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Research on Multipurpose Legumes in Malawi: Synthesis Report

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Acronyms

AFSUN	African Food Security Network
DSS	Decision Support System
EPA	Extension Planning Area
FFS	Farmer Field Schools
FISP	Farm Input Subsidy Program
GCFSI	Global Center for Food Systems Innovation
HESN	Higher Education Solutions Network
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
LUANAR	Lilongwe University of Agriculture and Natural Resources
MLM	Multipurpose Legume-Maize
MSU	Michigan State University
NGO	Non-governmental Organization
RFA	Request for Application
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USAID/Lab	US Global Development Lab
WHO	World Health Organization
WIEGO	Women in Informal Employment: Globalizing and Organizing

1. Executive Summary

1.1. Background

The mission of GCFSI is to create, test, and enable scaling of effective solutions and evidence-based approaches in food systems affected by critical global trends such as climate change, urbanization, and population growth. This report synthesizes findings from nine coordinated research projects that were conducted during the summer and fall of 2014 by a multidisciplinary team of researchers from Michigan State University (MSU) and Lilongwe University of Agriculture and Natural Resources (LUANAR). All research teams were charged with answering the question, *"Where and how can multipurpose legumes be scaled for sustainable intensification of maize systems and what would the potential impacts be, in the medium term, across the food system in Malawi?"*

The use of multipurpose legume technologies is a common component of "sustainable intensification." A legume is considered "multipurpose" when it serves several functions in a cropping system. For example, in addition to providing a food source for humans, a multipurpose legume may also provide a source of fodder for livestock; a reliable and sustainable source of soil nitrogen; wood that, when coppiced, can provide a source of fuel or building material; and, improved soil structure as a result of deep-rooted growth. The phrase "medium term" means during the next 5-10 year period.

The multipurpose legume that most GCFSI researchers focused on is pigeon pea (*Cajun cajanus).* This is because, in Malawi, pigeon pea best embodies the above-mentioned characteristics. Furthermore, Malawi is among the major producers of pigeon pea in Africa.[1]

Sustainable intensification refers to a set of agricultural practices and technologies that increase food production on existing cultivated land while "reducing negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Pretty, Toulmin, and Williams, 2011, p. 8). Sustainable intensification stems from agricultural system innovation that deals effectively with current and projected food system challenges, such as urbanization, demographic shifts, climate change, and scarcities of various key agricultural inputs (e.g., water, land, nutrients, energy).

[1] Simtowe et al. (2010) report that 65% of pigeon pea is consumed on-farm, of which 25% is exported and only 10% is distributed to the domestic market. Only the large, white-seeded varieties are exported. In general, due to the under-development of local markets, and reliance on export markets, farmers have little if any influence on the prices they receive.

The use of multipurpose legumes to sustainably intensify agricultural systems is a promising technology, but adoption rates among farmers in Malawi remain low. For the most part, low adoption rates have been primarily addressed via farmer education, but there is increasing recognition that factors such as socio-economic context and off-farm food system dynamics heavily influence farmer decision-making and, thus, the potential for scaling agricultural innovations.

This recognition that farmer decision-making and the scaling of innovation is a function of factors well beyond the farm gate provides the impetus for the GCFSI research and recommendations described in this report. The potential of multipurpose legume innovations to improve agroecosystem fertility and food security is well-described and accepted by sustainable agriculture practitioners and researchers. The factors associated with scaling the innovation, however, are less clear. Therefore, the goal of researchers was to more precisely identify factors that constrain or enable scaling of the technology. The outcome of such research was used to craft more integrated and targeted policy recommendations and to propose interventions that better respond to farmer capacity and decision-making.

To identify and connect the multiple factors that are important to scaling multipurpose legume technology and, thus, where investments should be targeted or where further research is needed, teams approached the guiding question through multiple entry points and from different disciplinary perspectives. Teams produced individual research reports, which are only briefly summarized in the synthesis. The synthesis draws from each of these reports to highlight complementary findings and propose a cogent set of recommendations. What becomes clear is that efforts to scale particular innovations must look beyond proximate factors, such as farmer education, to consider how the system constrains or enables particular choices. Researchers found that factors such as ecological suitability, access to markets and information, socioeconomic conditions, food-related infrastructure, existing policy, gender roles and relationships, and the capacity of food actors along the value chain in both rural and urban areas needed to be addressed in order to enable scaling the technology via farmer adoption.

The interdisciplinary interpretation of results thus recognizes that "problem solving requires the cooperation of individuals with a 'wide scatter of scientific backgrounds and interests'." However, in carrying out the research and organizing the data into a cogent set of findings, the challenges of interdisciplinary research were omnipresent. In addition, coordinating multiple teams across three institutions made for sometimes frustrating logistical and communication challenges; but, an interdisciplinary approach, as GCFSI is charged with enacting, is the only appropriate tack to take with such complicated systemic issues. Even so, individual research projects tended to reflect disciplinary bias, and a major task in writing the synthesis report was to reconcile and "harmonize" findings from the various reports.

1.2. Research Projects

The complete set of research reports that inform the synthesis are presented in Table 1, below.

Researchers believe that there is significant growth potential for multipurpose legumes in both domestic and export markets. Past intervention proposals and policy prescriptions highlighted the necessity of linking smallholder farmers to profitable markets, but did not address how local and regional markets can be supported to expand their capacity. The GCFSI research identified a number of ways that local and regional markets can be strengthened through support to actors, institutions, and infrastructure along legume value chains, and emphasized the necessity of

supporting interactions among small- to medium-scale entrepreneurs engaged in legume production and exchange. Importantly, a focus on local and regional markets is particularly relevant to women, as they are primarily responsible for local and regional legume production and exchange. However, in order to ensure that benefits accrue to women, a focus on strengthening and scaling the legume innovation system must proceed with interventions that recognize and address the constraints that women experience.

Table 1: GCFSI Research on Scaling Multipurpose Legume Innovation, 2014

MegaTrend 1: Population Growth, Climate Change, and Pressure on Land	
Climate Analysis, Hydrologic Modeling, Land Use Analysis	N Moore, J Messina, P Nejadhashemi, V Breeze, U Adhikari, B Peter, H Deindorfer, A Frake, M Devisser, M Herman
Impacts of Climate Change on Rice and Maize, and Opportunities to Increase Productivity and Resilience in Malawi	J Olson, G Alagarswamy, J Gronseth, N Moore, and L Zulu
Agroecology for Resilient Farming Systems	SS Snapp, V Morrone, WG Mhango, LC Zulu
MegaTrend 2: Rapid Urbanization and Transformation of Food Systems	
Traditional Urban Legume Exchange in Lilongwe, with a Focus on Pigeon Pea	SA White, MW Hamm, A Mbachi Mwangwela, JFM Kamoto, JJM Kampanje-Phiri, FC Chigwa, M Thondolo
Institutional and Policy Constraints to Innovation in the Malawian Legume Value Chains: Current Status and Business Actors' Coordination for Institutional Change	D Dentoni, F Krussmann, M Degnet, A Noor
Mapping Market Prospects for Grain Legumes in Malawi	J Dzanja, M Matita, H Kankwamba, M Dolislager, and D Tschirley
MegaTrend 3: Evolution in Skills Required by Food Systems	
Skills and Workforce Development	J Dirkx, T Smith, I Berzina-Pitcher, and M Vann
ICT4D: Using Participatory Video for Smallholder Farmer Training in Malawi	C Steinfield, S Wyche, H Chiwasa, J Mchakulu, and T Cai
Cross Cutting Themes	
Gender: Gender Analysis of the Pigeon Pea Value Chain	N Me-Nsope and M Larkins

1.3. Principal Conclusions

A discrete number of focus areas were identified for investment and support. Referred to as "keystone" issues due to their fundamental importance in creating an enabling system, those areas include (1) continued and strengthened farmer capacity building in relation to sustainable intensification, paying particular attention to local circumstances; (2) improved networking and communication capacity so that actors along the value chain have better and more efficient access to legume sources and price information; (3) improved infrastructure for processing, transportation and storage of seed and grain in both rural and urban environments, which serve the interests of small-scale entrepreneurs and farmers and which take into account projected rising costs of energy; (4) improved seed systems that better serve the agronomic and economic interests of legume producers and consumers; (5) improved access to information, paying particular attention to information asymmetries that currently favor the most powerful actors in the system to the detriment of small-scale farmers and entrepreneurs. For example, Dentoni et al. note that input suppliers may provide biased information to farmers that subjects them to "lock-in risks" and that farmers have few options for finding alternative, lower-cost options.

Though pigeon pea is consumed and grown primarily in the south, demographic shifts and movements of populations from the South to Central and Northern Regions suggest that there are market opportunities for expanded pigeon pea production in those regions. GCFSI researchers identified the Central Region as the best bet for scaling investments due to favorable climate and growing conditions and because initial efforts to introduce the legume have been met with positive responses from farmers.

2. Introduction

The primary mission of the Global Center for Food Systems Innovation (GCFSI) is to "create, test, and enable scaling of effective solutions and evidence-based approaches to a defined set of future critical global trends impacting food systems." Global trends have been captured by what GCFSI refers to as "megatrends," which include population growth, climate change, rapid urbanization, and the need for new skills in food systems given the impacts of the other trends on global food production, processing, and exchange. In addition, gender and information and communication technology (ICT) for development are cross-cutting themes. Solutions and approaches are advanced through center-led research and a competitive grants program. The creation and testing of solutions is done in a number of ways, including through center-led research and analysis that can aid in guiding investments and projects that, in turn, can promote the scaling up of innovations.

This report synthesizes the results of nine center-led research projects conducted in Malawi in 2014, which sought to answer the question: *"Where and how can multipurpose legumes be scaled for sustainable intensification of maize systems, and what would the potential impacts be in the medium term across the food system in Malawi?"*

The use of multipurpose legume technologies is a common component of "sustainable intensification." A legume is considered "multipurpose" when it serves several functions in a cropping system. For example, in addition to providing a food source for humans, a multipurpose legume may also provide a source of fodder for livestock; a reliable and sustainable source of soil nitrogen; wood that, when coppiced, can provide a source of fuel or building material; and, improved soil structure as a result of deep-rooted growth. The phrase "medium term" means during the next 5-10 year period.

The multipurpose legume that most GCFSI researchers focused on is pigeon pea (*Cajun cajanus).* This is because, in Malawi, pigeon pea best embodies the above-mentioned characteristics. Furthermore, Malawi is among the major producers of pigeon pea in Africa.[2]

Sustainable intensification refers to a set of agricultural practices and technologies that increase food production on existing cultivated land while "reducing negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Pretty, Toulmin, and Williams, 2011, p. 8). Sustainable intensification stems from agricultural system innovation that deals effectively with current and projected food system challenges, such as urbanization, demographic shifts, climate change, and scarcities of various key agricultural inputs (e.g., water, land, nutrients, energy).

Malawi was chosen as the geographic focus of the study due to the strategic relationship formed between GCFSI and Lilongwe University of Agriculture and Natural Resources in Malawi (LUANAR), which serves as the GCFSI East African research and scaling hub. The interdisciplinary research was conducted collaboratively, by GCFSI, LUANAR, and Wageningen University in The Netherlands.

[2] Simtowe et al. (2010) report that 65% of pigeon pea is consumed on-farm, of which 25% is exported and only 10% is distributed to the domestic market. Only the large, white-seeded varieties are exported. In general, due to the under-development of local markets, and reliance on export markets, farmers have little if any influence on the prices they receive.

According to a recent paper by Denning et al. (2009), agriculture accounts for 78% of the national labor force in Malawi and maize is grown by 97% of farming households, most of it unirrigated. Only 20% of households are able to produce surplus and sell their product; and over half operate at or below subsistence levels. In Malawi, maize yields an average of only 1.3 metric tons per hectare (compared to 10 tons/ha in Iowa), which is due to a range of factors, including growing climate unpredictability and depleted soils. The government has promoted higher maize yields through the farm input subsidy program (FISP), but the program is extremely expensive, creates dependence on petroleum-based farm inputs and the donor community, and does nothing to encourage a diversification of diet. There is a growing recognition from within Malawi that more sustainable alternatives to both FISP and a maize-centric diet are needed.

