Identifying Scalable Sustainable Intensification Pathways for the Rainfed N-deprived Maize-Legume Cropping Systems of Eastern and Southern Africa – The cases of Mozambique and Tanzania

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EXECUTIVE SUMMARY

Global agriculture faces a multitude of challenges in the 21st century, part of which includes meeting the food needs of a growing population, which is projected to reach 9.6 billion by 2050. Climate change, nutrient depletion, the burden of disease and food insecurity are amongst the issues that agriculture must address and contend with. In Africa, where agricultural productivity is already low, increasing agricultural productivity to satisfy the growing demand requires a range of interventions, among them intensification of agricultural production. However, questions have emerged regarding the potential consequences of such production rush to the environment. As a result, in recent years, the focus has shifted towards environmentally friendly intensification such as climate smart agriculture and sustainable intensification (SI). Sustainable intensification refers to a broad scope of agricultural systems which result in an increase in yield without negative environmental effects or expansion of land under agriculture. These systems include legume-maize intercropping systems, which are the focus of light case study presented herein. The overall aim of the study is to identify the key drivers and entry points for SI and the potential for innovation across contrasting farming environments and farm typologies. The current light study focusses on Tanzania and Mozambique which are part of an Australian Centre for International Agriculture Research (ACIAR) funded project – Sustainable Intensification of Maize-legume Cropping Systems in Eastern and Southern Africa (SIMLESA).

Critical success factors for SI vary from the type of production methods selected, the choice of water and soil conservation practices, support to farmers in terms of access to inputs such as fertilizers and seeds, access to extension and other knowledge services, enabling farm and household characteristics. Understanding of these factors within the context of different socio-economic and biophysical environments is essential for the design of agricultural research and development programmes that will promote SI pathways, particularly amongst smallholder farmers.

The study used a mixed methodology that comprised mainly a literature review, coupled with a key stakeholder consultation workshop held in Maputo. Available scientific knowledge and local perceptions of agricultural intensification (AI) and sustainable intensification (SI) that can help define a suitable research agenda and key entry points for SI in the most common cropping systems in both countries, i.e., maize-legume cropping systems, mixed maize-livestock systems and agroforestry systems were gathered from these sources. Analysis of the agro-ecological conditions of Mozambique and Tanzania shows both some similarities and contrasts. Maize-legume systems are common in both countries and the most important systems in
terms of number of explorations under the crops and the share of land dedicated in both countries. However, contrasting legume crops are used as the systems flagship across both countries. In Mozambique for instance, a wide range of legumes are used. Groundnuts, cowpea and common beans are the most commonly grown legumes crops mainly due to their marketability, with pigeon pea gaining some attention in recent years in central and northern Mozambique. In contrast, a well established pigeon pea market in Tanzania has made pigeon pea a reference legume crop in several agro-ecologies where it is currently grown and widely studied.

The literature review shows that there are several socio-economic characteristics that affect the adoption of sustainable agricultural practices in both countries. These included farm household characteristics such as education level, gender, relations with other farmers, type of land tenure systems, household income and land size. In other words, in addition to agro-ecological conditions that the farmers operate in, these factors are primary drivers of whether or not different farmers are likely to adopt maize-legume systems for sustainable intensification of agriculture. Review of the literature also shows that smallholder agricultural households have diverse socio-economic characteristics.

A workshop held in Mozambique with farmer representatives, researchers, universities and local agricultural authorities revealed that there was common understanding on the need for agricultural intensification. This however, does not always translate to sustainable intensification. There is need to unpack according to the perceptions of different stakeholders, including different typologies of farmers, what sustainability means and how the concept can be tailored to fit each typology. It was agreed that the feasibility of SI should take into account the agro-ecological and the diversity of farming systems across typologies. Inclusive innovation and improving human and financial capacity in relevant organisations was considered to be fundamental to the success of SI.

The following key lessons emerged from this light case study:

- Farms are diverse in time and space across both countries and are constantly evolving depending on the farmer resource endowment levels, access to information and support services;
- Single sized technological packages aiming at improving agronomic responses and efficiencies at field level built under the assumption of homogeneous farmer groups are prone to fail;
- Sustainable intensification is a knowledge intensive technology and the ability to downscale it to fit contrasting farm typologies and environments is largely affected by each country's technical capacity to involve all relevant actors in the co-generation of relevant agricultural information that can be used to aid farmer's decision making process;
- Model assisted research is a fundamental tool to be integrated into local research systems and used to timely generate relevant agricultural information to aid decision making;
Actively involving smallholder farmers in the design and testing of locally feasible SI technological innovations is key to help tailor SI to their reality, this can be achieved through personalized agricultural interventions aiming at jointly adjusting SI technological packages to suit each typology development needs. This study recommends using simple and flexible mutually exclusive farm typologies that are reflective of farmers contrasting biophysical and socioeconomic circumstances to co-design SI implementation and adoption profiles that will be the basis to tailor SI to each group needs. In addition, typology tailored agricultural interventions can add value to current farming systems design by providing farmers with the tools they need to improve their systems. Lastly, building better synergies between local actors is also considered fundamental in harmonizing SI concepts and intervention strategies.
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<th>Description</th>
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<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agriculture Research</td>
</tr>
<tr>
<td>AEZ</td>
<td>Agroecological zone</td>
</tr>
<tr>
<td>AGRA</td>
<td>Alliance for Green Revolution in Africa</td>
</tr>
<tr>
<td>AI</td>
<td>Agricultural Intensification</td>
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<tr>
<td>BAGC</td>
<td>Beira Agricultural Growth Corridors</td>
</tr>
<tr>
<td>CA</td>
<td>Conservation Agriculture</td>
</tr>
<tr>
<td>CIMMYT</td>
<td>International Maize and Wheat Improvement Centre</td>
</tr>
<tr>
<td>EI</td>
<td>Ecological Intensification</td>
</tr>
<tr>
<td>FCT</td>
<td>Foundation for the Science and Technology</td>
</tr>
<tr>
<td>GAP</td>
<td>Global Agricultural Productivity</td>
</tr>
<tr>
<td>IIAM</td>
<td>Institute of Agricultural Research of Mozambique</td>
</tr>
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<td>International Rice Research Institute</td>
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<tr>
<td>ISFM</td>
<td>Integrated Soil Fertility Management</td>
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<td>LEIA</td>
<td>Low External Input Agricultural systems</td>
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<tr>
<td>NAGC, Nacala</td>
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<td>SA</td>
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<td>Sustainable Intensification</td>
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<tr>
<td>SIMLESASA</td>
<td>Sustainable Intensification of Maize-legume Cropping Systems in Eastern and Southern Africa.</td>
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<td>SKAN</td>
<td>Sharing Knowledge Agrifood Networks</td>
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<td>SSA</td>
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CHAPTER 1: INTRODUCTION

