Republic of Mozambique

Report on Technology Need Assessment for Agriculture Sector Adaptation to Climate Change in Mozambique

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EXECUTIVE SUMMARY

The United Nations Framework Convention on Climate Change (UNFCCC) in its Article 4, paragraph 5, states that developed countries and other developed parties, included in Annex II, should take possible steps to promote, facilitate and finance the transfer and access to environmentally sound technologies and know-how to other Parties, particularly to developing countries, to enable them to implement the provisions of the Convention. In this process, the Parties composed by the developed country should support the development and enhancement of endogenous capacities and technologies in developing countries.

In compliance with such provisions, the developed countries established the technology need assessment process (TNA) to be implemented by developing countries driven by circumstance and capacity of the beneficiaries. The process includes:

1. A set of targeted activities national driven to identify and determine the priority technologies for adaptation and mitigation
2. Involvement of different stakeholders in the consultation process to identify (i) barriers to technology transfer, and, (ii) response measures to these barriers through sectoral analyzes; and,
3. Addressing technologies for mitigation and adaptation, identify regulatory options, develop fiscal and financial incentives and build capacity

Mozambique as UNFCCC signatory and part of the developing countries is implementing the TNA project to respond to the convention and to fill the technology gap identified in the ENAMMC as lacking to address climate change issues.

The project is being implemented in two phases, viz. (1) preparatory and (2) execution phases. The preparatory phase consisted of establishment of the organizational structure of the TNA process, project launching and sectors identification. This phase began with the first meeting of the Inter-Institutional Group on Climate Change (GIIMC) where the technological needs assessment (TNA) project was presented and the sectors to be part of the project for adaptation and mitigation were identified. For adaptation, agriculture, infrastructure, coastal zones and disaster management were identified as the most vulnerable while for mitigation, the identified sectors were energy and waste.

The execution phase includes (i) the identification of technologies; (ii) preparation of the report on the prioritized technologies; (iii) facilitate market analysis, analysis of barriers and proposed regulatory framework for the deployment and diffusion of technologies; (iv) prepare the action plan including proposed concepts programs; (V) participate in regional training seminars; and (vi) preparation of administrative reports and process and its submission.

This report presents the results of technologies identified and prioritized. Technologies identification was based on development priorities of the country and other climate change documents such as national communication, Nation Adaptation programme of Action (NAPA) and National Strategy for Adaptation and Mitigation to climate change (ENAMMC). Technologies were prioritized using multi-criteria analysis (MCA) and the process consisted on screening technologies and criteria and weighting the criteria used for the prioritization process. The screening of technologies and criteria as well as the prioritization of technologies were done at group discussion meetings facilitated by the consultant. The list of the technologies to be part of Barrier analysis and Technology Action Plan was based on the results of MCA and recommendations from the technical counsel of the Ministry of Agriculture and Food security (MASA). Based on MCA, the three priority technologies for agriculture sector adaptation to climate change in Mozambique were: (1) seed production and conservation and promotion of low cost storage systems of grain and seed; (2) conservation agriculture and (3) Drilling boreholes for multiple uses. Following the recommendation from the technical counsel of the Ministry of Agriculture of giving priority to water harvesting and conservation for building resilience in agriculture sector, the drilling of boreholes for multiple uses was substituted by Rainwater Harvesting and Conservation which ranked 4^{th} on MCA prioritization process.

Therefore, the technologies that Mozambique proposes for adaptation to climate change and that should be used in the following phases of identifying barriers and designing action plans for adaptation to climate change in Mozambique are: (1) seed production and conservation and promotion of low-cost of seed and grain storage systems; (2) conservation agriculture, and (3) rainwater harvesting and conservation.

CHAPTER ONE: INTRODUCTION

1.1 About the TNA project

Climate change (CC) is emerging as the global challenge to sustainable development of countries, particularly for economically vulnerable ones, through increasing the levels of climate risks to their natural and socio-economic systems exacerbating poverty around the most vulnerable communities and nations.

Mozambique is highly vulnerable country to climate changes ranking amongst the world top five most vulnerable countries (Global Risks Advisory Firm Maplecroft, 2011). The country vulnerability forced the government to join the global efforts of fighting against the effects of climate changes. In that context, the country signed on 12 June 1992, the United Nations Framework Convention on Climate Change (UNFCCC) which was ratified by the Parliament Resolution 1/94 of 24 August. The instrument of ratification was deposited with the United Nations Secretary General on 25 August 1995 and on 23 November 1995, the country became officially part of the UNFCCC. Subsequently, the country ratified the Kyoto Protocol through Resolution No. 10/2004 of 28 July. The instrument of ratification was deposited on 18 January 2005 and the country officially became part of the Protocol on 18 April 2005. In order to take advantage of the opportunities set out in the Kyoto Protocol, the Government of Mozambique appointed by Decree number 12/2006 of 15 June, the Ministry for Coordination of Environmental Action (MICOA) as National Authority for the Clean Development Mechanism.

By ratifying the UNFCCC, the country committed to: (i) integrate climate change issues in policies, strategies and development programs; (ii) promote the development, diffusion and transfer of adaptation and mitigation technologies; (iii) conduct research and systematic observations in the area of climate change; (iv) promote education, training and public awareness and a broad public participation in decision making on issues related to climate change; and (v) prepare periodically (4 in 4 years) national communication report that should contain information on the implementation of the Convention in the country, including the national contribution to global greenhouse gas (GHG) emissions, impacts, appropriate vulnerability and adaptation measures, mitigation options, measures that support and facilitate the implementation of the Convention (capacity building, technology cooperation, financing, etc.).

The Government of Mozambique has made efforts towards the fulfillment of some of the commitments made under the Convention. Examples were approval of Policy and Strategies for New and Renewable Energies, the Policy and Planning Law, National strategy of Water Resources management, the Gender and Environment strategy, the

Strategy for Science, Technology and Innovation, the Education Program, Environmental Communication and Dissemination (PECODA) to promote action and awareness of education and the Five-Year Government Programme 2010 to 2014. One of the objectives of the Government's Five-Year Plan was to develop and implement policies for adaptation and mitigation of climate change. It is in this context that the National Arising Reducing Emissions from Deforestation and Forest Degradation Strategy, and the National strategy for adaptation and mitigation of Climate Change (ENAMMC) were developed.

The ENAMMC was designed with a view to establish guidelines for action to enhance resilience, including the reduction of climate risks in national economy and communities by promoting the development of low carbon and green economy through integration of adaptation and mitigation into the process of sectoral and local planning. The ENAMMC recognizes that there is still lack of capacity to deal with climate change technologically from central to local and community levels, including the private sector. That lack of capacity is an obstacle to address the climate change impacts and to explore opportunities imposed by climate change. It is in line with the need to fill the technology gap that ENAMMC has one specific objective designed to explore opportunities of access to technological resources. This objective sets as a strategic action to promote the transfer and adoption of clean and resilient technologies to climate change is sought to be made through development and implementation of technology needs assessments and their action plans.

It is in this context that the technology needs assessment (TNA) project is being implemented in the country. The purpose of the TNA project is to assist the country to identify and analyze priority technology needs, which can form the basis for a portfolio of environmentally sound technology (EST) projects and programs to facilitate the transfer of, and access to, the ESTs and know-how in the implementation of Article 4.5 of the UNFCCC. The objective of the TNA project is to enable the beneficiary country to develop fully budgeted project proposals to secure international funding to implement selected adaptation and or mitigation technologies in priority sectors to support sustainable development.

Technology needs assessment is done through technology identification and periodization. The process and steps followed for technology identification and prioritization were as follows: (1) review of the literature on existing agricultural technologies for adaptation to climate change internationally, review national policies and institutional documents on climate change; (2) bilateral meetings with staff from the ministry of agriculture, research institutions, academia, non-governmental organizations and civil society for identifying technologies being implemented in the country for adaptation to climate change; (3) Technology characterization for enabling its prioritization; and (4) conduct group discussions with key stakeholders for technology prioritization.

This report presents the findings of the participatory process of technology identification and prioritization for adaptation to climate change in Mozambique. The report starts by providing country background and context of TNA project and its implementation followed by listing of existing national policies related to technological innovation, adaptation to climate change and development priorities. Vulnerability assessments in the country, Sector selection, institutional arrangement for the implementation of the TNA project, the technology prioritization process which includes, selection of technology options and criteria for assessing technology options, the assessment process and ends by proving conclusions of the assessment process.

1.2 Objectives of the TNA project

The objectives of the TNA in Mozambique is to enable the country to develop project concept notes or proposals to facilitate international funding to implement selected adaptation technologies in Agriculture, coastal zone and infrastructure and mitigation technologies in energy sector and waste to support sustainable development.

The objectives of the technology needs assessment project are:

- To identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities (TNA);
- To identify the barriers that hinder the acquisition, deployment, and diffusion of the prioritized technologies for mitigation and adaptation; and
- To develop Technology Action Plans (TAP) that specify activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries

1.3 Existing national policies related to technological innovation, adaptation to climate change and development priorities

Mozambique has development policies to reduce poverty and build resilience to CC through a number of actions in different sectors including access to basic health care, improving food security and nutrition, water and sanitation, access to clean and renewable energy. The implementation of these policies, have been limited by the challenges imposed by extreme weather events. The combined effect of cyclones and the 2000 floods, for example, resulted in the displacement of more than 500,000 people and massive destruction of infrastructure estimated at USD 600 million, reducing the GDP growth of 8.0% in 1999 to 1.5% in 2000. The same is recognized in the Social Security Basic Strategy, which points the exposure to natural shocks and climate change as one of the main causes of poverty.

The country has some sectoral instruments aligned with the need to reduce vulnerability to the impacts of climate change and promotion of low-carbon development. Example of these instruments is the Plan for Poverty Reduction (PARP), the Strategic Plan for Agriculture Development (PEDSA), the Social Action Basic Strategy, the Strategy of Tourism, the National Water Resource Strategy, the Master Plan for Disaster Management, the Disaster Management Policy, Intervention Strategy in Slums in Mozambique and its Action Plan, the Gender, Environment and Climate Change strategy, the Energy Strategy and the proposals of the national Development Strategy, the Emission Reduction Strategy from Deforestation and Forest Degradation (REDD+), amongst others. These instruments recognize explicitly that extreme weather events are one of the largest and main threats to performance of the sectors and development.

Despite the recognition of the importance of impacts of climate change on performance of the sectors and country development, the inclusion of climate change aspects in sectoral planning and in social and economic plan (PES), is still limited. However, there is an increasingly growing concern with climate change issues since the country has been affected by extreme weather events, revealing some of the potential impacts of climate change. As a response to this, there are pilot projects being developed in order to strengthen the technical and institutional capacity to integrate resilience to climate change in key sectors of the economy and to improve the evidence base for the future development policies and plans. In addition, the economic and social plan (PES) already includes programme for climate change. Climate change mitigation is beginning to be recognized as an opportunity, with references to the Energy Strategy (carbon tax and promotion of the use of indigenous energy resources as well as clean and renewable resources), the Biofuels Policy and the National Development Strategy (ENDe) and the strategy for Reduction of Emissions from Deforestation and Forest Degradation (REDD+).

In addition, the National strategy for adaptation and mitigation of Climate Change (ENAMMC) was developed with objective to establish the directives for action to build resilience to climate change including the reduction of climate risks at the community and the national economy, promoting the development of low carbon and green economy through integration of adaptation and mitigation into the sectoral and local planning process.

1.4 Vulnerability assessments in agriculture sector in Mozambique

According to Global Risks Advisory Firm Maplecroft (2011) Mozambique is a highly vulnerable country to climate change, ranking 5th as the world's most vulnerable country after Bangladesh, India, Madagascar and Nepal. According to **MICOA** (2005) the extreme vulnerability of Mozambique to climate change is due to:

- the long coastal zone (about 2700km),
- existence of areas with altitude below the sea level,
- the position of the country in the Inter-tropical convergence zone and downstream of 9 shared river basins,
- sharp fall of altitude from inland to the coast resulting in high runoff that causes floods in short period of time when there are high rainfalls in shared internationals river basins;
- poor infra-structure such as roads, dams for water harvesting and conservation, silos for grain storage;
- high levels of poverty (69,4% in 1997, 54,1% in 2003) and illiteracy (32% of men and 68% of women);
- poor purchasing power of inputs by the smallholder farmers who practice rainfed agriculture, low investment in advanced technologies and the fragility of infrastructures and social services with main emphasis on health and sanitation.

Climate change scenarios in Mozambique are manifested through change in temperature and rainfall patterns, rising sea level and extreme climate events such as drought, floods and cyclones. The occurrence of these events have negatively affected agricultural production and productivity, water resources, forest resources, infrastructure, health and others in different regions of the country every year.

Based on climate change projections made by the National Institute of Disaster Management (INGC) in 2009, vulnerability assessment was conducted in some of the key sectors for economic development of Mozambique which include coastal zones, water resources, fisheries, agriculture, pastures and livestock, and health. In the present report, it will only be presented the results of vulnerability assessment for agriculture and natural pastures and livestock given that in Mozambique these two are part of the agriculture sector which is the focus in this study.

Agriculture in Mozambique is the backbone for the country economic development and social development. The activity employs more than 80% of the country´s active work force and is a major source of food, nutrition and income for more than 70% of Mozambicans composed mostly of smallholder farmers (PEDSA, 2010). Agriculture contributes to poverty reduction and economic growth with about 23% to the GDP (INE 2011) and 20% to exports (FAO 2011). Agriculture activity is based on small-scale farmers, involving around 3.7 million rural families which produce 95% of the total agriculture production (TIA, 2008). The contribution of production made by small-scale farmers to the GDP generated by agriculture is estimated at about 95% (FAO, 2011) which makes this sub-sector one of the most important contributor to the country economic development.

Nevertheless, the contribution of the sector to the country' development is still limited due to occurrence of climate change extreme events that destroy crops and kill animals. Projections made by INGC in 2009 and 2012 indicate that climate variation from 2011 to 2030 and 2046 to 2065, respectively, will result in increase in temperature, reduced average annual rainfall and high variability. These variations are most likely to affect agriculture due to its extreme vulnerability of the sector to the effects of climate variability and change. The possible impacts of the projected changes include: reduction in yields due to increase in temperature, reduction in average annual rainfall and its high variability and increase in concentration of ozone (Brito and Holman, 2012; MICOA, 2013). In addition, reduction in yield may also be expected to occur due to emergence of aggressive species of pests and diseases. These new pests and diseases will destroy crops and kill animals.

Assessment of the impacts of changes in rainfall and temperature on six rainfed crops (cotton, groundnuts, cassava, sorghum, maize and soy) conducted by Brito and Holman (2012) showed that the effects of climate change on yields differed from one crop to another with maize being the most affected crop with an average projected reduction in the country of 11.1%, followed by soy with a projected reduction of 6.4%, then groundnuts with a reduction of 4.6%, cassava with 4.2%, sorghum with 3.5% and cotton as the least affected crop with reduction in the order of 2.9% of the current yields. The yield reduction is split into different geographic zones of crop yielding reduction starting as a cluster in the western zone of Tete province in relation with cotton crop, growing towards the coastal and southern area, with the most affected crops being sorghum, groundnut, cassava and soy, followed by maize as the most affected crop covering a larger area in Mozambique. The crop yields may reduce up to 30% of the current production in the most affected areas such is the case of maize in some areas of Tete province.

The increased daily temperature results in negative effects for maize, cotton, groundnut, sorghum and soy, with a decrease of 11.0%. The increased concentration of ozone (O3) will result in a negative impact on all crops, with an expected reduction of 37.0% for cotton, 28% for soy, 14% for groundnut and cassava and 9% for crops such as maize and sorghum. The projected reduction on yield of these crops in the next years will have negative consequences for food security and household income in Mozambique particularly due to severe yield reduction of Maize which is the major staple food crop in the country.