The integration of multipurpose legumes into maize-based farming systems, and the adoption/adaptation of multipurpose legume-maize (MLM) systems, is considered by many in the scientific community to be an innovation that can improve soil fertility, raise maize yields, and diversify and improve rural and urban household nutrition and livelihoods (Simtowe, Shiferaw, Abate, et al. 2010; Simtowe, Shiferaw, Kassie, et al. 2010). MLM systems refer to integrating legumes in the system through intercropping (maize and legume planted at the same time in the same field), or as a rotation (maize, a heavy user of soil nutrients, follows legumes, which enrich the soil through additions of organic matter and nitrogen). In addition, because legumes are primarily a women's crop in Malawi, developing the sector offers the possibility of improving the economic status of women. In other words, multipurpose legume technologies have the potential to "sustainably intensify" the food system in Malawi in both rural and urban ways.

2.1. Scaling Sustainable Intensification with Multipurpose Legume and Maize Technology

As it relates to rural smallholder production, sustained effort to improve soil organic carbon is required, and there is a growing body of evidence that the surest way to achieve this is to promote leguminous plants that are shrubby or viney (Table 2). These can provide substantial amounts of biomass over an 8- to 24-month time period (Snapp et al. 2010). In comparison, annual food legumes are grown for about four months and have a high harvest index, meaning that much of the plant is removed from the field, which minimizes the soil-improving residue biomass. In contrast, the above-ground residues produced by perennial leguminous shrubs and vines such as pigeon pea, mucuna, climbing beans and tephrosia are nitrogen-enriched and of mixed quality biochemistry, with 3-5 MG biomass per ha (Snapp et al. 1998; Snapp et al. 2010).[3]

[3] Root biomass measurements recently have been conducted for pigeon pea grown on over 40 fields in Central Malawi, where biomass ranged from 0.9 to 2.0 MG biomass per ha. This is expected to translate into improved soil organic C, although there is high variability from location to location, and detection of accumulation over time is difficult with the exception of longer-term research station trials in which gains of 15% or more have been demonstrated (Beedy, Snapp, Akinnifesi, & Sileshi, 2010; S. S. Snapp et al., 2010).

Table 2: Legume Types Grown in Malawi and Their Uses. Adapted from Mhango et al. (2013)

Value	Annual-Food Legume				Semi-Perennial Food Legume		Green Manure	Agro-forestry
	Soybean	Bean	Cow-pea	Ground-nut	Climbing bean (vine)	Pigeon Pea (shrub)	*Mucuna pruriens* (vine)	*Tephrosia vogelli (shrub)*
High protein food	High	High	High	High	High	High	Poor[4]	None
Biomass for Forage	Medium	Low	Low-Medium	Medium	Medium-High	High	High	High Biomass (not animal fodder)
Improve soil fertility	Medium	Low	Low-Medium	Medium	High	High	High	Medium-High
Good intercrop	Medium	Med-ium	Low[5]	Medium	Low[6]	High	Low[2]	High
Established market	High	High	High	High	High	Variable	Low to None	None
Maturity period	Medium	Short	Medium	Medium	Long	Long	Long	Long
Labor demand	Medium	Med-ium	Medium	High	High	Low	Low	High

In particular, the benefits of pigeon pea, grown in mixtures with maize or as a doubled-up legume system (pigeon pea and an understory of soybean or groundnut), rotated with maize, have been proven in country-wide trials (Snapp et al. 2014; Snapp et al., 2010). The climate resilience gains are particularly marked when maize hybrids are grown with targeted fertilizer applications in rotation with doubled-up legume and mucuna rotations. This has been shown to not only improve maize fertilizer response by 50% or more, but also to enhance yield stability dramatically.

Though multipurpose legumes have promising potential, adoption rates among smallholders remain low, a situation that is attributed to multiple factors, including the following:

- Maize is preferentially allotted space and labor by farmers, and farmers are loath to devote resources to legume cultivation if it is perceived that it will undercut their ability to meet the household's maize consumption needs (Alwang & Siegel, 1999; Bezner-Kerr et al. 2013; Snapp et al. 2002)

- Maize production is promoted through agricultural input subsidy programs, which do not foster a need for alternative approaches to yield improvements, such as the integration of multipurpose legumes (Mweninguwe, 2014)

[4] Requires extended cooking to detoxify.
[5] Competition for water is high, particularly by viney growth types.
[6] Competition for light is high; the viney growth type suppresses intercrops.

- Lack of reliable access to seed, especially improved seed (Simtowe et al., 2009; Snapp et al. 2002)

- Lack of awareness of varieties and benefits (Simtowe et al. 2009)

- Limited access to markets, inputs and government support (Mhango et al. 2013)

To date, most MLM research has focused on farmers and the constraints and conditions they experience that might hinder adoption. Snapp's ongoing work with the novel mother-baby trial methodology[7] demonstrates the innovative capacity of farmers in integrating new agronomic techniques into their cropping systems based on their own analysis of what agronomic practices have value (Snapp, 2002). That farmers make the decision not to integrate legumes into the system is partially attributed to weaknesses or '"blocking mechanisms" that signal other problems in the innovation system and in other areas of the value chain (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Carlsson, Jacobsson, Holmén, & Rickne, 2002; Wieczorek & Hekkert, 2012)

While a focus on the on-farm constraints that hinder adoption is important, it is necessary to recognize that post-farm-gate factors also play a role in farmer decision-making. The varying socioeconomic and environmental conditions throughout Malawi suggest that potential medium-term impacts of legume-maize innovations would be felt differently in different parts of the country, and would require a diversity of support measures that are responsive to local circumstances. For example, Snapp notes that "Central Malawi is at a tipping point in terms of interest in, and adoption of, pigeon pea systems" due to the rapid expansion of agronomic practices that integrate legumes, particularly among female farmers. This underscores the need for extension materials and practices that support their efforts. In the North, access to markets, inputs, and improved seeds are major limiting factors, though land is plentiful. In the South, where pigeon pea is more commonly grown, land is increasingly a limiting factor due to population growth, and farmers are more interested in acquiring short-season, pest-resistant, high-yielding seed varieties.

The synthesized research findings indicate that there is strong potential for scaling multipurpose legume technologies throughout Malawi, and the analysis suggests that the most dramatic and effective scaling results would be achieved by the following:

1. Supporting local and regional legume exchange via investments in small- and medium-scale producers and other entrepreneurs along legume value chains. Such investments should include (a) reducing transportation costs and improving transportation options for rural to urban legume exchange, (b) improving storage options and conditions for seed and grain storage in both rural and urban environments, and (c) improving opportunities and capacity in small-scale processing.

2. Focusing on pigeon pea as the best-bet multipurpose legume, because of its potential to (a) sustainably intensify maize production systems in the Malawian social and ecological context, (b) improve both rural and urban household nutrition, and (c) offer income generating opportunities for women.

[7] This approach involves centrally based mother trials in which a wide range of technologies are evaluated and then systematically linked to hundreds of farmer-led "baby trials" involving a subset of technologies chosen and fine-tuned by farmers (Snapp et al. 2002).

3. Focusing in Central Region due to its favorable climatic and environmental conditions, market access, and bourgeoning farmer interest in integrating multipurpose legumes into the crop rotation.

2.2. Research Question and Conceptual Approach

The multidisciplinary approach and the basic premise of the GCFSI research reflect recognition that qualities and components of agri-food systems are produced *in relation* to each other in particular places (Ericksen, 2008).[8] In other words, food system actors, such as farmers or urban legume vendors, face opportunities and constraints and make decisions within *a social, ecological, and political context*. The individual components of the system cannot be properly understood except in relation to other components.[9] Thus, the GCFSI research in Malawi rests on the premise that the development and scaling of multipurpose legume innovations is a complex social process (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007), and develops insight on post-farm-gate factors that could affect a farmer's capacity or willingness to adopt the MLM innovation.

Most data for the reports were collected during the summer months (June—August 2014) through a coordinated series of intensive studies. Figure 1 depicts the multidisciplinary nature of GCFSI Malawi research projects and shows the four basic thematic areas that projects addressed: agroecology and climate; markets, policy, and institutions; skills and education; and, gender and social factors. This approach to agri-food research recognizes that it is not only the activities associated with moving food from farm to consumer that comprise the food system, but also the context and relationships that shape *how* food systems are carried out.

Accordingly, a number of research teams paid particular attention to the social relationships that comprise innovation systems, as well as social positioning that affects how people are able to both influence and access innovation. For example, one research team applied a gender lens to the pigeon pea value chain, which yielded critical information about who does what, who knows what, and what opportunities and constraints exist for whom. Such an understanding helps suggest how interventions should be implemented, which aids in targeting investment.

[8] GCFSI's understanding of food systems is informed by Ericksen (2008), who critiques conventional definitions of food systems, which typically account only for the set of activities that move and transform food between the field and the plate/bowl. In addition to those activities, food systems are also (1) the relationships between social and ecological environments/practices that comprise food provisioning systems; (2) the results produced by these processes and practices on social and ecological environments, such as improved food security, pollution and social welfare, including economic development; and (3) other determinants of food security stemming from the interactions of the above factors.

[9] The approach is somewhat reminiscent of the farming systems approach to development, which was grounded in interdisciplinary research (Norman, 1995). In addition, recent framings such as "regional food systems" or "city-region food systems" also account for the integrated rural-urban dimensions of food systems and the important role that urban processes play in nutrition and food security (http://www.cityregionfoodsystems.org/, http://www.leopold.iastate.edu/regional-food-systems-working-group

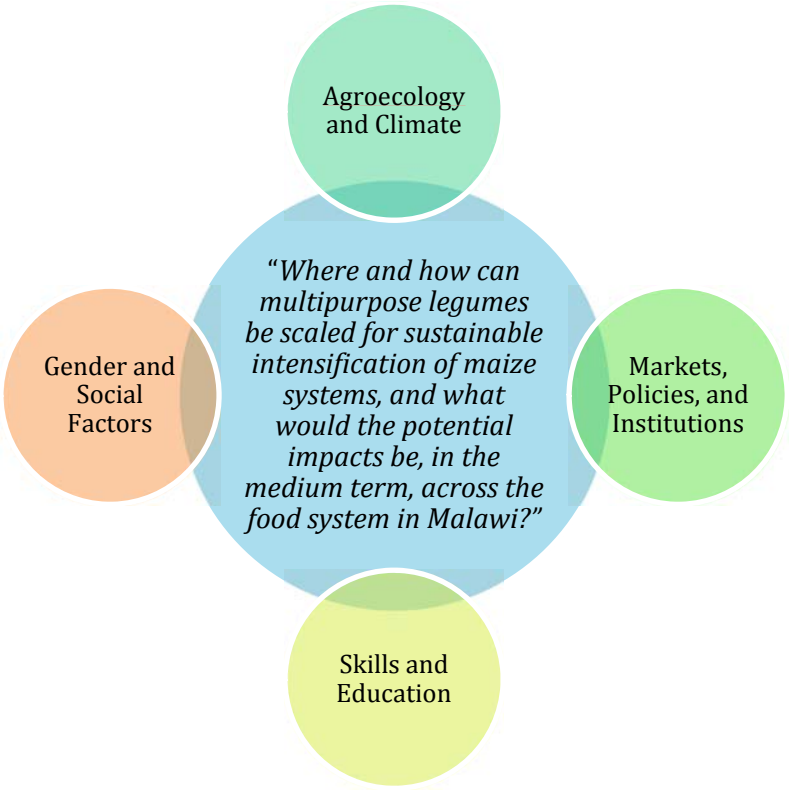


Figure 1: Primary Research Question and Multidisciplinary Research Approach

The complete set of research findings can be found in the reports described in (Table 1), which groups them by megatrend and cross-cutting theme.

The remainder of this synthesis report will identify key converging themes, present a prototype scaling plan and its likely medium-term impacts, and then conclude with next steps. A brief summary of each research project is contained in Annex A.

3. Integrated Analysis of Research Projects and Implications for Scaling Multipurpose Legume Technologies

This section focuses on convergent themes from the multiple research projects. In particular, we highlight themes that translate into clear areas for innovation investment and scaling. Individual reports may deal more specifically with individual legumes; the synthesis, however, deals with themes that have appeared in several reports. Prior to undertaking the research, there were discussions among teams about which multipurpose legumes to focus on. For some teams, such as Dentoni, Dzanja, and Steinfield, this was not a critical question due to the nature of their research. For others who wanted to obtain a deeper understanding of the particular constraints and opportunities associated with legume production and exchange, such as Me-Nsope and White, it was necessary to focus on one or two legumes because of the differences among legume value chains. Of all the legumes, pigeon pea was most often a central focus of authors. Me-Nsope and Larkins's

work[10] on the pigeon pea value chain, in particular, provides a unifying thread that links several of the reports together. However, even when dealing with pigeon pea specifically, many of the findings are more broadly applicable to the overall legume-maize innovation system.[11]

Scaling any intervention is inherently a systemic endeavor. That is, though scaling may occur at a particular point in the agri-food value chain, it is important to consider the social, political, economic, and environmental contextual factors and forces that propel such scaling. Therefore, in addition to a focus on production and the environment, a more intentional ethnographic approach in several of the projects seeks to inform policy and interventions so that they can more accurately engage with the socioeconomic and cultural dimensions of maize and legumes as they are meaningful to ordinary Malawians in both rural and urban areas. Inspired by Mzamu's (2012) call for food-related research and interventions that better reflect "local people's interests, values and meanings…," such interdisciplinary and ethnographic research moves what has traditionally been an agronomic approach to agricultural sustainability towards one that engages with the entire agri-food system and which "broaden[s] the theorization of food issues" (p. 7).