The global challenge for agriculture by 2050, is to sustainably produce enough food to meet the nutritional requirements of up to 9.6 billion people at affordable prices (GHI, 2014). A key solution towards addressing this challenge lies in interventions for increasing agricultural productivity in all regions of the world. In addition to the challenge for increasing food production, agriculture must contend with the effects of and on climate change, and the increasing burden of diseases. Whilst some regions such as Latin America and South East Asia are predicted to register high levels of food production by 2050, agricultural productivity in Africa lags behind most of the regions in the world. According to the Global Agricultural Productivity (GAP) report, at the current levels of total factor productivity rates, Sub-Saharan Africa (SSA) will only be able to meet 14% of its food requirements in 2050, whereas Asia and South East Asia will be able to meet up to 78% of their food demand. There is no doubt that increasing agricultural productivity is a key priority across all regions. Nevertheless, particularly in Africa the problem of low agricultural productivity is further compounded by climate change, and nutrient depletion in the rainfed Low External Input Agricultural systems (LEIA) practiced mainly by poor resource farmers. In the systems, increasing agricultural productivity to satisfy the growing demand requires a range of interventions, among them the intensification of agricultural production which include the adoption of conservation practices and optimizing resource productivity.

In Africa, where yields and input use are the lowest in the world, several approaches to increase soil fertility and yields have been tested over the years across Africa, among them Integrated Nutrient Management (Bationo and Waswa, 2011) and conservation agriculture (Thierfelder et al., 2013; Wall, 2007). Nevertheless, there is consensus that more needs to be done. Agricultural intensification, i.e., increasing production per unit production factor is seen as key to improve food security and income prospects especially among resource poor farmers. However, questions have emerged regarding the potential consequences of such production rush to the environment. As a result in the recent years, several approaches for an environmentally friendly intensification process have been theorized and are being tested worldwide, e.g., climate smart agriculture (Arslan et al., 2015; Lipper et al., 2014), sustainable intensification (SI) (Petersen and Snapp, 2015; Zimmerer et al., 2015) and ecological intensification (EI) (Tittonell, 2014).

In recent years, the need to sustainably intensify agricultural production to feed a growing world population has been on top of the agenda for most agricultural development practitioners (Petersen and Snapp, 2015; Zimmerer et al., 2015). For the particular case of Africa, where the highest population growth by 2050 has been projected and almost 80% of the population lives in rural areas practicing
agriculture as their main socioeconomic activity (Mellor, 2014), validating SI is critical to secure long term food security prospects among resource poor smallholder farmers. The diversity of SSA farming environments and heterogeneity across farmer groups makes it almost impossible to promote single sized technological packages. Therefore, like several other technological packages promoted to date, e.g., conservation agriculture (CA), identifying scalable options to downscale sustainable intensification into locally feasible practices that fit smallholder farmers biophysical and socioeconomic circumstances is critical to successfully engage all relevant stakeholders in the co-design of feasible intensification pathways. In this report, we critically reviewed key entry points for SI in the rainfed maize-legume cropping systems of Mozambique and Tanzania. This was carried out under the preposition that identifying the key entry points to effectively downscale SI into locally feasible and pragmatic measures fitting resource poor smallholder farmer’s circumstances is a critical step towards adoption.

1.1 Problem statement

Sustainable intensification (SI) refers to a broad scope of agricultural systems which result in an increase in yield without negative environmental effects or expansion of land under agriculture. The concept encompasses a broad range of methods of agricultural production and technologies, and emphasizes ends rather than means (Pretty and Bharucha, 2014). Although, the concept of sustainable intensification is contested due to the observation that in most cases where yield increases have been achieved, this has come at a cost to the environment (Pretty and Bhaurucha, 2014), win-win outcomes have also been observed as a result of agricultural practices that increase yields and promote environmental conservation (SIMLESa, 2016). Sustainable intensification in the context of smallholder agriculture, has potential to increase food and nutrition security, household incomes and alleviate rural poverty (SIMLESa, 2016; Vanlauwe et al., 2014).

Critical success factors for SI vary from the type of production methods that are selected, water and soil conservation practices choice, support to farmers in terms of access to inputs such as fertilizer and seed, access to extension and other knowledge services, enabling farm and household characteristics. Understanding of these factors within the context of different socioeconomic and biophysical environments is essential for the design of agricultural research and development programmes that will promote SI pathways, particularly amongst smallholder farmers. Amongst the most used sustainable intensification methods in Africa are maize-legume cropping systems. These cropping systems are practiced in a wide variety of contexts, and their adoption and success varies across time and space (SIMLESa, 2016; Knowler and Bradshaw, 2007). Smallholder farming systems are heterogeneous in terms of local agro-ecological conditions, farm household characteristics and resource endowments, the
institutional setting they operate in, as well as the decisions made in terms of crop choice and cropping patterns (Vanlauwe et al., 2014). Understanding of this heterogeneity of smallholder agricultural sector and the impacts that it has on farmer adoption of sustainable intensification agricultural technologies is important to enable upscaling of agricultural research and development outputs and to facilitate the increased adoption of sustainable intensification for food and nutrition security and poverty alleviation in Sub-Saharan Africa.

Over the years several initiatives have been implemented by various local and international agencies. Amongst the initiatives is the Sustainable Intensification of Maize-legume Cropping Systems in Eastern and Southern Africa (SIMLESA), an initiative of the Australian Centre for International Agricultural Research (ACIAR), managed by the International Maize and Wheat Improvement Centre (CIMMYT). Analysing the experience of SIMLESA and other related initiatives provides a case study for understanding the drivers of SI and potential for innovation across a heterogeneous smallholder agricultural landscape in Sub-Saharan Africa.

1.2 Objectives

The overall aim of the study is to identify the key drivers and entry points for SI and the potential for innovation across contrasting farming environments and farm typologies. This was achieved through the following objectives:

- Analysing how the agroecological diversity and socioeconomic circumstances affects local farming systems design and the adoption of SI technologies;
- Understanding how existing perceptions of SI across key stakeholder groups is hindering or can help stimulate SI adoption;
- Identifying the key entry points for the implementation of SI technologies among poor resource smallholder farmers engaged in the rainfed maize-legume systems.
CHAPTER 2 – STUDY AREA DESCRIPTION

The current light case study focus on Mozambique and Tanzania (Table I), which are together with Ethiopia, Kenya and Malawi, part of the Australian Centre for International Agriculture Research (ACIAR) funded project – Sustainable Intensification of Maize-legume Cropping Systems in Eastern and Southern Africa (SIMLESA). SIMLESA is commissioned to the CIMMYT Southern Africa Office who implements it through partnerships with the National Agricultural Research Systems (NARS) of the target countries.

Table 1. Key characteristics of sampled countries. Apart from being SIMLESA target countries, key selection criteria included, region, language group, land pressure level and rain seasons.

