence (Manderson, Kubayi, & Drimie, June 2016).

It is becoming clear that climate change will have drastic consequences for low-income and otherwise disadvantaged communities. Despite their vulnerability, these communities will have to make the most climate adaptations (Fenton, Reid, & Wright, 2015). It is possible for individual smallholders to manage their agricultural and natural resources better and in a manner that could substantially reduce their risk and vulnerability generally and more specifically to climate change. Through a combination of best bet options in agro-ecology, water and soil conservation, water harvesting, conservation agriculture and rangeland management a measurable impact on livelihoods and increased productivity can be made (Hansford, 2010.)

2.3 Theoretical framework of the project

The farmers with whom the project will be working face innumerable challenges including lack of resources (financial and other); limited access to technologies; limited skills; limited access to markets; limited understanding of the concept of climate change; high levels of dependence on social grants; and, for many, limited and/or insecure access to land. They also farm in some of the more agriculturally marginal areas of the country, and often in areas which are vastly overpopulated in terms of the land's capacity to support them – areas which suffer from considerable degradation of the natural resource base, including loss of forests, extreme soil erosion and loss of functioning wetlands.

The aim of this project is to assist farmers with identifying the practices most appropriate for their areas and their style of farming and encourage them to experiment with and innovate practices which can increase their resilience to the ongoing challenges presented by climate variability and/or long-term change.

This section looks at how the project will endeavour to achieve this aim in terms of the theoretical approaches and tools that will be used, engaging local and traditional knowledge, and its potential for achieving mitigation of climate change.

2.3.1 Approaches and tools to be used in the project

Climate Smart Agriculture is the overarching approach that will be used to inform the methodology of this project. All CSA practices, regardless of which agricultural approach they are derived from, are essentially practices that are beneficial for improving both the productivity of the land and the sustainability of the farming enterprises. In this way they should also improve the potential for strengthening food security and livelihoods. They are practices which, whatever the situation (except perhaps for the most marginalised areas) have the potential to directly benefit farmers and increase food production in the communities as a whole, irrespective of any climate change predictions. However, they also have the capacity to buffer farmers against any increases in temperature or changes in rainfall quantities and patterns occasioned by climate change.

The CSA approach incorporates institutional, economic, social and environmental factors as well (FAO, 2013). This project will draw particularly on technologies developed within the Conservation Agriculture (CA), Agro-ecology, and Soil and Water Conservation (SWC) practices which fall under CSA. The diagram below illustrates CSA as an overarching concept.

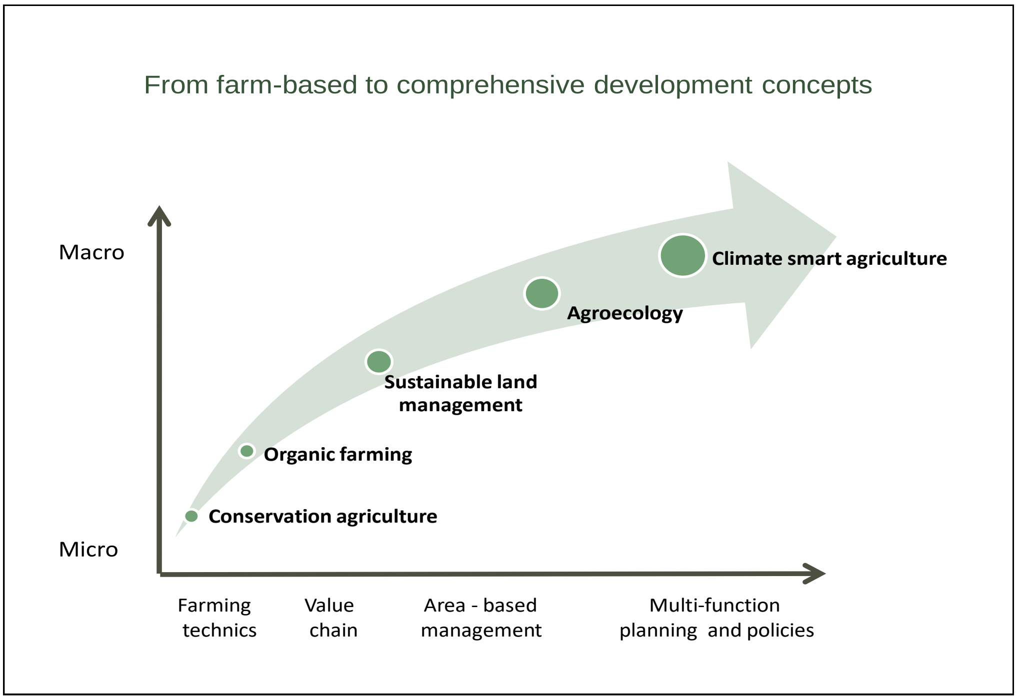


Figure 6 The FAO concept of CSA as an overarching approach to sustainable development (Arslan, 2014)

Climate smart interventions are highly location-specific and knowledge-intensive. Considerable effort can be required to develop the necessary knowledge and capacities to make CSA a reality. Implementing CSA practices often requires shifts in the way land, water, soil nutrients and genetic resources are managed to ensure that these resources are used more efficiently. Two joint principles guide the necessary changes of systems: more efficiency in the use of resources, to increase production while reducing emissions intensity of the food produced and consumed, and more resilience, to get prepared to variability and change. In large part, these are the same efforts required for achieving sustainable agricultural development which have been advocated over past decades, yet still insufficiently realised on the ground.

CSA methodologies employ site-specific assessments to identify suitable agricultural production technologies and practices which should prioritize the strengthening of livelihoods, especially those of smallholders, by improving access to services, knowledge, resources (including genetic resources), financial products and markets.

As the implementation of existing policies and strategies at national and regional level for support to smallholders is fragmented at best, the approach in this study will be to work directly with smallholders in local contexts to improve practices and synergise across sectors. The emphasis is thus at farm/household level. Here CSA aims to improve aspects of crop production, livestock and pasture management, as well as soil and water management as depicted in the diagram in Figure 7.

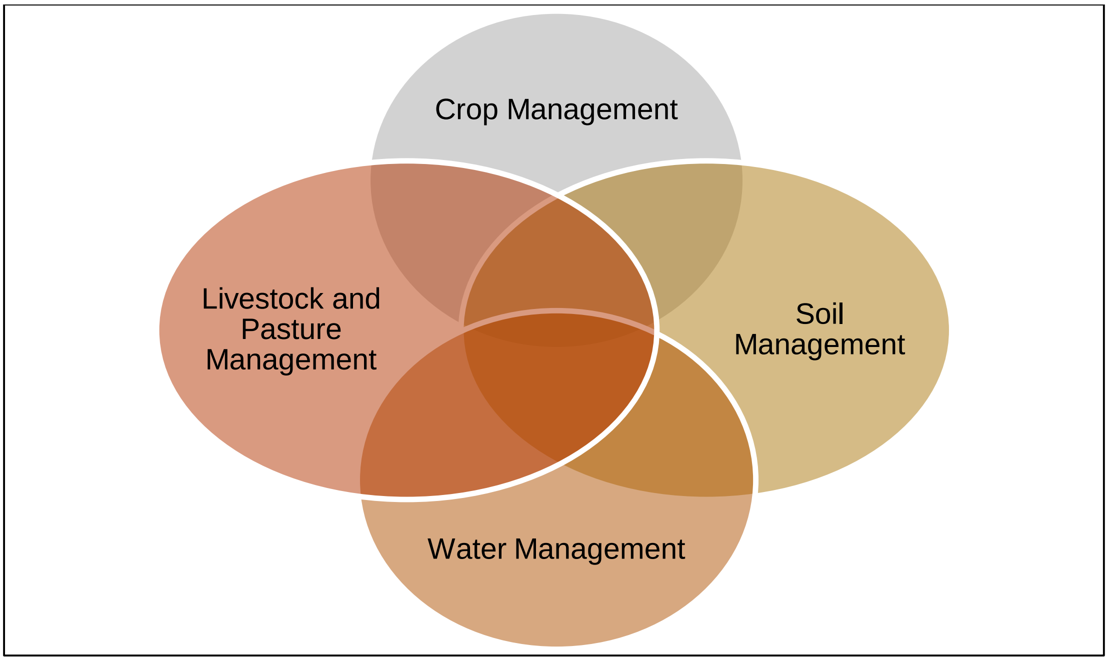


Figure 7 Household level implementation of CSA integrates across sectors (Arslan, 2014)

This research study aims to design a framework of methodologies, associated processes and a selection of best bet practices, informed by the issues that have been discussed, which can be used to assess, implement and monitor likely local CSA strategies.

An example is provided in the slide below for a research effort that explored adoption of practices across 130 projects across sub-Saharan Africa and Latin America (Knowler and Bradshaw, 2007). This analysis was conducted in 2003, well before South Africa formulated a coherent response process.