Additionally, the GCFSI researchers paid particular attention to dynamics that occur in the "informal" agri-food system, which comprises the activities of many small-scale local and regional agri-food entrepreneurs, including farmers, traders, and retailers. Informal local and regional food provisioning and exchange is critically important to both urban and rural livelihoods, as well as to urban and rural food security. Yet, non-farm agri-food livelihoods are rarely the focus of support or research, especially those agri-food livelihoods that are practiced in urban areas. The Malawi research reports by Dzanja, Me-Nsope, and White, in particular, highlight the opportunities for investment in local and regional food systems. Dzanja, for example, recommends investment in "packages of assistance" towards the support of small-scale processing, and is particularly optimistic about the prospects for soybean, pigeon pea, and groundnut (provided the problem of aflatoxin can be addressed; see Waliyar et al. 2013). White draws attention to the needs of small-scale urban legume retailers, noting that in such highly individualized and distributed systems retailers bear the brunt of the costs of transportation and must re-stock often, conditions that negatively affect their capacity to grow their profit margins. Me-Nsope, Snapp, and Dentoni highlight the necessity of improving the reliability of the regional legume seed system. Due to the diverse needs of farmers and variable ecological conditions throughout Malawi, it is important to bring a disaggregated perspective to development of this sector that addresses the particularities of farmers' economic, social, spatial, and ecological circumstances. Me-Nsope is particularly optimistic about the role of women in developing this sector for a number of reasons that will be discussed below.

3.1. Converging Themes and Areas of Focus for Innovation Scaling and Investment

The organizational schema of the structural dimensions of innovation systems proposed by Wieczorek and Hekkert (2012) serves as a useful reference point in thinking through how the maize-legume innovation system works, identifying factors that enable or constrain the generation and

[10] In cases where authors' names are given in the text without a date, this refers to reports prepared on the GCFSI research projects listed in Table 1 and implemented during the summer of 2014.

[11] Following Hekkert et al. (2007), we treat the multipurpose legume innovation as *embedded* within the legume-maize innovation *system:* "when using the concept of technological change, we do not refer to the technology development in the narrow sense, but to the development of technology in interaction with the system in which the technology is embedded" (pp. 413-414).

scaling of innovation, and determining points in the food system where investments in scaling make the most sense. Wieczorek and Hekkert identify four structural dimensions of innovation systems that "influence the direction and speed of innovation processes and hinder the development and functioning of innovation systems": actors, institutions, infrastructure, and interactions (p. 79). According to this research, systemic problem arise in the following ways:[12]

Actors' Problems: relevant actors may be absent, or present actors may lack the capacity to use resources or develop strategies.

Institutional Problems (hard and soft): relevant institutions are absent, or are affected by problems, characterized as being overly stringent or overly weak, that affect their capacity.

Interaction Problems: Also referred to as lock-in or network problems, which occur because different actors, for whatever reason, are unable to connect and provide mutual benefit, or there is a problem with the quality or intensity (either overly strong or overly weak) of interactions.

Infrastructural problems: physical, knowledge and financial infrastructure is either absent or of poor quality.

The GCFSI research found that problems throughout the agri-food system were constraining farmer uptake of multipurpose legume technologies. On the whole, an under-development of local **institutions** that serve the local food system stymies innovation because there is a lack of platforms that serve legume system **actors**, which could otherwise facilitate strong and trustworthy networks and access to resources and actionable information. Primary **actors,** including farmers and retailers, for example, lack the means with which to develop strategies or take business risks to address their problems. This is due to inadequate or dilapidated physical, financial, and knowledge **infrastructure,** which results in lack of access to capital, seeds, inputs, markets, and information. In the pigeon pea sector, weak **infrastructure**, uncoordinated **interaction,** and unreliable pricing information leads to a situation in which **institutional** incumbents, i.e., the export market, are favored. In effect, this tends to "lock in" certain ways of doing things and can block vibrant innovation processes. Further, so-called "soft" **institutions**, like gender, hinder innovation by blocking groups of people from fully taking advantage of what the system offers, while disproportionately favoring others. While social change is a long process, strengthening the innovation system means designing policies and practices that acknowledge and address such disparities, and which enable participation in spite of these inequities. Though such a catalog of problems seems overwhelming, in this synthesis report we identify a limited number of "keystone issues," investment into which can stimulate innovation processes in the maize-legume system. Keystone issues are those issues that are of critical importance to scaling the innovation. In general addressing the keystone issues will strengthen the capacity of actors to (1) improve and diversify income generating options, and (2) improve profit margins by reducing opportunity and transaction costs.

3.1.1. Keystone Issue: Networking Capacity

Local food exchange and provisioning systems throughout sub-Saharan Africa are widely dispersed and largely function through relationships between individual entrepreneurs. Though such a degree of decentralization and individualization provides for nimbleness and enables extensive legume-exchange networks that move food from rural areas to urban areas, actors in local food systems are

[12] A more extensive discussion of systemic problems can be found in the Wieczorek and Hekkert paper.

not strongly connected to wider legume networks. For example, small-scale entrepreneurs, farmers, and other actors often lack access to reliable price information and thus lack bargaining power, a situation which favors larger actors in the system.

Due to the extensive nature of legume exchange, and the remote location of farmers, many of whom do not have access to cell phones (Steinfield), communication among small-scale actors is poor and generally occurs on an ad hoc and individualized basis. Urban retailers or small-scale traders may travel to rural areas in search of legumes and may negotiate prices on the spot. Women, in particular, are constrained from full engagement with other actors by social roles that keep them close to the household. They are substantially less likely than men to own a cell phone.

Weak networking capacity is at least partially responsible for dramatic price fluctuations and uncertain conditions. Access to price information was identified by actors all along the value chain as being a critical need in order to mitigate such uneven and unpredictable pricing conditions. In addition, though phone-based information platforms like Esoko are intended to provide legume price information, different actors complained that "multiple information systems sometimes provide contrasting . . . pieces of information" (Dentoni) so that any reported prices could not necessarily be trusted. Moreover, as Dentoni notes, Esoko is only intended to provide price information; if farmers need information on, for example, inputs, they must seek out other platforms.

The ability to signal changes in urban demand to farmers is limited. This has implications for farmer decision-making and adoption of multipurpose legume technologies because farmers are not well aware of opportunities in urban markets. For example, White and Hamm found that demand for pigeon pea in Lilongwe markets was higher than expected and that some retailers could not keep up with demand. The conventional view of pigeon pea is that it is only eaten in the south. Because of this assumption, and due to the minimal communication infrastructure and weak connections between actors, it is likely that farmers in the Central Region are unaware of this unmet demand and, therefore, do not consider it a viable crop.

Limited networking and communication capacity is also a function of inadequate infrastructure, a situation we address in the next section.

3.1.2. Keystone Issue: Post-harvest Transportation, Storage, and Processing Infrastructure

There is a growing recognition of the importance of post-harvest issues in the food system. Most often, post-harvest issues are discussed in the context of smallholder farmers, though the GCFSI research found that many legume system actors along legume value chains are also constrained by post-harvest factors that go well beyond the farm gate. Addressing these factors can help to stimulate innovation in the entire system by removing some of the cost burden shouldered by small-scale farmers and entrepreneurs.[13]

[13] "Cost burden" refers to the highly individualized costs of doing business in a system with such poor infrastructure and high transportation costs. For example, because storage infrastructure is poor and insecure, small-scale retailers must acquire small amounts of legumes frequently, which requires high expenditures on transportation. Some small-scale entrepreneurs reported that acquiring larger stocks of legumes that can be held over a longer period of time, thereby decreasing transportation expenditures, increases the risk that those legumes will be attacked by pests in storage, resulting in degraded quality.

As Dentoni notes, legume production is scattered around the country. Legumes are transported by individual entrepreneurs who have to navigate poor road conditions, often in unsafe vehicles, resulting in high transportation costs. Ongoing and future energy shortages suggest that fuel is likely to become increasingly expensive. Such legume exchange practices mean that individuals in the system are burdened with high transportation and transaction costs. Combined with inadequate storage capacity, it is difficult to coordinate supply and demand across the country, which results in highly uneven and unpredictable legume prices throughout the year. Farm-gate prices and individual transactions vary significantly, which means that those working in the sector constantly face uncertainty about prices. Such an environment diminishes individual capacity to manage risk or to invest capital into growing their businesses.

Insect and other pest damage to legumes in storage are significant factors in both urban and rural settings and result in a diminished quality of legume that has to be discarded or sold at a reduced price, thereby cutting into incomes. In urban markets, many legume retailers complain that their legumes are often stolen, even in markets that have hired guards to protect markets overnight. To reduce the likelihood of theft, many retailers haul their legumes back and forth between the market and their homes, a practice that increases their expenditures and limits the quantities of legumes they can reasonably manage. Sometimes they acquire their legumes by traveling to other markets. In addition, many retailers manage storage constraints by acquiring only small amounts of legumes at any given time.

The processing sector faces energy constraints currently, and is likely to face them well into the future. Dentoni notes that "processing facilities require consistent energy supply to be competitive, yet the major processors' plants in Blantyre still suffer lack of supply." According to hivos.org, only 9% of Malawi is electrified, 94% of which is powered by hydro and 6% by thermal sources (HIVOS.org).[14] The capacity of the national power utility is stretched, and subject to day-to-day load shedding. Energy supply and costs must therefore figure into any development plan that requires additional energy inputs.

More generally, lack of mobility for social and economic reasons limits the ability of many to fully participate in and contribute to innovation processes. Women, for example, are limited in their ability to travel, and even those who theoretically might be able to travel, like those in women-headed households, are constrained by their household responsibilities. Many poor urban agri-food actors are also limited in how often and how far they can travel to acquire products, and many are able to acquire only as much as they can carry. These issues must be considered when designing farmer practices and development interventions.

3.1.3. Keystone Issue: Seed Systems

Recent research highlights the importance of the informal seed sector, which remains dominant despite past predictions that it would disappear with liberalization of the seed market. The commercial sector has been unable or uninterested in meeting the diverse legume preferences and needs of farmers. The legume seed sector in Africa has not become commercialized, due to the challenges associated with self-pollinated crops for which there is limited and highly differentiated

[14] Data is compiled from World Bank, WHO, UNDP, International Energy Agency, International Renewable Energy Agency, and Renewable Energy and Energy Efficiency Partnership.

demand.[15] In general, farmers save their own seed and rarely replenish their seed from private sector sources. There is a body of literature on how to support input and output markets for undeveloped legume production systems (e.g., Maredia, Howard, Boughton, and Kajisa (1999). Community-based seed ventures have been supported by many development actors in other areas of the world, as have small-scale traders and storekeepers who are involved in cleaning and selecting from farmer-produced seeds to supply the informal market. Current policy in Malawi requires that seed be certified, which may impede the development of local seed sectors.

3.1.4.Keystone Issue: Access to Information, Services, and Capital

Steinfield, Dentoni, Me-Nsope, and White call attention the inaccessibility of reliable and actionable information that agri-food actors can use to improve capacity or to access capital and other resources. Such a gap in services not only prevents farmers from using new information to enhance their own businesses, but, as Dentoni notes, such information asymmetries privilege the most powerful actors in the system, which works to block innovation processes. Though mobile phones are widely assumed to offer opportunities to close such gaps, Steinfield and Wyche found that penetration among smallholder farmers is much lower than expected.

Me-Nsope examined how access to information, services, capital and other resources differs by gender, and how it constrains women's potential. For example, she found that women are concentrated at specific points along the value chain, and only where they are able to balance the needs of the household with their participation in economic activities. As she explains, "inequalities with respect to resources or opportunities for income generation limit business investments . . . thereby having implications for the profitability of their businesses" (p. 58).