Measures to reduce vulnerability include the promotion of conservation agriculture; implementation of small-scale irrigation systems; management of agricultural practices; spread of drought-resistant crops; use of varieties adapted to each agro-ecological region; improvement of early warning systems in case of floods, droughts and cyclones and extension training in adaptation to climate change matters.

The vulnerability and adaptation of natural pastures and livestock were analyzed in the basin of the Limpopo River, because of the importance of cattle farming in the economy and livelihood of local communities. Due to lack of data needed for modeling, assessing the vulnerability of pasture was based on a systematic review of studies conducted in areas with environmental attributes and similar practices of livestock grazing management. The possible impacts of climate change in this sector include increasing the duration of the dry season in a time of food shortages and water shortages for livestock consumption due to reduced flow and dryness of natural water sources. These impacts may result in reduced livestock production levels due to increased livestock mortality and reducing the average weight gain and milk production, aggravating food shortages and food insecurity dependent rural communities in the creation of cattle (Brito and Holman, 2012).

The proposed adaptation measures for livestock sector include rainwater harvesting, improving the management and regulation of community pasture management practices; identification of livestock development zones, i.e. where livestock suffer less impacts of climate change and has comparative advantages for subsistence and family income; shift to sustainable and integrated methods of animal production; and dissemination of forage conservation methods.

1.5 Sector selection

1.5.1 An Overview of Expected Climate Change and its Impacts in Sectors Vulnerable to Climate Change

In 2009 the National Institute of Disaster Management (INGC) predicted climate change scenarios and their impact on some of the vulnerable sectors of the country. The predictions indicate climate change will result in changes in patterns of temperature, precipitation, increased frequency and intensity of extreme weather events (droughts, floods and tropical cyclones) and the rise of sea level. The studies indicated that changes in temperature patterns will result in increase in average atmosphere temperature of between 1.5° C and 3.0°C in the period between 2046 and 2065 accompanied by warm days and less cold days and an increase of maximum and minimum temperature. That will also result in rise in sea level and changes in the distribution and availability of fish stocks and effects on marine ecosystems (e.g. corals)

The same projections indicate changes in rainfall patterns which will result in more erratic rainfall, late start or early cessation of rains, change in intensity of rains with high likelihood of high intensity of rains in short time which will result in floods in flood prone areas as well as changes in duration of the rainy season. These changes will lead to increased frequency and intensity of droughts. That will affect the cropping season with consequent loss of income of up to 25% in some regions. The reduction in the potential agricultural income from marketing of food crops will affect the improvement of per capita income of most Mozambican families leading to poverty.

Furthermore, the projections indicate an increased frequency and intensity of extreme climate events (droughts, floods and tropical cyclones) which will result in persistent and increased occurrence of extraordinary flooding in risk areas, increase in the frequency and intensity of cyclones and strong winds and prolonged droughts.

As a result of change in temperature, an increase in sea level of about 15 cm, 30 cm and 45 cm is expected to occur due to thermal expansion and 15 cm, 110 cm and 415 cm due to reduction of continental ice caps in the years 2030, 2060 and 2100, respectively. That will lead to reduction of agricultural land in green and lowlands areas and threaten many coastal urban centers such as Maputo, Beira and Quelimane which are already in a critical situation in terms of vulnerability (human lives, property, social infrastructure) due to climate change.

The studies indicated that the changes on climate will have impacts on coastal zones, water resources, fisheries, agriculture and pastures and livestock. The impacts of the projected climate change per each of the vulnerable sector will be following:

- *Coastal zones*: Climate change will cause sea level to rise due to thermal expansion of ocean water and possibly reduction of ice caps. This may cause significant retreat of the coastline in some areas which would result in coastal erosion, destruction of social and economic infrastructure and destruction of coastal ecosystems. In addition, the expected increase in intensity of tropical cyclones will exacerbate the activity of waves and tides, affecting the sedimentation rate which in turn will negatively impact coastal ecosystems. Climate change impacts on coastal zones of Mozambique will also affect other countries sharing river basins with Mozambique
- *Water resources sector*: the expected impacts are increased frequency of floods in some basins and limited water availability for drinking, agriculture and industry due to reduced water flow caused by reduced rainfall.
- *F*isheries sector: the expected impacts are: (1) reduction in shrimp recruitment rates due to increased salinity in estuaries due to reduction in rainfall; (2) significant increase in mortality of shrimp due to the expected increase in seawater temperature; (3) reduction in shrimp recruitment due to changes in the coastal zone mainly caused by rising sea level and destruction of mangroves; and (4) reduced fishing effort because of high intensity and frequency of cyclones that will destroy boats and fishing infrastructure. These impacts result in the decline of the shrimp population, reduction of the fishery income, reducing the volume of exports and income of families dependent on coastal fisheries.
- *Forest sector:* the expected impacts coming from expected changes in temperature, rainfall and soil conditions are: change in ecological behavior, change in biodiversity and reduction on its occupied spatial extension. These changes will also have socio-economic impact because many families depend on the production and sale of charcoal for subsistence, since agricultural productivity is low due to low rainfall.
- *Agriculture sector*: climate change will result in low yields due to increase in temperature, reduced average annual rainfall and high variability. That will result in food insecurity and reduced household income.
- *Natural pastures and livestock*: the expected impacts include increasing the duration of the dry season is a time of food shortages and water shortages for livestock consumption due to reduced flow and dryness of natural water sources. These impacts may result in reduced livestock production levels due to increased livestock mortality and reduced average weight gain and milk

production, aggravating food shortages and food insecurity of livestock dependent rural communities.

Given the projected impacts, the TNA group decided to select some of the vulnerable sector to be part of the first phase of the project for adaptation. Such sectors were selected due to their high vulnerability and importance for national development. These include: coastal zones and infrastructure and agriculture.

1.5.2 Process and results of sector selection

Based on climate change projections conducted by INGC in 2009 and other relevant documents as national development priorities and vulnerability assessments, the Inter- Institutional Group for Climate Change (GIIMC) identified 14 sectors which are vulnerable to climate change. These sectors are: (1) Water resources, (2) Infrastructures, (3) Agriculture, (4) Food security, (5) Forests, (6) Industry, (7) Energy, (8) Health, (9) Tourism, (10) Transport, (11) Biodiversity and conservation areas, (12) Coastal zones, (13) Human Settlements, and (14) Fisheries, (MITADER, 2015).

For the implementation of TNA project, the national group of the TNA which is composed by the GIIMC assessed the different vulnerable sectors and identified critical sectors to be part of the first phase of the TNA project for adaptation and mitigation. For adaptation, the group selected agriculture, infrastructure and coastal zones. Agriculture was included because it is a key productive sector for the country's development and due to its role in ensuring food security. Despite availability of mature technologies and knowhow to increase agricultural production, crop losses still occur when extreme weather events take place. This technology needs assessment will help identify bottlenecks that prevent the deployment and diffusion of these technologies and will help to establish conditions for scaling up these technologies. The infrastructure and coastal areas were chosen by being highly vulnerable to cyclones and floods which result in destruction of infrastructure, especially in coastal areas where there are socio-economic valuable infrastructure which they are also being threatened by the rising sea level and coastal erosion.

CHAPTER TWO: INSTITUITIONAL ARRANGEMENT FOR THE TNA AND STAKEHOLDER INVOLVEMENT

2.1 National TNA team

In Mozambique, the TNA consists of six components as indicated in Figure 1 below. These are: (1) National steering committee, (2) National group of TNA, (3) National TNA Committee, (4) Coordination team, (5) The consultants and (6) the thematic working groups. The description of the responsibility of each component is provided below.

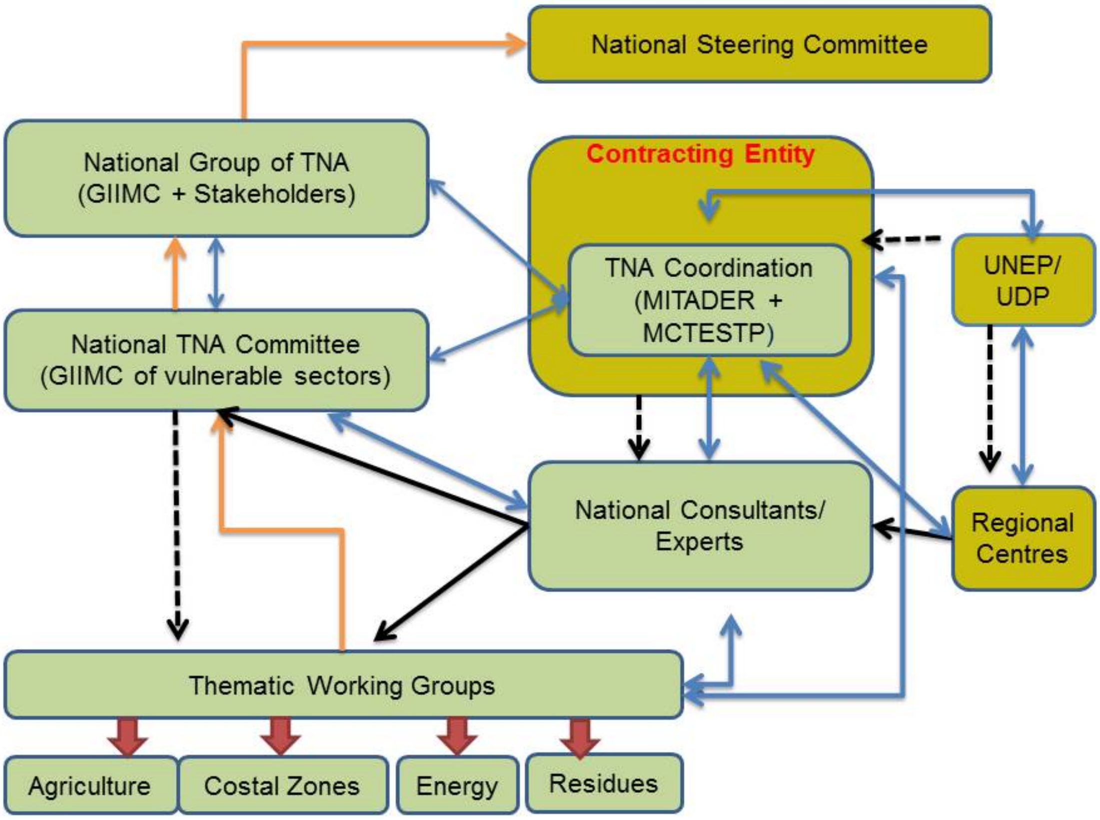

Figure 1: The TNA structure for Mozambique

2.1.1 National steering committee

The National steering committee is led by the Minister or Deputy Minister of MITADER and is composed of permanent secretary of the Ministry of Science, Technology and Higher Education and National Directors of Ministries of Mineral Resources and Energy (MIREME); Agriculture and Food Security (MASA); Sea, Interior Waters and

Fisheries; Land, Environment and Rural Development (MITADER); Public Works, Housing and Water Resources (MOPHRH); national Association of Municipalities and representatives of private sector (FEMA) and UNEP in the country. The responsibility of the committee is to guide the GIIMC and provide political support for acceptance of the TNA process. The Committee is technically assisted by the coordinators of the project indicated by MITADER and MCTESTP

2.1.1 National Group of TNA

The National group of TNA is composed of the Inter- Institutional Group for Climate Change (GIIMC) and all other stakeholders involved in the process such as private sector and civil society. The Group ensures a broad participation of stakeholders in the assessment and decision on the outcome of the project to ensure its successful implementation.

2.1.3 TNA Project Coordination

The coordination of the TNA project is done by MITADER and MCTESTP. MITADER has the responsibility for overall coordination of the project, facilitating communication among members of the various bodies established for the implementation of TNA Project including circulation, production and dissemination of information and project management (preparation and submission of progress reports and business plans). The MCTESTP coordinator of the technological mechanisms in the country, has responsibility to assist and understand the specific requirements and performance of technologies

2.1.4 National TNA Committee

The national TNA committee is composed of representatives of the Inter- Institutional Group on Climate Change (GIIMC) relevant to the TNA process. These include: environment, agriculture, water, infrastructure, coastal zones, energy, private sector (FEMA), TNA coordinators, UNAC, disaster management. The national committee is responsible for: (i) Identification of national development priorities and priority sectors to consider in the assessment of technology needs; (ii) decide on the establishment of thematic groups; (iii) approve technologies and adaptation and mitigation strategies recommended by the thematic groups; and (iv) approve the Technological Action Plan (the policy script needed to remove barriers and create a favorable environment) and develop cross technological national action plan for adaptation and mitigation

2.1.5 Consultants or National Experts

The consultants are national experts in the areas of adaptation or mitigation selected by the National TNA Committee in consultation with UDP. The responsibilities of the national consultants are the following:

i. Assist in identification and categorization of country priority sectors, and the identification and prioritization of adaptation and mitigation technologies through a participatory process with broad involvement of all stakeholders;

ii. Facilitate the process of the working groups in the analysis of how the prioritized technologies can be implemented in the country and how the implementation can be improved through barriers analysis and developing an enabling framework. The results will be included in the report on barrier analysis and enabling framework (BA & EF);

iii. Prepare the Technological National Action Plan, which will outline key elements of an enabling framework for the transfer of technology. This will include market development measures, institutional measures, and financial regulations and human and institutional capacity needs. It will also include a detailed action plan for implementation of the proposed policy measures and assess the need for foreign aid to cover the additional costs of implementation.

iv. Prepare the TNA, BA&EF, TAP and the final report for the country. The TAP report must include project ideas.

2.1.6 TNA Thematic Groups

Four thematic groups were formed and were responsible for coordinating the sectoral analysis under the TNA. The Thematic Groups were coordinated by the relevant sector ministries and also included representatives from other sectors, including academic institutions, private sector relevant to the success of the process. Thus the following thematic groups were constituted:

- Agriculture - coordinated by the Ministry of Agriculture and Food Security (MASA) and composed of representatives of the following sectors: DINAS, IIAM, hydraulics, water, weather, SESTAN, National Directorate of Rural Development, National Union of farmers (UNAC)
- Infrastructure including coastal areas - coordinated by the Ministry of Public Works, Housing and Water Resources and composed of representatives of roads and bridges, housing, environment, fisheries, National Institute of

Hydrography and Navigation (INAHINA), Centros de Desenvolvimento Sustentável (CDS) and disaster management

- Energy and residues - coordinated by MIREME and composed of representatives of the following sectors renewable energy, fuels, mineral resources, statistics, transport, private sector (FEMA), PETROMOC EDM, FUNAE)

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Stakeholder's engagement started during the launching of the TNA project. The process involved the identification of potential institutions and entities to be part of the TNA committee which includes the Inter- Institutional Group on Climate Change (GIIMC) and relevant sector and institutions for the TNA process. The TNA coordinators, with input from the TNA Consultant, carried out a stakeholder mapping exercise prior to the process, and this exercise followed the selection of the priority mitigation and adaptation sectors by the National TNA Committee. The stakeholders were mapped using a sectoral approach. The list of stakeholders mapped and invited to be part of the TNA project implementation are given in table 3.

The identified relevant sectors and institutions include: environment, agriculture, water, infrastructure, coastal zones, energy, private sector (FEMA), TNA coordinators, National Union of farmers (UNAC) and National Disaster Management Institute.

These institutions and sectors were engaged to ensure maximum local stakeholder ownership of the project. In this context, stakeholders were given a central role in the project implementation.