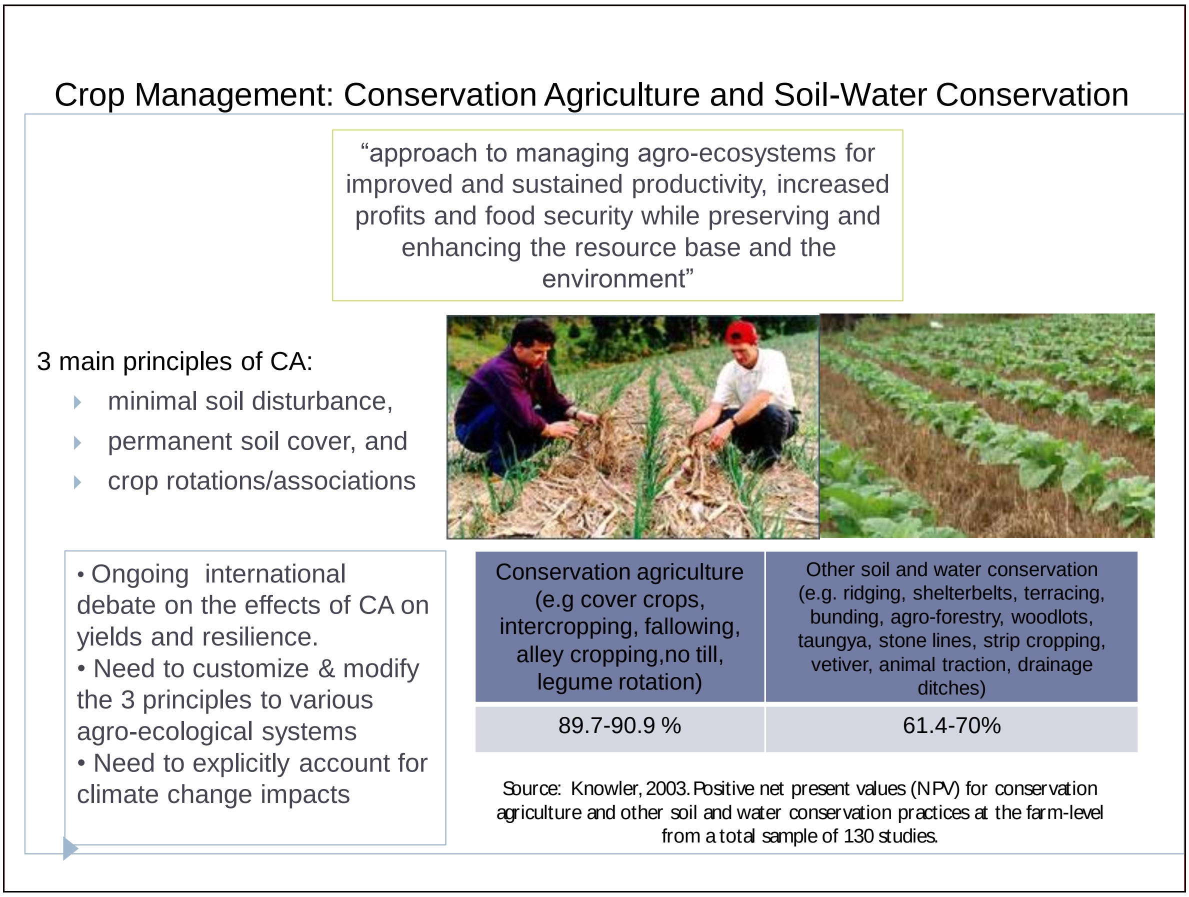


Figure 8 Exploration of CA and SWC practices for crop management

Knowler and Bradshaw (2007) further explored the viability of synthesising adoption of such practices into a set of universal variables that could be used for both assessment and policy with the aim that these variables would then become part of a decision support system to be used for assessing implementation strategies and practices. They found however that there were very few, if any, universal variables that could explain adoption of climate smart practices and recommended that efforts for promotion be tailored to reflect particular conditions and individual localities -- this foreshadowed the approach that was later promoted by the FAO.

The Consultative Group for International Agricultural Research (CGIAR), has developed a participatory climate change and food security vulnerability assessment toolkit, and a decision support system for identifying appropriate CSA practices (CGIAR, 2017). Both of these will also inform the project's work with farmers.

2.3.2 Working with local and traditional knowledge in the implementation of CSA

Most of the CSA practices with which the project will be concerned are likely to be quite site specific, which makes local and traditional knowledge extremely relevant for implementing such practices at a ground (community) level. It should be acknowledged that some of the CSA practices correspond with many existing local practices. Local and traditional knowledge is deeply embedded in many communities and the associated practices are considered cost effective and easy to out-scale to other communities.

The literature indicates that for adoption of CSA practices to be successful it should be built on existing local and traditional knowledge (FAO, 2013). However, local understanding of the practices and reasons to take up a practice often differs to that in the scientific domain. It is important for development practitioners and researchers to have some understanding of the local and traditional knowledge to allow better implementation of improved practices (e.g. CSA practices). Building links between the scientific information and local and traditional knowledge presents a potential opportunity for developing a holistic approach for dealing with the negative impacts of climate change at community level. The Association for Water and Rural Development (AWARD) is implementing a programme to increase resilience in the Olifants River Basin-the approach, involving systemic social learning, is one example of this (Kruger and Selala, 2017; AWARD, 2017).

It is important to note that the depths of such knowledge and the implementation of such practices varies considerably between communities in different areas across South Africa. In areas with a long continuous tradition of indigenous agricultural practices, such knowledge is strong and the practices well understood. Such areas include much of Limpopo Province, and the coastal sections of the former Transkei homeland in the Eastern Cape Province, historically inhabited by the amaPondo and amaThembu clans. However, in many other areas – such as those to which people were forcibly relocated during the establishment of the former homelands -- there is not such a long continuous tradition and many of the farming practices have been derived from people's acquaintance, often as farm labourers, with the conventional agriculture practiced by the white commercial farmers. Even in these areas, however, it is possible to find traditional practices such as 'matamo' (construction of small ponds) or 'gelesha' (ripping the ground to improve infiltration, prior to planting) (Dension and Manona, 2007).

Communities are already needing to use local, traditional and indigenous knowledge to help cope with the negative impact of climate change. This includes knowledge of food preservation techniques (e.g. fermentation and sun drying), knowledge of indigenous plants (e.g. for use in natural pest control), seed selection to avoid drought and disease control in livestock. The list below shows some other local and traditional practices which correspond with CSA principles and practices:

- Seasonal weather forecasting (Use of shift in seasonal migration for birds as an indicator for weather forecasting)
- Selection of seed to avoid the risk of drought and pest
- Water harvesting techniques (e.g. roof water harvesting)
- Use of ash for seed preservation
- Soil and water conservation using planting basins, furrows and ridges
- Use of sunken and raised beds to accommodate for water holding capacity and soil types
- Mixed cropping or intercropping and diversification
- Use of supplementary feed for livestock
- Preservation of pasture for use by young, lactating and sick animals in cases of drought
- Transhumance to avoid risk of livestock loss
- Culling of weak livestock for food
- Diversification in the herd to survive climate extremes (Kruger and Selala, 2017).

CSA may provide a valuable opportunity to revive local and traditional knowledge and practices, as they have considerable potential for amelioration of some of the negative impacts of climate change on small-scale agriculture.

2.3.3 Potential for mitigation through this approach

The actual contribution of smallholder farming systems to climate change is debatable but is generally accepted to be comparatively low (Manderson et al. 2016). Mitigation within the smallholder context would fall primarily within the ambit of increasing carbon stocks through sequestration in the soil. Limited and isolated attempts have been made to set up carbon trading arrangements for smallholder communities, mostly around the concept of preserving natural vegetation and forests (Turpie et al. 2008).

Systems have been explored for payment for ecosystem services for communities based in high priority water provisioning areas such as the Drakensberg escarpment (Mander et al, 2007, Blignaut et al, 2008). These systems have been based on incentive payments towards good resource management – mostly in the ambit of grazing and fire management systems. Most of these processes have stalled after the conceptual phases due to lack of buy in by government departments, who would need to be the custodians of such approaches (Sherbut G. 2012).

Carbon sequestration through wide scale planting of trees has been explored, but implementation again has been halted due to lack of institutional buy in. A viable option is presently seen in regenerative CA systems, where carbon sequestration is a very real option – and within the abilities and control of individual smallholders (Smith, Pretorius, Trytsman, Habig, & Wiese, 2015; Blignaut et al 2015). It is this latter option that could most likely be explored within the present research process.

3 KEY APPROACHES AND DEFINITIONS

3.1 Climate Smart Agriculture (CSA)

As discussed earlier, CSA is not a single agricultural technology or practice that is intended to be applied across the board; rather, it relies on site-specific assessments to identify suitable agricultural production technologies and practices. The FAO characterises CSA as an approach that:

> 1. Addresses the complex interrelated challenges of food security, development and climate change, and identifies integrated options that create synergies and benefits and reduce trade-offs;
>
> 2. Recognizes that these options will be shaped by specific country contexts and capacities and by the particular social, economic, and environmental situation where it will be applied;
>
> 3. Assesses the interactions between sectors and the needs of different involved stakeholders;
>
> 4. Identifies barriers to adoption, especially among farmers, and provides appropriate solutions in terms of policies, strategies, actions and incentives;
>
> 5. Seeks to create enabling environments through a greater alignment of policies, financial investments and institutional arrangements;
>
> 6. Strives to achieve multiple objectives with the understanding that priorities need to be set and collective decisions made on different benefits and trade-offs;
>
> 7. Prioritizes the strengthening of livelihoods, especially those of smallholders, by improving access to services, knowledge, resources (including genetic resources), financial products and markets;
>
> 8. Addresses adaptation and builds resilience to shocks, especially those related to climate change, as the magnitude of the impacts of climate change has major implications for agricultural and rural development;
>
> 9. Considers climate change mitigation as a potential secondary co-benefit, especially in low-income, agricultural-based populations and
>
> 10. Seeks to identify opportunities to access climate-related financing and integrate it with traditional sources of agricultural investment finance (FAO, 2013).

While this project will incorporate all of these different aspects of CSA to some degree it is particularly concerned with the implementation of CSA at a local level with small-scale and emerging farmers, and is therefore informed mostly by points 1, 2, 3, 4, 7, and 8.

The FAO's description of CSA, given above, also makes it clear that appropriate technologies that have been developed under different agricultural regimes can be entirely compatible with the broad concept of CSA. Within the project there will be particular emphasis on technologies developed within the practices of Conservation Agriculture (CA), Agroecology, Natural Resource Management, Agroforestry and Soil and Water Conservation (SWC) (McCarthy and Brubaker, 2014).

3.1.1 CSA Practices

At farm/household level CSA aims to improve aspects of crop production, livestock and pasture management, as well as soil and water management (FAO, 2015). Below, each of these elements is discussed briefly.

Crop and Soil Management

Soil fertility management is important to ensuring the soil's capacity to store nutrients for uptake by plants. Management of soil fertility in the context of CSA entails adding organic matter and improving the efficiency of nutrient inputs such as manure and compost so as to enable more production with proportionally less inorganic fertiliser. Minimum tillage helps reduce net losses of carbon dioxide by microbial respiration and oxidation and builds soil structure and bio pores through soil biota and roots. Improving soil fertility helps save energy in farming and it helps sequester carbon in soil. Use of mulch and crop residues for soil cover provides a substrate for micro-organisms living in the soil which helps improve and maintain water and nutrients in the soil, protects the soil surface from wind, heat and rain and also helps regulate soil temperature by keeping it cooler (FAO, 2015). In dry conditions, soil cover helps reduce water requirements by making more efficient use of soil water and in wetter conditions it facilitates the infiltration of water, reducing soil erosion.

Intercropping that includes legumes which host nitrogen-fixing bacteria in their roots contributes to optimum plant growth and reduces GHG emissions induced by fertilisers. Crop rotation, which is the alternating of different crops over a number of seasons (e.g. planting maize in the summer of the current year and rotating it with soya bean in the following season), helps reduce pests and diseases over time (FAO, CGIAR and CCAFS, 2015).

Livestock Management

Climate change has led to a reduction in the quality and quantity of forage available for livestock as well as increasing heat stress in animals in some regions. Improving livestock resilience and increasing productivity is linked to other CSA practices such as soil and water management and also by including other approaches such as paying attention to viable insurance schemes for smallholders and niche/new local value chains.

Land management practices include methods for reducing land degradation, such as restoring grasslands, grazing management and re-vegetation. Interventions to improve feed resources directly increase productivity. For example, in cattle farming improved pastures, the selection of agroforestry species and the use of nutritious diet supplements can help mitigate the effects of climate change.
Improved grazing management can contribute to carbon sequestration and emissions can be further reduced by management of farm manure (FAO, 2013).

Forestry and Agroforestry

Forestry and agroforestry play a pivotal role in global efforts to address the negative impacts of climate change. In smallholder systems, forests form part of a complex rural landscape and provide ecosystem services such as food, biofuel and biodiversity. Climate change threatens the delivery of these ecosystem services as trees are an important carbon sink and their potential can be improved through afforestation (FAO, 2013). Agroforestry involves planting trees and shrubs in agricultural production systems- both cropping and grazing systems. This helps address the challenge of food insecurity by increasing the adaptability of these systems by increasing sources of income, diversifying production and spreading the risk against agricultural and market failures thus increasing the resilience of the production system. In smallholder farming systems, increasing the resilience of forest systems to enhance the flow of ecosystem services requires integrated approaches that consider the wider landscape (FAO, 2010).