<table>
<thead>
<tr>
<th>Selection criteria</th>
<th>Mozambique</th>
<th>Tanzania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Southern</td>
<td>Eastern</td>
</tr>
<tr>
<td>Rain seasons</td>
<td>One (Uni-modal)</td>
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<td>Language group</td>
<td>Lusophone</td>
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<td>Target cropping systems</td>
<td>Maize-legume *livestock integration and agroforestry in highlands of central Mozambique</td>
<td>Maize-legume</td>
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<tr>
<td>Land pressure level</td>
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<td>Farming environments</td>
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<td>Farming groups</td>
<td>Smallholder farmers grouped across resource endowment categories</td>
<td>Smallholder farmers grouped across resource endowment categories</td>
</tr>
<tr>
<td>Market structure</td>
<td>Unstructured</td>
<td>Semi-structured</td>
</tr>
</tbody>
</table>

In its first phase (2010-2014) SIMLESA covered a total of 5 countries across Eastern and Southern Africa. A second phase of SIMLESA that runs from 2014-2018 (SIMLESA Phase 2) is already underway and, besides phase one countries, also includes Botswana, Rwanda and Uganda as spill over countries. Apart from SIMLESA, Mozambique and Tanzania have, over the last 10 years, been part of Portfolio 1 investment countries for the Alliance for Green Revolution in Africa (AGRA), having received over 40 million dollars each for agricultural intervention across the countries major breadbasket. Both SIMLESA and AGRA intervention have focused on the intensification of maize-legume cropping systems through Conservation Agriculture (CA) and Integrated Soil Fertility Management (ISFM) platforms. Therefore,
both countries are key to generate information that can help advance the state of knowledge on SI and define a relevant research agenda for the future. Because SI needs to be tailored to fit local agroecological conditions, a comparative analysis of two contrasting agroecologies – dry and wet environment – will be performed.

2.1 Data collection approach

The study used a mixed methodology that comprised mainly a literature review, coupled with a key stakeholder's consultation workshop held in Maputo. Available scientific knowledge and local perceptions on agricultural intensification (Al) and sustainable intensification (SI) was gathered from these sources. These can contribute to define a suitable research agenda and key entry points for (SI) in the most common cropping systems, i.e., maize-legume cropping systems, mixed maize-livestock systems and agroforestry systems, for both countries.

The stakeholder meeting was organised in Maputo in April, 2016. In this meeting, key stakeholders – farmer representatives, researchers, universities, local agricultural authorities and development agencies, were involved in a one-day workshop aiming at gathering information to help understand current perceptions, challenges and opportunities to sustainably intensify agricultural. 

The literature study focussed on the analysis of peer reviewed and grey literature over the last 10-20 years on agricultural induced socioeconomic transformation and the identification of key entry points for SI, as well as in the potential traps for its successful promotion-adoption in both countries and across SSA. It is worthy to emphasize that SSA agriculture is highly diverse and complex, mostly practiced in contrasting farming environments and farmers of contrasting levels of resource endowment which affect their livelihood strategies and overall farming design and management. To account for the biophysical and socioeconomic diversity, this study also reviewed how the internal farm household dynamics, across typologies would help identify specific intensification pathways. Here, crossing agronomical, biophysical and socioeconomic information was believed to be critical for understanding how each group reacts to shocks and what changes are required to sustainably intensify agriculture across these groups and regions.
CHAPTER 3 - RESEARCH FINDINGS

3.1 Mozambican agroecological diversity and production potential

3.1.1 Agroecological diversity

Mozambique has 801 thousand square kilometers and a total cultivated area of approximately 3.2 million hectares distributed across 3.6 million farms (INE, 2011): small scale farmers, medium and large scale commercial farmers (Table II). The major difference between these three groups lays on average size of the cultivated land, labour type, and production means available to carry on farm activities, e.g. land preparation and crop management activities, access to credit and the final objective of their production. The country has a vast mosaic of agroecological zones, 10 in total (Figure 1-left). This makes agriculture a highly complex and diverse activity since the existing edaphic and climatic gradients shape farming systems design and management strategies within and across regions. Mozambican agroecological zones are distributed across five altitude zones, as proposed by Gouveia and Azevedo (1954). However, these altitudes are grouped into three main zones – low, medium and high altitude as described below:

1. **The low altitude zone which ranges from 0-500 m**:
   a. The low zone, from 0 to 200 m, occupying over 40 % of the area of Mozambique, with more or less smooth plains and gently undulating areas predominating. These zones are mainly located in Southern Mozambique (R1, R2, R3) spreading across Maputo, Gaza and Inhambane provinces;
   b. The sub-planaltic and low-planaltic zone of central Mozambique, with an elevation ranging from 200 to 500 m, comprising nearly 30 % of the total area, transitional to the following so-called plateau zones. This includes part of the R4, R5 and R6 in Manica, Sofala and Tete provinces;

2. **Medium altitude zone: 500-1000 m** covering about 1/4 of the territory and its found across R4, R5, R6, R7, R8 in Manica, Tete, Zambezia, Nampula and Niassa and Cabo Delgado:
   a. The median-planaltic zones, elevation ranging from 500 to 1000 m, undulating to moderately rolling country

3. **High altitude zones: above 1000 m** covering a very small area, 4 % and 0.2 %, respectively:
   a. High planaltic zone, elevation ranging from 1000 to 1500 m, rolling to moderately steep, and mountainous zone of Manica (R10), Tete (R10), Niassa (R10), Zambezia-Nampula (R10),
b. Mountainous and hilly country side, with heights above 1500 m in Cabo Delgado (R9) province.