In urban areas, there is a relative lack of extension services to support urban agri-food actors, a situation that exists throughout sub-Saharan Africa. However, White and Hamm found that many retailers desired such services. In the area of storage, for example, some retailers said that their existing practices were no longer effective, but they had no recourse for finding additional information. Lack of access to capital or loans, which is perhaps due to the low profitability of legume production, was widely identified as a major constraint.

4. Recommendations for Scaling of Multipurpose Legume – Maize (MLM) Systems

In this section, we offer a foundation for developing a detailed scaling plan, and cover the basic "where, how, and when" questions related to the target groups and zones where scaling would be worthwhile (section 4.1 below), what interventions would be needed to facilitate scale-up (section 4.2), and over what time frame the interventions should be implemented (section 4.3). Two principles underlie our proposed scaling approach. First, an effective scaling plan must address issues all along the legume value chain, covering both on- and off-farm components of the MLM system, including assembly, processing, and marketing at the wholesale and retail levels, both domestically and for export. The scaling plan must recognize locally specific conditions and desired outcomes, and provide technical support and capacity building along the value chain. Second, scaling MLM systems is a complex endeavor. The multidisciplinary nature of our collective research activities has helped to identify a diversified set of scaling interventions that consider the local

[15] Commercially oriented farmers may favor more uniform varieties, while smallholders may favor characteristics such as drought tolerance or some specific growth habit. This can be highly variable among individual farmers depending on their preferences, social context, and geographical location.

biophysical environment, market opportunities and constraints, and socioeconomic factors, including gender issues and the welfare of the various actors within the value chain.

While soybean, groundnut, and common or climbing beans can be incorporated into an MLM system, we focus on pigeon pea and the pigeon pea value chain for several reasons (some already cited earlier): (a) pigeon pea fixes 90% of its own nitrogen (N) requirements and does not need an inoculant; (b) pigeon pea has a relatively long growing season, which allows it to contribute more N to the soil; (c) pigeon pea has established markets, for both domestic use and exports; (d) pigeon pea can be used for domestic consumption with less processing than soybean, and (e) pigeon pea is considered a women's crop, and developing the value chain offers an opportunity for improving income-generating options for women.[16] Despite these positive qualities, and its acceptance by farmers and consumers, pigeon pea has received less attention than other multipurpose legumes.

4.1. Target Groups and Target Zones

In recommending whom to target for adoption of improved MLM technology, and where, we will take into account biophysical conditions, location of markets, and other socio-economic factors, including gender.

4.1.1. Target Groups and "Pathways to Intensification"

GCFSI research has identified two target groups or "pathways to intensification" through adoption of improved MLM technology (Table 3). Each group will require a distinctly different approach to MLM scaling. Group 1 consists of farm households with good land, labor, and capital resources and a commercial market orientation. Group 2 reflects the majority of farmers in Malawi, and consists of farm households with average or below-average resource endowments, especially in areas of degraded soils, for whom the beneficial effect of legumes on soil fertility would improve household food security and nutrition. Each of these two groups should be subdivided into two further groups, based on geographical location and what that implies for biophysical growing conditions and market access. (Determination of target zones is discussed in more detail in section 4.1.2.)

[16] For some farmers, however, the combination of soybean + pigeon pea together with maize represents a sustainable and high-productivity option.

Table 3: Target Groups and Pathways for Scaling MLM Technology by Zone

Zone \ Target Group	Group 1: <10% of farmers. Farmers with access to capital resources. The strategy focuses on developing access to commercial or export markets.	Group 2: 70% of farmers. Farmers with minimal access to capital resources. The strategy focuses on developing nutrition and livelihood security and improved soil fertility
North and Central (lower population density, more land, better growing conditions)	Soya and pigeon pea as cash crops (domestic livestock feed and export, respectively)	Pigeon pea rotation with maize (potential for climbing bean in northern region, where there is higher elevation)
South (higher population density, less land, more variable production conditions)	Pigeon pea for the Blantyre export market	Intercropping with maize in order to improve soil fertility and strengthen resilience in response to increasingly uncertain climate conditions

Figure 2 below provides another perspective on the two most promising pathways for sustainable intensification. With suitable support, including improved input and output markets (discussed further in section 4.1.3), households in Group 1 face a straightforward pathway to adoption of improved varieties of soybean and pigeon pea, combined with targeted fertilizer and drought-tolerant maize varieties. The pathway for Group 2 is one of rehabilitation of soils, and farmer education regarding the integrated MLM production system.

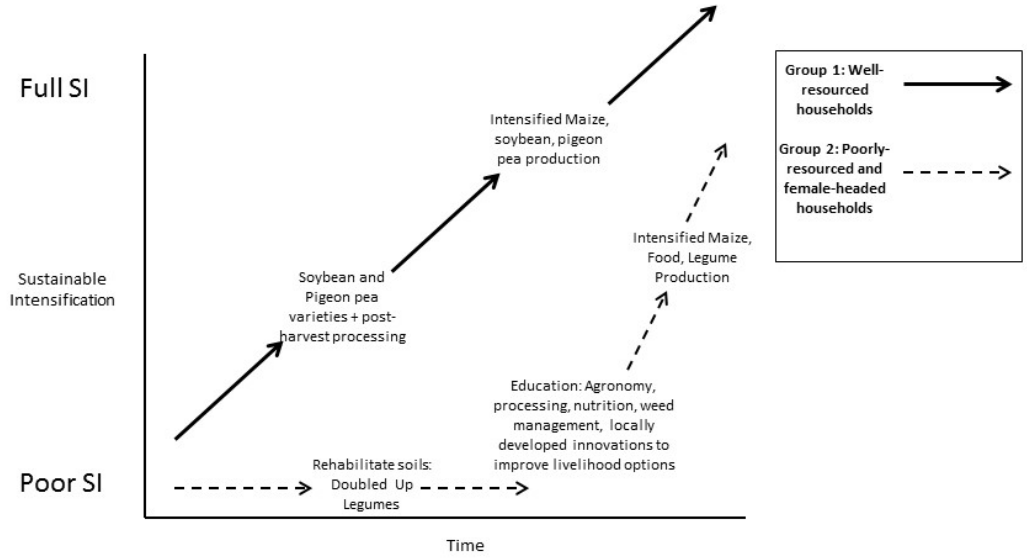


Figure 2: Differentiated Pathways for Scaling MLM Technology

To be sure, these two target groups and pathways represent very broad categories. We recognize the need to refine approaches according to place and people. For example, since pigeon pea is a crop that is managed primarily by women, special care must be taken to ensure that benefits that result from scaling will continue to accrue to women. We make this caution explicit here because it is often the case that when investments are made into certain technologies, those with power and privilege are the first to benefit and may exercise control in ways that exclude those most in need of support. To counter this tendency, in the next section we offer specific intervention areas on which to focus that, if done well, will benefit those most in need of support.

4.1.2.Target Zones

As noted above, our approach is to identify target zones based on a combination of geophysical, market, and socio-economic factors. This information is incorporated into a set of composite maps.

For the period 2001–2010, Figure 3 maps areas within Malawi with respect to three levels of historically observed agricultural productivity (above-average, average, and below-average), and two levels of variability of productivity, or sensitivity to bio-physical factors: "resilient" (low variability) and "sensitive" (high variability) (Messina and Crawford, 2015).[17] The six boxes at the top of the figure show the percentage of Malawi's total area that falls into each of the six categories. Nearly 75% of the land area falls into the average productivity/sensitive category (48%) and the average productivity/resilient category (24%). Average productivity areas are concentrated in the South and Center, and high productivity in the North. Sensitive areas are concentrated in the South, and to a lesser extent in the Center. A conclusion from this map is that the South has a high proportion of areas with below-average yields (red) and sensitivity to climate shocks (dark blue). Given its small farm sizes, the South is likely to be where many members of Target Group 2 are found.

Figure 4 shows zones that are ideally suited to pigeon pea cultivation, in terms of temperature and rainfall. Underlying Figure 4 is a calculation of the area of land within each Extension Programming Area (EPA), and of the percentage of total EPA land area that is optimal for pigeon pea (higher percentages are shaded darker). Central Malawi has a preponderance of EPAs with a high proportion of land that is optimal for pigeon pea.

[17] The focus of Messina and Crawford (2015) is on maize, but the analysis of agricultural productivity variability is equally relevant to the MLM technology.

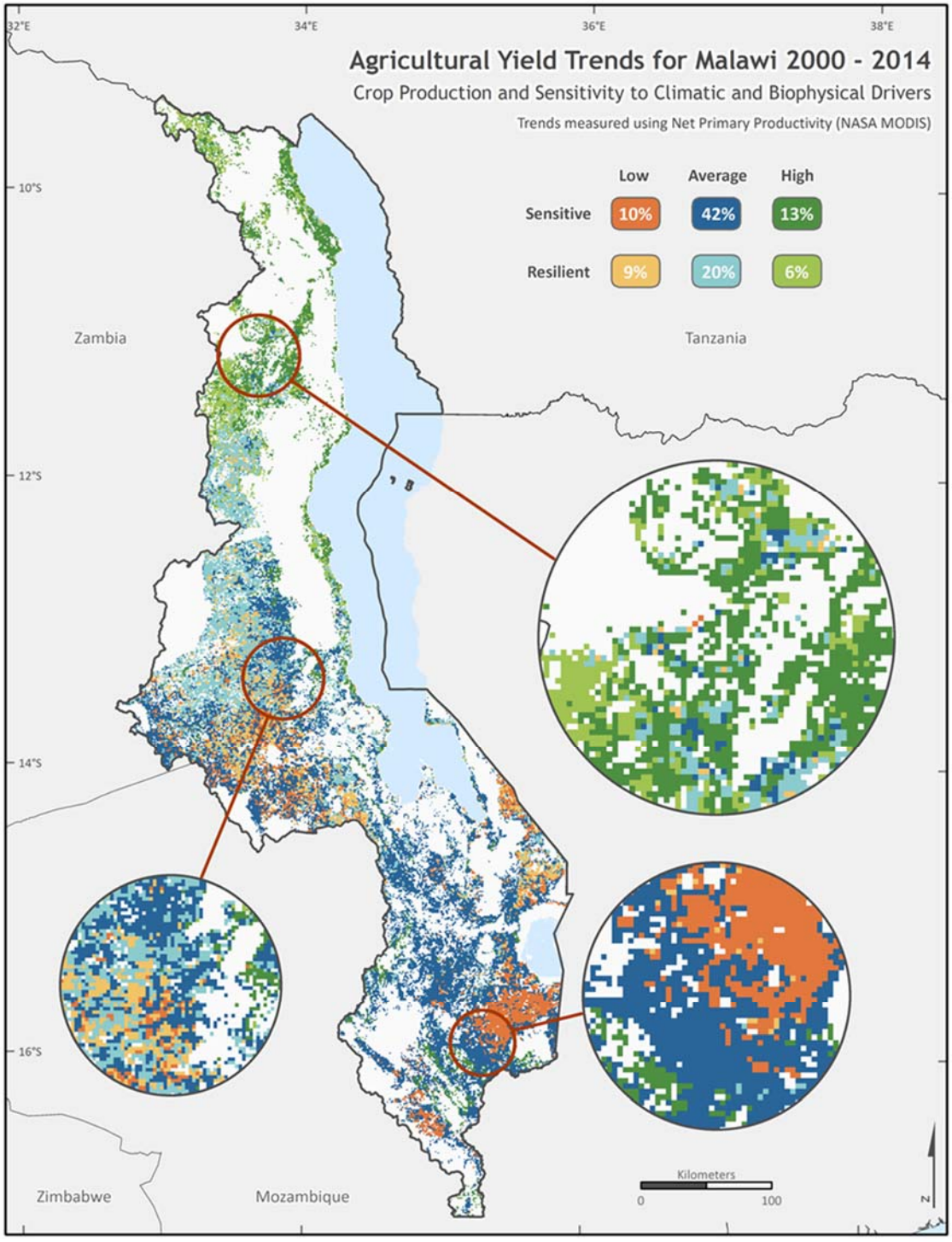
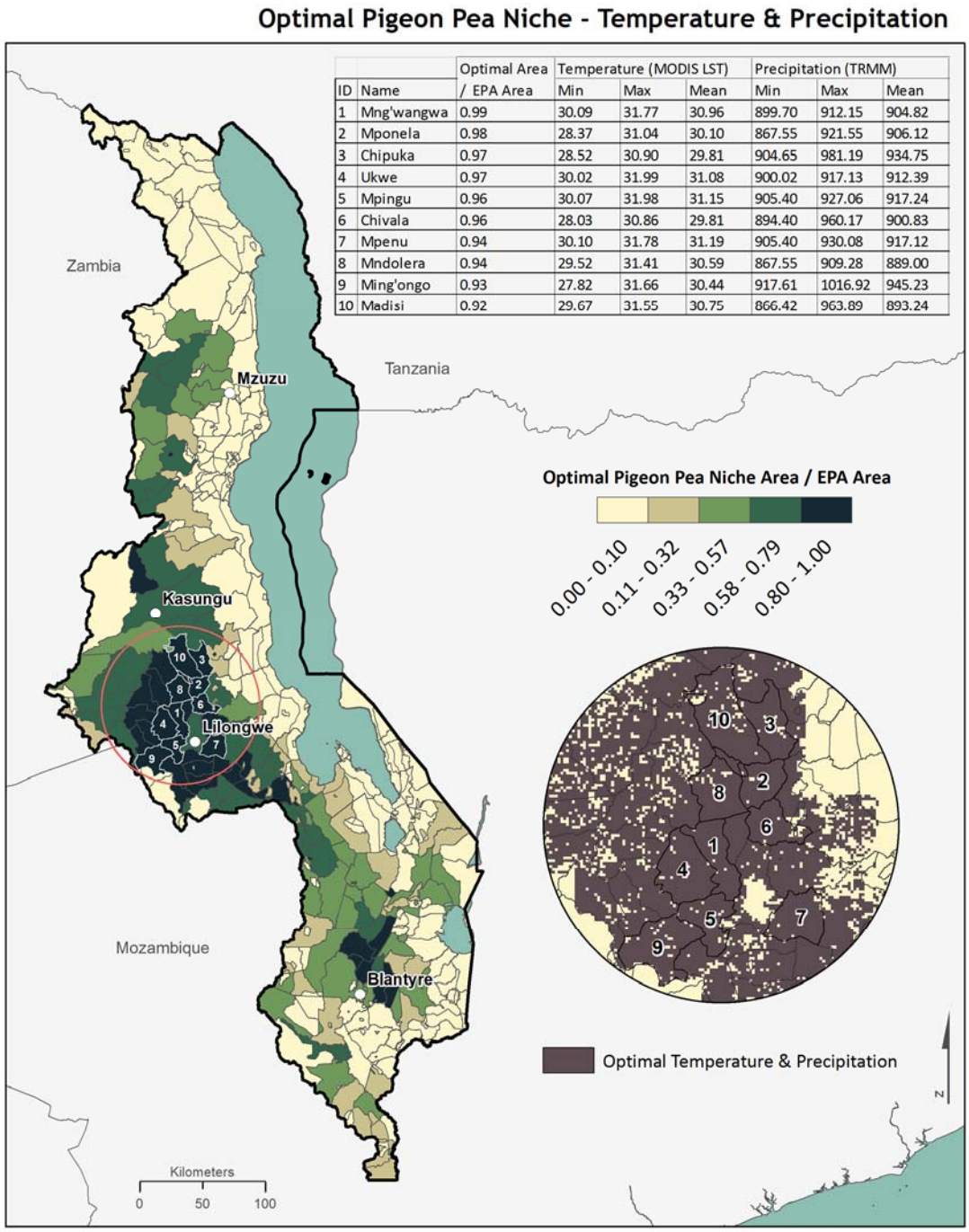