Energy Management

Energy inputs are an important component in feeding the world population. It is estimated that the food sector accounts for 30% of the world's energy consumption, however most energy is dependent on fossil fuel which could be detrimental for food security. Many smallholder farming communities depend on harvested wood for cooking and heating and the increasing population and demand for food will likely increase the demand for energy (Bogdanski, 2012). This could lead to a widened gap between demand and supply and subsequently exacerbate the negative impacts of agriculture on the environment through change in land use and increased levels of emissions. Integrated food energy systems (IFES) is one approach to addressing these issues. It involves growing food and energy crops on the same plot of land, such as in agroforestry systems where trees can be grown for wood and charcoal. IFES can also be implemented through the use of by-products such as biogas from livestock residues and animal feed from by-products of ethanol produced from maize. IFES systems such as these are easy to implement, however more complex systems are less frequently implemented due to the technical and institutional capacity required to implement them. These include solar thermal, geothermal, wind and water power that have high start-up costs and require specialised support for installation and servicing (FAO, 2010).

3.2 Soil and Water Conservation (SWC)

Soil and water are fundamental to rural livelihoods. As their conservation can contribute to raising the standard of living, this should have a central place in development strategies (IFAD, 1992). Soil degradation as described by the IFAD (1992) is the reduction in the fertility of the soil through the removal of soil by water, wind and exploitative cropping. This starts with the destruction of the soil structure where pores are destroyed and cannot retain and transport water which then limits root development and growth (International Centre for Theoretical Physics, 2010; Baptista et al, 2015).

It was estimated that as much as 65% of agricultural land in Africa had been degraded around 2 decades ago (Craswell and Latham, 1992). In addition, in the sub-Saharan African region very few countries are yet able to curb this degradation of land while accelerating agricultural production (International Fund for Agricultural Development, 1992; Rockstrom, 2000, FAO 2015).

Soil cover plays a crucial role in reducing surface runoff as it absorbs impacts from droplets and slows down water running down the slope. Soils need to be able to infiltrate water to avoid pooling and surface channeling. Excessive tilling destroys soil structure and passages water goes through resulting in uncontrolled flow of water. Water infiltration is also very much dependant on available soil organic matter which acts as a sponge sucking and keeping in water for the use of plants. Water that has hit the ground, infiltrated and been absorbed by plants can also be lost to the atmosphere. These forms of water loss are evaporation and transpiration, collectively known as evapotranspiration (Rockstrom, 2000; ARC-Institute for Soil, Climate and water, 2009).

Degradation of soils also takes place through soil sealing, compaction and salinization. Further soil degradation has the potential to accelerate water shortages through the destruction of water bodies, negatively impacting on water quantity and quality and thus putting livelihoods at great risk.

Soil erosion is also impacted by the topography of the land; the length and steepness of slopes heavily influence the severity of erosion as does soil type; with sandy and silt soil types being more erodible than clays (International Fund for Agricultural Development, 1992).

Wind is the other major natural cause of soil erosion more especially with continuous tillage. The drying up of fine soils that have been greatly disturbed accelerates wind erosion.

Africa has a history of responses to land degradation, indirectly inclusive of soil and water conservation strategies. It has been a longstanding traditional practice throughout the African continent that lands would be left lying fallow after a few years of cultivation. This was done to allow the regeneration of vegetative cover and build-up of nutrients in the soil (International Fund for Agricultural Development, 1992).

Some techniques that have been introduced over the years include:

Stone lines: These are built along the contours with the purpose of minimizing or stopping the movement of water and soil down the slope. The length of the stone lines depends on the length of the field but their width should be 0.4m-0.6m and should be at least o.5m high to trap soil and water. (Food and Fertilizer Technology Centre for the Asian and Pacific Region, 1995; Mati, 2007).

Trash lines: These are lines similar to stone lines, except that organic material is used to build up the 'structures'. They mostly use straw and weeds collected from the field and placed along the contour. They also have potential for increasing soil fertility through cover and decomposition.

Ridges: These are structures consisting of raised soil bunds running along the contour for slowing down water thus reducing erosion.

Furrows and swales: These are structures built by digging drainage channels along the contour; the soil is then placed either uphill to create bench terraces or downhill to increase the infiltration capacity of the ditches.

Drainage channels or diversion ditches: These are channels that collect surface run-off and discharge this water more carefully and safely in another locality, such as a small pond or grass covered area. These ditches can be lined with concrete, stone or bricks, more so in areas where there are heavy rains and large volumes of water with steep slopes. The size of the ditch is dependent on the volume of the water flowing over the surface.

Planting basins: These are hand dug water collecting structures of about 20cm width and 20cm depth. These can be can also be dug before planting ensuring sufficient moisture in the soil, after planting they can partly be left open to catch more water thus speeding up seeding time. These are perfect for collecting water especially in drier areas and give reasonably good yields. Organic manure or compost can be incorporated into the basins for increased soil fertility.

Contour ploughing: This is another method for encouraging water penetration and conserving soil moisture by ploughing along contours. (FFTC, 1995; Mati, 2007).

Green manures: These crops are grown specifically for improving the soil properties and the also act as a fertilizer. These can either be planted in between crops or on land lying fallow to be used the following season. These crops are good for improving sandy soils, high clay soils or exploited soils that are nutrient deficient. They are normally ploughed back into the soil when they are still green and still have a lot of nutrients in them.

Cover crops: These are similar to green manures and are crops grown specifically for covering the surface of the soil; they protect the soil from the splash impact of the rain drops and further reduce speed and erosivity of rainfall. Cover crops play an important role in maintaining soil structure and replenishing organic matter increasing soil physical and chemical properties. They also provide a good environment for crop growth through stabilizing soil temperatures.

Mulch: Mulch is almost a similar concept to that of cover crops in its purpose, but mulch refers to crop residue or grass that is brought in to cover the soil surface. It is spread on bare patched or in between crops or around trunk of fruit trees to increase soil moisture and prevent erosion.

Vegetative strips: These are planted strips of vegetation such as grass and shrubs running across slopes reducing momentum of water thus slowing it down and depositing sediment. The continuously deposited promotes the formation of bench terraces over time. (Mati, 2007).

Windbreaks: These re similar to vegetative strips, with a slightly different function. Windbreaks mostly consist rows of trees and/grasses that are carefully grown at certain intervals to reduce the impact of wind on both soils and crops. For this measure tree species with a strong root system are most suited to withstand strong winds. These are normally positioned at right angles to the prevailing winds and along contours if that is possible.

Rainwater harvesting (RWH): There are a number of ex situ and in situ techniques that have bene employed. Storage of the harvested water is best done in the soil, but numerous underground and above ground structures have also been built. Roof RWH is perhaps the most common. This water is normally used for domestic purposes, with agricultural uses being secondary (Food and Fertilizer Techno logy Centre for the Asian and Pacific Region, 1995; Mati, 2007).

3.3 Conservation agriculture (CA)

Conservation agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It aims to stabilize yield and improve production over time by protecting the soil through cover, increasing soil moisture and restoring fertility (Kruger, Selala, & Dlamini, 2016).

3.3.1 Relevance

Conservation agriculture provides potential solutions to a wide-ranging number of challenges, including economic viability, ecological sustainability and the social acceptability of farming. It is also a viable method for smallholder and commercial farming at all scales, addressing both food and job security.

Conservation agriculture speaks to a number of current conditions:

- The increasing costs and declining profit margins of farming enterprises using conventional tillage.
- The decline and collapse of soil quality and soil ecosystem services. While competitive yields are no longer possible without the use of inorganic fertilizer, declining yields trends in some areas show that the effectiveness of this practice is reaching its limit and that soil ecosystem services should be restored to regain soil productivity, reduce risk and increase profitability. Soils can be rebuilt or recuperated with CA through quality application of all its principles.
- The impact of climate change on weather patterns, water regimes, biodiversity and ecosystems services will put increasing pressure on farmers to adapt their farming systems and management styles to increase their resilience and sustainability.
- A growing awareness, knowledge and self-organisation among farmers (as stewards of the land and natural resources), scientists and agribusiness to use and promote sustainable agricultural practices. The networking of these key actors creates so-called innovation platforms, which are ideal structures to promote and scale out CA.
- While greater efficiency and competitiveness is needed in farming practices, this requires healthy soils, robust biodiversity and innovative farmers.
- The need to rebuild the status and image of farming, which has been severely damaged by a negative environmental footprint and poor socio-economic conditions. CA innovation platforms have the ability to generate or contribute to social capital in rural societies to the benefit of the society as a whole (Smith et al. 2017)

3.3.2 Benefits

Conservation agricultural systems deliver multiple benefits in terms of yield, sustainability of land use, income, timeliness of cropping practices, ease of farming and eco-system services. (Smith, Kruger, Knot, & Blignaut, 2017). CA aims to conserve, improve and make more efficient use of soil, water and biological (e.g plants, animals, insects and microbes) resources. CA aims to improve soil structure, soil health and water holding capacity in the soil, which in turn reduces the degradation of land by farming (Kruger, Selala, & Dlamini, 2016). CA increases soil organic matter content and soil moisture retention, while sharply reducing run-off, erosion by wind and water and soil surface temperatures (helping to protect soil biota from extreme heat). As the health of soil fauna improves, soil organisms naturally till the soil, drawing nutrients from the surface down into the root zone, reducing soil compaction (thereby facilitating root penetration and water infiltration) and breaking down organic matter to make nutrients readily available for crops (Hobbs et al., 2008). Crop rotations allow for the inclusion of crops that contribute to increased soil fertility (e.g. nitrogen-fixing legumes).

Application of Conservation Agriculture practices facilitates other sound management practices, such as:

- **Integrated soil fertility and acidity management**. CA improves soil fertility and thereby reduces the amount of fertilizer required and saves time, money and energy. It is possible to have a sustainable biological system without the use of fertilizers.
- **Integrated weed management**: CA reduces the need for herbicides over time. It is possible to have complete weed control without using chemicals.
- **Integrated pest and disease management**: Management of pests and diseases includes crop diversification, timing of planting, promotion of natural balances between pests and predators in insects and naturally occurring microbes as well as physical control methods. This reduces the need for expensive pesticides and fungicides to a minimum.
- **Integration of animals**: Systems that include fodder production and management for livestock create an added benefit. This practice can include winter and summer forage crops such as Dolichos, sunn hemp, fodder rye, fodder radish and hairy vetch, as well as longer term grass species. Besides improving the physical, chemical, biological and water holding properties of the soil, such species, including annual or perennial cover crops, can successfully be used as animal feed.