The annual rainfall ranges from 272.2 mm in the semi-arid plains of southern Mozambique to more than 2000 mm in the highland of central and Northern Mozambique. Two well defined seasons can be found in Mozambique. The wet and rainy season which runs from November to March-April where almost 78-99% of the total rainfall falling during this period. Finally, there is the dry season from April to October. The rainfall distribution patterns influence Mozambique’s agricultural production potential. Central and North Mozambique median-planaltic and high altitude zones, host most of the highly productive agroecological regions of the country with an expected production potential of more than 5.0 ton/ha for maize in almost 70% of the region and 3.0 ton/ha for soybeans distributed across the Beira (BAGC) and Nacala Agricultural Growth Corridors (NAGC) respectively (Figure 1 - Right). Nevertheless, the average maize yields are around 1.2 ton/ha for maize and less than 0.5 ton/ha for most legume crops (FAOSTAT, 2014).
<table>
<thead>
<tr>
<th>Altitude</th>
<th>Description</th>
<th>AEZ</th>
<th>Farming Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low altitude</strong></td>
<td>In land semi-arid zone in Maputo province</td>
<td>R1</td>
<td>Dry land maize and pastoralism</td>
</tr>
<tr>
<td></td>
<td>Semi-arid littoral in South Mozambique, Inhambane and Maputo Province</td>
<td>R2</td>
<td>Dry land maize-legume based systems. Coconut based systems in the cost intercropped with groundnuts and cassava</td>
</tr>
<tr>
<td></td>
<td>Arid and semi-arid parts of in land Gaza, North Maputo and Inhambane province</td>
<td>R3</td>
<td>Dry land maize, lowland irrigated rice and maize systems (Chókwê) with commercial vegetables; cotton based systems; crop-livestock systems</td>
</tr>
<tr>
<td></td>
<td>Covers almost 80% of Manica province and part of Sofala in central Mozambique</td>
<td>R4</td>
<td>Maize-legume with Banana based systems in the highlands of Manica</td>
</tr>
<tr>
<td></td>
<td>Coastal area of central Mozambique covering Sofala and Zambezia province</td>
<td>R5</td>
<td>Maize-legume, rice based systems and commercial sugar cane</td>
</tr>
<tr>
<td></td>
<td>Semi-arid region of Southern Tete and northern Manica and Zambezia</td>
<td>R6</td>
<td>Livestock dominated systems with dryland maize, sorghum</td>
</tr>
<tr>
<td></td>
<td>The largest agroecological region, covering 5 provinces in Central and Northern Mozambique, namely Zambezia, Nampula, Tete, Niassa and Cabo Delgado</td>
<td>R7</td>
<td>Maize-legumes and cassava-legume systems; Cotton and tobacco based systems. Groundnuts, beans, pigeon pea and cassava are important legume crops</td>
</tr>
<tr>
<td><strong>Medium altitude</strong></td>
<td>Northern Mozambique litoral covers Zambezia, Nampula and Cabo delgado</td>
<td>R8</td>
<td>Coconuts based systems</td>
</tr>
<tr>
<td></td>
<td>Highlands of Cabo Delgado – planalto de Mueda</td>
<td>R9</td>
<td>Maize, sorghum, Cowpea and cassava based systems</td>
</tr>
<tr>
<td></td>
<td>Manica, Tete, Zambezia and Niassa highlands</td>
<td>R10</td>
<td>Maize-legume systems, small patches of wheat in Rotanda, and commercial vegetable gardens</td>
</tr>
</tbody>
</table>
Figure 1 Mozambique agroecological zones map (left) and expected production potential of different crops (right) (Fato et al., 2011; Reddy, 1984)
3.1.2 Cropping systems and farming environments

Maize is the main food crop occupying approximately 1.43 million hectares, i.e., 44.3% of the total share of cultivated land. Tete, Manica and Zambezia province in Central Mozambique have together the largest area dedicated to maize (INE, 2011). Sorghum and millet despite being highly adapted to the dry semi-arid areas of South, occupy less than 15% of the total cultivated land, most of it in smallholder farming systems. Small scale explorations, which occupy 99.3% (INE, 2011) of the total cultivated land, are responsible for the vast majority of commercialized grain. Cassava (32.2%) and sweet potatoes (26.7%) are the second most grown and consumed crops, especially in Zambezia and Nampula provinces. Here cassava is an important maize substitute, therefore, occupying considerably more land than maize in smallholder farm explorations. Legume crops, occupy approximately 36% of the Mozambique total cultivated land. Peanuts primarily grown for oil extraction, followed by cowpea and pigeon pea are the most grown legume crops. Common beans and bambara groundnuts are less expressive crops, with beans grown mainly as cash crop in central and northern Mozambique highlands. Legumes are grown both as food and cash crops. Across central and northern Mozambique, tobacco and cotton based systems are also common cash crops. In banana based systems, bananas are common cash crops in central and northern Mozambique medium to high altitudes of Manica and Nampula provinces. In South, the in land dryland areas of Mozambique, mainly Gaza and Inhambane, cashew based systems are common. In the coastal regions of Inhambane and Zambezia provinces, coconuts based systems are a common income source for smallholder farmers. Nevertheless, coconuts production has decreased considerably in the last years due to coconut lethal yellowing (Bila et al., 2015).

Main cropping systems:

a) Livestock dominated systems in the semi-arid and arid areas of southern Mozambique and south of Tete province.

b) Maize legume cropping systems are the most dominant cropping systems in Mozambique, spreading across all agroecologies. In this system, maize and legumes are grown mainly as a staple food crops and also commercially. Maize and legumes are mainly grown as intercrops. Sole crops are mainly used when both are planted for commercial purpose to maximize yields and income. In the central and northern provinces on Zambezia and Nampula, maize is substituted by cassava dominated systems. Mixed crop-livestock systems can also be found in certain areas of central and northern Mozambique. In these systems, traditional races have been slowly substituted by dairy cows making an additional source of income for smallholder farmers.

c) Banana based systems can be found mainly in the high lands of central and northern Mozambique. Here bananas are mainly grown as cash crops for most smallholder farmers.
d) Cotton based systems

e) Coconuts and cashew based systems

3.2 Tanzanian agroecological diversity and production potential

3.2.1 Agroecological diversity

Tanzania has a mainland area of 881 thousand square kilometres. It is characterized by a Tropical climate with temperatures determined by altitude (Figure 2). According to data from the World Bank Tanzanian agriculture country study report (WorldBank, 1994), altitudes range from less than 750 to 1500 m above sea level from the coastal plains to the inland plateaux which accounts for three-fifths of the countries land. The climates in these regions are warmer with mean average temperatures around 24 degrees Celsius. Accounting for less than one-fifth of Tanzania mainland, there are the highland areas with altitudes ranging between 1500 to 2300 m. The highlands are characterized by a moderately cool climate with average temperatures around 17 degrees Celsius.