Figure 3: Call-outs Highlight Areas with Distinct Climate Drivers of Agricultural Production

Sensitive areas (pixels) display high inter-annual variability often due to climate. The resilient areas in each category had lower yield variability over time. Southern Malawi has the greatest concentration of climate-sensitive but typically productive areas (~ 1 ton per hectare; shown in dark blue) and a clear clustering of chronically low-yielding areas (< 750 kg per hectare; shown in red).



ID	Name	Optimal Area / EPA Area	Temperature (MODIS LST) Min	Max	Mean	Precipitation (TRMM) Min	Max	Mean
1	Mng'wangwa	0.99	30.09	31.77	30.96	899.70	912.15	904.82
2	Mponela	0.98	28.37	31.04	30.10	867.55	921.55	906.12
3	Chipuka	0.97	28.52	30.90	29.81	904.65	981.19	934.75
4	Ukwe	0.97	30.02	31.99	31.08	900.02	917.13	912.39
5	Mpingu	0.96	30.07	31.98	31.15	905.40	927.06	917.24
6	Chivala	0.96	28.03	30.86	29.81	894.40	960.17	900.83
7	Mpenu	0.94	30.10	31.78	31.19	905.40	930.08	917.12
8	Mndolera	0.94	29.52	31.41	30.59	867.55	909.28	889.00
9	Ming'ongo	0.93	27.82	31.66	30.44	917.61	1016.92	945.23
10	Madisi	0.92	29.67	31.55	30.75	866.42	963.89	893.24

Figure 4: Optimal Pigeon Pea Growing Areas (Source: J. Messina)

The following maps, developed by Nejadhashemi et al., show the most suitable locations for pigeon pea expansion according to water, climate and market accessibility. Each map was divided into five classes using the natural break classification technique. Class 5 represents the best scenario while Class 1 represents the worst.

Based on the analysis, which combines data on water availability and pigeon pea suitability with market access, the next three maps illustrate the areas that are most suitable for pigeon pea scaling.

Figures 5-7 show the best locations with market access in cities with population of 20,000, 50,000, and 100,000, respectively.

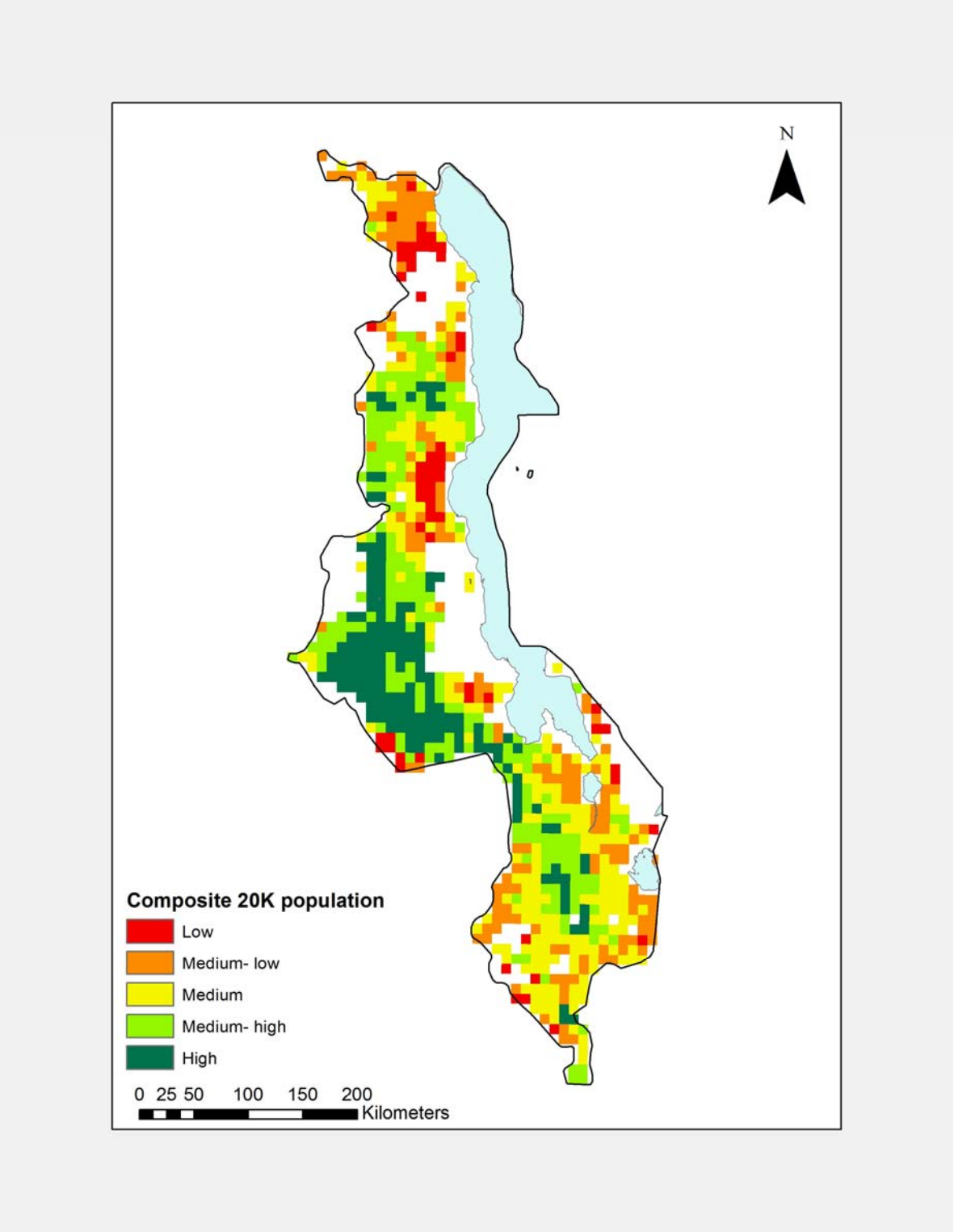


Figure 5: Composite Map (Water Availability + Pigeon Pea Suitability + Travel Time to 20K Population)

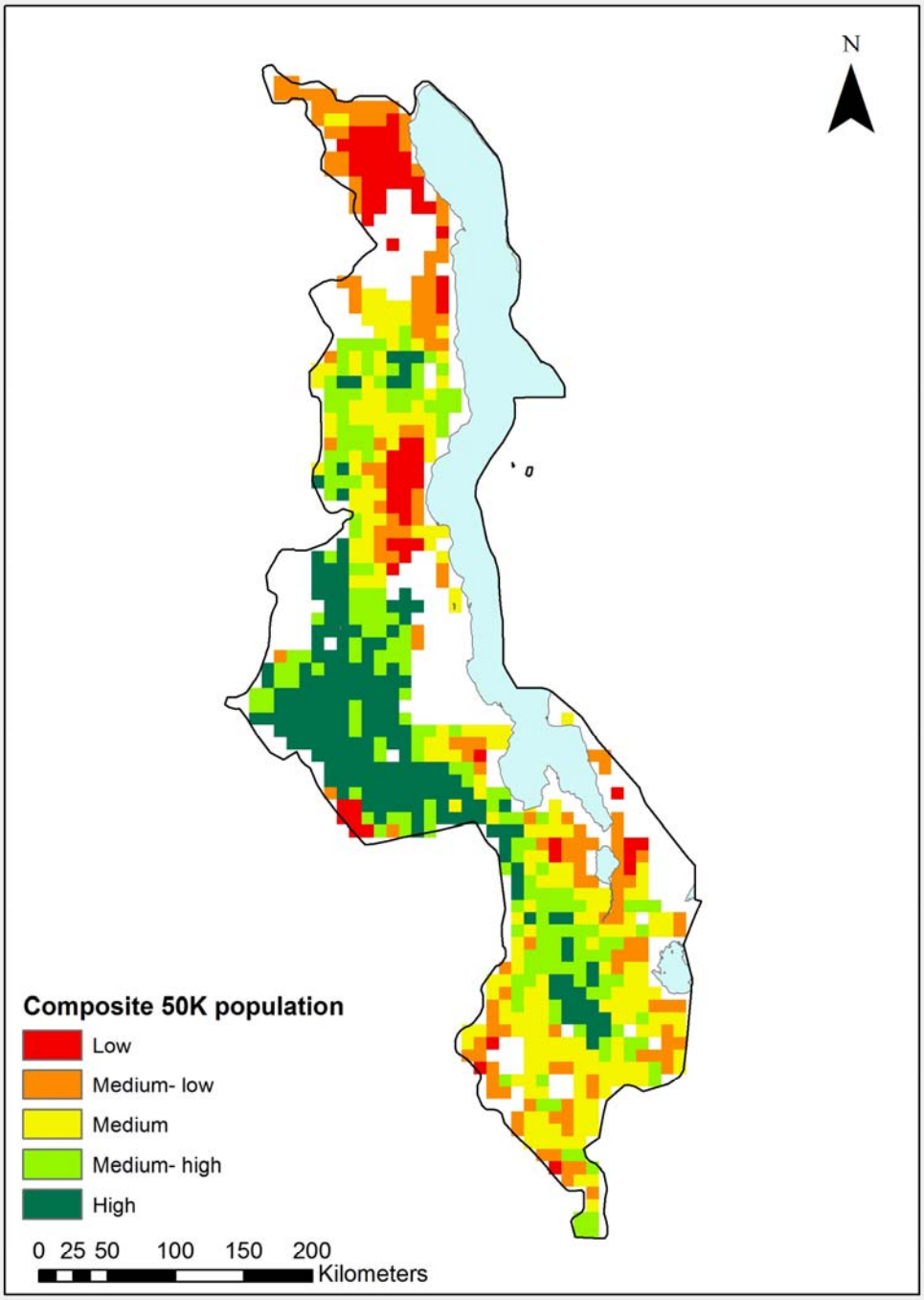


Figure 6: Composite Map (Water Availability + Pigeon Pea Suitability + Travel Time to 50K Population)