In terms of its economic benefits, CA aims to help farmers achieve profits by increasing yields while reducing production costs, maintaining soil fertility and conserving water for sustainable agriculture and improving livelihoods (Kruger and Smith, 2015). CA also reduces input costs by cutting fuel consumption in mechanized systems (planting is done using single-pass machinery), seed costs (due to direct planting) and fertilizer inputs, though herbicide use may increase (Knowler and Bradshaw, 2007). Pesticide use may decrease – crop rotation systems under no-till are particularly resistant to pests and disease, since those that are crop specific have no host in the intervening years, and because robust soil biota increase the soil's resistance to pathogens (Hobbs et al., 2008).

The success of CA under diverse agro-ecological conditions is now being documented in South Africa as well and would justify investment of human and financial resources, whenever and wherever conditions permit it (Blignaut, et al., 2015).

3.3.3 Three principles of Conservation Agriculture

Conservation agriculture involves three key practices which should be implemented together:

- **Minimum mechanical soil disturbance:** The soil is not ploughed before planting; instead seed is planted directly into a mulch-covered field using specialised no-till planters.
- **Permanent organic soil cover (mulching):** The crop residue is left on the field, mulching is introduced or a cover crop is planted.

- **Diversified cropping (Including cover crops)** : Mixing, diversifying and rotating crops reduces weeds, controls pests and diseases and improves soil fertility (FAO, 2013).

Minimum soil disturbance

The idea is to disturb the soil as little as possible. For zero tillage, the soil is disturbed only where the seed and fertility amendments (fertilizer, manure, compost) are to be placed. For minimum tillage there may be lines ripped or small basins dug for planting of seed. The whole field is never ploughed. This has the following benefits:

- minimal destruction of the soil structure
- minimal exposure of the soil to wind and water erosion
- slower mineralization of organic matter, resulting in build-up
- minimal disruption organisms in the soil which improve the soil structure
- conservers time, energy and money as there is less ploughing and fertility amendments are placed only in the planting areas (Kruger and Smith, 2015).

Figure 9 Planting basins prepared using a hand hoe (left) and rip lines prepared using a ripper tine

The figures show some minimum soil disturbance options for smallholder farmers. Note that the area between the planting basins and rip lines is not disturbed and that the soil is covered by a mulch formed from crop residues. On the left are planting basins prepared using a hand hoe and on the right are rip lines prepared using a ripper tine, with seed and fertilizer boxes attached to the beam of a standard animal drawn plough.

Soil cover

The UN Food and Agriculture Organisation (FAO) describes the advantages and function of soil cover as follows:

> *In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer protects the soil from the physical impact of rain and wind but it also stabilizes the soil moisture and temperature in the surface layers. Thus this zone becomes a habitat for a number of organisms, from larger insects down to soil borne fungi and bacteria. These organisms macerate the mulch,*

> *incorporate and mix it with the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure. At the same time this soil organic matter provides a buffer function for water and nutrients. Larger components of the soil fauna, such as earthworms, provide a soil structuring effect producing very stable soil aggregates as well as uninterrupted macro-pores leading from the soil surface straight to the subsoil and allowing fast water infiltration in case of heavy rainfall events.* (FAO, What is Conservation Agriculture, 2017)

The soil should remain covered either with crop residues, other types of mulch or growing plants at all times. Generally, in CA the crop residue is left on the field to cover the soil. Other types of mulch can also be placed between the rows and planting basins or planting holes.

Figure 10 left and right: Soil cover provided by maize stover or residue from a previous season.

Mulch not only reduces soil erosion, it can reduce soil temperature by at least 4°C, creating better conditions for soil organisms to thrive.
When properly managed, soil cover can provide the following benefits:

- improved water infiltration resulting in a higher soil water content
- reduced direct raindrop impact and run-off in the field; thus reducing soil erosion
- reduced evaporation and improved conservation of soil moisture
- even, cool soil temperature
- weed prevention
- food and habitat for soil organisms that contribute to biological processes and soil fertility

(Kruger and Smith, 2015)

While crop residue can be used to cover the soil, cover crops may be needed if the gap between crops is too long or in areas where smaller amounts of biomass are produced (for example, semi-arid regions or areas of eroded and degraded soils. Cover crops provide the following benefits:

- Protect the soil during fallow periods
- Mobilize and recycle nutrients
- Improve the soil structure and break compacted layers and hard pans

- Permit a rotation in a monoculture
- Can control weeds and pests (FAO, 2017).

Cover crops can be planted in relay with the main crop or included seasonally as summer or winter mixes. Unlike commercial crops, which have greater and direct market value, cover crops are grown to improve soil fertility or provide animal fodder directly under controlled grazing conditions or as stored hay.

If used to improve soil fertility, food crops should be mixed with soil enriching crops that will:

- fix nitrogen into the soil (legumes) and cycle plant nutrients
- grow fast and provide a lot of above-ground (leave) and below-ground (root) biomass and
- improve soil biology, soil fertility and soil structure both when they are growing and when they are decomposing in the soil.

Figure 11 Left: A cover crop mixture of fodder rye, fodder radish and black oats growing in a maize field late in the season.

Figure 12 Right: Intercrop of cover crops (sunflower, sun hemp) and maize (Bergville, KZN)

Diversified cropping

Diversity ensures a natural balance in the field, creating a living soil, maximising the efficient use of water and protecting against weeds, pests and disease attack on crops. Biodiversity on top of the soil is mirrored by biodiversity below the soil (ie the more life there is on top of the soil, the more life there will be below the soil) , which ideally also includes the presence of living roots in the soil for the entire year. Maximum cover on top of the soil by plants, either living or dead, serve as armour to the soil providing protection from excessive sun and driving rain. This keeps the soil cooler in summer and warmer in winter. This all leads to the build-up of carbon in the soil, which is vital for sustainability. For every 1% of added carbon to the soil, the water holding capacity of that soil doubles (Kruger and Smith, 2015).

Mixed cropping involves planting various crops together in one plot. Inter-cropping involves planting different crops together at the same time while crop rotation means that different crops are planted in the same place at different times. Using these two practices together maximizes their benefits. Mixed cropping has the following benefits:

- **Soil fertility is replenished:** nitrogen-fixing legumes add 'top-dressing fertilizer' to the soil

- **Crops use nutrients in the soil more efficiently:** different crops have different feeding zones reducing their competition for nutrients
- **Pest and disease control is improved**: the life cycles of pests and diseases are broken by the introduction of a different crop
- **Soil structure is protected and enhanced by the presence of roots of different plants:**
    - the roots mobilise the soil
    - the roots provide a network of living matter which later dies and rots, creating humus
    - when the roots die the spaces they leave improve the porosity and drainage of the soil
    - the roots secrete weak acids to dissolve minerals in the soil then draw these back up in solution- the function being enhanced by different root types
    - roots also secrete a portion of their photosynthetic energy in the form of sugars that feed the microbes, which in turn provide soil mineral nutrients to the roots
    - the exploitation of different soil layers by different crops helps prevent the formation of a hard pan

When using crop rotation, planting at least three different crops is optimal. A good rotation that will also provide fodder for livestock is to plant maize in October/November, followed by a winter cover crop of black oats for grazing planted in February/March, followed by soya beans planted the following October/November (Kruger and Smith, 2015).

Figure 13 A field inter-cropped with beans and maize planted in double rows or tramlines (From Mahlathini Organics, 2015

Figure 14 A plot of maize and beans that are inter-cropped.

3.3.4 A note on soils

There is an increased interest in and understanding of soil health aspects in the management of agricultural soils. Habig and Swanepoel (2015) makes the following comments regarding soil:

> *Soil quality can be described as the integration of the physical, chemical and biological properties of the soil for productivity and environmental quality. While fertile, high quality soil can support long-term agricultural production, infertile soils must be actively rehabilitated in order to achieve adequate yields* (Doran & Zeiss, 2000). *The three principles of CA -- minimum soil disturbance, permanent soil and cover crop diversification, all aim to increase and sustain soil organic matter (SOM).*

Soil organic matter in turn has a considerable impact on soil biology, especially soil microbial diversity and activity.

Habig and Swanepoel go on to say that

> *...stimulation of microorganisms in the rhizosphere and the improved physical condition of soils in crop rotations and mixed cropping systems have been observed, particularly when the cropping systems have contained legume species. Synergistic associations between soil biota and plant roots (rhizosphere) are facilitated through the release of root exudates, leading to improved nutrient cycling, plant growth stimulation, and disease resistance, resulting in increased soil quality, crop health and yield* (Govaerts, et al., 2007). *It has been argued that increased soil microbial diversity will increase the potential of an ecosystem to function more efficiently under a variety of environmental conditions (ibid)*.

Soil microorganisms are sensitive to soil management practices and as such become important early indicators of soil quality. They are a good proxy indicator for soil health. Habig and Swanepoel note that:

> *The processing and recovery of essential nutrients from accumulated SOM is mediated by soil microbial functions which require extracellular enzyme activity to process complex organic compounds into utilizable subunits. Levels of soil microbial enzymes have shown significant correlation with total organic carbon and total nitrogen in soils*.

Both microbial diversity and enzyme activity are now being used as indictors of soil health and as a management tool in CA systems. New soil testing systems have been designed to incorporate these elements and present results in a meaningful and practical way for farmers (Haney, 2017)

3.3.5 Constraints to Conservation Agriculture

Conservation Agriculture has faced challenges to adoption. Farmers may also choose certain practices within CA and disregard others depending on their circumstances. Major constraints to adoption for smallholders, as noted by Thiefelder et al (2014), are trade-offs in mixed crop-livestock systems in that most smallholders keep livestock such as cattle, sheep and goats which require the crop residue for fodder, leaving inadequate soil cover. Other constraints noted are the intensity and difficulty of control of weeds on CA plots, labour constraints and lack of access to inputs and markets.

3.4 Agroecology

Agroecology as an approach emphasises the need to maintain productivity in agriculture while also minimising negative environmental and socio-economic impacts. Agroecology draws, naturally, on the fundamental principles of ecology itself, in particular the way in which natural ecosystems work:

- Interconnection: Nature as a network of interconnected living systems
- Cycles: A constant cycling of matter throughout an ecosystem, making maximum use of all components and eliminating waste
- Energy: Solar energy captured through a diversity of plants powers the system
- Partnerships: Ecosystem components operating in collaboration rather than competition
- Diversity: Ecosystems derive strength and resilience through diversity

- Dynamic balance: Systems operating in a fluid dynamic balance of interactions between components as a fluctuating network

These principles are translated into those underpinning Agroecology as:

- Enhanced recycling of biomass
- Secured favourable soil conditions for plant growth, through management of organic matter and enhancing soil biotic activity
- Minimised losses, through flow, of energy air and water and through micro-climate management
- Species and genetic diversity (including biodiversity above and below ground)
- Enhanced beneficial biological interactions and synergisms between system components

Among the many vital concepts perhaps those most relevant in relation to CSA are: Resilience; Diversity; and Synergy. Agroecology has a particular focus on these and suggests that traditional or indigenous farming systems (often referred to as 'peasant farming systems') at their most functional often reflect a strong adherence to these principles, and the challenge is to scale-up to more commercial levels. However, as discussed earlier, even formerly robust traditional systems are under increasing pressure from climate change (Agroecology, 2015).