CHAPTER THREE: TECHNOLOGY PRIORITIZATION FOR AGRICULTURE SECTOR

3.1 Key Climate Change Vulnerabilities in Agriculture sector

In Mozambique, agriculture continues to be the most important sector of the country's economic development. The sector employs more than 80% of the economically active population estimated at about 23 million (INE, 2007) most of which are smallholder subsistence farmers (99.7% in 2001). Agriculture activity in Mozambique is of low input out-put nature characterized by low yields resulting from no use or little use of pesticides, fertilizers, irrigation and mechanization in the production process (Chilonda *et al*. (2011). As a result, the sector is highly vulnerable to climate change (MICOA, 2012).

The high vulnerability of the agriculture sector to climate change is due to limited capacity of smallholder farmers to adapt to climate change. The situation is exacerbated by the fact that agriculture activity is rainfall dependent in a situation where rainfalls are becoming more unpredictable in occurrence and distribution. As a result drought is the most limiting factor followed by floods and cyclones. The country has been experiencing drought events which have driven the country to food insecurity.

The vulnerability of the country to climate change is expected to continue and even to worsen given that climate change projections indicate that climate variation from 2011 to 2030 will result in increase in temperature, reduced average annual rainfall and high rainfall variability (INGC, 2009).

Some of the measures proposed that are believed to be able to help farmers adapt to climate changes include:

a) implementation of small-scale irrigation systems;
b) improvement of agricultural management practices;
c) diffusion of drought-resistant crops;
d) use of crop varieties adapted to each agro-ecological region;
e) improvement of early warning systems for floods, droughts and cyclones
f) training of extension officers in adaptation to climate change matters
g) crop diversification and introduction of drought tolerant crops and crop varieties
h) improve production and productivity through provision of appropriate technology and inputs to counter climate change impacts
i) integrated pests and diseases control in field and during storage
j) strengthen agro- ecological zoning and land use planning

k) develop programs and national action plan for soil conservation and nutrition including the promotion of conservation agriculture
l) improve animal nutrition through pastures and forage production management techniques
m) improved epidemiological surveillance and control of animal diseases
n) Improve and expand technical assistance to farmers

The main focus of the TNA is to reduce vulnerability and increase resilience to drought through identification and prioritization of technologies that will (a) increase availability of agricultural and livestock output through promotion of seed and grain production and low cost storage systems, (b) reduce crop and livestock losses in regions prone to drought by promoting irrigation and water harvesting, (c) improve soil and water conservation measures through promotion of conservation agriculture, (d) increase family income and (e) help establish alternative forms of subsistence.

3.2 Decision context

Mozambique defined adaptation and the reduction of the climate risk as a national priority and strategic actions to creating resilience and reduce climate risk in the communities, ecosystems and national economy. To realize the strategic actions, the country has integrated climate change issues in policies, strategies and development programs to respond totally or partially to impacts of climate change on agriculture and food and nutrition security. Some of the key policies, strategies and programmes where climate change issues receive attention are:

- Strategic Plan for Agricultural Development (PEDSA) which was approved by the Council of Ministers in May 2011;
- The National Investment Program of the Agricultural Sector (PNISA)
- The Master Plan for Agricultural Extension (2007-2016) (PDEA), approved by Council Advisory of the Ministry of Agriculture in May 2007
- The National Program of Agricultural Extension (PRONEA)
- The Outsourcing Management Manual (DNEA 2012)
- The action plan for agriculture adaptation to climate change (2015-2020)
- The National Strategy for Adaptation and Mitigation of Climate Change 2013 – 2025 (ENAMMC), approved by the Cabinet in November 2012

PEDSA recognizes the need to develop climate resilience for the country and define resilience as priority action for the agricultural sector. The local adaptation plans prioritize the need for a climate resilient agriculture. Under the national strategy for adaptation and mitigation to climate change (ENAMMC), a process was initiated to develop adaptation plans at district level. Several plans have been completed and these plans put climate resilient agriculture as top priority.

The Agriculture Adaptation Action Plan to Climate Change (2015-2020) seeks to address vulnerability of smallholder farmers to climate change who practice rainfed agriculture. The Action Plan for agriculture adaptation to climate change binds directly with all 4 pillars of the Comprehensive Africa Agriculture Development Programme (CAADP). The Action Plan for Agriculture Adaptation to Climate Change will provide practical means to implement the intentions and general guidelines of the different policies. The Action Plan will achieve this by focusing on development of resilience among small farmers in the country.

3.3 Overview of Existing Adaptation Technologies for Agricultural sector and Their Main Adaptation benefits

According to Clements *et al.* (2011) the technologies for adaptation in agriculture sector can be grouped into seven categories, which are indicated below, viz.,

- Planning for Climate Change and Variability which include (Climate Change Monitoring System, Seasonal to inter-annual prediction, decentralized community-run early warning systems, index-based climate insurance;
- technologies for sustainable water use and management which include sprinkler and drip Irrigation, fog harvesting, rainwater harvesting, drilling borehole;
- soil management which include slow-forming terraces, conservation tillage and integrated nutrient management,
- sustainable crop management which include crop diversification and new varieties, biotechnology for climate change adaptation of crops, ecological pest management, seed and grain storage;
- sustainable livestock management which include livestock disease management, selective breeding via controlled mating;
- sustainable farming systems which include mixed farming, agro-forestry; and
- capacity building and stakeholder organization which include community-based agricultural extension agents, farmer field schools, forest user groups and water user associations.

The benefits of adaptation technologies for the agriculture sector include:

- appropriate planning and successful implementation of climate change adaptation measures;

- increased production and productivity through sustainable water use and management;
- increased production and productivity with sustainable soil use (prevention of degradation and erosion);
- increased farmers production, productivity and income in a changing climate;
- increase livestock production and productivity and
- building capacity of farmers, extensions and stakeholders on climate change effects and their prevention.

3.4 Criteria and process of technology prioritization

Technology prioritization was conducted using the Multi-Criteria Analysis (MCA). The process for conducting MCA was done in two stages, viz., (1) identification of objectives, technology options and criteria for assessing technologies and (2) group discussions with technical staff from the Ministry of Agriculture and Food Security for screening technologies and criteria, weighting the criteria and conducting technology assessment. The second stage was accomplished by conducting two group discussion meetings where the first meeting consisted only on screening technology options and criteria and weighting the criteria and the second meeting for the technology assessment using the set of criteria selected.

3.4.1 Identification of objectives

The objective of the MCA in Mozambique was to identify a set of technologies that the country can use in agriculture sector to increase resilience to climate change and reduce climate risks to people and property, restoring and ensuring the rational use and protection of the natural and built capital taking into account the major climate change events affecting the agriculture sector in Mozambique (drought, floods and cyclones).

3.4.2 Identification of technology options

Based on the current challenges faced by the agricultural sector with climate change events and the vulnerability of the sector to predicted climate change, a list of 26 possible adaptations technologies were identified to improve the resilience of the agriculture systems, improve livelihood of farmers and reduce climate risks through expert views and bilateral meetings with relevant stakeholders. Technologies of benefits to small-scale vulnerable food crop and livestock growers and to local biodiversity and forest resources were integrated. The technology identification exercise drew from multiple sources and the socio-cultural context, including (1) adaptation technologies proposed in previous national adaptation Programme for

Action (NAPA); (2) National strategy for adaptation and mitigation of climate chance, (3) technologies currently in practice and supported by national agricultural policy (conservation agriculture); (4) initiatives in the pipeline (e.g. green house vegetable production); (5) appropriateness of technologies in the local context (seed production and grain and seed storage); and (5) social acceptability.

As in Clements *et al.* (2011) the adaptation technologies identified were then regrouped under different categories, viz., sustainable water use and management, planning for climate change variability, soil management, sustainable crop management, sustainable livestock management, sustainable farming system, land use management, and capacity building of stakeholders. The list of adaptation technologies and their typology is presented in Table 1.

Table 1: List of technologies for adaptation in agriculture sector and their typology

Technology typology	Technology
Planning for climate change and variability	System monitoring of climate change
	seasonal and inter-annual forecast
	Improving agrometeorological and agro-hydrological forecasting network and early warning system
Management and sustainable use of water	Drip and sprinker irrigation
	Drilling multiuse boreholes
	Rainwater harvesting
Soil Management	Terracing
	Farming conservation
	Conservation Agriculture
	Integrated nutrient management
Sustainable crop management	Crop and variety diversification
	Cultivation of tolerant varieties
	Development of improved varieties
	Strengthening breeding programmes for adaptation to climate change
	Ecological management of pests
	Services for rapid diagnosis of pests and diseases
	Upscaling the implementation of IPM technologies to control pests and diseases of major economic importance
	Greenhouse vegetable production
	Production, conservation of seed and grain and promotion of low cost storage systems
Sustainable cropping systems	Agro-forestry systems including the mixed cropping
Capacity building and organization of parts	Farmer field school
	Community based agricultural extension
	Association of water users
	Groups of forestry users
	Education and sensitization for adaptation to climate change

3.4.3 Identification of criteria

As in the technology identification process, criteria for assessing technologies were identified based on literature review but taking into account the socio-cultural and economic context of the potential beneficiaries of the technologies to be selected from the technology prioritization process. In total 17 criteria were identified. The list of criteria identified is presented in table 2.

Table 2: Criteria, criteria categories, points and preferred value for assessing technologies for adaptation to climate change

Catergory	Criteria	Point	Preferred value
Cost	Cost of installation	0 = high; 100 = Low	Low
	Cost of maintenance	0 = high; 100 = Low	Low
Economic (Economic impact of the technology)	Catalyzes private investment	0 = very low ; 100 = very high	high
	creates jobs	0 = very low ; 100 = very high	high
	Improve the income of producers	0 = very low ; 100 = very high	high
Environmental	Supports ecosystems services	0 = very low ; 100 = very high	high
	Protects biodiversity	0 = very low ; 100 = very high	high
	Protecting environmental resources	0 = very low ; 100 = very high	high
Climate related	Reducing vulnerability and improving resilience	0 = very hard ; 100 = very easy	high
Social	Reduce poverty	0 = very hard ; 100 = very easy	high
	Reduces inequality	0 = very hard ; 100 = very easy	high
	Improves health	0 = very low ; 100 = very high	high
Political/Institutional	Consistency with national policies and development priorities	0 = very low ; 100 = very high	high
	Ease of implementation	0 = difficult; 100 = Easy	high
	Use and maintenance or replicability	0 = difficult; 100 = Easy	high
Technology related	Rapid diffusion rate	0 = very low ; 100 = very high	high
	More efficient compared to other alternatives	0 = very low ; 100 = very high	high

3.4.4 Screening of technology

During the preparation of group meetings, a list of technologies and criteria were sent to the potential participants to the group discussion meetings (see the list in annex 1) for pre-screening. The aim of the pre-screening process was to identify a set of technologies which each the potential participants think are important for climate change adaptation in agriculture sector in Mozambique and to provide their view and perceptions of the potential benefits. Given that no feedback was received from that process, the list of technology for prioritization was produced during the first group discussion meeting.

The screening of the technologies involved assessing the technical feasibility and adaptation benefits of each of the 26 identified potential adaptation technologies based on the likely future scenarios of climate impacts on Mozambican agriculture, expert knowledge and stakeholders views, namely, (1) technical potential of the technology; (2) contribution to improve adaptation resilience; (2) cost of the technology and, (4) contribution of the technology with national development strategy and policies. The screening was conducted through discussion with a group of 8 technical staff from the Ministry of Agriculture and Food security (list of participants presented in annex 2, and a short-list of fourteen (14) technologies retained to use in technology prioritization process. The list of technologies selected during the group meeting is presented in table 3.

Table 3: List of shortlisted technologies for adaptation to climate change in agriculture sector and their typology

Technology typology	Technology
Planning for climate change variability	Seasonal and inter-annual forecast
	Improving agrometeorological and agro-hydrological forecasting network and early warning system
Management and sustainable use of water	Drip and sprinker irrigation
	Drilling multiuse boreholes
	Rainwater harvesting and conservation
Soil management	Conservation Agriculture
Sustainable crop management	Crop and variety diversification
	Development of improved varieties
	Strengthening breeding programmes for adaptation to climate change
	Upscaling the implementation of IPM technologies to control pests and diseases of major economic importance
	Greenhouse vegetable production
	Seed and grain production and conservation and promotion of low cost storage systems
Sustainable cropping systems	Agro-forestry systems including the mix cropping
Capacity building and organization of parts	Farmer field school
	Education and sensitization for adaptation to climate change

3.4.5 Screening of criteria

From the 17 criteria the consultant had identified, the group discussed on the importance of the different criteria for assessing technologies and a set of 9 criteria was selected for screening the technologies for adaptation to climate change in agriculture. The different criteria were categorized into cost, economic, social, environmental, political or institutional and climate related. The list of criteria selected for comparing the technology options, their categories and rating as well as the preferred value are presented in Table 4.

Table 4: List of criteria used to evaluate the technology options and their category, scoring points and preferred value

Criteria	Criterion	Criteria category	Points	Preferred value
C1	Cost of installation and maintenance	cost	0=high; 100=low	Low
C2	Job creation	Economic impact of technology	0=very low; 100=Very high	High
C3	improve incomes	Economic impact of technology	0=very low; 100=Very high	High
C4	protect biodiversity	Environmental	0=very low; 100=Very high	High
C5	Reduce vulnerability and improve resilience	Climatic	0=very low; 100=Very high	High
C6	Reduce poverty and inequality	Social	0=very low; 100=Very high	High
C7	Coherence with national police and priorities of development	Political or institutional	0=very low; 100=Very high	High
C8	Easy implementation	Political or institutional	0=very low; 100=Very high	High
C9	Quick diffusion rate	Technological	0=very low; 100=Very high	High

3.4.6 Weighting of criteria

The nine criteria were weighted; the process involved assigning weight to each criterion to reflect the weight of importance that stakeholders assign to each of the specific criterion. For assigning the weights, the criteria were arranged in descending order of relative importance and then the weights between 1 and 100 were assigned. The results of the criteria prioritization is indicated in table 5.

Table 5: Criteria weights of nine criteria for assessing technologies

Criteria	Criterion	Allocation of budget (total = 100)	Weight (%)
C1	Reduce vulnerability and increase resilience	20	20%
C2	Coherent with national development polices and priorities	16	16%
C3	Easy implementation	15	15%
C4	Cost of installation and maintenance	10	10%
C5	Improves farmers income	10	10%
C6	Protect biodiversity	8	8%
C7	Reduce poverty and inequality	8	8%
C8	Quick rate of difusion	8	8%
C9	Job creation	5	5%
	Total allocated	**100**	

3.4.7 Ranking of technologies

In this step, the outcome and performance of each technology was evaluated against each of the criteria. The consultant had the responsibility of building consensus around a particular score for each technology on the respective criterion. Technologies were ranked using a scale from 0 to 100. The description of each ranking score is presented in table 6.

Table 6: Scores used to rank technologies and their description

Score	General description
0	Used when information on a technology does not apply to the criterion
1-20	Extremely weak performance; strongly unfavorable.
21-40	Poor performance, major improvement needed.
41-60	At an acceptable or above level
61-80	Very favorable performance, but still need improvement
81-100	Clearly outstanding performance which is way above the norm.

3.5 Results of technology prioritization

The performance of the technology against the criteria was assessed considering available country knowledge and relevant expert input. The technologies were then scored on a scale of 0-100 by the stakeholder group, consisting of 8 experts. The results of the MCA exercise were carefully examined by members of the technical working group to see if the ranks were logical. It was ensured that the scores given to different options against different criteria were consistent and reflective of the technological merits. The scope of the technology options was re-discussed.