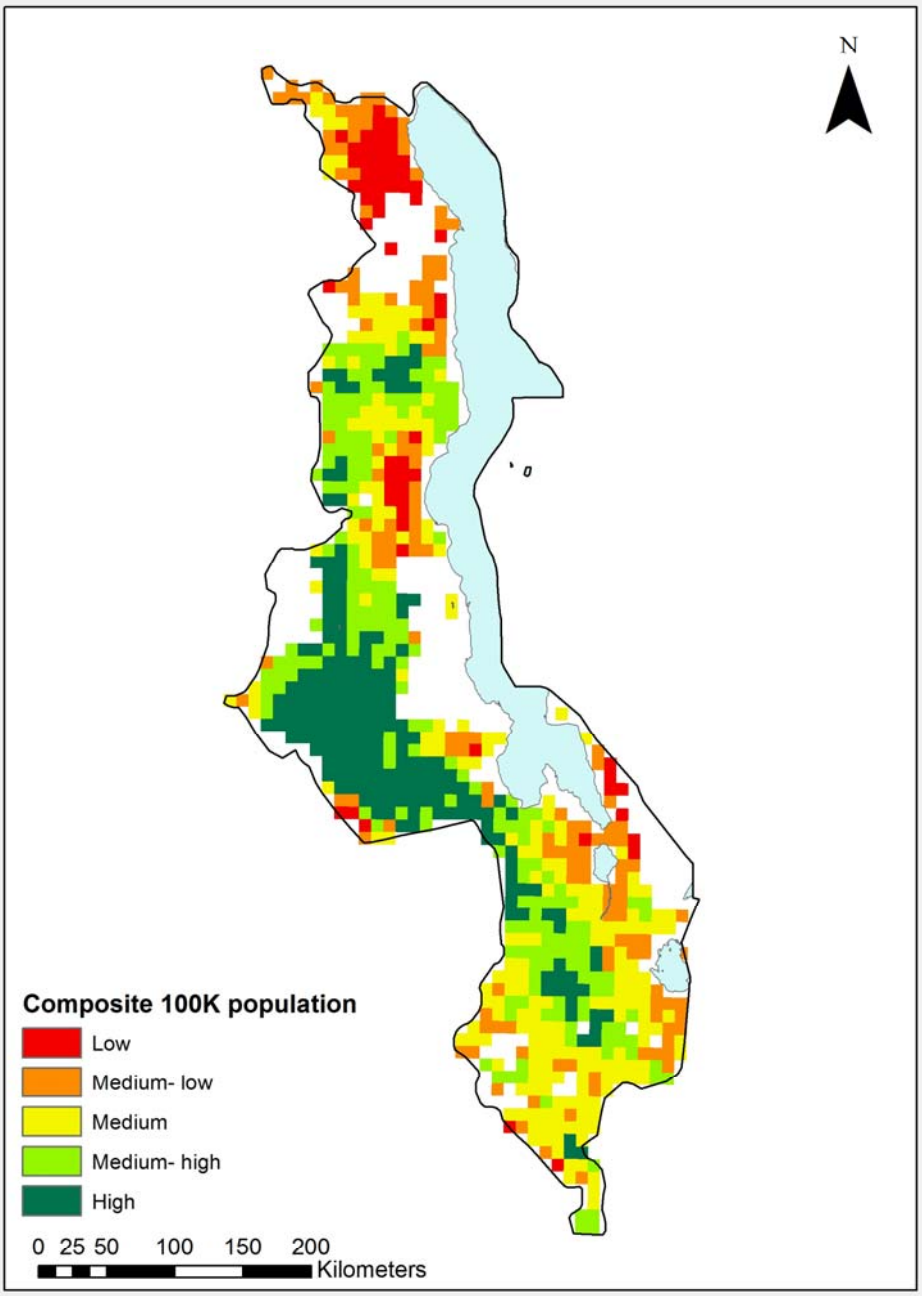


Figure 7: Composite Map (Water Availability + Pigeon Pea Suitability + Travel Time to 100K Population)

To interpret the maps described above, and derive their implications for scaling interventions, we divided Malawi into three regions: Southern, Central, and Northern. The general characteristics of these zones are as follows:

a. Southern. Primary zone for production of pigeon pea for export. Proximity to urban and export markets in Blantyre. Relatively high and variable rainfall, with a risk of flooding and rain during harvest time, gives less-than-optimal conditions for pigeon pea and maize. Relatively small land holdings (approx. 0.5 ha) and significant number of landless households.

b. Central. Optimum conditions for pigeon pea-maize production, in terms of rainfall, temperature, and soils with good moisture-holding capacity. Proximity to major urban market in Lilongwe, and effective access to export market out of Blantyre. Larger land holdings (approx. 1.0 ha) with plots that are often contiguous.

c. Northern. Generally good legume-maize (and tobacco) productivity already, so less need for new technology. Relatively large land holdings (approx. 1.5 ha) and lower population density. Expansion of production for urban markets, with some connection to export market traders from Blantyre.

Several overall points emerge with respect to targeting, based on an analysis of biophysical conditions, acceptability to farmers, soil fertility needs, location of production, consumption, sales and markets, and other socio-economic factors:

a. In order to reach large numbers of farmers (both Groups 1 and 2), pigeon pea scaling interventions should focus on Central Malawi, given its geophysical suitability and proximity to the large urban market in Lilongwe.

b. If the objective is to targeted Group 1 farmers who export of pigeon pea through Blantyre, or Group 2 farmers who are challenged by low and variable productivity, interventions should focus on Southern Malawi.

c. Good production conditions in Northern Malawi (above average land sizes and productivity) and presence of tobacco as a cash crop make farmers there relatively unlikely to perceive the benefits from shifting to improved MLM technology, at least in the near term.

Our recommendation that the most efficient investment of scaling resources would focus in the Central Region does not mean that pigeon pea is not a valuable technology for other regions in Malawi. Indeed, in the south, pigeon pea is commonly grown and farmers have evolved various ways of including it in their cropping systems. The south is also home to Blantyre and all pigeon pea exporting infrastructure. However, increasing climatic variability as well as high and unpredictable rainfall may not favor the expansion of MLM systems in southern Malawi, where a high water table combined with heavy rain can kill maize roots. In the north, on the other hand, land availability and soil fertility are not currently pressing issues, so that the impetus for adoption of MLM systems is

low.[18] Conditions in the Central Region, however, combine to produce a situation in which pigeon pea is at a "tipping point in terms of interest and adaptation" (Snapp et al. 2015).

4.2. Investments Needed to Support Scaling MLM Systems in Central Malawi

Investments into scaling MLM systems in central Malawi can be targeted in discrete areas along the pigeon pea value chain. In Central Region, pigeon pea is produced by women, though they lack the means or infrastructure with which to process it, and are often constrained by social roles from marketing or transporting it. We believe that there will be unique opportunities to enhance the well-being of communities through interventions that are specifically designed to meet the needs of women and which account for their social positions within society and relevant constraints and opportunities. Furthermore, we recommend that investments be specifically geared towards enabling the participation of women. It is worth noting here that such investments should be intentionally decentralized in ways that mirror local and regional food exchange and provisioning systems. In other words, investments should reinforce and support local and regional food exchange and provisioning systems by supporting the small-scale livelihoods that comprise those systems.

Importantly, for all these identified intervention areas it is critical to consider organizational form and how best to involve marginalized populations. Focusing on technical aspects of interventions without attention to who benefits, who has access to resources, and who may bear the brunt of any additional work risks perpetuating the social conditions that create inequality. For example, collective activity, properly considered and implemented, can work to support women and other marginalized people in leveraging resources and opportunities. We recognize that there are major hurdles in developing and managing such organizations, e.g., building trust, but such organizational forms are familiar to many people, and their value is already proven.

GCFSI has identified a number of intervention areas where scaling investments should be focused: (1) build farmer knowledge and capacity regarding appropriate agronomic practices, (2) seed systems, (3) storage and transportation infrastructure, (4) small-scale processing, (5) access to information, capital, and financial services, and (6) networking and collective action. These areas are briefly discussed in the next several sections.

4.2.1. Build Farmer Knowledge and Capacity Regarding Appropriate Agronomic Practices

Both Me-Nsope and Snapp found that adoption of pigeon pea must be supported by extension that explores and teaches appropriate agronomic management practices. Fines and community norms that work to keep livestock out of legume fields are effective at southern locations where pigeon pea has been grown for some time and is an important cash crop, whereas fines are rarely enforced in areas where pigeon peas are only beginning to be adopted (about 10% of farmers), such as in Central Region. Farmer field schools (FFS), for example, have been shown to be an effective means to catalyze inquiry-based learning in agroecology in an African context, with a recent study in East Africa showing proven benefits for illiterate and female farmers as well as better-off farmers. There is evidence that farmer innovation is enhanced by FFS curriculum that is action-learning oriented and teaches science-based principles as well as good farm management practices. In addition, the

[18] It is worth noting here, however, that pigeon pea was introduced into the Northern Region some time ago, and has persisted there due to favorable conditions. Most pigeon pea produced in the Northern Region is apparently transported to Blantyre by independent traders who work on behalf of the export companies.

combination of ICT videos and cell phone-based educational materials with FFS are being explored for effectiveness in enhancing knowledge.

One area related to agronomic practices that was identified as a key to broad uptake of pigeon pea is that of livestock management, to counteract the problem of crop damages caused by livestock trampling or eating of the plants.

4.2.2.Seed Systems

As noted previously in this report, the legume seed sector has not been well supported, although government input subsidy programs such as FISP have expanded access for improved seed varieties and fertilizer to support intensified maize, soybean, and pigeon pea production. Women are generally responsible for seed selection and have certain criteria for the seeds they choose. Expanding their involvement in seed multiplication and distribution would give them additional income-earning opportunities. To support development of the seed sector, researchers must become more responsive to the criteria that matter to pigeon pea farmers. In addition, building community seed systems would entail training and empowering farmers to better carry out seed multiplication.

Promising approaches for development of a seed sector that can both meet the needs of farmers and provide a platform for livelihood generation might refer to recent work on integrated seed systems (Amadou M Bèye, Remington, Wopereis, & Diagne, 2013; Amadou Moustapha Bèye & Wopereis, 2013; Louwaars & de Boef, 2012). This work explores how seed systems might integrate the formal and informal seed systems so that they best serve farmers' diverse needs. The work recognizes the limitations and strengths of both systems, while recognizing that any approach will have to be locally tailored and pluralistic in nature.[19] A recent paper by Martens, Scheibe, and Bergey (2012) explores the viability of a decision support system (DSS) that can help to develop the sector through informed decision-making. This decision support tool is designed to help farmers decide where to locate small-scale seed production businesses, taking into account variables such as transportation and storage, issues that have been identified as being paramount in scaling multipurpose legumes. The paper reports that, as of its publication in 2012, 17 small seed companies had been started and were distributing seeds to farms in Tanzania, Malawi, Kenya, and Mozambique.

4.2.3.Storage and Transportation Infrastructure

Better storage can help mitigate lack of market power by farmers (especially women), minimize need to travel, reduce food loss, improve incomes, and maintain quality of seed. Hand in hand with storage improvements is the need for improved transportation infrastructure, a well-recognized priority but one that is especially critical for food system performance. Transport costs have a doubly negative impact on the net returns of food system actors, by raising the costs of inputs and the prices paid by consumers, and reducing prices received by farmers.

The costs of transportation might be reduced by encouraging individual urban retailers to pool their resources to hire trucks to travel to outlying markets or different regions, thus relieving individual retailers from making these trips on their own. In addition to reducing transportation costs, such

[19] According to Beye and Woperis (2013), the integrated seed system model recognizes "that no single public, private, community- or NGO-based intervention can support seed sector development. The individual farmers themselves use different seed systems for different crops, and the seed sector development needs to be approached in a pluralistic manner, including public, private, community-based, or NGO stakeholders, each of them assuming specific responsibilities in dissimilar seed value chains" (p. 21).

collective activity also reduces the need to be away from one's market stall. Better communication infrastructure may reduce situations in which retailers travel to rural areas in the absence of reliable knowledge about where legumes might be found, and incur costs searching for products. Developing more exchange hubs with good storage facilities in both remote and well-traveled areas may improve the reliability of the exchange system, as well as reduce losses of legumes through exposure to pests and environmental conditions.