Links to Food Security and Food Sovereignty: the Socio-ecological Nexus

One of the main objectives of Agroecology is to enhance both food security (in that people have enough of the right kinds of food, readily available at all times), and food sovereignty (where people have control over how the food is produced). For both of these the underlying principle involves a reduction in external inputs/influences, and a corresponding increase in farmers' and consumers' own control over food production processes. This mirrors the fundamental agroecological principle of a minimisation (ideally to zero) of external inputs such as fertilisers and pesticides, with the system itself providing these internally. The coalition between the social and ecological components of agroecology is intended to display the characteristics identified in list below:

- High levels of interaction and synergies between different farming components,
- High levels of diversity at the farm and landscape level,
- High levels of independence, self-organisation and cooperation in and between social networks
- Respect for and incorporation of traditional knowledge and practices and
- And High levels of reflection, planning and development of human capital.

Links to CSA

While Agroecology is considered a preferred approach in all situations, it is suggested that it, in particular its ability to strengthen resilience, is especially appropriate in the face of climate change (Agroecology, 2015). See Figure 15 below:

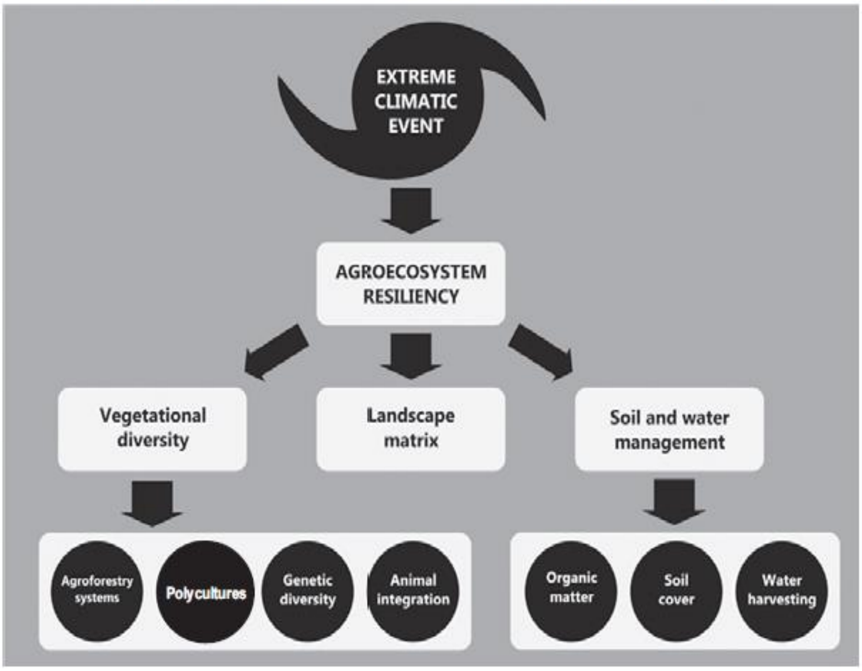


Figure 15 : Landscape, on-farm diversity and soil and water features that enhance ecological resilience to extreme climatic events

3.5 Natural Resource Management (NRM)

Natural Resource Management (NRM) is about the management of natural resources in such a manner that ensures environmental, social and economic sustainability for both present and future generations. Sustainable environment and natural resource management can play a significant role in reducing poverty for people residing in rural areas. About 75% of the world's poor people live and rural areas and depend on natural resources for their livelihoods (Prato and Longo, 2012). The people residing in rural areas are the most prone to challenges associated with degradation of natural resources. They are vastly affected by the impacts of climate change; degradation of ecosystems and biodiversity; declining of suitable agricultural land both in quality and quantity and reduction of forest resources (IFAD, 2012). Livelihood and food security of rural people depend highly on the productivity of land and water resources; however, farming activities in these areas occur under very marginal rainfed lands with increased water scarcity, energy and limited agricultural inputs.

Agricultural development is an important tool for addressing poverty, however the intensification and expansion of agriculture can contribute to ecosystem degradation. Well-managed agricultural systems, however, can address elements of poverty while achieving better environmental outcomes. At the same time, small-scale farmers are the most dependent on natural assets and are often located in fragile, marginal and degraded areas (Lipper et al, 2009).

Effective natural resource management cannot be facilitated by one body; an integrated approach which involves a range of stakeholders including government departments, catchment management authorities, Landcare, Bushcare and Coastalcare networks, land owners and the general community is required (Ochola et al, 2010). This approach recognises that natural resources are not only important for direct use, they also support basic service provision, local economic development and social wellbeing.

3.5.1 Overview of natural resources

Natural resources can be distinguished using different frameworks. The Millennium Ecosystem Assessment framework distinguishes natural resources as:

- Provisioning services: natural resources responsible for supporting human life
- Regulating services: responsible for basic ecosystem processes
- Cultural services: provide non-material ecosystem benefits
- Supporting services: responsible for basic long term ecosystem services.

Natural resources provide a wide range of services that support human livelihoods through provision of basic soil and water resources for crop and livestock production; regulating air, water, and climatic processes; supporting the biophysical processes of photosynthesis, soil formation and nutrient cycling; and helping provide a diversity of social, cultural, spiritual, recreational aspects to life (IFAD, 2012). However, more specifically, the key natural resources on which we all -- including the poor -- are dependent are land, water, forests, fisheries, climate, crop genetic resources and mineral resources. Availability and sustainability of these resources is heavily influenced by human behaviour. For example, land quality is affected by land degradation caused by previous or current land management practices; water availability is influenced by the efficiency of irrigation infrastructure while water quality is affected by human actions which may lead to soil erosion and sedimentation and pollution by agricultural, industrial and human waste; agricultural genetic resources and biodiversity have been manipulated by both farmers and scientists through genetic selection (IFAD,2012).

In western and central Africa the major challenge with regards to natural resources is the degradation of soil and water resources. Population growth is exerting pressure on woodland for fuelwood and expanding agriculture (IFAD, undated). In the eastern and southern African regions deforestation, soil fertility loss, soil compaction, water scarcity and overgrazing have been identified as the main problems. In these areas the International Fund for Agricultural Development (IFAD) has implemented a series of climate smart interventions to deal with these problems. In Lesotho, for example, it has implemented the Machobane farming system which addresses the adverse effects of monocropping by practising intensive relay cropping on contours for erosion control and moisture conservation. The farming system uses wood ash and farmland manure to enhance soil fertility (IFAD, undated).

Table 5 below summarises the status of the various ecosystem services.

Table 5 Global status of provisioning, regulating, and cultural ecosystem services (adapted from FAO, 2013)

Service	Sub-category	Status	Notes
Provisioning services			
Food	Crops	Increasing	Substantial production
	Livestock	Increasing	Substantial production
	Capture fisheries	Decreasing	Overharvesting
	Aquaculture	Increasing	Substantial production increase

	Wild food	Decreasing	Declining production
Fibre	Timber	+/-	Forest loss in some regions and growth in others
	Cotton, hemp, silk	+/-	Declining production of some fibers, growth in others
	Wood fuel	Decreasing	Declining production
Genetic resources		Declining	Extinction and crop genetic resource loss
Biochemical, natural, medicines, pharmacies		Declining	Extinction and overharvest
Fresh water		Declining	Unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating services			
Air quality regulation		Declining	Decline in ability of atmosphere to cleanse itself
Climate regulation	Global	Increasing	Net source of carbon sequestration since mid-century
	Regional and local	Declining	Preponderance of negative impacts
Water regulation		+/-	Varies depending on ecosystem change and location
Erosion regulation		Declining	Increased soil degradation
Water purification and waste treatment		Declining	Declining water quality
Disease regulation		+/-	Varies depending on ecosystem change
Pest regulation		Declining	Natural control degraded through pesticide use
Pollination		Declining	Apparent global decline in abundance of pollinators
Natural hazard regulation		Declining	Loss of natural buffers (wetlands, mangroves)
Cultural services			
Spiritual and religious values		Declining	Rapid decline in sacred groves and species
Aesthetic values		Declining	Decline in quantity and quality of natural lands
Recreation and ecotourism		+/-	More areas accessible but many degraded

3.5.2 Legislative and policy context of Natural Resource Management

The South African Constitution and legislation such as the Conservation of Agricultural Resources Act (CARA), National Environmental Management: Biodiversity Act (NEMBA), National Environmental Management Act (NEMA) and the Environmental Conservation Act (ECA) guide the management of natural resources in South Africa.

The constitution of South Africa addresses environmental rights, stating that every individual has a right to:

a) an environment that is not harmful to their health or well-being and,

b) Thave the environment protected for the benefit of present and future generation, through reasonable legislative and other measures that:

- *prevent pollution and ecological degradation.*
- *promote conservation.*

• *Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development* (Constitution of the Republic of South Africa, 2003):

Table 6 summarises the South African environmental protection legislation responsible for ensuring the correct management of natural resources.

Table 6 Summary of environmental protection legislation (Pollard and du Toit, 2005).

ACT	PURPOSE
National Environmental Management Act (NEMA) (107 of 1998)	Seeks to provide for cooperative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote cooperative governance and procedures for coordinating environmental functions exercised by organs of state. It further seeks to provide for certain aspects of the administration and enforcement of other environmental management laws
Environmental Conservation Act (ECA) (73 of 1989)	Seeks to ensure effective protection and controlled utilization of the environment, utilising an environmental impact assessment (EIA) tool.
NEMA: Biodiversity Act (10 of 2004)	Recognises the State's obligation to manage, conserve and sustain biodiversity and its components and genetic resources
NEMA: Protected Areas Act (57 of 2003)	Creates a national system of protected areas in order to protect and conserve ecologically viable areas representative of biodiversity in the country. It further seeks to achieve cooperative environmental governance and to promote sustainable and equitable utilisation and community participation.
Conservation of Agricultural Resources Act (CARA- 43 of 1983)	Seeks to provide for the conservation of natural agricultural resources by maintaining the production potential of land, combating and preventing erosion and weakening or destruction of water resources, protecting vegetation and combating weeds and invader plant species.
National Water Act (36 of 1998)	Seeks to ensure that South Africa's water resources are protected, used and managed in ways which take into account factors such as inter-generational equity, equitable access, redressing the legacy of past racial and gender discrimination, promoting sustainable and beneficial use, facilitating social and economic development and providing for water quality and environmental protection.
Marine Living Resources Act (18 of 1998)	Provides for the conservation of the marine ecosystems, the long-term sustainable and equitable utilisation of marine living resources and orderly, fair and equitable access to exploitation, utilisation and protection of certain marine resources.
National Forests Act (84 of 1998)	• Promotes the sustainable management and development of forests for the benefit of all • Restructures forestry in state forests to protect certain forests and trees. • Promotes community forestry and greater participation in all aspects of forestry activities. • Promotes sustainable use of forests for environmental, economic, educational, recreational, cultural, health and spiritual purposes.
National Veld and Forest Fire Act (101 of 1998)	Seeks to prevent and combat veld, forest and mountain fires and establishes a variety of institutions, methods and practices for achieving this purpose.

This legislation is implemented and enforced at national, provincial and local levels of government, as well as through traditional leadership structures and statutory and non-statutory bodies (Cousins et al., 2007).