In order to investigate the sensitivity of technology ranking on allocated weights, the weight assigned to each criterion was re-assessed by taking into consideration any uncertainty and conflicting objectives of multiple stakeholders. The overall ranking of the different options was finally agreed by all stakeholders and the expert based on the sensitivity analysis. The results are presented in table 7.

Table 7 Results of scoring of 14 technology options using 9 weighted criteria

Technology option	Criteria and their weighting in the brackets								
	C1 (10%)	C2 (5%)	C3 (10%)	C4 (8%)	C5 (20%)	C6 (8%)	C7 (16%)	C8 (15%)	C9 (8%)
Seed production and conservation and promotion of low cost storage systems of grain and seed	65	80	95	20	97	80	95	70	70
Conservation agriculture	80	10	80	80	95	75	100	85	70
Drilling boreholes for multiple uses	30	10	80	40	95	80	95	60	60
Rain water harvesting and conservation	20	50	80	40	90	80	95	60	30
Crop diversification	70	40	80	50	90	80	90	90	80
Production and conservation of forage and livestock supplementation	40	50	80	50	95	80	80	70	60
Agro-forestry, pasture and mix cropping systems	80	50	80	60	90	75	90	80	60
Greenhouse vegetable production	40	60	90	50	90	60	90	60	10
Drip and sprinker irrigation	20	50	90	40	80	70	90	40	20
Education and sensitization campaigns for adaptation to climate change	50	10	40	60	60	60	90	70	80
Strengthening crop and animal breeding programmes for adaptation to climate change	50	10	40	30	70	60	95	50	10
Upscaling the implementation of Integrated Pest Management (IPM) technologies to control pests and diseases of major economic importance	60	50	50	80	60	60	90	40	10
Improvement of agrometeorological and agro-hydrological network and early warning system and dissemination of information	20	10	60	5	70	10	90	20	20
Farmer field schools	70	10	50	40	60	60	80	70	50

Where:
C1 = cost of installation and maintenance; C2 = job creation; C3= improve incomes
C4=protect biodiversity; C5 = Reduce vulnerability and improve resilience; C6 =- Reduce poverty and inequity; C7 = coherence with national policies and priorities of development; C8 = Easy implementation; C9 = Quick diffusion rate

The results of technology ranking are presented in Figure 2. The three highly ranked technologies in descending order of importance were: (1) seed production and conservation and promotion of low cost storage systems for seed and grain; (2) conservation agriculture and (3) drilling boreholes, with 81, 80 and 74 points. Other technologies that had high scores were rainwater harvesting and conservation and diversification of crops and varieties which ranked 4th and 5th, respectively with 73 and 72 points.

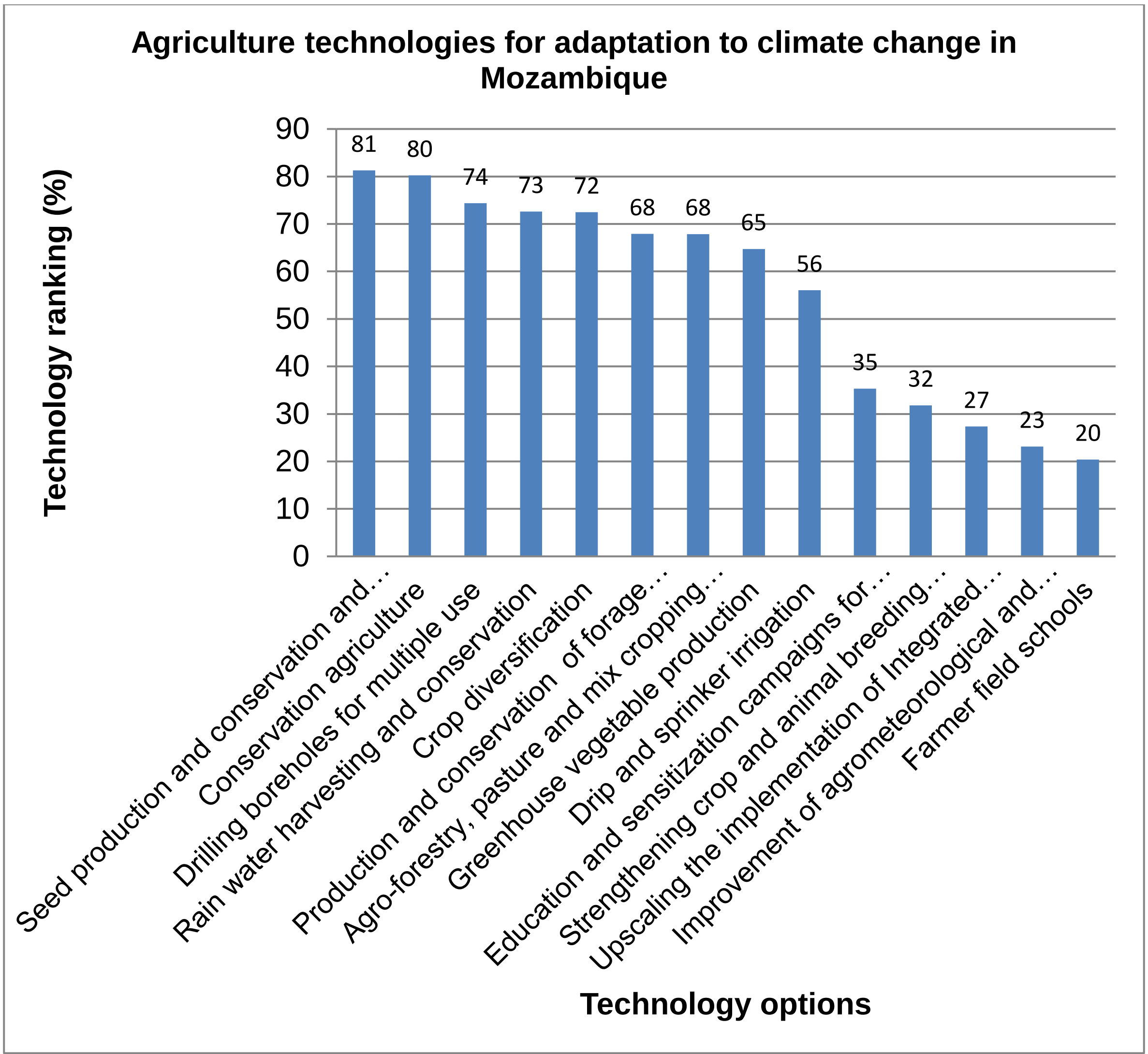

Figure 2: Ranking of agricultural technology for adaptation to climate change

CHAPTER 4: SUMMARY AND CONCLUSIONS

Mozambique is highly vulnerable to climate change which occurs in the form of change in temperature and rainfall and occurrence of intense and frequent climate extreme events (drought, floods and tropical cyclones). The detrimental impacts of these events are already being felt on agriculture sector. Since agriculture, especially crop and livestock production is highly dependent on rain which is already impacted negatively by climate change and climate variability, adaptation in the agriculture sector is of key importance and is covered by the TNA project.

Amongst the climate chance extreme events, drought is the most devastating due to its high intensity and frequency, presently being reported to occur with frequency of 7 in every 10 years. The effect of drought on agriculture sector is exacerbated by the limited availability of water for crop irrigation and livestock watering. Therefore, rainwater harvesting and conservation can play important contribution towards improving resilience of the agriculture sector to climate change.

Through MCA, three technologies were prioritized for agriculture adaptation to climate change. These are: (1) seed and grain production and conservation and promotion of low cost storage systems (2) conservation agriculture and (3) drilling boreholes for multiple uses. After presenting the results of MCA to the technical counsel of the Ministry of Agriculture and Food Security it was recommended to give priority to rainwater harvesting and conservation as priority technology for resilience of the agriculture sector. Given that only three technologies should be used in Barrier Analysis and in preparation of Technology Action Plan, it was decided to substitute drilling boreholes for multiuse by rainwater harvesting and conservation. Hence, the technologies to be included in barriers analysis and technology action plan are: (1) seed production and conservation and promotion of low cost storage systems for seed and grain; (2) conservation agriculture and (3) Rainwater harvesting and conservation. It is important to mention that conservation agriculture is a technology currently being promoted in the country as adaptation technology to climate change. The Ministry of Agriculture has developed the Action Plant for Conservation agriculture which has already been approved by the Counsel of Ministries of Mozambique.

LIST OF REFERENCES

Brito, R. and Holman, E.H.A. 2012. Responding to climate change in Mozambique: Theme 6: Agriculture. Maputo: INGC.

Chilonda P., Xavier V., Luciano L., Gemo H., Chamusso A., Zikhali P., Faria A., Govereh J., Manussa S., Acubar B., Musaba E., Osvaldo L., Alage N., Macome E. and Manganhela A. 2011. MOZSAKSS: Monitoring agriculture sector performance, growth and poverty trends in Mozambique

Clements R., Haggar J., Quezada A. and Torres J. 2011. Technologies for Climate Change Adaptation: Agriculture Sector. In Xianli Zhu (ed). TNA guidebook series. UNEP

FAO 2011. World Agriculture. Toward 2030/2050. Rome

Global Risks Advisory Firm Maplecroft 2011. Climate change vulnerability index. Available on http://maplecroft.com/about/news/ccvi.html. Accessed on 20th August 2016

INE 2007. Recenceamento geral da população e habitação. Available at http://www.ine.gov.mz/operacoes-estatisticas/censos. Accessed on 20th August 2016

INE 2011. Evolução da produção agrícola das culturas alimentares básicas [Online]. Available on http://www.ine.gov.mz:82/pxwebine/pxweb/temp/agricult_produc_culturas2007525152248.xls. Accessed on 20th July 2016

INGC. 2009. Main report: INGC Climate Change Report: Study on the Impact of Climate Change on Disaster Risk in Mozambique. [Asante, K., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A, Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. Mozambique.

Ministério da Agricultura, 2014. Plano de Acção para Adaptação da Agricultura às MudançasClimáticas, Maputo, Moçambique

Ministério para a Coodenação da Acção Ambiental (MICOA), 2005. Avaliação da vulnerabilidade as mudanças climáticas e estratégias de adaptação, Ministério para a Coordenação da Acção Ambiental, Maputo

Ministry for the Coordination of Environmental Affairs (MICOA), 2007. National Adaptation Programme of Action (NAPA). Maputo, Mozambique

Ministério para a Coodenação da Acção Ambiental (MICOA), 2012. Estratégia Nacional de Adaptação e Mitigação de Mudanças Climáticas. Moçambique

Ministério para a Coodenação da Acção Ambiental (MICOA) 2013. National Communicationculture. Maputo, Mozambique

MITADER 2015. Termos de Referência para Avaliar as Necessidades Tecnológicas de Adaptação e Mitigação as mudanças climáticas em Moçambique. Maputo, Moçambique

Rebecca Clements, Jeremy Haggar, Alicia Quezada and Juan Torres. 2011. TNA Guidebook Series. Technologies for Climate Change Adaptation in Agriculture Sector. GEF/UNEP

TIA 2008, in Strategic Plan for Agriculture Development, PEDSA 2010-19, MINAG, Oct. 2010

LIST OF ANNEXES

Annex 1: List of entities and or institutions proposed by the consultant to be part of the group discussions

1. Ministério da Agricultura e Segurança Alimentar
a. Direcção Nacional de Extensão
b. Direcção Nacional de Agricultura e Silvicultura (Aviso Prévio)
o Direcção Nacional de Veterinária -
c. Direcção de planificação e cooperação internacional
d. SETSAN
e. IIAM (DARN, DCA)
f. Instituto de irrigação
2. INGC
3. INAM (Previsão climática)
4. FEWSNET
5. Link (ONG)
a. UEM (Faculdade de Agronomia e Engenharia Florestal and Faculdade de Ciências)
6. UNDP
7. PMA
8. FAO
9. UNDAF
10. MITADER

Annex 2: List of participants in the group discussion meetings for technology prioritization

Order	Name	Institution	Contact
1	Paula Panguene	DINAB, MITADER	paulapanguene@yahoo.com.br, +258843183190
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Annex 3: Timesheets of selected technologies

Sector : Agriculture	
Technology: Seed production and conservation and promotion of low cost storage systems of grain and seed	
Introduction	Seed and grain production and conservation is key to the attainment of household food security among resource poor farmers in developing countries (Wambugu et al, 2009). While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. Therefore the basic objective of good storage is to create environmental conditions that protect the product and maintain its quality and its quantity, thus reducing product loss and financial loss. There are two reasons for food storage: domestic security and maintaining value prior to sale. Farmers may not accept improvements which incur costs when storing primarily for home consumption because an improvement in the quality of a food produced for home consumption does not achieve a higher monetary value for the farmer
Technology characteristics	In order to reduce the food insecurity, appropriate production technologies and good storage environment is needed. Appropriate production technologies can increase productivity and quality while good storage environment can contribute to lower the possibility of: • Biological damage by insects, rodents and micro-organisms • Chemical damage through acidity development and flavor changes • Physical damage through crushing and breaking. Good storage involves controlling temperature, moisture, light, pests and hygiene.
Institutional and organizational requirements	Most developing countries are in the tropics. They are often in areas of high temperature, high rainfall and humidity, which are ideal conditions for the development of micro-organisms and insects, causing high levels of crop damage and deterioration of crops in store. Thus, an assessment of different production and storage methods has to be undertaken before investing in one. Existing local methods are usually low-cost so adapting what is already there, rather than introducing new technology, is often a more realistic economic option for households
Operation and maintenance	Adopting new production and storage methods is likely to require technical training. For example, in addition to constructing a new silo, training or advice on maintenance, health and safety regulations, quality control and seed storage behavior (sensitivity to light and moisture) could be needed. It is important to monitor progress, in order to resolve problems, build on developments, and record successes and failures. Socio-economic impacts should be considered, such as who benefits and how additional income or time is distributed between and within households or businesses.
Endorsement by experts	
Adequacy for current climate	
Scale/Size of beneficiaries group	
Advantages	The establishment of safe, long-term storage facilities ensures that grain supplies are available during times of drought (UNEP, 2010; 36). It is important to be able to store food after harvest so as not to be compelled to sell at low prices. Appropriate storing techniques can prolong the life of foodstuffs, and/or protect the quality, thereby preserving stocks year-round
Disadvantages	The cleaning and drying of grain for storage are essential measures. However, difficulties in achieving the desired freedom from excess moisture and foreign matter are frequently encountered. Failure to adequately clean and dry grain can lead to pest infestations. Over-drying of grains can also negatively impact seed quality. Losses of seeds from insects, rodents, birds and moisture uptake can be high in traditional bulk storage systems. Controlling or preventing pest infestation may require chemical sprays. Some markets will not accept seeds and grains treated with these chemicals
Cost to implement adaptation technology	Costs requirements vary between storage methods. If the produce is for consumption, rather than sale, then investing large amounts in a new technology will not prove cost-efficient. On the other hand, if the amount of food for sale increases, then the investment can be paid back over time. Calculating the existing profit and potential profit with new technology is useful for businesses to estimate this payback period. The amount people are prepared to invest in new technology may depend partly upon who owns the equipment and facilities. In some cases, farmers will invest in a new technology if they have total ownership of it while

	in other cases, storage may be collectively owned and so costs can be shared. Access to credit is often dependent on where people live, educational levels and on being able to raise collateral. Adopting new storage methods for low-income farmers will be possible if they are given assistance with literacy and numeracy, and possibly some kind of group training.
Additional cost to implement adaptation technology, compared to "business as usual"	
Direct benefits	
Reduction of vulnerability to climate change, indirect	Grain storage has been established to prepare for droughts and hunger and malnutrition (UNEP, 2010; 36). Grain storage provides an adaptation strategy for climate change by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought (UNEP, 2010; 62). Efficient harvesting can reduce post-harvest losses and preserve food quantity, quality and the nutritional value of the product (FAO, 2010; 3). Innovations for addressing climate change include technologies for reducing waste of agricultural produce (BIAC, 2009). In fact, the establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector (CARE, 2010).
Economic benefits, indirect Employment	
Growth & Investment Social benefits, indirect Income	
Environmental benefits, indirect	
Opportunity for implementation	Before initiating technology development work, it is important to assess the need for improvements. IT Publications and UNIFEM (1995) suggest an opportunities assessment checklist that can be usefully discussed with producers during a preliminary appraisal: • Problems with existing storage techniques • Disadvantages of existing storage techniques greater than advantages • Possibility of improved storage of reducing the loss of produce/possibility of increase on quality of produce for sale or consumption by better storage • Possibility to keep surplus produce stored away rather than having to sell any extra produce immediately • Possibility to sell any extra produce • Increased profit through improved storage • Time for learning improved techniques for collecting materials and making the new equipment/ money for storage materials • Access to new technical knowledge and skills required for producing, maintaining and using the new technology • Benefits against investment on time, money and effort in improving storage
Barriers for implementation	A common constraint is that produce has to be sold off immediately to pay off debts to landowners or creditors. This is the most widespread reason for deciding that investing in new storage technology is impossible. It has to be considered also that additional time input for constructing and maintaining storage facilities will be perceived as worthwhile only if the increase in income is sufficient.
Market potential	
Status	
Timeframe	
Acceptability to local stakeholders	