Agriculture is mainly rain fed with minimal irrigation infrastructure. The growing season is mainly influenced by contrasting moisture regimes between the North and South regions (Table III). In northern Tanzania, two main growing seasons are possible due to bimodal rains. Here, the short season runs from October to January and the long rainy season runs from March to June. In the South a single growing season – unimodal rains run from November to June. Rainfall patterns are highly diverse and influenced by altitude. Characteristically unreliable rainfall ranging from 400-600 mm/year can be found in unimodal rain seasons in the South arid and semi-arid low to medium altitude regions in AEZ-I and AEZ-II. In part of the North arid and semi-arid medium to high altitude regions (AEZ-II and AEZ-III), unimodal rains of 500-800 mm/year also occur. In contrast, the highlands have more reliable rains ranging from 800-1500 mm/year distributed across the western (AEZ-IV, 800-1500m, Unimodal), southern (AEZ-V, 800-1000, 800-1400m) and 900-1300m in the alluvial plains, AEZ-VII. Bimodal rains are mostly found in the western (AEZ-IV) and northern highlands (AEZ-VI), and also across the granitic mountains (AEZ-VI). Here, very reliable rains of 1000-2000 mm/years occur.
<table>
<thead>
<tr>
<th>Altitude</th>
<th>Zone</th>
<th>Description</th>
<th>AEZ</th>
<th>Farming Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Coastal Zone</td>
<td>Low altitude plains (&lt;750m) on marine secondary and tertiary sediments</td>
<td>I</td>
<td>Cassava-cashew-coconuts</td>
</tr>
<tr>
<td></td>
<td>Inland Sediment</td>
<td>Medium altitude Plains (750 - 1,000m) on Karoo sediments</td>
<td>VII</td>
<td>Wetland paddy and sugarcane</td>
</tr>
<tr>
<td></td>
<td>Rukwa-Rusha Rift</td>
<td>Rift depression (800 - 1,200m) with lake sediment</td>
<td>VII</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Central Plateaux</td>
<td>Medium alt. plains (1,000 -1,300m) on granite</td>
<td>IV</td>
<td>Crop-livestock</td>
</tr>
<tr>
<td>altitude</td>
<td>Eastern Plateaux and mountain blocks</td>
<td>Medium altitude plains (1300-1,500m) on Precambrian metamorphic rocks</td>
<td>II and III</td>
<td>Pastoral and Crop-livestock</td>
</tr>
<tr>
<td></td>
<td>Northern Rift and Volcanic Highlands</td>
<td>Medium to high altitude plains (1,000 - 2,300m), with volcanic and rift landforms</td>
<td>VI</td>
<td>Wetland rice-sugarcane</td>
</tr>
<tr>
<td>High</td>
<td>Western Highlands</td>
<td>Medium to high altitude plain (1,200 - 1,900m) on volcanic or sedimentary rock</td>
<td>V</td>
<td>Maize-legumes Banana-coffee Crop-livestock Agroforestry</td>
</tr>
<tr>
<td>altitude</td>
<td>Southern Highlands</td>
<td>High altitude plateaux</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ufipa Plateau</td>
<td>High altitude (1,500 - 2,200m) on metamorphic and sedimentary rock</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

*Table III. Tanzania’s agroecological zones and farming systems. Adapted from: Puaw (1984); Wickama et al. (2014) & WorldBank (1994)*
Figure 2 Tanzania Land resource zones. ISRIC, Digital Soil Library, Wageningen
3.2.2 Cropping Systems and farming environments

Cropping systems in Tanzania are highly influenced by altitude and contrasting edaphic-climatic conditions across agroecologies (Table IV). Maize-legume cropping systems, were by 1994 practiced by 1.3 million households, occupying approximately 35.7% of the total share of cropping land (World Bank, 1994). In this system, maize and legumes are cultivated mostly by smallholder farmers for both food and income. Most of the maize and grain legume available in local cereal market comes from these systems (Savini et al., 2016). Nevertheless, these systems also include cash crops such as tobacco, banana and coffee in the medium to high altitude environments and cotton mostly in the semi-arid low to medium altitude zone. Cassava-cashew-coconut systems mainly practice across the coastal line accounted for 21%. The high share for cashew based systems in coastal area was a direct result of the 1960’s government stimulus to the cashew industry which was the country main export crop up until the decline of the sector in the 1980’s (Damiani, 1972). The decline of the cashew subsector, sow banana-coffee based systems – previously with 16.6% share of the total cultivated land become one the most important source of income for smallholder and commercial farmers (World Bank, 1994) across the high rainfall environments.

In the semi-arid areas of Tanzania (AEZ-I, II and III), continuous dry land maize systems with traditional bush fallows had been the major cropping systems (Hatibu et al., 2003; Nyadzi et al., 2006). However, in recent years, the growing concern over decreasing soil fertility and yields in these continuous maize systems have led to changes in the local farming systems. Continuous dry land maize systems have systematically been substituted by maize-legume cropping systems and rotational woodlots in agroforestry systems (Table IV). In the low rainfall semi-arid regions, maize is the main staple food crop. Millet and sorghum despite being important they less preferred than maize (Hatibu et al., 2003), despite being considerable more drought tolerant than maize and would offer a better yield responses under the increasingly erratic rainfall patterns. Legume crops, mainly pigeon pea and beans are an important part of local diets but also a key income source for smallholder farmers.

In the high rainfall agroecological zones, which spread across the Tanzanian highlands, farming systems are more diverse, integrating banana, coffee, annual crops and cattle grazing, i.e., integrated crop-livestock-orchard systems. According to Baijukya et al. (2005) three farming systems are characteristic of these zones, namely 1) banana-coffee based systems\(^1\) - these systems are mainly grown in home gardens (Kibanja) of the densely populated highland areas in the AEZ-V and AEZ-VI; 2) the annual crop cultivation areas (Kikamba) dominated by maize-legume systems where pigeon pea, beans, maize and in some cases cassava are the main crops. The systems are mainly found in

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\(^1\) Changed to mixed cropping of banana/coffee/beans/maize and root crops with maize, and root crops in pure stands area has increased in detriment of sorghum and millet whose cultivation was stopped. High dairy cattle introduced in substitution of indigenous cattle.
areas of medium to high agricultural potential, i.e., Western Plateaux (AEZ-IV) and Southern Highlands (AEZ-V).

**Table IV** Tanzania’s main crops and cropping systems of high and low rainfall agroecological zones. For cropping systems description, agroecological zones are grouped based on rainfall patterns, i.e., high and low rainfall.

<table>
<thead>
<tr>
<th>Agroecological zone</th>
<th>Cropping systems description – crops and sequences</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semi-arid and arid zone - Low rainfall</strong></td>
<td>1. Dry land maize systems with traditional bush fallow and continuous maize systems</td>
<td>Hatibu et al. (2003)</td>
</tr>
<tr>
<td><strong>Massai Steppe agroecological Zone</strong> (Southern Kilimanjaro in western Pare lowland in north-eastern Tanzania)</td>
<td>2. Maize-legumes systems: pigeon pea intercrops and relay cropping to diversify food and income</td>
<td>Kimaro et al. (2009)</td>
</tr>
<tr>
<td>- Reddish sandy clay soils (SaC) – Rhodic Lixisol, of low fertility formed on a basement complex</td>
<td>3. Rotational woodlot systems in agro-forestry systems with tree fallows</td>
<td>Kimaro et al. (2008)</td>
</tr>
<tr>
<td>- Unimodal and Bimodal rainfall. The short rains (<em>Vuli</em>) from October to January. The long rainy season (<em>Masika</em>), lasts from February to May.</td>
<td>4. Pastoralism</td>
<td></td>
</tr>
<tr>
<td><strong>Humid highland - High rainfall agroecological zone</strong></td>
<td>1. Banana and coffee based systems</td>
<td>Baijukya et al. (2005)</td>
</tr>
<tr>
<td>Extends across the Kyamtware division, the West Usambara highlands in north eastern Tanzania rising from 1500 - 2300m above sea level.</td>
<td>2. Integrated crop – hood/fruit - livestock systems.</td>
<td>Mulie et al. (2015)</td>
</tr>
<tr>
<td>- Deep soils (&gt;1m depth), Alumihumic Ferralsols in Kyamtware division to Humic, Haplic and Chromic Acrisols. Luvisols and Lixisol for most mountainous upland in Lushoto District and fluviols with pockets of Gleysol are most frequent in the bottom of the valleys</td>
<td>3. Banana-beans and banana-maize intercrops</td>
<td>Wickama et al. (2014)</td>
</tr>
<tr>
<td>- Bimodal rainfall pattern with mean annual rainfall of 2000 mm. Short rains last from October to late December and account for 25% of total annual rainfall. Long rains are from mid-March to end of June</td>
<td>4. Maize-legume systems</td>
<td></td>
</tr>
</tbody>
</table>