3.6 Agroforestry

Agroforestry is a dynamic, ecologically-based, natural resource management system that through the integration of trees on farms and in the agricultural landscape, seeks to diversify and sustain production for increased social, economic and environmental benefits for land users at all levels (ICRAF, 2006). Agroforestry acknowledges the use of trees and shrubs on farms to support agricultural production while protecting the soil and water resources, enhancing biodiversity, carbon sequestration and improving landscape values.

A number of different definitions for agroforestry have been put forward. The United Nations Food and Agriculture Organisation defines agroforestry as:

> *'the dynamic, ecologically based, natural resource management system that, through integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels'* (Dawson I K et al 2013).

Other definitions focus on agroforestry as the incorporation of trees into farm systems for commercial and natural resource management benefits (JVAP, 2006). or the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of a spatial arrangement or sequence; which must consist of an interaction (positive or negative) between the woody and non-woody components of the system that is significant either ecologically and/or economically (Lundgren, 1982). The rising interest in agroforestry has been motivated by several factors including accelerated tropical deforestation, degradation and shortage of land due to population pressures and growing interest in sustainable farming systems and environment (Nair, 1993). Adapting to multi-dimensional farming approaches such agroforestry is important in achieving sustainable livelihoods (Mery et al., 2005).

3.6.1 Agroforestry systems

Agroforestry consist of three major systems which within there are practices associated with each system. Nair (1993) catagorises these systems as agrisilvicultural, silvopastoral and agrosilvopastoral systems. The criterion used to classify these systems depends on the system's structure, function, socioeconomic nature and environment. The systems <u>structure</u> speaks to how the different components of the systems are arranged, i.e. spatial and temporal arrangements. <u>Function</u> refers to the major role of the system e.g. windbreaks, shelterbelts, soil conservation. <u>Socioeconomic</u> relates to the level of inputs required by the system (does the system require low or high inputs) and its economic purpose (is the system used for subsistence, commercial or intermediate production). Finally, the <u>environment</u> refers to the system's suitability to the particular environment or ecological ecosystem e.g. how suitable is the system to the arid, semi-arid, tropical highlands, lowland humid tropics, etc. (Nair 1993). In theory, all agroforestry systems share the following attributes:

- **Productivity:** Agroforestry systems should aim to maintain or increase production as well as productivity (of the land) through increased output of tree products, improved yields of associated crops, reduction of cropping system inputs and increased labour efficiency.
- **Sustainability:** By conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils, agroforestry can achieve and indefinitely maintain conservation and fertility goals.
- **Adoptability:** The word "adopt" here means "accept," and it may be distinguished from another commonly-used word adapt, which implies "modify" or "change." However, in this context it means that improved or new agroforestry technologies that are introduced into new areas should conform to local farming practices for ease of acceptability.

3.6.2 Economic and environmental benefits of agroforestry

Agroforestry offers a number of economic and environmental benefits.

Economic benefits

Agroforestry can add economic value in terms of fodder, soil fertility and timber or fuelwood.

Fodder

Implementation of silvopastoralism by dairy farmers increases their economic benefits. In central Kenya, it was observed that farmers planted fodder shrubs, especially *Calliandra calothyrsus* and *Leucaena trichandra*, to use as feed for their stall-fed dairy cows (Franzel, Wambugu and Tuwei, 2003). Their farm-grown fodder remarkably improved milk production and as it was substituted for relatively expensive purchased dairy meal it increased the farmers' income. Fodder shrubs also conserve soil, supply fuelwood and provide bee forage for honey production (SOFO, 2005). In the Philippines, a combination of improved fodder grasses and trees (*Gliricidia sepium*) also brought improvements in farmers' income from livestock production, increased crop production and reduced farm labour, especially for herding and tethering (Bosma *et al*., 2003).

Soil fertility

The use of improved tree fallows has proven to be a viable means to increase crop yields while nourishing the soil through nitrogen fixation and nutrient cycling. Farmers in Malawi and Zambia enjoyed improved maize yields following planting improved fallow tree species (Franzel, Phiri and Kwesiga, 2002). Although maize planted on improved fallows would not outperform the fertilised maize, long term soil fertility and improvement is achieved which benefits farmers who cannot afford fertiliser. Biomass transfer (the manual transfer of green manure)increases vegetable yields, extending the harvesting season and improving the quality of produce (SOFO, 2005). For example, in western Kenya, farmers incorporated *Tithonia diversifolia* leaves plus a bit of phosphorus on their vegetable plots and observed improved returns.

Timber and fuelwood

Production of timber and fuel wood in an agroforestry setting is becoming a common practice around the world. Timber species such as *Paulownia* spp are normally planted together with cereal crops in many areas of North China Plain. These tree species are very deep rooted and impose minimum competition on crops. They produce high quality timber and excellent fuelwood (Sen, 1991; Wu and Zhu, 1997).

Environmental benefits

Literature indicates that agroforestry can provide a greater range of environmental benefits than conventional types of annual crop cultivation. These include improved water use and quality, reduced erosion/improved soil, increased biological and ecological diversity and improved climate resilience. Murniati, Garrity and Gintings (2001) found that households engaging in diversified farming systems which included mixed perennial gardens depended much less on gathering forest products than did farms cultivating only wetland rice. Hence, the pressure on tree felling and unsustainable hunting practices in the nearby forests and parks were reduced. The findings suggest that promoting diversified farms with agroforestry in buffer zones can enhance forest integrity.

Water use, soil water and water quality

Monoculture agricultural systems do not fully utilise rainfall due to losses from evaporation, runoff and deep drainage (Siriri et al. 2013). Integration of trees and crops improves the productivity of transpired water by increasing biomass production per unit of water used (Ong et al. 2007). Intercropping results in microclimate modification increasing the soil water, gas exchange and water use efficiency of the understorey crop (Kinyamario et al. 1996). Agroforestry improves the water use of a production system by allowing for utilisation of offseason rainfall, where the perennial plants make use of the additional soil water. Pruning residues and plant litter decompose into organic matter, which improves the infiltration capacity of the soil and resulting in better water storage (Siriri et al. 2013). Agroforestry also contributes to reduction of nonpoint source pollution through planting of riparian buffers along water bodies (U.S. Department of Agriculture National Agroforestry Centre, 2012).

Erosion / soil improvement

Adoption of land use practices such as agroforestry improves the physical and chemical properties of the soil, enhances soil infiltration capacity and influences soil water distribution processes (Neris et al. 2012). Previous research confirms that agroforestry enhances soil fertility, improves soil structure and soil organic matter, reducing the risk of erosion (Lehmann et al. 1998; Lott et al. 2009 & Duguma & Hanger 2011). Terracing of slope areas with woody perennial reduces soil erosion.

Biological diversity and ecology

Agroforestry systems provide a favourable environment for biological diversity. Biodiversity groups can range from insectivorous birds and bats, tree seed-dispersing birds, pollinators enhancing crop yield and amphibians providing biocontrol services. Traditional coffee-based agroforestry systems in the Americas have proven to be critical for protection of migration corridors for birds. A system comprised of these biodiversity groups can be achieved through the integration of various agroforestry practices leading to the creation of a complex mosaic of patches in an ecosystem (Leakey and Simons 1998). Each of these patches is composed of many niches occupied by different organisms, resulting in an ecologically stable and biological diverse system.

Climate resilience: mitigation and adaptation

Three quarters of the world's poorest people live in rural areas, and their livelihoods depend on crop farming which is largely subsistence and dryland production; these people are first to be impacted by climate change. Climate change events such as the shifting of seasons, prolonged drought and increased temperatures occurring in the Southern Africa highlight the need for these farmers to adapt to climate change. Climate change can be addressed through two broad elements: mitigation and adaptation. Agroforestry has been found to contribute significantly to climate change mitigation (Nair and Nair 2014).

Mitigation

Climate change mitigation can be achieved through the reduction of greenhouse emission and carbon sequestration. In the context of agroforestry, reduction of greenhouse gas emission is achieved through tree farming by high storage of carbon, in the soil especially when mulching and conservation agriculture practices are applied (Blignaut et al 2008). Another key element of mitigation is carbon sequestration. Carbon sequestration is realised in agricultural systems that minimise soil disturbance and actively build soil organic carbon (SOC). The modernisation of agriculture has resulted in the depletion of carbon as a result of deforestation, intensive cropping, soil erosion and unsustainable agricultural practices. Where trees or shrubs are included on farms as part of an agroforestry system, the amount of carbon sequestered is increased compared with monoculture agricultural systems, while also providing biomass-based fuel alternatives.

Adaptation

The IPCC (2007) defines adaptation as the "adjustments in human and natural systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities". Agroforestry is increasingly recognised as a farming system that enhances the resilience of smallholder production systems in the face of climate change. Due to the diverse nature of agroforestry, it increases farm profitability of output per unit area through protection against adverse climatic conditions. Agroforestry can also improve the financial diversity and flexibility of a farming enterprise. For example, fruit trees on farm or home gardens produce fruits that contribute to the family's diets in terms of vitamins and minerals, while non-timber products such as mushrooms or groundnuts provide financial income until the timber matures.

4 PRACTICES

This chapter aims to draw out specific practices under CSA and the associated methodologies and practices. These 'lists' are to form the basis for defining practices within the decision support system to find best bet options for practices within a 'basket of options'.

Presently many of these practices could be seen to be complimentary or even overlapping and it is specifically those where interesting synergies could be created that are to be given specific attention.

Table 7, summarised from the research team's present understanding, illustrates some of the practices which address the three pillars of CSA; improvement of crop productivity, mitigation of climate change impacts and climate change adaptation.

These practices include elements of natural resource management, soil and water conservation (SWC) and conservation agriculture (CA.). Agroforestry and agroecology are briefly dealt with in separate sections below, for the sake of clarity.

It is important to note that these practices cannot be introduced only as technologies but that they fit into larger processes of awareness raising, learning and experimentation. These will be touched on in Chapter 5 below and will be discussed in more detail in Deliverable 2 of this research process.