Sector : Agriculture	
Technology: Conservation Agriculture	
Introduction	Conservation agriculture (CA) is an agriculture system that aims at soil and water conservation. It combines three principles: minimal soil disturbance (no-till practice), permanent soil cover (cover crops, residues and mulches) and crop rotation or crop association. Consequently, soil organic matter is conserved and water retention is increased while erosion and pollution are reduced
Technology characteristics	• Most CA practices have been historically practiced. • Adapting CA to some crops may require specific machinery for seeding. • CA induces a decrease in machinery use, fuel and time-saving in operations. • CA is suitable for arid and semi-arid regions, to areas with soils suffering from low organic matter content and for areas prone to desertification • CA should be avoided in soils with high clay content, in humid areas with shallow water table, in saline soils and for crops with no residues left
Institutional and organizational requirements	More research and trial should be done in different agriculture zones, namely in arid regions. Capacity building and knowledge transfer is required for the adaptation option to be implemented and successful deployment of CA.
Operation and maintenance	CA requires the use of specific seed machinery for seeding and sufficient large areas to adopt crop rotation (namely for cereals and legumes). To maintain soil fertility agriculture residues should not be removed. Training is required for technicians and furtherer to farmers.
Endorsement by experts	CA is widely acknowledged worldwide. Nevertheless, in Mozambique, such technology is not endorsed by all experts in the matter. Further investigation is required
Adequacy for current climate	No negative consequences are mentioned concerning adopting CA under current or future climate. On the contrary, it is known that CA is adapted to arid and semi-arid conditions and can have a role in reducing GHG emissions.
Scale/Size of beneficiaries group	All farmers growing rainfed or irrigated field crops or even fruit crops in arid and semi-arid zones may benefit from the technology
Disadvantages	Farmers benefiting from agriculture residues (as forage in mixed farming systems) will not profit from CA, as conventionally, post to harvest, they rent the land for grazing. However, controlling grazing and keeping a part of the residues might be feasible Farmers renting properties on a short term basis contract cannot take advantage from CA. Small holders are unable to apply economically viable crop rotations, and unable to access to machinery. In some cases yields might decrease.
Cost to implement adaptation technology	CA has less expenditure in capital cost (for machinery), in labor and energy than conventional agriculture. In field crops, the cost of implementing the technology is reduced to the cost of the seeder or planter.
Additional cost to implement adaptation technology, compared to "business as usual"	Cost depends on the type of crops. In fruit orchards, the cost is minimal (only cost of green cover seeds). The cost of production is reduced as plowing is not practiced. In field crops, less machinery is involved. When compared to business as usual, there is no additional cost rather there is reduction
Direct benefits	Long term cost without adaptation will increase as farmers will face an increase in chemical and ever water use to preserve soil fertility and increase in the cost of production. In CA the cost of production is maintained as the inputs do not augment, as soil fertility and water content are preserved. The major saving will be in terms of costs for tillage and land preparation for plantation. Yield variation is not significant, but production is sustained with minimal annual variation
Reduction of vulnerability to climate change, indirect	Soil is preserved from the impact of climatic adverse (wind, rain, solar radiation) and evaporation is reduced, which increases soil water content and soil organic matter. Better resilience to drought and flash floods

Economic benefits, indirect Employment	No specific increase or decrease is expected
Growth & Investment Social benefits, indirect Income	Investment in machinery is required An overall yield stability, and a reduction in cost of production, farmer's income is hence increased. Better resilience to climate change. In case of cereals, revenue may be increased with shift from a monoculture of maize with till to a rotation of maize-legume with no till.
Environmental benefits, indirect	Reduction in GHG emissions as the soil is not disturbed. Less flooding through better water retention and slower run-off. Soil water content increased by 2%-3%. Better nutrient use efficiency, and hence reduction of inputs and pollution. Increased biodiversity in the soil. Reduced desertification.
Opportunities and Barriers	No institutional or policy barriers exist. Nevertheless, the land tenure system could be sometimes a barrier for applying CA. Opportunities are numerous in terms that CA is not only a technology to cope with climate change, but also a mitigation mean as it reduces GHG emissions due to soil disturbance. CA is also an opportunity to combat desertification and reduce flood risk. CA is an opportunity to improve livelihood in arid and semi-arid areas of Mozambique
Market potential	CA is a non-market technology by itself. However crops issued from CA will be more environmental friendly and with lesser pesticide residues. Such traits would give them a higher competitive potential on the market.
Status	CA in Mozambique is still at its early stages, in experimental plots in semi-arid areas. Experiences should be widened to different agro-climatic zones as well as to different agriculture systems (small holders, mixed farming).
Timeframe	Medium to Long Term
Acceptability to local stakeholders	CA is hindered by economic and social constraints: small holdings, and the inherited ideas on tillage which would be difficult to change

Sector : Agriculture	
Technology: Drilling boreholes for multiple use	
Introduction	This technology addresses the problem of water shortage during droughts and dry spells in the rain season. Due to climatic changes such as prolonged drought, ground water resources are negatively affected. This results in inadequate recharging, lowering of water tables and drying of boreholes. Discontinuity of water supply during this period can halt economic development and hinder human health and well-being. Those mostly affected by the drought are the rural communities in Mozambique who have to travel long distances in order to have access to clean water. Groundwater abstraction is the process of taking water from a ground source, either temporarily or permanently. Abstraction can be either manual, where water table is high or mechanized, usually by using a rotary drilling rig which is able to reach deep aquifers of several hundred meters. Tube wells and Boreholes can be used as alternative domestic water supplies specially during drought periods. Tube wells consist of a narrow, screened tube (casing) driven into a water bearing zone of the subsurface. Tube wells penetrating bedrock with casing not extending below the interface between unconsolidated soil and bedrock is called a Bore hole. Life time is about 10 years.
Technology characteristics	Tube wells consist of a narrow, screened tube or casing driven into a water bearing zone of the subsurface. Boreholes are tube wells that penetrate bedrock, with casing not extending below the interface between unconsolidated soil and bedrock. Tube wells can often be installed by hand-auguring while boreholes require a drilling method with an external power source. A hand-powered or automated pump is used to draw water to the surface or if the casing has penetrated a confined aquifer, pressure may bring water to the surface. A tube well consists of a plastic or metal casing; usually 100-150 mm diameter, in unconsolidated soils, a "screened" portion of casing below the water table that is perforated, a "sanitary seal" consisting of grout and clay to prevent water seeping around the casing and a pump to extract the water. To further enhance productivity, it is proposed that the boreholes/tube wells have a *Solar powered pump for water supply photovoltaic system (PVP).* In this system, the women and children will not spend time operating the hand pump. The time would then be used in other productive activities. The

	water pump is powered by solar and might involve pumping the water into an overhead tank which later flows down using gravity. The PVP equipment mainly comprises: • PV generator which generally constitutes one or more polycrystalline photovoltaic solar module; • Inverter which converts direct current (DC) into alternating current (AC). This is not applicable when the pump is for DC; • Pumping system, this could be DC or AC; and, • Overhead tank for water storage. • New technical skills of drilling for deeper intrusion into the ground in order to extract water more efficiency; fixing the damaged wells; drilling provision wells for dry season. • Widely used in place of surface water in rural households
Institutional and organizational requirements	Technical advice should be given whenever necessary by skilled persons. If used for drinking purposes, arrangements should be provided to test quality of water in a regular basis
Operation and maintenance	Tube wells can be installed by hand-auguring; Boreholes require a drilling method with an external power source. A hand powered or automated pump is used to draw water to the surface. Major components of a tube well are: • Plastic or metal casing • In unconsolidated soils, it is necessary to have a screened portion of casing below the water table that is perforated • A sanitary seal consisting of clay to prevent water seeping around the casing • A pump to extract water • Technology should be implemented based on the following data: • Population distribution • Ground water resources • Water point location • Geological environment Water quality should be monitored if drinking purpose To increase borehole water supply during droughts: • Drill new boreholes • Repair damaged borehole
Endorsement by experts	Drilling boreholes is widely acknowledged worldwide
Adequacy for current climate	Negative consequences of the adaption option is associated with ground water shortage
Scale/Size of beneficiaries group	Small.
Disadvantages	High installation costs and that the technology is not usually applicable to deep boreholes and high water consumption rates. Diesel pumps are best applied in such cases.
Cost to implement adaptation technology	The cost depends on geographical location, soil type-sandy or rocky and distance to site. The cost of implementation varies greatly, depending on the depth of water table, geological drilling area, the cost of materials as well.
Additional cost to implement adaptation technology, compared to "business as usual"	Additional cost is required for monitoring of water quality, tank and pipes
Direct benefits	• Availability of good quality water for domestic and agricultural purposes • Women empowerment by providing readily available water and committing time spent looking for water to family and other socio-economic activities • Reduced incidences of water borne diseases
Reduction of vulnerability to climate change, indirect	Climate Change in Mozambique is projected to result to more frequent and severe droughts and associated increased water resources stress, particularly in arid and semi-arid areas (INGC, 2009). Ground water is relatively less likely to be affected by climate change compared to surface water sources and will therefore be a good water source option especially in arid and semi-arid areas. Drilling of boreholes and tube wells can help improve access to groundwater by rural populations. It

	will prevent reliance on poor quality alternative supplies and reduce man hours spent on travelling to far distance reliable water points. Some of the benefits of the technology include better access to water for irrigation and other uses such as watering livestock. It also increases the productivity of women as they now access water near their homes.
Economic benefits, indirect Employment	• Employment – medium (drilling) • Investment – Tube wells or Borehole, hand pump/pump
Growth & Investment Social benefits, indirect Income	Social benefits: • Income ✓ Decrease the expenditure for purchasing water from other sources ✓ Income through employment (horticulture during dry season, agriculture, bottled water industry) • Education ✓ Technical advice should be given whenever necessary by experts. ✓ Awareness programs, school education and research on this technology - medium • Health ✓ Medium impact - Decrease in waterborne diseases, ✓ If ground water is polluted it can have negative impacts on health
Environmental benefits, indirect	• Impact on ground water quality and quantity – high (this technology can increase the pressure for ground water withdrawal) • Impact on surface water quality and quantity –No impact • On flood forming – No impact • Release of GHG – very little (only during construction) • Ensuring the environment and sanitation; limiting epidemic diseases among the community
Opportunities and Barriers	Opportunities • Save time and cost • Continuous water supply • Off season vegetable production Barriers • Water can contain iron, fluoride etc. • Ground water abstraction • Lack of hydro-geological data • Arsenic and fluoride contamination in deep wells. • Low community awareness on sanitation.
Market potential	High potential in rural areas, where there is no centralized water supply system. The technology is small-scale, proven and less capital-intensive. It has market potential nationwide.
Status	Ground water abstraction is common in Mozambique, and in many rural and urban areas with shallow water tables, hand dug shallows wells are important domestic water sources. In most areas, the bore-holes needed to abstract groundwater would require a depth of as much as 150 m and the cost of sinking such a bore-hole is high. Drilling of boreholes has continued to increase as an option by the government and private developers to address increasing water demand accession by population growth and supply unreliability occasioned by frequent draughts.
Timeframe	Short Term, Medium Term and Long Term
Acceptability to local stakeholders	Because of the low cost, this technology will be acceptable to stakeholders

Sector : Agriculture	
Technology: Rain water harvesting and conservation	
Introduction	Rainwater harvesting is defined as a method for collecting, storing and conserving water from roof top and surface runoff from rain for household consumption and agriculture in arid and semi-arid regions. Rainwater harvesting could be achieved from roof top ground surface (roads) that constitutes the catchment area where the rainfall or water runoff is initially captured. Surface water flowing along the ground during rain is usually diverted toward a reservoir below the surface. Rainwater harvesting can be categorized according to the type of catchment surface used, and by implication the scale of activity. Rainwater harvesting represents an adaptation strategy to climate change for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture
Technology characteristics	For rainwater harvesting technology, agricultural roads or regular village roads used in transport could be considered. Equipment needed to implement this technology include the following: • drainage canals • settling pond where collected water is settled for sedimentation • Collection pond: it is recommended to collect water in earth made pond, otherwise from concrete material. • Pump: it is only needed if the collected water should to be pumped to the upstream areas. Knowledge Requirements for the Selection of Rainwater Harvesting Technology are the following: • Rainfall quantity (mm/year) • Rainfall amount, pattern and the type of rainfall pattern which prevails will often determine the feasibility of a rainwater harvesting technology. A climate where rain falls regularly throughout the year will mean that the storage requirement is low and hence the system cost will be correspondingly low and vice versa. • Collection surface area (m2) • Available storage capacity (m3) • Number of users • Cost • Alternative water sources – where alternative water sources are available, this can make a significant difference to the usage pattern. • Water management strategy – whatever the conditions, a careful water management strategy is always a prudent measure. In situations where there is a strong reliance on stored rainwater, there is a need to control or manage the amount of water being used so that it does not dry up before expected
Institutional and organizational requirements	• The Government, particularly the Ministry of Public Works and Housing and Water Resources should be involved for the implementation of this technology. • Municipalities could be involved to organize system operation when the catchment area for harvested water is a public domain. • Government and donors could play a key role in providing subsidies for equipment purchases by making the technology accessible to a larger number of farmers, particularly small-scale farmers, who may have problems raising capital investment funds • No specific institutional or organizational requirements; the system is tailored at farmer's scale