2 Surrounding plains, have altitudes around 600 m
Finally, there are the pastoral and crop-livestock systems practiced mainly across the grasslands (Rweya) which serve mostly for communal grazing. In the Rweya bambara nuts, cassava and yams are cultivated under shifting cultivation. Tea is also cultivated in the Rweya, mainly as a supplementary cash crop. Nevertheless, like in other East African highlands, bananas are an important cash food and crop for smallholders in the Tanzanian highlands (Wickama et al., 2014). Coffee, despite being also grown in the Kibanja, it is mostly grown in large commercial farms, with surrounding smallholder farmers working as paid labour.

3.3 Farm characteristics in Tanzania and Mozambique—size and socioeconomic profile

In terms of farm categorization, small scale farms dominate the agricultural sector in both countries. For the specific case of Mozambique, farmers are grouped in three major categories: small-scale (0-5ha), semi-commercial (5-20ha) and large scale commercial farmers (>20ha). These typologies emerged in late 1960-1970s right after the independence, with Mozambique mainly copying from the Tanzanian experience, which for long was the model of Mozambique’s agricultural planning. The parastatal companies back in the mid 1970’s to late 1980’s and the export tailored crops – cashew nuts and cotton – implemented in the early post-independence years are examples of that influence. In both countries, small-scale farmers are the major contributors to the country food provision. In Mozambique for instance, small scale farms represent 99.3% of the agricultural explorations occupying 96.4% of the total cultivated land (INE, 2011). Nevertheless, the Mozambican and Tanzanian farm categorization like many in SSA are somehow a rigid version of the proposed by Dorward et al. (2009) where poor resource small holder farmers would fall within the “hanging in” subsistence farming households. However, several structural changes have occurred since the 1970’s e.g., the bankruptcy of most state-owned agricultural enterprises in the 1980s and the markets’ liberalisation in the 1990s. All these structural changes, forced the farm enterprise to evolve in order to adapt to the new context. Farms became more diverse and the asymmetries between groups increased. Here, farmer’s resource endowment levels, livelihood strategies, management capabilities and the ability to manage their farms in order to meet the household food security and income generation goals become highly diverse across groups (Cunguara and Darnhofer, 2011). All these structural changes call for a renewed look into how the “whole farm enterprise” operates in the increasingly dynamic and diverse farming circumstances. Understanding this would help making agricultural intervention more reflective of farmer circumstances and needs.
CHAPTER 4 – SYNTHESIS

4.1 Emerging issues and entry points for SI in Mozambique and Tanzania rainfed maize-legume cropping systems

4.1.1 Cross-country agroecological diversity and farming systems design

The existing agroecological diversity and farming environments across both countries is a key similarity between the countries’ agricultural sector structuring. In both countries, farming systems have adjusted mainly to local agroecological conditions and market dynamics. Maize-legume systems are the most important systems in terms of number of explorations under the crops and the share of land dedicated to both crops. However, contrasting legume crops are used as the systems flagship across both countries. In Mozambique for instance, a wide range of legumes are used. Groundnuts, cowpea and common beans are the most grown legumes crops mainly due to their marketability, with pigeon pea gaining some attention in recent years in central and northern Mozambique (INE, 2011). In contrast, a well-established pigeon pea market in Tanzania has made this a reference legume crop in several agroecologies where it is currently grown and widely studied (Adu-Gyamfi et al., 2007; Silim et al., 2005).

Despite maize-legume systems being the widely practice in both countries, mainly due to their share in local diets, these systems are not practiced in isolation (Figure 3). Farming systems are more diverse. In certain agroecologies, maize-legume systems are integral part of a very diversified and integrated farm enterprise that also includes cattle, fruit and cash crop based systems in both countries (Bajukya et al., 2005; Lukanu et al., 2009). Banana based systems are found in both countries and coffee based systems in Tanzania appear to be the most significant (Bajukya et al., 2005). In Mozambique, cotton and tobacco based systems implemented mainly in contract farming can still be seen across the mid altitude and highland regions. Commercial vegetable production mainly by innovative and semi-intensive market oriented farm household are also common in both countries (Ngowi et al., 2007). The crop diversity and multiple livelihood strategies adopted by farmers (Soini, 2005) are an important dynamic to be analysed, but their productivity has been analysed in isolation from the maize-legume systems. Nevertheless, resource relocation in these systems is critical to validate technology adoption among poor resource farmers (Rusinamhodzi et al., 2016). Therefore, the potential impact of the resources mobilized and generated on these systems to whole farm household management decisions and livelihood strategies in these niche based farming systems on both countries needs to be further explored since it is key to validate SI. This is in part a direct result of the single sized crop based agricultural intervention model that mainly focus on major staple food crops.
4.1.2 Farmers socioeconomic circumstances and their potential impact on SI adoption

Like other technologies promoted to date across Africa, the validation and wide adoption of SI practices will largely depend upon each country capacity to effectively downscale this complex and knowledge intensive technology into practical onsite measures that fit small scale farmer’s contrasting circumstances. Therefore, understanding and smartly solving common adoption traps when co-designing SI interventions is paramount for success. Nevertheless, several threats to SI are posed, as is the prevalence of a supply driven agricultural intervention model, (Bembridge, 1987; Binns et al., 1997), centred on single sized technological packages. Supply driven agricultural intervention have failed to capture the complex and strong social dimension of technology adoption not only in Africa but across the world (Vanclay, 2004a).

Land access and tenure is generally known to influence adoption of soil and water conservation measures. Nevertheless, Knowler and Bradshaw (2007) found that most of the studies had not established a significant relationship between land tenure and adoption of conservation agriculture in particular. In Tanzania, however, Kassie and colleagues (2013) found that land tenure influenced the
adoption of conservation tillage, soil and water conservation, use of chemical fertiliser and use of animal manure but did not influence legume intercropping or use of improved seeds.

The farm size can also impact on the adoption of conservation agricultural practices. The observed adoption of legume intercropping, chemical fertilisers and conservation tillage by households with smaller pieces of land, led Kassie and co-workers (2013) to conclude that this reflected farmer effort to intensify production and employ land-saving techniques. In the case of SI, farm size relationship with intensification is an area to be addressed across Mozambique and Tanzania, two countries with different land pressure levels. In Mozambique, where land access is not yet an issue, there is a high risk of farmers engaging in extensification rather than intensification as a way to improve production (Leonardo et al., 2015). Nevertheless, in non-land constrained areas, taking also the example of Mozambique, improving labour productivity is fundamental and could be achieved through mechanization. In these context, the household characteristics can influence, either positively, or negatively, the probability of adoption of conservation agricultural practices. Household size, i.e., the number of farm active people can influence adoption of labour intensive practices. Kassie et al. (2013) found that larger households were more likely to adopt use of animal manure, than those households with a smaller size. In a study conducted by Bandiera and Rasul (2006) on the adoption of sunflower by households, 17% of the non-adopter households cited lack of labour as a reason for not adopting the crop.