Table 7 Practices which contribute to Climate Smart Agriculture

Category	Description	Practices	Description of the practices
Water management	Under irrigation	Irrigation scheduling and water availability in the root zone	Irrigation scheduling refers to application of irrigation water based on crop water requirements
	Rainfed	Deficit irrigation (DI) also known as supplemental irrigation (SI) Water harvesting Soil management practices which minimise soil water losses (runoff, evaporation, deep percolation) and improve soil water holding capacity (e.g. mulching, improved soil fertility) Crop management practices that enhance growth and yield (greater water use efficiency)	Application of irrigation in rainfed systems during the critical stage of crop development Ex-situ (capturing runoff water) and in-situ (storing water in the soil profile) water harvesting Soil fertility is improved by increasing the organic matter content of the soil which improves the water holding capacity of the soil. Mulching refers to covering of the soil surface by crop residues to minimise soil evaporation. Developing drought resistant crop varieties (improving water productivity)
Crop management	Crop specific innovations which contribute to CSA	Crop rotation Integrated pest management Mixed cropping/ intercropping Breeding of high yielding crop varieties (early maturing, drought tolerant) Integrated nutrition management Choice of crops that have high yielding potential under different environmental condition (drought tolerant crop varieties) Micro climate management	Crop rotation assists in improving soil fertility In dry land maize is normally planted with legumes (e.g. dry beans or cowpeas) in between High yielding early maturing crops assists in resource use efficiency (water and nutrients) This includes concepts in organic farming and agroecology including composting, green manures, cover crops, vermiculture etc. The choice of the crops should also be based on the environmental condition they are grown in Practices here include tunnels and shade house structures where evaporation and temperature extremes can be controlled to various degrees.
Soil management	This relates to improvement and/or management of soil fertility and health	Practices aimed at ensuring comprehensive soil cover by vegetation (Mulching, close spacing) Maintaining and increasing soil carbon levels (CA systems) Minimising the impact of rainfall-runoff (more infiltration) Minimising use of inorganic fertilizers	Mulching refers to use of plant residues (usually from the crop planted in the previous season) to cover the soil surface to minimise soil evaporation, reduce runoff, improve soil water infiltration and contribute to soil organic matter. Conservation agriculture (CA) is an agricultural practice which is based on the three main pillars, these are, minimum soil disturbance (no till), crop rotation and soil cover
Livestock management		Improved pasture Grazing land management Agroforestry species Animal health innovations (e.g. vaccination)	Cultivated pastures, either under rainfed conditions or irrigation (e.g. growing of Lucerne for direct grazing and or hay production) Vaccinations are important to reduce the risk of animal diseases which could lead to animal death
Forestry and agroforestry	Ensuring sustainable ecosystem services provided by trees (e.g. food, fibre, fuel)	Agroforestry systems on farm	Planting of trees with cash crops increase the productivity of the land while increasing diversity on the farm. (some of the agroforestry species are legumes (e.g. pigeon pea) which also contributes toward nitrogen fixation
Energy management	This aims to increase energy efficiency	Diversification of energy sources	Use of sustainable renewable energy to reduce reliance fossil energy, including wind, water and solar energy. Biofuels could be considered.

We continued from there to focus in on potential practices for field cropping, presented in the table/flow diagram below:

Table 8 Summary of potential CSA practices in smallholder cropping systems

APPROACH	OBJECTIVE	CSA PRACTICES	EXAMPLES / CASE STUDIES
SOIL MANAGEMENT	Improvement of soil fertility	Use of site specific fertilizer recommendation and more efficient use of fertilizer (using the right, source, at right time, at right place and applying the right rate) planting legumes, manure, green manure, liming to manage soil acidity (surface liming and incorporation).	*It has been shown that yields with fertilizer exceed those without by a factor of 2 to 3 (Rasmussen et al., 1998).*
	Improvement of soil health	Minimum tillage/ no till, crop diversification, inclusion of cover crops, agroforestry options (multipurpose, fast growing trees and fodder species) push-pull technology	*Blanco-Canqui and R. Lal (2007) found that no till based cropping systems increases soil organic carbon in the top layers of the soil profile compared to plough tillage based cropping systems. This contributes to increase SOC and thus improve soil health. Contribution to CSA (reduces GHG) emissions)*
WATER MANAGEMENT	Management of available water	**Improved irrigation practices** (drip irrigation, furrow irrigation, moist tube irrigation), **improved water retention** (soil cover (mulching with crop residues), improved organic matter (manure and crop residues), minimum tillage (CA))	*Improved irrigation systems (drip irrigation) contribute towards water use efficiency thus water productivity. Drip irrigation significantly roots or shoot ratio compared to other irrigation systems (e.g. Sprinkler irrigation) (Kang et al., 2001)*
	Improvement of water availability	Rain water harvesting (situ and in-situ), small dams, check dam, small earth dams, infiltration pits and ridges.	*Harvested water is often used of supplementary irrigation (SI). Study by Owies and Hachum (2012) found that SI has a potential to double the yields in wheat production (under rainfed conditions).*
SOIL AND WATER CONSERVATION (SWC)	Erosion control	Contour planting, gabions, grass water ways, stone bunds, diversion ditches, swales, furrows, zai pits, terraces, stone packs, strip cropping, pitting, half moon basins	*Combinations of stone bunds and zaï pits could double the yield of millet and sorghum compared to unimproved land (Landolt, (2011) and Bayala et al., (2012). This indicates that these SWC practices contribute to CSA in that they improve productivity.*
CROP MANAGEMENT	Improvement of crop variety	Breeding improved varieties (early maturing, drought tolerant, improved nutrients), seed saving, OPV and heirloom varieties	*Under the drought tolerant maize for Africa (DTMA) project, Revere et al. (2010) reported newly developed varieties as having potential to improve the maize yield by 10 to 14 %.*
	Management of pests and weeds	Crop rotation, intercropping, integrated pest management (home made brews), planting in tunnels, integrated weed management (close spacing to suppress the weeds)	*Intercropping coffee with banana can increase the plot revenue by 50% in both fertilized and unfertilized conditions (Van Asten et al., (2011). This is because coffee is a shade tolerant tree. Therefore crop management practices contributes toward improved yield and income.*

A further focus on vegetable production led to the compilation of the diagram below. A number of the practices may overlap with the cropping systems practices. They are mentioned again as the activities are scale dependent and specific methods and processes may vary.

Table 9 Summary of potential SCA practices for smallholder vegetable production systems

CATEGORY	OBJECTIVE	CSA PRACTICES	EXAMPLES/ CASE STUDIES
SOIL MANAGEMENT	Improvement of soil fertility	Inorganic fertilizer, integrated nutrient management, Agro-forestry options, use of grain legumes, use of animal manure (e.g. chicken, cattle, goat) **Improved manure options** (Composting, liquid manure, teas, worm farming) **Deep fertility beds** (deep and shallow trenches, double digging, banana circle, eco circles)	*Mafongoya et al. (2006) found that, inorganic fertilizers, grain legumes, animal manures, integrated nutrient management and agro-forestry options are appropriate options for improving soil fertility in small-scale* farming
	Improvement of soil health	**Returning organic matter to the soil** (use of green manure plants, use of grass in crop rotation, use of crops residues) **Diversification** (cover crops, mixed cropping)	*At the same organic carbon content in the soil, the soil biological activity and physical condition are remarkably improved when under grass rather than vegetables (Haynes and Tregurtha, 1999).*
WATER MANAGEMENT	Management of available water	**Improved irrigation or water saving practices** (drip irrigation, bottle irrigation), **Improving water retention** (soil cover ((mulching with crop residues), improved organic matter (manure and crop residues), minimum tillage (CA)) **Use of grey water** (tower gardens, homemade water filters)	*Use of greywater can contribute to 15% water saving and 27% cost saving on water bills. (Faruqui and Al-Jayyousi 2002)*
	Improving availability of water	Rain water harvesting (ex-situ and in-situ), small dams, check dam, small earth dams, infiltration pits and ridges, tanks	*In Singapore, use of water harvested from roof tops could results in a 700% increase in domestic vegetable production, satisfying domestic demand by 35.5% (Astee and Kishnani, 2010).*
SOIL AND WATER CONSERVATION (SWC)	Erosion control	Cover crops, stone bunds, diversion ditches, swales, furrows, zai pits, terraces, stone packs, strip cropping, pitting, half moon	*Cover crops have become important in conservation tillage practices because they control soil erosion and help increase soil tilth* (Phatak, 1992)
CROP MANAGEMENT	Crop variety improvement	Breeding improved varieties (early maturing, drought tolerant, improved nutrients)	*Many new, improved, nutrient-dense indigenous and standard vegetable varieties are being released for which small-holder farmers are finding growing markets in both rural and urban settings (Afari-Sefa et al., 2012)*
	Management of pests and weeds	Crop rotation, intercropping, **integrated pest management** (used of pesticides, plating in tunnels) integrated weed management (close spacing to suppress the weeds) use of compost teas	*Martin and Brathwaite (2012) found that compost tea, a product of compost, has also been shown to suppress soil-borne diseases including damping-off and root rots (Pythium ultimum, Rhizoctonia solani, Phytophthora spp.) and wilts (Fusarium oxysporum and Verticillium dahliae).*

4.1 Agroforestry

The table below provides a classification system for agroforestry techniques and process and outlines practices. Here combinations for gardening, cropping and grazing systems are provided.

Table 10 Agroforestry systems and practices (Source: Nair 1991)

Major agroforestry systems	Agroforestry practices associated with each system	Major components	Agroecological adaptability
Agrisilvicultural systems (crops - including shrub/vine/tree crops - and trees)	Improved fallow Woody species planted and left to grow during the 'fallow phase'	Woody leguminous crops	In shifting cultivation areas
	Taungya Combined stand of woody and agricultural species during early stages of establishment of plantations	Forestry plantation species and common agricultural crops	For all agro ecological zones with forestry plantations
	Alley cropping (hedgerow intercropping) Woody species in hedges; agricultural species in alleys in between hedges; microzonal or strip arrangement	Fast growing woody species, legumes	Subhumid-humid areas
	Multilayer tree gardens Multispecies, multilayer dense plant associations with no organized planting arrangements	Different woody species of varying form and growth habitats	Areas of fertile soils
	Multipurpose trees on crop lands Trees scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries	Multipurpose and certain fruit trees; herbaceous agricultural crops	All ecological regions
	Plantation crop Combinations Integrated multi-storey (mixed, dense) mixtures of plantation crops Mixtures of plantation crops in alternate or other regular arrangement Shade trees for plantation crops; shade trees scattered Intercropping with agricultural crops	Woody plantations like coffee, cocoa, coconut and certain fruit trees. Fuelwood/fodder species. Shade tolerant species	Humid lowlands or tropical humid/sub humid highlands
	Homegardens Intimate, multi-storey combination of various trees and crops around homesteads	Fruit trees, woody species, vines etc. shade tolerant agricultural species	All ecological regions
	Trees in soil conservation and reclamation Trees on bunds, terraces, raisers, etc. with or without grass strips; trees for soil reclamation	Multipurpose and fruit trees and herbaceous agricultural crops	In sloping areas (highlands, reclamation of degraded, acid, alkali soils etc.
	Shelterbelts and windbreaks, live hedges Trees around farmland/plots	Woody species that are tall growing and spreading	Wind prone areas

	Fuelwood production Inter planting firewood species on or around agricultural lands	Firewood species	All ecological regions
Silvopastoral systems (trees + pasture and/or animals)	Trees on rangeland or pastures Trees scattered irregularly or arranged according to some systematic pattern	Multipurpose trees and species of fodder value	Extensive grazing areas
	Protein banks Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production	Legume fodder trees	
	Plantation crops with pasture and animals	Woody plantation crops Example: cattle under coconuts in south- east Asia and the south Pacific	In areas with less pressure on plantation crop lands
Agrosilvopastoral systems (trees + crops + pasture/animals)	Homegardens involving animals Intimate, multi-storey combination of various trees and crops, and animals, around homesteads	Predominated by fruit trees	All ecological regions
	Multipurpose woody hedgerows Woody hedges for browse, mulch, green manure, soil conservation, etc.	Fast growing and coppicing fodder shrubs and trees	Humid to sub humid areas with sloping terrain
	Apiculture with tree	Trees suitable for honey production	Depends on the feasibility of apiculture
	Aquaforestry Trees lining fish ponds, tree leaves being used as 'forage' for fish	Trees and shrubs preferred by fish	Lowlands
	Multipurpose woodlots For various purposes (wood, fodder, soil protection, soil reclamation, etc.)	Multipurpose species	Various

4.2 Agroecology

The key Agroecological approaches can be found to fit into the broader CSA, CA and agroforestry systems and practices already mentioned above. For the sake of creating a complete picture, these are listed again briefly below (Agroecology 2015).