Operation and maintenance	Maintenance is required for the cleaning of the reservoir and inspection of the gutters, pipes and taps and typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of the major rainfall season with regular inspections. In regions with unpredictable rainfall, more regular maintenance and cleaning will be required to ensure that the equipment is maintained in good working order. Cracks in the storage reservoirs can create major problems and should be repaired immediately to avoid water loss. Maintenance of the catchment area to avoid damage by people and animals and to keep it free from vegetation is required
Endorsement by experts	The technology is successfully applied in different countries. Its utilization is now an option along with more traditional water supply technologies, particularly in rural areas. This is considered as an innovative harvesting technology and is acknowledged by all experts
Adequacy for current climate	Fits well, both for present and expected climate, namely in areas where heavy rainfall occurs (i.e. coastal areas) and to a lesser extent inland
Scale/Size of beneficiaries group	Several farmers may share one medium to large reservoir. One farmer can have its own small tank if the harvested water is collected from his private land/road. All greenhouse plant growers, especially on the coastal and mountainous areas where enough precipitation is encountered
Disadvantages	• Limited supply and uncertainty of rainfall. Rainwater is not a reliable water source in dry periods or in time of prolonged drought. • Low storage capacity could limit rainwater harvesting potential, whereas increasing storage capacity will add to construction and operating costs making the technology less economically viable. The effectiveness of storage can be limited by the evaporation that occurs between rains. • When runoff is generated from a large area and concentrated in small storage structures, there is a potential danger of water quality degradation, through introduction of agro-chemicals and other impurities. • Limited availability for space to store water in greenhouse exploitations; land tenure system with high rental cost hampers toe allocation of arable land for water storage
Cost to implement adaptation technology	The initial cost of storage container is relatively high. It typically depends on construction quality, reservoir size, reservoir type (cement, plastic, earth) and other factors. A large, high quality storage container can be a major investment for poor farmers. The storage capacity of the container needs to meet the demand for water during extended dry periods. Economies of scale for storage are high; the larger the reservoir the lower the price per cubic meter. Reservoir type is also a determinant factor: prices may vary from few dollars for earth excavations to more for cement reservoirs. the storage unit is the most costly element, and usually represents about 90% of the total cost.
Additional cost to implement adaptation technology, compared to “business as usual”	The cost of the storage is the addition if compared to normal road cost. Additional costs include the distribution network and the system maintenance and cleaning. If compared to water pumped from wells, there is no additional cost
Direct benefits	Rainwater harvesting and its application to achieving higher crop yields can encourage farmers to diversify their enterprises, such as increasing production, upgrading their choice of crop, purchasing larger livestock animals or investing in crop improvement inputs such as irrigation infrastructure, fertilizers and pest management. Rainwater harvesting from roof tops or greenhouse tops is convenient because it provides water at the point of use and farmers have full control of their own systems. The technology promotes self-sufficiency and has minimal environmental impact. Running costs are reasonably low. Construction, operation and maintenance are not labor-intensive. Water collected is of acceptable quality for agricultural purposes.
Reduction of vulnerability to climate change, indirect	• Rainwater harvesting contributes to climate change adaptation at the agricultural farm level primarily through: • Diversification of agriculture water supply. • Increased resilience to water quality degradation. • Reducing the pressure on surface and groundwater and sustaining water resources management
Economic benefits, indirect Employment	Creation of jobs to support construction of rainwater harvesting systems and to provide training to users

Growth & Investment, Social benefits, indirect Income	Rainwater harvesting and its application to achieving higher crop yields can encourage farmers to upgrade their enterprises, by up scaling their exploitation, improving and diversifying their choice of crop. Improved health improves school attendance Health: increases per capita water availability. Lack of water can have serious health effects and allow for spread of disease and illness if the reductions continue for even modest lengths of time Education: training elements from capacity building
Environmental benefits, indirect	Promotion of rainwater harvesting will enhance groundwater recharge Rainwater harvesting is one of the most promising alternatives for supplying water in the face of increasing water scarcity and escalating demand. The pressure on water supplies, increased environmental impact from large projects and deteriorating water quality, constrain the ability to meet the demand for freshwater from traditional sources. Rainwater harvesting presents an opportunity for the augmentation of water supplies allowing the same time for self-reliance and sustainability. Rainwater harvesting in urban and rural areas offers several benefits including provision of supplemental water, increasing soil moisture levels for urban greenery, increasing the groundwater table via artificial recharge, mitigating urban flooding and improving the quality of groundwater. In homes and buildings, collected rainwater can be used for irrigation, toilet flushing and laundry. With proper filtration and treatment, harvested rainwater can also be used for showering, bathing, or drinking. The major benefits of rainwater harvesting are summarized below: rainwater is a relatively clean and free source of water rainwater harvesting provides a source of water at the point where it is needed it is owner-operated and managed it is socially acceptable and environmentally responsible it promotes self-sufficiency and conserves water resources rainwater is friendly to landscape plants and gardens it reduces storm water runoff and non-point source pollution it uses simple, flexible technologies that are easy to maintain offers potential cost savings especially with rising water costs provides safe water for human consumption after proper treatment is low running costs Its construction, operation and maintenance are not labor-intensive.
Opportunity and barriers for implementation	Using rainwater harvesting technology therefore offers a real opportunity to increase productivity in regions with low and irregular rainfall, and also in areas where salinity problems are dominant. It is an opportunity to reduce the dependence of polluted waters taken from river downstream and from the lowered groundwater table prone to salinity in summer The cost of rainwater storage systems is often cited as a potential obstacle to wider dissemination of this technology. For poor farmers, some form of financing mechanism, preferable accompanied by a subsidy, will be the only way of promoting rainwater harvesting systems. A lack of national policy towards rainwater harvesting could also present an obstacle to widespread implementation, access to funding and technical assistance. Community-owned systems can suffer from lack of protection, care and maintenance.
Market potential	The technology is small to medium-scale, proven and less capital-intensive. It has market potential
Status	Rainwater systems can be classified according to their reliability, yielding four types of user regimes: • Occasional - water is stored for only a few days in a small container. This is suitable when there is a uniform rainfall pattern with very few days without rain and when a reliable alternative water source is available. • Intermittent - in situations with one long rainy season when all water demands are met by rainwater. During the dry season, water is collected from other sources. • Partial - rainwater is used throughout the year but the 'harvest' is not sufficient for all domestic demands. For example, rainwater is used for drinking and cooking, while for other domestic uses (e.g. bathing and laundry) water from other sources is used. • Full - for the whole year, all water for all domestic purposes comes from rainwater. In such cases, there is usually no alternative water source other than rainwater, and the available water should be well managed, with enough storage

	to bridge the dry period. User regimes to be followed depends on many variables including rainfall quantity and pattern, available surface area and storage capacity, daily consumption rate, number of users, cost and affordability, and the presence of alternative water sources. The storage reservoir is usually the most expensive part of the rainwater harvesting system such that a careful design and construction is needed. The reservoir must be constructed in such a way that it is durable and watertight and the collected water does not become contaminated. All rainwater tank designs should include as a minimum requirement
Timeframe	Immediate implementation (short to medium term).
Acceptability to local stakeholders	Easy to accept for all farmers. However, access to water can be sensitive to national policies and investment priorities.

Sector : Agriculture	
Technology: Seasonal and inter-annual prediction	
Introduction	This technology allows for a forecast of weather conditions for a period of three to six months ahead. Seasonal forecasts are based on existing climate data; in particular, on sea surface temperatures, which are then used in ocean-atmosphere dynamic models, coupled with the synthesis of physically plausible national and international models7. Seasonal forecasts can be developed using mathematical models of the climate system (Alexandrov, 2006).
Technology characteristics	
Institutional and organizational requirements	
Operation and maintenance	
Endorsement by experts	
Adequacy for current climate	
Scale/Size of beneficiaries group	
Advantages	Although knowledge and understanding of the socio-economic circumstances is important and must be taken into account, Meinke and Stone (2005; 221) have demonstrated how knowledge of climatic variability can lead to better decisions in agriculture, regardless of geographical location and socio-economic conditions. Within agricultural systems, this technology can increase preparedness and lead to better social, economic and environmental outcomes. It helps decision making, from tactical crop management options, commodity marketing to policy decisions about future land use (idem). According to their research, and based on a range of temporal and spatial scales, the types of agricultural decisions that could benefit from targeted climate forecasts are listed in Table 4.3. Moreover, SIP is linked to a great variety of practical applications, from security related issues, such as water resource management, food security, and disaster forecasts and prevention; to health planning, agriculture management, energy supply and tourism. It is an important element in some policy/decision making systems and is key to achieving the longer-term goals of climate change adaptation strategy (Troccoli et al, 2007). In Eastern Europe for instance, SIP is taken into consideration for the strengthening of drought preparedness and management, including drought contingency plans, at the local, national, sub-regional and regional levels (Alexandrov, 2006).
Disadvantages	When considering the limitations of this technology, it is worth mentioning that despite important achievements relating to adaptation strategies based on seasonal forecasting systems, significant levels of skill are generally only found in regions strongly connected with the El Niño Southern Oscillation (ENSO) (Arribas et al, 2009). This is a quasi-periodic, inter-annual variation in global atmospheric and oceanic circulation patterns that causes local, seasonal rainfall to vary at many locations throughout the world (Meinke and Stone, 2005; 228). In fact, ENSO forecasting is the main example of seasonal climate prediction which is why there is continuous improvement in the techniques involved. For example, the Met Office in the UK has developed a new seasonal forecasting system (GloSea4)

	that is flexible, easy to upgrade and enables improved forecasting over the El Niño regions.9
Knowledge and monitoring requirements	To use this tool effectively, Meinke and Stone suggest a participatory, cross-disciplinary research approach that brings together institutions (partnerships), disciplines (such as climate science, agricultural systems science, rural sociology, and many other disciplines) and people (scientists, policy makers and direct beneficiaries) as equal partners: "climate science can provide insights into climatic processes, agricultural systems science can translate these insights into management options and rural sociology can help determine the options that are most feasible or desirable from a socio-economic perspective" (2005, 221). The interpretation of the seasonal predictions of climate are not easy for most agricultural technicians and farmers to interpret as they are given as probabilities of positive or negative variations in temperature or precipitation. Although it must be recognized that all such predictions have an uncertainty associated with them, agricultural stakeholders need a lot of assistance as to how to identify the likely seasonal trends. Equally, meteorological services need staff with skills to present the information in a way that the public can interpret and make use of it.
Cost to implement adaptation technology (Costs and Organizational Requirements)	To implement this technology it is necessary to establish a meteorological service with skilled, trained and experienced personnel. This implies high costs if a country or region is starting from scratch, although these costs could be substantially reduced by using offices in public buildings and by partnering with scientific institutes and Global Producing Centers.
Additional cost to implement adaptation technology, compared to "business as usual"	
Direct benefits	
Reduction of vulnerability to climate change, indirect	
Economic benefits, indirect Employment	
Growth & Investment Social benefits, indirect Income	
Environmental benefits, indirect	
Opportunities for implementation	As with most part of technologies applied at a national level, opportunities for implementation can be found where there is strong political will of implementing a national action plan to cope with climate change because of the type of investment required, and where communities work in vertical networks (with government and formal institutions).
Barriers to implementation	Access to forecasting (weather and seasonal) and climate information is common across most adaptation contexts. However, as with other interfaces between communities and experts, it will require investment in appropriate methods of communication and knowledge exchange (Ensor, 2009) such as targeted campaigns to promote the information usage and e-platforms promoted in local communities. Making seasonal forecasting relevant to small-scale farmers and making sure the information reaches them represent the main challenges. For this reason, communication strategies are the key to using this technology effectively. Based on her experience in Lesotho, Ziervogel has pointed out that although seasonal climate forecast information is useful to some farmers, disseminating the information is a challenge. This is because it is often disseminated in English rather than Sesotho and via a press release that does not have the follow-up support that farmers would like. As a result, they are unable to examine the information in greater depth. This hampers discussion between farmers and experts as to what are the information needs and how it might be used (Ziervogel, 2007). Kirshen et al (2003;4) have pointed to some specific communication challenges that need to be taken into account, based on lessons learned from climate change adaptation experience in West Africa: • Distribution: there is not always equitable distribution of the forecasts to different village groups • Measurements: farmers think in terms of crop production, livestock health, and water availability, not rain quantity

	• Concepts: it is important to explain that a forecast is based on probabilities, not certainties and that it covers a specific region or area • Media: most farmers can be reached by traditional media but they might have specific questions that need to be answered directly. The Climate Forecasting for Agricultural Resources (CFAR) project10 has run workshops in which 'key' farmers (i.e. those who interact a lot with other famers) explain forecasts. These farmers then act as intermediaries to spread the forecast to other farmers in their villages.
Market potential	
Status	
Timeframe	
Acceptability to local stakeholders	

Sector : Agriculture	
Technology: Drip and sprinkler irrigation	
Introduction	Efficient water use irrigation systems (EWUIS) integrate different irrigation systems like drip, mini-sprinklers and their variances. This equipment enable more efficient water use when compared to flood or ground irrigation, through minimizing water evaporation and leaching into the group, and by applying water directly to the root area on a timely basis, according to plants need. Therefore, EWUIS do not involve only "hard technologies" or equipment, but also "soft technologies" enabling the monitoring of irrigation according to plant needs and soil condition. Supplementary irrigation for cereals through sprinklers is included within EWUIS. Since plant needs are affected by the type of crop, the vegetation stage and climatic conditions, monitoring irrigation through EWUIS is a mean of adaptation to climate change
Technology characteristics	Drip irrigation involves the delivery of water through a pipe distribution network under particular quantity and low pressure and works by applying water directly to the soil at low flow rates (0.22 to 0.45 GPH). Micro-sprinkler irrigation refers to an irrigation system that applies water through small devices. Water is sprinkled, sprayed, or misted through emitters operating by throwing water through the air, usually in predetermined patterns. Depending on the water throw patterns, the micro-sprinklers are referred to as mini-sprays, micro-sprays, jets, or spinners. The sprinkler heads can be mounted on a support stake or connected to the supply pipe. They operate at low pressure and have a wide range of flow rates (5 to 50 GPH). Both systems require: • A pump which takes water from the source and provides pressure for delivery into the pipe system. Pressure may vary form 2-3 bars (drip) to more than 10 bars. • Filters and eventually a fertilization mixer and a water reservoir • Main pipes and secondary pipes which deliver water from the pump to the laterals • Drip emitters or mini-sprinklers and their variances • Monitoring plant water need through tensiometers or through programs addressing irrigation quantity and frequency provided by technicians
Institutional and organizational requirements	EWUIS is applied at farm level. It usually involves use, management and maintenance by individual farmers. Monitoring irrigation requires capacity building which involves: research institute, extension services (Ministry of Agriculture, NGOs…), cooperatives and farmers groups. Organizational requirements could be needed through water user associations or "water committees" that distributes and ensure the maintenance of the distribution system outside the farm gate, whenever the water source is collective
Operation and maintenance	Operation and maintenance consist primarily of carefully cleaning drippers or tubing or nozzles in order to avoid leakage or plugging. Moreover, building workers capacities is required in order to accurately install the system, manage it and control water flow.