Kassie et al. (2013) studied the adoption of SA practices by 681 farm households spread across 60 villages in Tanzania. There was strong evidence that socioeconomic factors such as access to markets, household income and family size affected the adoption of different conservation measures. Of the seven technologies studied, namely; legume intercropping, legume crop rotations, use of animal manure, conservation tillage, soil and water conservation practices, use of chemical fertilizer, and introduction of improved seeds, the authors found that 67% of the households used improved seed varieties, and 46% were practicing legume intercropping. There was higher use of animal manure (23%) than use of chemical fertiliser (4%). Maize-legume crop rotations were practised by 17% of the households, whilst only 11% of the households practiced conservation tillage and 18% of households used soil and water conservation techniques. Results show that access to market and plot influences farmers’ adoption decisions. Market linkages, in particular distance to the markets also influenced household probability of technology adopting. In Tanzania, households closer to markets had a greater probability of using chemical fertilisers. Here, the number of traders (agro-dealers) that a farmer knows inside and outside the village can also positively influence adoption of certain technologies.

Not less important is the access to relevant agricultural information, opportunities on contracts for output markets, credit and inputs, that can influence a household’s decision to adopt. Kassie et al.
(2013), found that households participating in rural institutions were more likely to adopt several of the CA practices.

Knowler and Bradshaw (2007) reviewed and synthesised literature on CA adoption, based on 31 published empirical analyses articles, having concluded that there were generally no universal variables that could explain the adoption decisions of farmers. Therefore, there was need to tailor make conservation agricultural interventions to the needs of specific targeted communities. For that, grouping farms in functional typologies can help shed light on how systems work impact the field and regional dynamics in order to trigger a conscious change of practice. Nevertheless, despite the idea of agricultural typologies being pinpointed as a critical tool to improve agricultural planning, back in the 1970’s (Kostrowicki, 1976), rigid typologies mainly based on farm size have dominated the agricultural intervention in SSA until recent years (Nainggolan et al., 2013; Valbuena et al., 2008), when understanding social processes within and across groups became relevant. In Malawi, Franke et al. (2014) grouped farmers in typologies to map their likelihood to benefit from legume intensification systems. Despite the late developments in farm categorization, agricultural interventions in SSA still fail to incorporate the complex social dynamics that are characteristic of smallholder farm enterprises into the design of locally feasible technological packages.

4.1.3 Impact of farmer perceptions and networks on technology adoption

Tenge, Graaf and Hella (2004), conducted a study in the West Usambara Highlands in Tanzania to investigate the socio-economic factors affecting farmers’ adoption of soil and water conservation practices and found that involvement in off farm activities, insecure land tenure, location of fields and a lack of short term benefits negatively influenced the adoption of Soil and Water Conservation (SWC) technologies by the farmers. The authors recommended that socioeconomic considerations should be made in the design of SWC programmes, and flexibility in the programmes is essential to cater for different farmers. They also recommended the use of participatory approaches in the design of SWC programmes. In part, the departmentalization of agricultural interventions and the focus on field level agronomic efficiency have failed to incorporate farm incomes and their potential impact on technology adoption. Nevertheless, Vanlauwe and Giller (2006), studying soil fertility management measures in SSA found that farmers are likely to adopt practices from which they see a direct and immediate benefit. In the same study, preferential fertiliser uses were reported across crops and systems. The same is more likely to happen with SI and this raises the importance of demonstrating short term benefits of different technological interventions (Giller et al., 2011), which is fundamental to trigger a conscious adoption process.

Mbaga-Semgalawe and Folmer (2000) conducted a study to investigate the adoption behaviour of improved soil conservation measures by rural households in North Pare and West Usambara in Tanzania. They linked farmers’ perceptions of the erosion problem, the adoption decision and the
level of investment devoted to soil conservation among adopters. The results showed that household perceptions on the soil erosion problem were influenced by gender, marital status and promotional activities conducted by SWC programmes. Participation in promotional activities of SWC programmes influenced the adoption decision process at all three levels. In addition, farmers who considered soil erosion a priority problem in agricultural production, and participated in labour-sharing groups and had off-farm income were likely to be more willing and able to use improved soil conservation technologies and put more effort in conservation. The level of investment in SWC by households was influenced positively by availability of family labour, education levels and negatively by the duration of the SWC programme.

Three case studies on CA as practised in Arumeru, Mbeyha and Karatu regions of Tanzania were studied by Shetto et al., 2007. The findings showed that farmers considered the initial costs incurred when practising conservation, e.g. buying new implements and cover crop seed, as being high. In addition, CA was found to increase the demand for draft power. Farmers with higher literacy levels and more financial resources adopted CA faster than the others. The study found that large scale farmers who had greater access to resources and the youth who were business-minded were more interested in CA technologies. The youth, however, were constrained from adoption by lack of resources including land.

The importance and influence of farmer networks is also highlighted by Shetto et al., (2007) who reported that farmers’ engagement in CA was highly correlated with whether fellow farmers were involved or not. This study also emphasizes the importance of streamlined technological packages, such as CA, with existing practices like contouring and agroforestry. In addition, active involvement of all relevant stakeholders, e.g. farmer organisations, the private sector and researchers is essential to raise awareness of the benefits of CA. Bandiera and Rasul (2006) studied adoption of sunflower by farmers in the Zambezia region of Mozambique. The project involved, amongst other things, distribution of sunflower seeds to farmers and giving them access to an oil press after production. They investigated how a farmer’s decisions to adopt a new crop were related to the adoption decisions of family and friends. They found that a farmer whose family and friends had adopted the crop had a high probability of adopting it as well.

Grawboski and Kerr (2014) studied the adoption of minimum tillage, basins and direct seeding as forms of CA in Angonia and Tsangano districts of Mozambique. The adoption of basin and direct seeding was driven by prospects of higher income levels as a result of expected higher maize yields, and the ability of the technology to utilise less labour. The fertiliser subsidies offered by NGOs were also an additional driver of technology adoption. On the other hand, some farmers who were cash and/or labour constrained preferred to continue using conventional tillage, since it produced higher yields than CA in the absence of fertilisers. The authors recommended the need to consider the heterogeneity of farmers in terms of resource endowment when designing conservation agriculture.
programmes, and where necessary to promote conventional tillage emphasising reduction of soil erosion. A similar finding was reported by Roxburgh and Rodriguez (2016), who also acknowledge the fact that not all farmers might be able to adopt CA techniques, and recommended the promotion of basic agronomic management practices as a first step to increase productivity amongst poor performing farmers. The study was conducted under the SIMLESA project activities and used participatory modelling to identify feasible sustainable intensification pathways.