- **Crop rotations:** Cereals and legumes are planted in sequence/rotation. Nutrients are conserved and provided from one season to next and pest and disease life cycles are interrupted,
- **Polycultures**: Two or more crop species are planted together to improved nutrient use efficiency, optimal water management and pest regulation
- **Agroforestry systems:** trees are grown together with annual crops to maintain and improve fertility, improve nutrient uptake, support life above and below the ground and create mulch.
- **Cover crops and mulching:** Grass-legume mixtures are planting into existing cropping systems, or as relay or off season crops in a seasonal cropping system to reduce erosion, improve nutrient balances, improve weed management and manage pest life cycles.
- **Green manures:** These are fast growing cover crops. In this system, the plants are cut and incorporated into the soil at particular growth phases (prior to flowering) to maximise nutrient provision to following crops and improve soil structure.
- **Crop-livestock mixtures:** Integration of livestock fodder into the cropping system, creates many synergies. As an example, fodder shrubs planted at high density, intercropped with livestock pasture and timber producing trees, that are directly grazed by livestock, creates a system where external inputs are not required.

5 SUPPORTING PRACTICES

5.1 Tools to support Natural Resource Management in a rural / communal context

5.1.1 Livelihoods approaches

Climate smart agriculture can also be supported by using the livelihoods approach which combines the principles of Participatory Rural Appraisal and the sustainable livelihoods approach. This approach differentiates five livelihood capitals, namely: human capital, social capital, physical capital, natural capital and financial capital (Lax and Krug, 2013), as illustrated in Figure 16 below.

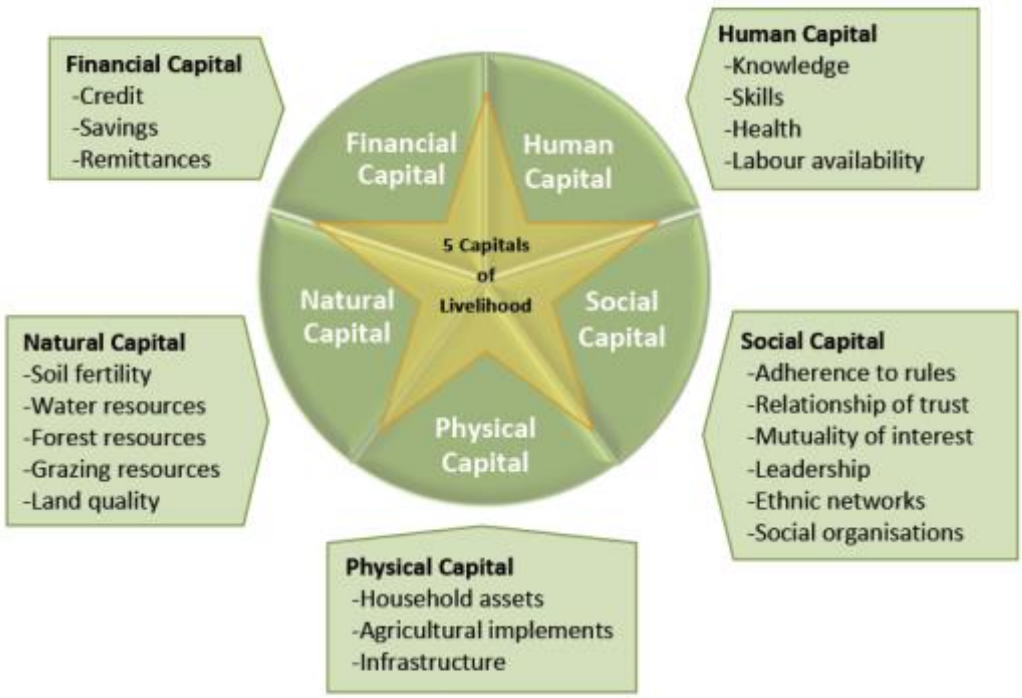


Figure 16 Five capitals of sustainable livelihood assessment (Lax and Krug, 2013)

5.1.2 Landscape approaches

The landscape approach enables the achievement of Climate Smart Agriculture objectives by ensuring that the management of production systems and natural resources is represented by an area big enough to produce important ecosystem services and yet small enough to be carried out by people using land and producing those services (FAO, 2013). The landscape approach was recently redefined to include societal concerns related to conservation and development of trade-offs. This approach is designed to include an integration of poverty alleviation, agricultural production and food security. The unique attributes of this approach are adaptive management, stakeholder engagement and the simultaneous achievement of multiple objectives (Sunderland, 2012). Climate Smart Agriculture promotes the adoption of practices that ensures ecosystems resilience and therefore introduction of

CSA to communities through participatory and people-centred approaches is important to achieve adoption.

5.2 Community of practice

Communities of Practice (CoP) are groups of people who share a concern or passion for something they do and learn how to do it better as they interact regularly (Wenger, 1998). People in communities of practice share similar views or interests but bring individual perspectives to problem solving and thus create a social learning system that goes beyond the sum of its parts. Communities of practice develop their practice through problem solving, information sharing, experience, coordination and synergy and practice (Jakovljevic *et al*, 2013). The benefits of forming communities of practice are that they allow individuals to test their ideas through collaboration, obtain feedback and interact in ways they would not if they were learning alone. Communities of practice also serve as a platform to create relationships that not only benefit them but also those in the immediate community, which makes them more effective. The real challenge of communities of practice is to develop the community and the practice simultaneously. Community development refers to the development of skills of the people involved in coordination, facilitation and knowledge management of the community. Development of the practice entails that resources, information and knowledge are captured and enhanced over time. A community of practice has flexible boundaries, meaning that membership involves whoever is interested in the practice, members participate in different ways and to varying degrees (Wenger, 1998).

The key components of a community of practice are that it must have a shared purpose, shared needs and shared values; the necessary enablers such as technology, time, budget, support and incentives; a form of leadership; defined processes such as communication strategies; and a membership which represents a variety of views, competencies and behaviours (Jakovljevic et al, 2013).

A community of practice typically goes through several stages of development. After members find each other and identify their common cause, they negotiate with each other and define their shared enterprise. They then begin to develop a practice by engaging in joint activities and adapting to changing circumstances. At a later stage, members may withdraw from joint activities but still maintain contact, with the community still functioning as a source of knowledge. Eventually, the community may reach a stage where it no longer plays a role in members' lives but they still remember it as an important part of their identity (Hovland, 2005).

Linking knowledge, policy and practice

Communities of practice can play a significant role in linking practitioners, knowledge producers and policy processes to analyse, address and explore solutions to problems. By creating an environment for reflection, interpretation and feedback they can encourage collaboration between researchers and practitioners, allowing researchers to better gauge the relevance of their work. They provide a platform from which researchers can work together to influence policy and policy makers can engage with knowledge creation, linking the domains of research and policy through complex social networks. The structure of a community of practice also can provide a space where development practitioners, policy makers and researchers can engage with communities within a context of learning where they engage with the members' needs and capacities, with the community reserving the right to accept or reject new ideas and practices rather than be controlled by professionals. (Hearn and White, 2009).

5.3 Community learning networks

Community learning networks are connections formed and maintained by local people with the aim to share information and support each others' learning. These networks are important in bringing together local people, development practitioners, researchers and other role players together to access and share resources and information that can encourage communities to take up improved practices (Steepes and Jones, 2002). These learning networks or learning groups typically form part of a larger CoP that involves a number of different stakeholders. Learning networks are also based on shared values and practices and are entirely voluntary and open-ended in that participants belong to these networks as long as they find them useful as individuals. These groups provide a safe base for participants to think and work together, reach out to others , mobilise support and engage in joint planning, implementation and review activities. The groups create an enabling environment ofr participants. (Stimie et al. 2010)

5.4 Community savings groups

Community savings groups have been around for a long time and are prevalent in villages in Africa, Asia and Latin America where banking services do not cater well for the rural poor. Savings groups are also called rotating savings and credit association (ROSCAs), savings and credit groups (SCGs), village savings loans or merry-go-rounds – the various models typically have similar objectives. Community managed savings and credit groups are a convenient way to save money, gain access to small loans, obtain emergency insurance and ultimately gain a means of livelihood in order to build economic empowerment. Savings groups are self-managed and respond directly to the unmet financial need of the rural poor (Seifert, 2016). In South Africa, savings groups have gained popularity over the years, due to their convenience, financial security and ease of access. Financial exclusion from the mainstream economy has led to the development of community-based solutions for the black population through savings groups. Women typically make up the bulk of the members These groups can form a sable and useful organisational unit on which to build learning groups and communities of practice and provide the added advantage of members' ability to contribute financially to their chosen activities (Mathebula, Mahlathini Development Foundation 2014 pers comm).

5.5 Participatory Innovation Development (PID)

Local innovation is the process by which people find new and improved ways of doing things and take initiative to try out these new practices using their own resources. They may be doing this as a way of exploring new possibilities and discovering alternatives to coping with changes in their natural resource base, asset availability or other socio-economic contexts which may be a result of changes in policy, natural disasters or other external factors. Through these processes of exploring, experimenting and adopting new practices, people come up with local innovations that were developed and are understood by them. Local innovation can take place at an individual level, through groups or may include the community at large (PROLINNOVA, 2009). The emphasis is on people being actively involved in discovering and exploring new ways of doing things. Participatory Innovation

Development, sometimes referred to as farmer-led joint research, is a process whereby local people work together with researchers and development practitioners to investigate possible ways to improve their livelihoods. Research in this context entails going beyond on field trials but also looking at the value chain, community relationships and ways to manage communal resources. In the context of climate change, PID can help farmers explore ways of adapting and improving the resilience of their farming systems through improved climate smart practices such as those encompassed in conservation agriculture (Van Veldhuizen et al, 2013).

5.6 Farmer Field Schools

Farmer Field Schools (FFS) is a participatory approach that aims to capacitate farmers to analyse their own production systems, identify problems, consider various options and adopt the technology or practice best suited to their farming system. The limitation of FFS however is that it reaches a relatively small group of farmers at a time while incurring high costs financially and in terms of management time (FAO, 2010).

5.7 Social, technical and institutional interventions to support CSA

The successful implementation and adoption of climate smart agricultural practices in rural landscapes can be achieved when coordinated with local rural development activities. Creation of an enabling environment in terms of policy and legislation and the use of effective natural resource assessment tools is needed to pave a way for CSA as well as investing in participatory approaches that take into consideration all the stakeholders involved within the landscape. Proper monitoring and evaluation strategies should be in place to ensure sustainability and adoption.

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