Endorsement by experts	EWUIS is growing worldwide. Drip and mini-sprinkler and their variances are tested on a wide range of crops grown under different climatic conditions and management practices. They are recommended by many experts and researchers around the world
Adequacy for current climate	Fits well, both for present and expected climate change.
Scale/Size of beneficiaries group	• Beneficiaries include fruit tree, vegetable, banana, grapevine and even potato growers, in areas with permanent or seasonal water scarcity. Drip and mini-sprinklers are not fit for cereals (wheat, barley, etc.) and forages. • It is recommended to avoid adopting drip irrigation in areas where there are problems of soil salinity. • Micro sprinklers suit all applications in the irrigation of seedlings and mature trees. They can be used in orchards, greenhouses, nurseries and in areas where drippers are not practical. • Mini-sprinkler system is particularly beneficial to avoid frost damage on crops. • Will be only considered for supplementary irrigation for cereal growers.
Disadvantages	• High initial cost associated with the costs of system components. • Need of energy source for pumping and applying water under the required pressure. • The head unit and water reservoir require a minimum surface area that sometimes is not available in small holdings. • Reliance on a clean source of water and therefore may not be suited to areas where rainfall is becoming less predictable. • In some cases, implementation costs are higher than that of gravity-fed irrigation systems; however the later requires annual land preparation and plowing, which is not necessary in EWUIS. • Drip systems are also exposed to damage by rodents or other animals. • It can be difficult to combine drip irrigation with mechanized production as tractors and other farm machinery that can damage pipes, tubes or emitters; however special adjustments or arrangements could be conceived in such cases. • Implementation of mini-sprinklers is related to climatic conditions, water resources and cost. Even moderate winds can seriously reduce the effectiveness of sprinkler systems by altering the distribution pattern of the water droplets. Likewise, when operating under high temperatures, water can evaporate at a fast rate reducing the effectiveness of the irrigation.
Cost to implement adaptation technology (Costs and Organizational Requirements)	• Initial cost includes the cost of the system including the head unit. This cost depends highly upon the size of the irrigated area, the topography, the specific type of technology, automatic devices, materials used, the quality of irrigation water as well as the amount of labor required. • The cost of installing a drip irrigation system ranges from 1000$ to 2500$/ha. • The cost of a micro-sprinkler irrigation system ranges from 1200$ to 3000$/ha. • Finally, the average life of EWUIS is around 10 years.
Additional cost to implement adaptation technology, compared to "business as usual"	Among the additional costs we mention: cost of designing the irrigation system, the energy (electricity/diesel to pressurize water), cost of the training to farmers on how to use this technology, and cost of monitoring irrigation. Nevertheless, if in ground water irrigation gravity is not enough, pumping would require more energy as more water is used for irrigation. The same figures are observed with sprinkler system. Note that land preparation for surface irrigation requires annually more labor, time and energy costs when compared to EWUIS, which makes the latter much cost-effective.
Direct benefits	• EWUIS enables reducing the cost of the production by reducing the required labor for land preparation and irrigation in surface irrigation. This is currently the major benefit for farmers. • Saving water by improving water delivery efficiency: it is the primary motivator for the implementation of EWUIS, meaning more plant growth for less water. Drip irrigation could reach an overall efficiency of almost 80% compared to surface and sprinkler irrigation having respectively efficiencies around 50% and 70%. • Contributing to food security by increasing crop yields (reduction in fertilizers through injecting fertilizers to the system in a controlled manner "fertigation

	process") and increasing yields of rainfed crops when supplementary irrigation is applied. • Drip system increases resistance to fungal diseases since crop leaves are not watered and reduces of weed growth since the wetted area is limited. • Water savings resulting from EWUIS could be used to increase irrigated areas, thus increase yield and income.
Reduction of vulnerability to climate change, indirect	Avoid over exploitation of water resources, reduce GHG emission through minimal pumping hours from a diesel pump and from fertilizers use. In drip systems, herbicide application is also reduced.
Economic benefits, indirect Employment	Creation of jobs to provide training to farmers and to sell the technology for users; reduce labor needed for surface irrigation. Potential increase in investments in importing or producing locally irrigation systems. Reduce investments in maintaining traditional distribution systems and in weed control through plowing. Reduce investments in maintaining agriculture terraces damaged by flood irrigation. All these factors will improve growth.
Growth & Investment Social benefits, indirect Income	EWUIS can provide significant water, fertilizers, herbicides, energy and labor savings (especially in drip system) and yield increase (especially in supplementary irrigation). The cost of production is reduced and farmers' income is increased.
Environmental benefits, indirect	The improved water quality and the reduction of chemical use minimize soil and groundwater pollution.
Opportunities for implementation	• EWUIS is a versatile technology that can be employed in conjunction with other adaptation measures such as supplemental irrigation and the multi-cropping and fertilizer management as well as conservation agriculture, etc. • Water savings increase the opportunities of better using water reserves for different purposes (domestic, agriculture use, etc.) • Barriers include lack of access to finance for purchasing the equipment, and the procurement of energy source. • A higher amount of initial investment involved than other systems. • Technical conditions such as soil clay presence, irregular rainfall or steep slopes can increase implementation and maintenance costs or affect system efficiency. • The yield of existing crops (fruit trees) irrigated by gravity or another open system can be affected by changing to drip system. • A low level of public awareness for the importance of sustainable water management and use, and the lack of technicians providing monitoring of water needs and irrigation programs to farmers. • Another barrier is the inadequacy of the traditional water committees as well as the periodic distribution system among collective users of a determined water source. Drip irrigation provides optimal benefits when applied on a daily basis. Nevertheless, in the current context some farmers get their water share every 2- 3 weeks.
Market potential	The technology has a market potential nationwide.
Status	The use of this technologies still limited in the country.
Timeframe	Short to medium term.
Acceptability to local stakeholders	Easy to accept for all involved stakeholders. Yet, the adjustment of water shares and their period could be a problem if water users associations are not created and empowered to make the necessary adjustments.

Sector : Agriculture	
Technology: Crop diversification and varieties	
Introduction	The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added

	crops with complementary marketing opportunities. Major driving forces for crop diversification include: • Increasing income on small farm holdings • Withstanding price fluctuation • Mitigating effects of increasing climate variability • Balancing food demand • Improving fodder for livestock animals • Conservation of natural resources • Minimizing environmental pollution • Reducing dependence on off-farm inputs • Depending on crop rotation, decreasing insect pests, diseases and weed problems • • Increasing community food security.
Technology characteristics	New and improved crop species can be introduced though two different processes: • Farmer experimentation with new varieties. Farmers have introduced new and improved species over centuries, mainly in regions that constitute world centers of cultivated crop diversification, such as Meso-America, the Andes, Africa and parts of Asia, in response to environmental stress conditions. There are many thousands of existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions. Agricultural researchers and extension agents can help farmers identify new varieties that may be better adapted to changing climatic conditions, and facilitate farmers to compare these new varieties with those they already produce. In some cases farmers may participate in crossing select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire. • The introduction of new crop species to diversify the crop production systems needs to take into account the following inter-related categories: iii. Availability and quality of resources including irrigation, rainfall and soil fertility. iv. Access to technologies such as seed, fertilizer, water, marketing, storage and processing. v. Household related factors covering food and fodder self-sufficiency requirement as well as investment capacity. vi. Price and market related factors including output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly. vii. Institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies.
Institutional and organizational requirements	In order to support farmer innovation, communities have to be linked to research programmes and should have access to research products. These links might be direct or through intermediary organizations such as NGOs and development organizations. In all cases, these links have to be made explicit and institutionalized. Support for the decentralized selection by farmers of preferred varieties (as well as their production and marketing) should be seen as part of a wider set of interventions to decentralize service delivery to farmers. Institutional recommendations include establishing farmers' committees in order to synchronize diversification on neighboring farms or plots that share common ecosystems. The committee exercises some authority by establishing the most appropriate crop portfolio and can provide a body that supports local farmers to access financing and technical support. Production can also be coordinated in relation to market demand, either staggering to provide a stable supply or coinciding to make a bulk sale. Government policy supporting diversification is key to facilitating access to inputs and technical skills and building national markets and developing links to external markets.
Operation and maintenance	
Endorsement by experts	
Adequacy for current climate	
Scale/Size of beneficiaries group	
Disadvantages	Farmer experimentation using only native varieties can limit the range of benefits and responses that may be found amongst the materials being tested, although local

	adaptation and acceptance are ensured. At the same time, problems can with the introduction of exotic species (from other origin centers) that after being introduced turning into pests. There are several examples of introduced species that have escaped control becoming pests or agricultural weeds (Ojasti, 2001; Hall, 2003). A limitation of crop diversification is that it may be difficult for farmers to achieve a high yield in terms of tons per hectare given that they have a greater range of crops to manage. In terms of commercial farming, access to national and international markets may be limited by a range of factors including government policy including subsidies, the price and supply of inputs, infrastructure for storage and transportation, amongst others. Farmers also face risk from poor economic returns if crops are not selected based on a market assessment. For example, drought tolerant crop varieties may fetch a low market price if there is not sufficient demand.
Knowledge and monitoring requirements	
Cost to implement adaptation technology (Costs and Organizational Requirements)	Costs of farmer experimentation are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties (if not available 'wild' locally) and labor time. Where farmers are implementing a project initiated by an external agency, capital costs for training, technical experts and field staff, on farm trial equipment (an experimental plot may be established), and site visits may also be required. In a project in Mexico, estimated total costs of a five-year project involving around 1,000 farmers came to around $300,000 (Smale et al, 2003). Financial requirements of diversification revolve around the costs involved in researching the species to be planted and training in the management of diversified systems. Preliminary feasibility and market research need also to be considered in the financial requirements. Infrastructure (such as transport and storage) and marketing costs should also be considered.
Additional cost to implement adaptation technology, compared to "business as usual"	
Direct benefits	
Reduction of vulnerability to climate change, indirect	
Economic benefits, indirect Employment	
Growth & Investment Social benefits, indirect Income	
Environmental benefits, indirect	
Opportunities for implementation	Opportunities for new and improved crop varieties arise where attractive native species can be developed for sale on national and international markets. By implementing market development strategies and integrating various actors across and within the input-supply, production, sale/storage, and marketing stages of the value chain the production, profitability and competitiveness of crops can be increased. Opportunities may also arise for innovative partnerships between producers, research institutes and the private sector. The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that local species have low productivity. In the same vein, several communities in developing countries have lost ancient knowledge about resistant species. The main barrier to diversification is market demand which can lead farmers to produce fewer crops or monocultures and to rely on chemical inputs. In turn, this can increase vulnerability of both the agricultural system itself to external factors such as climate change, and also the farmer to price fluctuations.
Barriers to implementation	
Market potential	
Status	
Timeframe	
Acceptability to local stakeholders	

Sector : Agriculture	
Technology: Agro-forestry and Mix cropping	
Introduction	Mixed farming is an agricultural system in which a farmer conducts different agricultural practice together, such as cash crops and livestock. The aim is to increase income through different sources and to complement land and labor demands across the year. Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. The crops can be grown together at the same time, in rotation, or in separate plots when materials from one are used to benefit another. Agro-forestry systems take advantage of trees for many uses: to hold the soil; to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall; and to provide shade, construction materials, foods and fuel. In agro-forestry systems, every part of the land is considered suitable for the cultivation of plants. Perennial, multiple purpose crops that are planted once but yield benefits over a long period of time are given priority. The design of agro-forestry systems prioritizes the beneficial interactions between crops, for example trees can provide shade and reduce wind erosion. According to the World Agro-forestry Centre, "agro-forestry is uniquely suited to address both the need for improved food security and increased resources for energy, as well as the need to sustainably manage agricultural landscapes for the critical ecosystem services they provide24". Agro-forestry is already widely practiced on all continents. Using a 10 per cent tree cover as threshold, agro-forestry is most important in Central America, South America, and South East Asia, but also occupies a large amount of land area in Africa.
Technology characteristics	Mixed farming systems can be classified in many ways. They can be based on land size, type of crops and animals, geographical distribution, market orientation, and so on. Three major categories are distinguished here (FAO, 2001). On-farm versus Between-farm Mixing On-farm mixing refers to mixing on the same farm, and between-farm mixing refers to exchanging resources between different farms. On-farm mixing enables the recycling of resources generated on a single farm. Between-farm mixing can be used to resolve waste disposal problems where by crop farmers use waste from animal farms for fertilizer. Mixing within Crops and/or Animal Systems This practice involves multiple cropping or keeping different types of animals together. For example, grain legume association can provide grain with nitrogen. With plant inter-cropping farmers can make the most of the space available to them by selecting plants and cropping formations that maximize the advantage of light, moisture and soil nutrients. Examples of mixed animal systems include chicken-fish production where chicken waste serves as fish fodder. Diversified versus Integrated Systems In a diversified system some components exist as independent units. In an integrated system, maximum use is made of resources, making the system highly interdependent. There are a broad range of classifications for Agro-forestry systems. These include: structural classification (composition, stratification and dimension of crops); to classification based on the dominance of components (such as agriculture, pasture, and trees); functional (productive, protective or multi-purpose); ecological; and socio-economic. Generally, however, agro-forestry systems can be categorized into three broad types: agro-silviculture (trees with crops), agrisilvipasture (trees with crops and livestock) and silvopastoral (trees with pasture and livestock) systems. Agro-forestry is appropriate for all land types and is especially important for hillside farming where agriculture may lead to rapid loss of soil. The most important trees for incorporating into an agro-forestry system are legumes because of their ability to fix nitrogen and make it available to other plants. Nitrogen improves the fertility and quality

	of the soil and can improve crop growth. Some of the most common uses of trees in agro-forestry systems are: • Alley cropping: growing annual crops between rows of trees • Boundary plantings/living fences: trees planted along boundaries or property lines to mark them well • Multi-strata: including home gardens and agroforests that combine multiple species and are particularly common in humid tropics such as in South East Asia • Scattered farm trees: increasing a number of trees, shrubs or shaded perennial crops (such as coffee and cocoa) scattered among crops or pastures and along farm boundaries. Any crop plant can be used in an agro-forestry system. When selecting crops, the following criteria should be prioritized: • Potential for production • Can be used for animal feed • Already produced in the region, preferably native to the zone • Good nutritional content for human consumption • Protect the soil • A Lack of competition between the trees and crops.
Institutional and organizational requirements	The organizations promoting this technology need to have qualified technicians both in agronomy and livestock production. These organizations must identify the farmers that are familiar with the technique of multiple crops in the area and develop positive relationships with them. The institutional context is essential to natural resource management and agro-forestry. The main categories of institutions with a bearing on agro-forestry are shown in Table 4.20.
Operation and maintenance	
Endorsement by experts	
Adequacy for current climate	
Scale/Size of beneficiaries group	
Disadvantages	One limitation is that production levels in mixed systems (tons per hectare, milk per animal daily, increase and reproduction rates), can be lower than in specialized systems (monoculture) (FAO, 1999). Another disadvantage is that where farmers depend on wild animal stock rather than domesticated species, they may face increased vulnerability in instances where animal population levels are affected due to climate change (for example, where livestock populations need to be trimmed). Partly because of overgrazing, some mixed farming systems of the tropical highlands of Asia and Central Africa are among the most eroded and degraded systems of the world (FAO, 1996). Integrating crops and livestock can help improve soil nutrient and reduce the stress on farming land. Agro-forestry systems require substantial management. Incorporating trees and crops into one system can create competition for space, light water and nutrients and can impede the mechanization of agricultural production. Management is necessary to reduce the competition for resources and maximize the ecological and productive benefits. Yields of cultivated crops can also be smaller than in alternative production systems, however agro-forestry can reduce the risk of harvest failure.
Knowledge and monitoring requirements	
Cost to implement adaptation technology (Costs and Organisational Requirements)	As for most cases, to estimate the costs of implementing this technology the cost of wages, agricultural tools, and inputs (such as seeds and fertilizers) must be considered. Infrastructure for supporting livestock will be an added cost in crop-animal systems. The main financial needs are associated with credits for the acquisition of inputs, investment in training and in the dissemination of this technology. Investment is needed also to obtain the necessary qualitative and quantitative micro-climate information for managing the synchronization of mixed crop cycles (phenologies).