4.2.4.Small-scale Processing

Currently, processing of pigeon pea is done exclusively by exporters. Processed pigeon peas are legumes that have been dehulled and split, which requires a mechanized process. Split pigeon pea is preferred due to the reduction in required cooking time.[20] It appears that any processed pigeon pea that reaches the market has been processed by exporters and then taken out of the export value chain for one reason or another. The effect is that processed pigeon peas that reach the market are priced at three times the amount of what they are at the farm gate prior to processing. Improving the ability of small-scale entrepreneurs and farmers to process pigeon pea can bring down the market price for urban consumers, as well as create a new revenue stream in the informal legume sector.[21] In addition, Dentoni suggests that more distributed processing clusters could decrease costs associated with energy and transport. Also, to address the energy constraints faced by the processing sector, distributed and renewable energy supplies paired with small-scale processing may prove to have greater advantages than reliance on a centralized energy supply system.

4.2.5.Access to Information, Capital, and Financial Services

Greater access to information about market prices and volumes traded can benefit both farmers and traders. The GCFSI study of the informal urban food system by Hamm and White highlighted the information needs, which are different than the needs of farmers, required by the various informal urban agri-food actors. Stimulating urban legume demand requires improving the capacity of urban retailers to handle a larger volume of business and to address issues of food quality and food safety. A Lilongwe City Council official interviewed by White stated that the municipality needs empirical evidence that can inform market upgrades and support urban food provisioning and exchange. This is a relatively neglected area of research, though organizations such as AFSUN (African Food Security Network) and WIEGO (Women in Informal Employment: Globalizing and Organizing) are working on these issues throughout sub-Saharan Africa. Moving forward in this area requires collaboration between urban agri-food actors and municipal decision-makers to identify and understand each other's needs, interests, and constraints, as the basis for identifying potential solutions and organizations that could help implement them. As one example, GCFSI core faculty members have expertise in assessing needs and designing solutions in the area of food safety.

Inadequate access to capital and financial services also emerged from the GCFSI studies as a commonly cited constraint. This is a well-studied area. The GCFSI studies conducted in 2014 highlighted the importance of these constraints for processors and urban food traders in both the

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[20] Cooking time is a major concern due to the expense of and difficulty in obtaining a cooking fuel source.

[21] The only reference we could find to a small-scale pigeon pea processor was on the New Agriculturalist website (http://www.new-ag.info/99-5/focuson/focuson6.html), and references this publication: *A new small-scale processor for pulses by H M Nimal Jayantha and K B Saxena, ICRISAT Information Bulletin No. 54, 1998*. GCFSI is aware of at least two innovators who create machines designed for small-scale entrepreneurs, one of which is based at Michigan State, and the other in Senegal (per private communication with Cynthia Donovan at the Legume Innovation Lab at MSU).

formal and informal systems. Related interests expressed by private sector food system actors included a desire to learn better business management practices, including how to manage credit.

4.2.6. Networking and Collective Action

Through networking, food system actors can access information on ways to improve performance. Country-wide networks can be facilitated and strengthened by encouraging organized collective action in both rural and urban contexts, which can reduce costs to individuals and stimulate innovation system by enabling risk taking; improving the ability of extension agents to deliver services and learning opportunities; providing organizational models that encourage cost sharing (in transportation, for example); improving information sharing among members; and improving the ability of small-scale entrepreneurs to influence policy-makers and other authorities, as well as mitigate power asymmetries. The capacity of groups and the strength of networks should be built through responsive service provision and policymaker engagement with agri-food actors. Asymmetries between actors can be minimized by providing better platforms for accessing information, and by building infrastructure and networks to connect actors. Me-Nsope sums up the advantages of collective action: "Group/collective action has potential to increase farmers' bargaining power, increase volume available for sale, fetch better prices, and enlarge access to capital, thereby supporting investments in storage infrastructure, business training, and other resources. . . . Group action could be particularly beneficial to women who face mobility constraints" (p. 7)[22].

4.3. Time Frame for Scaling

A rough estimate of the general time frame for the six categories of scaling interventions discussed above is shown in Table 4. The implicit scale of the interventions is the Malawi national level, and the implicit assumption—for purposes of this exercise—is that significant impacts would be achieved within the indicated time frame, so that little if any further investment would be needed.

Table 4: Time Frame for Implementing Scaling Support Interventions Within Malawi

Intervention	**Time Required to Implement**
Extension on agronomic practices	One to two years
Establishing storage facilities	Two years
Establishing processing facilities	Two years
Building seed system	Two to three years
Creating access to information, financial services, and capital	Two to three years
Networking and collective action	Two to three years

[22] In her paper, "How do Institutions for Collective Action Evolve," Elinor Ostrom uses case studies of collectively managed irrigation systems to discuss the evolution of collective action to manage resources. She compares management systems that have been created and managed by the users themselves versus those systems that have had rules imposed by external experts. Citation: Ostrom, Elinor. *How do Institutions for Collective Action Evolve?* Institute of Economic Growth, 2008.

5. Estimated Medium-term Impacts of Scaling MLM Systems

Because each region is characterized by a different circumstances and needs, medium-term impacts will also vary. In the Central and South Regions, improving the seed system and access to quality and appropriate seed stock should take precedence. In the Central Region, Snapp suggests that effective community livestock management is a critical factor in enabling the effective integration of pigeon pea in the cropping system. As evidence, she cites those efforts undertaken by community members once it was perceived that pigeon pea represented an important source of income, a change that occurred as a result of improved access to reliable markets. In urban markets, evidence of impacts of sustainable intensification would be reflected not by agronomic practice, but by improved availability of legumes at consistent prices and improved incomes for urban retailers. Such measures can improve the capacity of the system to absorb increased production of legumes, thus increasing their attractiveness to farmers as a sound investment of time, land, and labor.

Overall, the MLM system offers two advantages relative to maize cultivation alone: (a) higher yields, and (b) greater yield stability, where the addition of legumes results in a system with greater drought resilience and greater resistance to the higher temperatures that are resulting from climate change. For adoption of the MLM system to be widespread, farmers who may be concerned about allocating less land to maize and more to legumes would need to be convinced of the value of advantages (a) and (b) cited above.

Target group 1 represents at most 10% of the roughly 2.5 million farm households in Malawi. Jayne et al. (2010) report that only 1 to 3% of households account for 50% of maize sales. Benefits to group 1 would include increased family income (including cash income), some increased family consumption of nutritious legumes, and a more sustainable farming system in terms of maintenance of soil fertility.

Target group 2 represents approximately 70% of farm households. Benefits to group 2 would include increased food security (reduced need to meet household requirements for maize and legume production through purchases), improved nutritional status, and more resilient and sustainable farming systems.

Other anticipated impacts include (a) in the Central and South Regions, an improved seed system and access to quality and appropriate seed stock; and (b) in urban markets, greater availability of legumes at consistent prices and improved storage conditions.

6. Next Steps

This synthesis report, and the individual research project reports, are intended to summarize the linked research projects carried out by GCFSI core faculty and colleagues at LUANAR in 2014, and to help assess the extent to which those projects met the two major intended overarching objectives, namely to answer questions regarding (a) the potential scale-up of the MLM technology within Malawi, and (b) the medium-term impacts of intensified MLM systems.

Beyond that role, the reports contributed to the formulation of the RFA for GCFSI innovation grants to be awarded to faculty members from LUANAR and from Chancellor College in Malawi. These grants are intended to help strengthen the innovation hub established at LUANAR, and potentially to support cost-effective extensions of the research and innovation evaluation work carried out by GCFSI core faculty and LUANAR colleagues in 2014.

Looking forward, GCFSI plans continued support for the innovation hub hosted by LUANAR. In addition to the innovation grants program, consideration is being given to (a) a student innovation grants program targeted to the East Africa region and managed by LUANAR, and (b) potential short courses for LUANAR leadership, faculty members, and students, e.g., in communication and "research translation" skills, in research and grant proposal writing, in "human-centered design" of innovative technologies, or in university advancement programs such as fund-raising.

7. Annex A: Report Summaries

This section provides very brief summaries of the work undertaken by research teams, as well as links specific recommendations made in the synthesis to the reports that contain more in-depth discussions of those points.

The table below shows which reports provide the data for the synthesized findings and how they support recommendations based on GCFSI's mission statement. The table is followed by a brief summary of each individual research report.

Annex Table A1: Recommendations and Sources by Research Report

Recommendation	Summary of finding and original report to refer to for more information
Decision to focus on pigeon pea as a best-bet multipurpose legume	Snapp's research on pigeon pea has progressed over a number of years in collaboration with LUANAR researchers and showed promising results among farmers in several different regions. Several other characteristics of this particular multipurpose legume made it appropriate for GCFSI scaling recommendations (1) nutritional profile makes it potentially valuable to improving diet, (2) as a "women's crop" it offers the potential to economically empower women, (3) its ability to sustainably intensify maize production, which is important given the major trends that GCFSI is charged with addressing: climate change and urbanization. The individual research reports that address pigeon pea specifically are those by White and Hamm, Me-Nsope and Larkins, and Snapp et al.

Recommendation	Summary of finding and original report to refer to for more information
Decision to focus scaling plan in the Central Region	Pigeon pea is widely described as a legume that is more prevalent in the south part of Malawi. This is often presented as a reason to *not* focus on it in the Central Region. However, Snapp's research indicated that it was at a "tipping point" in terms of farmer adoption in Central Region. Research findings from two other teams suggest that pigeon pea is in enough demand in the Central Region to warrant additional investment into its promotion in farmers' fields and in urban markets.
Decision to invest in off-farm infrastructure and capacity of urban markets	A primary mission of GCFSI is to scale technology. A number of authors involved with multipurpose legume research noted that farmer decision-making to adopt a technology is influenced by post farm-gate factors (e.g., storage and marketing infrastructure, and policies or programs affecting marketing arrangements). Not surprisingly, the existence of viable markets is one major incentive for farmers. The capacity of local and regional markets to accommodate increased supply of legumes, however, has not been well explored. Therefore, GCFSI researchers were motivated to conduct an analysis that explored these off-farm dynamics of maize-legume systems, and how they can be supported to incentivize farmer legume production. The White, Me-Nsope, Dentoni, and Dzanja papers provide deeper discussion of post farm-gate factors, and explore where and how policies and interventions could strengthen local and regional market capacity.

Recommendation	Summary of finding and original report to refer to for more information
Decision to focus on the local and regional food systems, especially as it relates to the so-called "informal sector"	The White, Dzanja, Me-Nsope papers emphasize the need to focus on local food systems, which have been largely neglected in favor of investments intended to connect farmers to local markets. In view of climate change, the high cost of transportation in Malawi, and predicted energy scarcities, building the capacity in local and regional food systems was determined to be an important area of investment and one that fulfilled the GCFSI mandate. Furthermore, the gender analysis determined that women would especially benefit from investments in and support to local and regional food exchange systems. The gender analysis by Me-Nsope provides additional detail about how to support women's economic activities in the legume sector, especially in relation to pigeon pea.