4.1.4 Stakeholder perceptions of SI and their impact on adoption

In Maputo Stakeholder Consultation Workshop organized in the frame of this case study, it was concluded that there is a good understanding and perceptions of sustainable agriculture intensification among key stakeholders (Figure 4). Nevertheless, the focus on AI appeared to be a key issue to be addressed for most of the participants. The focus on improving agronomic performance, i.e., improving yields and optimizing resource productivity is characteristic of low external input systems and is line with finding from Roxburgh and Rodriguez (2016). The following issues have emerged from the workshop discussions:

1. There is a need to understand the perceptions of different actors on SI and how it differs from the mere need to intensify agriculture. The importance of aligning SI technologies with the 3Ps trichotomy, i.e., People - Planet – Profit is critical to tailor SI and make it reflective of farmer’s needs. In the specific case of Mozambique, Tanzania and SSA, the main challenge is how can a balance between the 3Ps be adjusted to the different socioeconomic and agroecological realities contrasting smallholder farmers. The main issue that emerged was what sustainability should be to each typology and how the concept can be tailored to fit each typology? In a study on technology adoption profiles among Australian farmers, Vanclay (2004a) found that perceptions about sustainability differed between researchers and farmers. To farmers, sustainability was mostly about keeping up and being able to stay in farm. Therefore, matching these perceptions is critical to improve farmers’ likelihood to engage in technology adoption.

2. It was agreed that the feasibility of SI should take into account the agroecological and the diversity of farming systems across typologies. Here, farm heterogeneity between farmers with contrasting resource endowment and information access will lead to the adoption of contrasting livelihood strategies which in turn affects the crop and resource management strategies at both homestead and field level. Because of these dynamics, it is believed that there is no single sized technology that will fit all farmers’ circumstances. Therefore, SI technologies will need to be adjusted to the needs of each target group and typology taking their socioeconomic circumstances, agroecological reality and developmental needs as the starting point. Nevertheless, typology-tailored interventions contrast with current supply
driven interventions, which fail to recognize that one of the key traps to SI adoption would be the mismatch between farmers and researchers' view of the problem.

3. Inclusive innovation as defined by Vadakkepat et al. (2015) is critical to validate SI in Mozambique. Nevertheless, the active involvement of farmers in the design of locally feasible SI technological packages will largely depend on the existence of well-trained extension and research personnel that can actively involve farmers in the process. This can be achieved through typology targeted agricultural interventions, i.e., focusing on each group's unique circumstances and developmental needs, since it is the closest approach to 1:1 peer tutoring defined in Maertens and Barrett (2013) as the most effective learning approach. Personalizing agricultural intervention and allowing farmers to experiment and learn by doing in their own fields is a more effective way to trigger adoption (Cameron, 1999; Munshi, 2004) compared to the conventional supply driven approach which is flawed by agency problems.

4. To improve human and financial resources access, building the technical capacity of field extension workers and researchers was considered fundamental to validate SI.

Figure 4 Cross-comparison of perceptions about agricultural intensification and sustainable agricultural intensification (respectively Portuguese acronym IA and IAS) in Mozambique
CHAPTER 5 - CONCLUSIONS AND REMARKS

The main finding generated by the case study presented herein is that, despite the fact that maize-legume cropping systems are a key component of Mozambique and Tanzania farming mosaic, these systems are not isolated and are practiced across certain niche based systems that are mainly shaped by agroecological conditions, market dynamics and also by the typology of the farm household enterprise.

Form the above, the following key lessons can be learned from this exercise:

a) Farms are diverse in time and space across both countries and are constantly evolving depending on the farmer resource endowment levels, access to information and support services. Therefore, understanding the socioeconomic and biophysical circumstances where each farm is managed and how this affects the whole farm design and management decisions is key to effectively identify locally feasible sustainable intensification pathways;

b) Single sized technological packages aiming at improving agronomic responses and efficiencies at field level, built under the assumption of homogeneous farmer groups, have failed to stimulate adoption, since the technologies promoted were not reflective of the existing diversity. Therefore, shifting from field level based agronomic interventions to an integrated sociotechnical approach, centred in whole household intervention, is paramount for the identification and co-design of farmer friendly and relevant intensification pathways;

c) Like other technological packages promoted to date (e.g., CA) SI is also a knowledge intensive technology and the ability to downscale it to fit contrasting farm typologies and environments will be largely affected by each country’s technical capacity to involve all relevant actors in the co-generation of relevant agricultural information that can be used to aid farmer’s decision making process.

d) In SSA, where agricultural research is scantily funded and access to relevant agricultural information is limited and a key bottleneck for farmers and policymakers to make informed decisions, model assisted research is a fundamental tool to be integrated into local research systems and used to timely generate relevant agricultural information to aid decision making;

e) Building human and institutional capacity to design and implement locally feasible SI interventions is fundamental.

f) Actively involving smallholder farmers in the design and testing of locally feasible SI technological innovations is key to help tailor SI to their reality. This can be achieved through personalized agricultural interventions aiming at jointly adjusting SI technological packages to suit each typology development needs;

a) Building better institutional synergies to minimize departmentalization of actions and achieve impacts.
**RECOMMENDATIONS**

While maize and legumes are the major food crops produced in Mozambique and Tanzania, therefore, key to validate SI, current production systems are far more complex and diversified than that. Nevertheless, most agricultural interventions to date, have focused mainly on improving the agronomic performance at field level ignoring the socioeconomic and biophysical dynamics at the household level and their potential impact on field level management decisions. Understanding how the “whole farm” operates, i.e., how management decisions are made and what affects them, what is produced and for what purpose (cereals, vegetables and fruit trees where possible), what incomes are generated, how resources are used and impact the overall household ability to materialize the annual income and food security prospect is key to map technology adoption profiles. Therefore, shifting the scope of agricultural intervention towards understanding the functionality of the whole farm household from the homestead to the field is key to effectively tailor SI. However, diversity of farms must be taken into consideration. Given the diversity of farms and livelihood strategies, not single sized technology will fit all groups. Therefore, the active involvement of farmers in the co-design and implementation of technological packages that are reflective of their biophysical and socio-economic circumstances is key to help tailor SI.

What is required then?

a) To build simple and flexible mutually exclusive farm typologies that are reflective of farmers contrasting biophysical and socioeconomic circumstances and can be used to co-design SI implementation and adoption profiles that will be the basis to tailor SI to each group needs;

b) Co-designing typology tailored agricultural interventions that can add value to current farming systems design by providing farmers with the tools they need to improve their systems design and management through the implementation of smarter and more efficient resource use strategies;

c) Building better synergies between local actors is also considered fundamental in harmonizing concepts and also intervention strategies.
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