	In Eritrea, a large-scale five-year agro-forestry project led by the Ministry of Agriculture aimed at creating healthy and well-managed forest plantations to withstand the impacts of climate change was presented 149 as part of the country's NAPA strategy. The project had a total cost of just over US$ 5 million, as detailed below:
Additional cost to implement adaptation technology, compared to "business as usual"	
Direct benefits	
Reduction of vulnerability to climate change, indirect	
Economic benefits, indirect Employment	
Growth & Investment Social benefits, indirect Income	
Environmental benefits, indirect	
Opportunities for implementation	The main opportunity for implementing mixed farming is that it improves and guarantees the range of products a farmer has available to sell at market. One option to increase productivity while maintaining economic and environmental benefits of mixed farming is specialization. Partnerships with specialized farms are formed to facilitate the exchange of crops and waste products from manure. For example, the traditional association between nomads and farmers reaping where nomadic cattle converts crop residues into manure for cultivation. More recent developments include partnerships between dairy farmers and vegetable growers. Similarly, in organic farming in Europe between specialized organic farms there is an exchange of secondary products and crop residues for manure (FAO, 1999).The main obstacle for the implementation of this technology is farmers' reluctance since mixed farming is considered to have low productivity in comparison with monocultures which have a high yield in terms of tons per hectare (t/ha). The best way to overcome these barriers is to demonstrate mixed farming systems with better productivity levels; to disseminate the benefits of this technology, and to provide training. Agro-forestry provides an excellent opportunity to promote sustainable forest management while improving income-generating opportunities for local communities. Agro-forestry can provide a more diverse farm economy and stimulate the whole rural economy, leading to more stable farms and communities. Economic risks are reduced when systems produce multiple products. Likewise, this approach prioritizes conservation and rehabilitation measures such as watershed rehabilitation and soil conservation. Key barriers to the practice of agro-forestry are: • Poor access to agro-forestry inputs/resources including land tenure, tree tenure, water, seeds and germplasm, and credit. • Agro-forestry production or management issues relating to knowledge about agro-forestry systems, quality control, storage, processing of products, access to technical outreach services, and upfront costs versus long-term gain • The main benefits of agro-forestry are perceived in the medium term at least five to ten years after establishment, this means that farmers must be prepared to invest in their establishment and management during several years before the main benefits are generated • Marketing of agro-forestry products and services. Lack of access to transport, handling, processing, and marketing infrastructure, bans/restrictions on timber products, over-production, and lack of demand for products.
Barriers to implementation	
Market potential	
Status	
Timeframe	

Acceptability to local stakeholders	

Sector : Agriculture	
Technology: Farmer field schools	
Introduction	The Farmer Field School is a group-based learning process that has been used by a number of governments, NGOs and international agencies originally to promote integrated pest management (IPM). The first FFS were designed and managed by the Food and Agriculture Organization (FAO) in Indonesia in 1989. They were developed in response to perception that small farmers were not managing agrochemical-based agriculture well, particularly pest management through the use of pesticides. Many farmers did not have the resources to use pesticides, and sometimes wrong uses and storage caused the problems of poisoning. Furthermore many pests seemed to rapidly develop resistance to the pesticides. FFSs bring together concepts and methods from agroecology, experimental education and community development, as a group-based learning process. Overall, FFSs look to reinforce the understanding of farmers about the ecological processes that affect the production of their crops and animals, through conducting field learning exercises such as field observations, simple experiments and group analysis. The knowledge gained from these activities enables participants to make their own locally-specific decisions about crop management practices. Although FFSs were initiated as a training process for pest control in field crops, the principles have now been adapted to all agricultural production systems from livestock to coffee production.
Technology characteristics	The FFS approach represents a radical departure from earlier agricultural extension programmes, in which farmers were expected to adopt generalized recommendations that had been formulated by specialists from outside the community. The basic features of a typical rice IPM Farmer Field School are as follows (from Pontius et al, 2002; Bijlmakers, 2005): • The IPM FFS is field-based and lasts for a full cropping season • A FFS meets once a week with a total number of meetings that might range from at least 10 (up to 16) meetings • The primary learning material at a FFS is the cropping field • The FFS meeting place is close to the learning plots, often in a farmer's home and sometimes beneath a tree • FFS educational methods are experiential, participatory, and learner centered • Each FFS meeting includes at least three activities: the agro-ecosystem analysis, a 'special topic', and a group dynamics activity • In every FFS, participants conduct a study comparing plots with different managements • An FFS often includes several additional field studies depending on local field problems • Between 25 and 30 farmers participate in an FFS. Participants learn together in small groups of five to maximize participation • All FFSs include a 'field day' in which farmers make presentations the results of their studies • A pre- and post-test is conducted as part of every FFS for diagnostic purposes and for determining follow-up activities • The facilitators of FFSs undergo intensive season-long residential training to prepare them for organizing and conducting FFS • Preparation meetings precede an FFS to determine needs, recruit participants, and develop a learning contract • Final meetings of the FFS often include planning for follow-up activities. The curriculum of the FFS was built on the assumption that farmers could only implement integrated crop management once they had acquired the ability to carry out their own analysis, make their own decisions and organize their own activities. The process of empowerment, rather than the adoption of specific management techniques, is what produces many of the developmental benefits of the FFS. Climate change brings many complex and unpredictable changes that affect the viability and management of farming systems. Not only are there trends in the change of

	temperature and rainfall, but also increased climate variability especially in the duration and intensity of the seasons. This affects a whole range of conditions relating to the performance and management of different farming systems, from planting time, to flowering, to the prevalence of different pests and diseases. To cope with this increased variability farmers will need a greater understanding of the processes that affect the performance of the different production systems they manage and undergo constant experimentation and adaptation of these production systems. More so even than the agronomic knowledge that farmers acquire from participating in farmer field schools, the habits and abilities of constant adaptation are essential for farmers to be able to cope with climate change.
Institutional and organizational requirements	
Operation and maintenance	
Endorsement by experts	
Adequacy for current climate	
Scale/Size of beneficiaries group	
Disadvantages	Educating farmers through FFS requires more time from both farmers and extension agents than simple technology transfer or technical recommendations. The experimentation conducted may initially generate more failures than successes, but so too have technical recommendations in the contexts of small farmer agriculture. In the medium term farmers participating in FFS leads to more sustainable impacts.
Knowledge and monitoring requirements	
Cost to implement adaptation technology (Costs and Organizational Requirements)	The development of the FFS was through a national IPM programme in Indonesia, which ran between 1989 and 2000, funded by the United States (US$ 25 million grant), World Bank (US$ 37 million loan) and the Indonesia government (US$ 14 million). FAO provided technical assistance to the National IPM Programme through a team of experts based in Indonesia, and on a smaller scale in Bangladesh, Cambodia, China and Nepal. In total, during the 15-year period between 1989 and 2004, approximately US$100 million in grants were allocated to IPM projects in Asia that used the FFS approach under the guidance of FAO. As a result, more than two million farmers across Asia have participated in this type of learning (Bartlet, 2005). The cost of conducting a season-long field school for 25 farmers has ranged from $150 to $1,000 depending on the country and the organization. In some cases, the graduates of FFS have saved $40 per hectare per season by eliminating pesticides without any loss of yield. In other cases, graduates did not experience any savings because they were not previously using any pesticides. However, their yields increased by as much as 25 per cent as a result of adopting other practices learnt during the FFS, such as improved varieties, better water management and enhanced plant nutrition The conceptual and methodological problems associated with assessing the impact of IPM field schools have resulted in disagreements among experts about the advantages of this intervention. One widely circulated paper written by World Bank economists has questioned the benefit of ‘sending farmers back to school’ (Feder, Murgai and Quizon, 2004a and 2004b). By contrast, a meta-analysis of 25 impact studies commissioned by FAO (van den Berg, 2004) concluded that in the majority of studies there were substantial reductions in pesticide use and in a number of cases of increased yield due to training. Furthermore the ‘empowerment’ impacts of the training resulted in widespread and lasting developmental impacts, such as continued learning, increased social and political skills to enable improved agro-ecosystem management.
Additional cost to implement adaptation technology, compared to “business as usual”	
Direct benefits	
Reduction of vulnerability to climate change, indirect	

Economic benefits, indirect Employment	
Growth & Investment Social benefits, indirect Income	
Environmental benefits, indirect	
Opportunities for implementation	Despite arguments among economists and policy makers, there has been widespread enthusiasm for IPM and FFS among farmers and development practitioners in a number of Asian countries. Participation in FFS has always been voluntary. None of the IPM projects and programmes supported by FAO provided financial incentives to participants. On the contrary, participation in FFS has always involved a considerable cost in terms of time and effort. Despite these costs, two million farmers decided to participate. In most countries, the demand for places in an FFS has been ahead of supply, and drop-out rates have been very low. Furthermore, there are many examples of farmers who decided to train other members of their community and continue working as a group after the training came to an end. More information on farmer field schools can be found at the following addresses: Global Farmer Field School Network and Resource Centre: http://www.farmerfieldschool.info/ and www. share4dev.info/ffsnet/documents/3155.pdf. Farmer field schools require substantial changes to the capacity of agricultural extension services, both in terms of the policies of agricultural development and the abilities of those who execute it. Re-training of agricultural extension services both represents an investment, but also resistance at all levels can be a significant impediment. Also since FFS has become a popular concept, there is the danger that the name is used for any kind of group training, but that does not really follow the concepts of building the learning capacity of the participants.
Barriers to implementation	
Market potential	
Status	
Timeframe	
Acceptability to local stakeholders	

Sector : Agriculture	
Technology: Integrated Pest Management	
Introduction	Integrated Pest Management (IPM) sometimes attributed as Ecological Pest Management is a mean to regulate pest infestation and keep it below thresholds causing economical damages through different strategies used into a holistic approach, while providing protection against hazards for plants, humans, animals and the environment. IPM aims at producing healthy crops, by protecting the plants from pest outbreaks through environmentally sound means, which has minimal disturbance to agriculture ecosystems.
Technology characteristics	IPM relies on different components, into which the use of chemical pesticides is the least important. The major alternative components are: - Crop management: i) introducing tolerant/resistant varieties and rootstocks to pest, ii) using diversified cropping pattern including intercropping, long crop rotations and agro-forestry, iii) pruning and burning damaged parts to reduce pest inoculums, - Soil management: i) improving soil fertility through green covers, including legumes in crop rotations, ii) increasing soil organic matter through the application of organic fertilizers, iii) improving soil structure through reducing compacting by minimal tillage… - Pest management: i) releasing beneficiary insects ii) providing habitats and managing field boundaries for the released insects, and to attract other predators such as birds and bats, iii) change planting strategies for better weed control, iv) adopted different techniques to control pests (i.e. a single pest on one crop, several

	pests on the crop, several crops of one exploitation, and several exploitations within a region)… (UNEP RISOE Center, 2011c).
Institutional and organizational requirements	Institutional arrangements are needed to reduce the administrative restrictions and conditions to import some features of IPM (insects, traps…). IPM success relies on collective action which involves farmers' groups, extension services and research institutes. Hence, organization of farmers and communication within the scientific community and establishing links between farmers, extension service and researchers is essential. Continuous capacity building and knowledge transfer are required. Moreover, knowledge of pests, their life cycle, damages, their predators or antagonists, the possibility of integrating different techniques for pest control, the feasibility of pest control are required. Technicians of the extension service should be subject to multi-disciplinary training.
Operation and maintenance	Since IPM is mostly a soft technology and relies on the organizational aspect, operation and maintenance consist mainly on monitoring. Monitoring comprises not only pest population and field conditions but also the quality of the end product (pesticide residues). Besides, other technologies, including early warning systems are required to conduct pest monitoring, and evaluate their risk. Linkage between responsible of weather stations and all the parties mentioned above is necessary.
Endorsement by experts	IPM is worldwide recognized and adopted in most countries. All agriculture experts, including local experts acknowledge this technology.
Adequacy for current climate	IPM has been used under current climate for the past three decades.
Scale/Size of beneficiaries group	Since IPM can be applied to all crops, all farmers are considered as beneficiaries.
Disadvantages	Since IPM requires quite a good organizational frame between different parties, it is not an easy technology to implement. The impact of IPM on a small scale (farm level) depends also from the available means for pest control. In many cases alternatives to chemicals are not developed yet, which obliges the farmer to return to pesticide spraying. Moreover, the adoption of IPM requires sometimes several years to develop a self-regulating control of pest populations, which could break the patience of farmers to pursue it.
Cost to implement adaptation technology	The cost of adaptation varies according to the scale of implementation and on the crop. Most of the cost will be for training the extension service, capacity building for farmers and for the dissemination of the information through different means (seminars, pilot projects, booklets, media
Additional cost to implement adaptation technology, compared to "business as usual"	The additional cost will be the cost of the traps, pheromones, selective pesticides (compared to economic pesticides) and the cost of pest resistant/tolerant varieties compared to ordinary varieties. However, the cost of these items will be counterbalanced by a reduced number of spraying (including the cost of energy and labor).
Direct benefits	Long term cost without adaptation will increase as farmers will face an increase in chemical and in cost of production. IPM fosters farmers to adopt alternative means of pest control, enhancing the self-regulating effect on pest populations, which will decrease the use of chemicals, energy and labor for spraying. IPM relies more on field observation rather on preventive spraying, which augment farmers' resilience and results into a decrease of the cost of production. IPM might sometimes induce a decrease in yield; nevertheless, it is counter balanced by a better quality of the product, and a more constant production along the years. Several experts assume that the cost of production can be reduced by IPM between 15 and 30% depending on the crop.
Reduction of vulnerability to climate change, indirect	IPM is an environmental technology that integrates diversity of crops, conservation of soil fertility, protection of beneficiary insects and predators, and thus increases the resilience of the crops and farmers to climate change.

Economic benefits, indirect Employment	No specific increase or decrease is expected. Growth & Investment — Investment in diversified cropping, monitoring tools, production and release of beneficiary insects, and mostly investments in capacity building and extension.
Growth & Investment Social benefits, indirect Income	Since the cost of production is expected to decrease by 15-30%, and pesticide residues alleviated from exported crops (i.e. apple, citrus, banana, potato, tomato…). The production will be more likely to be exportable and hence increasing income for farmers. Education — Technicians and farmers will benefit from trainings to increase their knowledge in IPM and its benefits. Health — Reduction of health hazards as chemical residues in crops are negligible and farmers are less exposed to spraying.
Environmental benefits, indirect	Reduction in GHG emissions in general, as IPM requires less fossil energy (decrease up to 30%, UNEP RISOE CENTER, 2011C). The environment is preserved as agro-biodiversity is fostered, beneficiary insects are maintained, soil fertility is enhanced and water pollution from pesticides is minimized.
Opportunities and Barriers	IPM is most of all a market opportunity for farmers as it is either pesticide-free (organic) or with minimal traces, which makes the product easier to export into more restrictive international markets. It is also an opportunity to promote organic farming, reduce the imports of chemicals, and increase farmer's knowledge. IPM is an opportunity to link all stakeholders together, promote research and knowledge transfer. The major barrier for the deployment of IPM is not only the absence of funds but the lack of organization and coordination amongst different parties, including farmers themselves. Farmers lack trust in the current extension service within the Ministry of Agriculture and rely more on the service providers which in all cases are reluctant to IPM as it hinders their pesticides sales. There are no facilities for IPM in terms of policies (taxation of pesticides…) and subventions, while farmers tend to adopt the use of pesticides because of their readiness and short term quick effect. Besides, selective pesticides used in IPM have higher prices.
Market potential	Several lots of exported fruits have been lately rejected by the destination countries due to pesticide residues. Products resulting from farms adopting IPM are likely to be much more competitive on the market, because of their quality, especially for export.
Status	Mozambique has been promoting IPM through different projects involving the Ministry of Agriculture and other research institutions. Nevertheless, none of these initiatives has been widely adopted
Timeframe	Short to Medium Term
Acceptability to local stakeholders	Farmers cannot see the real advantage of IPM as it takes time to illustrate its benefits. Moreover, they believe that a sustainable production with higher yields is due to generous spraying of pesticides. Service providers are in many cases indisposed to collaborate due to the expected loss in pesticide sales and due to administrative constraints for the import of beneficiary insects, traps, pheromones or other items required for IPM. Nevertheless, exporters, big farmers (which are key farmers followed by others), the consumers and the Ministry of Agriculture are aware of the necessity of IPM.