Annex Table A2: Tabular Summaries of GCFSI Research Projects

Title	Authors	Objective or Question	Method	Findings
Climate and land use analysis	N Moore, V Breeze, H Deindorfer	What methodologies and tools can better characterize how ag productivity and land use are changing over space and time in relation to changing biophysical parameters?	Climate and land use models employed to: • Analyze past trends in timing of start of rainy season • Analyze agricultural productivity trends—shows inconsistency between published statistics and declining trends revealed by satellite imagery • Map optimal production locations for pigeon pea and marginal maize + pigeon pea	• Shift to later start of rainy season, by average of six days • Refer to maps in section 4 of this synthesis report.
Hydrologic Analysis	P Nejadhashemi, U Adhikari, M Herman	What is the impact of climate change on the land-water resources in Malawi?	Used SWAT (Soil and Water Assessment Tool) to compare baseline and future water balances for eight watersheds and six climate change scenarios.	• Calibrated watershed models, available for use by LUANAR researchers • Climate change models gave different results: generally showed increases in annual soil moisture content and surface runoff—more so in the north and sometimes with decreases in the south

Title	Authors	Objective or Question	Method	Findings
Impacts of climate change on rice and maize	J Olson, G Alagarswamy, J Gronseth, N Moore, and L Zulu	How are farmers and policy-makers responding to changes in agricultural production due to climate change?	• Four global climate models were downscaled to a DSSAT crop model. • Key informant interviews and a literature review on government policies and farmer responses to climate change.	• Temperatures slowly warming and number of hot days over 35°C increasing • Rainfall declining in the north, though still relatively high • In south, dry spells in January and February more intense and rainy season shortening • Increase in temperature and rainfall variability and extreme values • Yields in cool, high-elevation areas will increase as temperatures rise • Most of south will see yield declines as heat and water stress become limiting and reduce the response to fertilizer
Agroecology for resilient farming systems	SS Snapp, V Morrone, WG Mhango, LC Zulu	What is the geographic extent of multipurpose legume cultivation? Researchers also collected data to inform the design of Farmer Field Schools.	Interviews with 323 farmer experimenters.	• Female farmers more likely to expand MLM area • Agroecological knowledge leads to improved adoption • Prototype extension messaging developed • Livestock is a problem and alternative management strategies are needed

Title	Authors	Objective or Question	Method	Findings
Traditional legume exchange in Lilongwe	SA White, MW Hamm, A Mbachi Mwangwela, JFM Kamoto, JJM Kampanje-Phiri, FC Chigwa, M Thondolo	What constraints do small-scale legume entrepreneurs experience and how might they affect the urban "pull" factors that influence the integration of legumes into maize-based farming systems?	108 interviews of traders in 21 markets in or around Lilongwe.	• Provides evidence-based recommendations to municipalities on how to support small-scale retailers • Improved knowledge and made recommendations on legume sourcing, storage, and transportation
Institutional and policy constraints to legume value chains	D Dentoni, F Krussmann, M Degnet, A Noor	How do institutional and policy issues currently constrain innovation in legume value chains, and how are business actors responding to these constraints?	Interviews with 59 business actors plus stakeholder and value chain network analysis	Five main constraints identified: • Uncoordinated information systems for farmers • Weak credit and input markets • Poor infrastructure • Problems with farming as a business, and with cooperative formation • Weak public monitoring and auditing of quality standards
Mapping market prospects for grain legumes	J Dzanja, M Matita, H Kankwamba, M Dolislager, and D Tschirley	What are the market growth prospects for grain legumes in Malawi over the next 15 years?	• Analyzes the 2010/11 Integrated Household Survey to determine pattern of production, marketing, and consumption of legumes • Maps structure of legume markets in Lilongwe • Assesses growth prospects for legume based on direct and derived demand	• If income growth continues, legumes will enjoy strong domestic and export markets • It is necessary to reduce aflatoxin contamination; assist small-/medium-scale food processors; identify and test small-scale food processing technology to help small firms compete with imports

Title	Authors	Objective or Question	Method	Findings
Skills and workforce development	J Dirkx, T Smith, I Berzina-Pitcher, and M Vann	What is the capacity of LUANAR to meet the demands of the workforce development system for post-secondary education?	• Created 9 educational capacity variables: accessibility, purpose and vision, curriculum, teaching, research and knowledge, support, collaboration, value, responsiveness • Focus group discussions with LUANAR faculty members and students	• Access is complicated by increasing student enrollment numbers • Students would benefit from more hands-on learning opportunities • Government and donor funding is insufficient • Much collaboration with external stakeholders, but little coordination • Proposal: establish a "food systems accelerator" or business incubator, and establish a corps of research fellows within the lecturers
Participatory video for farming training	C Steinfield, S Wyche, H Chiwasa, J Mchakulu, and T Cai	To test the use of participatory videos to improve the capacity of extension agents to deliver agricultural support and education to smallholder farmers	• Filmed videos with low-cost battery-operated equipment and local community actors.	• Mobile phone usage is low in rural areas (less than 30%) and even lower among women. • Participatory videos were found to produce knowledge gains equal to or better than those from live training sessions • Integrating participatory video and live training sessions provided even higher short-term knowledge gains

Title	Authors	Objective or Question	Method	Findings
Gender analysis of the pigeon pea value chain	N Me-Nsope and M Larkins	To examine gender issues along the pigeon pea value chain and their implications for participation and accrual of benefits for both men and women	• Data collected from key informants in Malawi's three regions • The Gender Dimensions Framework (Rubin et al. 2009) was used to examine gender-based constraints to participation in the value chain, control over benefits, and implications for legume adoption and for household food security.	• Women are more knowledgeable about pigeon pea and have specific preferences about cooking time and taste, which must therefore inform breeding work • Women experience gender-related constraints that restrict mobility and access to resources (land, labor, capital) • Export companies and their traders have market power that results in high prices for processed pigeon pea in domestic markets

8. References

Alwang, J., & Siegel, P. (1999). Labor shortages on small landholdings in Malawi: Implications for policy reforms. *World Development, 27*(8), 1461-1475.

Barkovic, D. (2010). Challenges of Interdisciplinary Research. *Interdisciplinary Management Research, 6*, 951-960.

Beedy, T., Snapp, S., Akinnifesi, F., & Sileshi, G. (2010). Impact of Gliricidia sepium intercropping on soil organic matter fractions in a maize-based cropping system. *Agriculture, ecosystems & environment, 138*(3), 139-146.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy 37*(3), 407-429.

Bèye, A. M., Remington, T., Wopereis, M. C., & Diagne, A. (2013). Development of an Integrated Rice Seed Sector in Sub-Saharan Africa: Meeting the Needs of Farmers. In *Realizing Africa's Rice Promise*, Wopereis et al. (Eds.), 2013, Ch. 14, pp. 179-187.

Bèye, A. M., & Wopereis, M. C. (2013). Cultivating knowledge on seed systems and seed strategies: Case of the rice crop. *Net Journal of Agricultural Science, 2*(1), 11-29.

Bezner-Kerr, R., Shumba, L., Dakishoni, L., Lupafya, E., Berti, P., Classen, L., . . . Shumba, L. (2013). Participatory, Agroecological and Gender-Sensitive Approaches to Improved Nutrition: A Case Study in Malawi: FAO, WHO.

Bezner-Kerr, R., Snapp, S., Shumba, L., & Msachi, R. (2007). Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. *Experimental agriculture, 43*(04), 437-453.

Campbell, L. M. (2005). Overcoming obstacles to interdisciplinary research. *Conservation biology, 19*(2), 574-577.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A. (2002). Innovation systems: analytical and methodological issues. *Research policy, 31*(2), 233-245.

Denning, G., Kabambe, P., Sanchez, P., Malik, A., Flor, R., Harawa, R., . . . Magombo, C. (2009). Input subsidies to improve smallholder maize productivity in Malawi: Toward an African Green Revolution. *PLoS Biol, 7*(1), e1000023.

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change, 18*(1), 234-245.

Gandhi, R., Veeraraghavan, R., Toyama, K., & Ramprasad, V. (2007).). Digital Green: Participatory video for agricultural extension. Paper presented at the International Conference on Information and Communication Technologies and Development, 15-16 December.

Golde, C. M., & Gallagher, H. A. (1999). The challenges of conducting interdisciplinary research in traditional doctoral programs. *Ecosystems, 2*(4), 281-285.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological forecasting and social change, 74*(4), 413-432.

HIVOS.org. Malawi Energy Profile. The Hague: HIVOS, Practical Action.

Louwaars, N. P., & de Boef, W. S. (2012). Integrated seed sector development in Africa: a conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement, 26*(1), 39-59.

Maredia, M., Howard, J., Boughton, D., & Kajisa, K. (1999). Increasing Seed System Efficiency in Africa: Concepts, Strategies and Issues. *MSU International Development Working Paper No. 77*. East Lansing.

Martens, B. J., Scheibe, K. P., & Bergey, P. K. (2012). Supply Chains in Sub-Saharan Africa: A Decision Support System for Small-Scale Seed Entrepreneurs. *Decision Sciences, 43*(5), 737-759. doi: 10.1111/j.1540-5915.2012.00370.x

Mhango, W. G., Snapp, S. S., & Phiri, G. Y. (2013). Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. *Renewable Agriculture and Food Systems, 28*(03), 234-244.

Mweninguwe, R. (2014). Ineffective subsidies. No. 6 2014. Retrieved 6 July 2015, from http://www.dandc.eu/en/article/malawis-subsidies-farms-are-only affordable-donor-support-not-what-needed-boost-agriculture

Mzamu, J. J. (2012). The Ways of Maize: Food, Poverty, Policy and the Politics of Meaning among the Chewa of Malawi. Ph.D. dissertation, University of Bergen, Norway.

Norman, D. W. (1995). *The farming systems approach to development and appropriate technology generation*: Food & Agriculture Organization.

Odeny, D. A. (2007). The potential of pigeonpea (Cajanus cajan (L.) Millsp.) in Africa. *Natural Resources Forum, 31*(4), 297-305. doi: 10.1111/j.1477-8947.2007.00157.x

Ortega, D. L., Waldman, K. B., Richardson, R. B., Clay, D. C., & Snapp, S. (2015). *Sustainable Intensification and Farmer Preferences for Crop System Attributes: Evidence from Malawi's Central and Southern Regions*. Paper presented at the Agricultural and Applied Economics Association, 2015 AAEA & WAEA Joint Annual Meeting San Francisco, California.

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5-24.

Rosenfield, R., Sherwani, J., Ali, N., & Rosé, C. P. (2009). Orality-grounded HCID: Understanding the oral user. *Information Technologies and International Development, 5*(4), 37.

Rusike, J., Lo Monaco, G., & Heinrich, G. M. (2003, October 8-11, 2002). *Linking technology development and dissemination with market competitiveness: pigeon pea in the semi-arid areas of Malawi and Tanzania*. Paper presented at the Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress. , Leopard Rock Hotel, Vumba, Zimbabwe.

Simtowe, F., Shiferaw, B., Abate, T., Kassie, M., Monyo, E., Madzonga, O., . . . Muricho, G. (2010). Assessment of the current situation and future outlooks for the groundnut sub-sector in Malawi. *International Crops Research Institute for the Semi-Arid Tropics*.

Simtowe, F., Shiferaw, B., Asfaw, S., Abate, T., Monyo, E., Siambi, M., & Muricho, G. (2009). Socio-economic assessment of baseline pigeonpea and groundnut production conditions, farmer technology choice, market linkages, institutions and poverty in rural Malawi. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Simtowe, F., Shiferaw, B., Kassie, M., Abate, T., Silim, S., Siambi, M., . . . Kananji, G. (2010). Assessment of the current situation and future outlooks for the pigeonpea sub-sector in Malawi. Nairobi: ICRISAT.

Snapp, S. (2002). Quantifying farmer evaluation of technologies: The mother and baby trial design. *Quantitative Analysis of Data from Participatory Methods in Plant Breeding*, 9.

Snapp, S., Jayne, T. S., Mhango, W., & Ricker-Gilbert, J. (2014). Maize Yield Response to Nitrogen in Malawi's Smallholder Production Systems: Michigan State University, Department of Agricultural, Food, and Resource Economics.

Snapp, S., Jones, R., Minja, E., Rusike, J., & Silim, S. (2003). Pigeon Pea for Africa: a versatile vegetable—and more. *HortScience, 38*(6), 1073-1079.

Snapp, S., Kanyama-Phiri, G., Kamanga, B., Gilbert, R., & Wellard, K. (2002). Farmer and researcher partnerships in Malawi: developing soil fertility technologies for the near-term and far-term. *Experimental agriculture, 38*(04), 411-431.

Snapp, S., Mafongoya, P., & Waddington, S. (1998). Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa. *Agriculture, ecosystems & environment, 71*(1), 185-200.

Snapp, S., Rohrbach, D., Simtowe, F., & Freeman, H. (2002). Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? *Agriculture, ecosystems & environment, 91*(1), 159-174.

Snapp, S. S., Blackie, M. J., Gilbert, R. A., Bezner-Kerr, R., & Kanyama-Phiri, G. Y. (2010). Biodiversity can support a greener revolution in Africa. *Proceedings of the National Academy of Sciences, 107*(48), 20840-20845.

Tripp, R. (2006). Strategies for Seed System Development in Sub-Saharan Africa-A study of Kenya, Malawi, Zambia, and Zimbabwe. *Journal of SAT Agricultural Research* 2(1).

Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and Public Policy, 39*(1), 74-87.

Wopereis, M. C. S., Johnson, D. E., Ahmadi, N., Tollens, E., Jalloh, A. (Eds.) (2013). *Realizing Africa's Rice Promise*. CAB International.

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