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Final report

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1 Acknowledgments

The spatial analysis on Hot Spots for Food Security across Eastern Africa was possible thanks to the data sets provided by Stanley Wood from IFPRI and Chris Funk and Molly Brown from NASA USA.

2 List of acronyms

ArcGIS	Geographic Information System Software
ACIAR	Australian Centre for International Agricultural Research
APSIM	Agricultural Production Systems Simulator
APSFarm	Whole farm configuration of APSIM
APSRU	Agricultural Production Systems Research Unit
CIESIN	Centre for International Earth Science Information Network
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
DTMA	The Drought Tolerant Maize for Africa Initiative
ENSO	El Nino Southern Oscillation
ESA	Eastern and southern Africa
FTE	Full time equivalent
GCP	Generation Challenge Program
GIS	Geographic Information System
GPS	Global Positioning System
GRUMP	Global Rural-Urban Mapping Project
GXE	Genotype by environment
GXEXM	Genotype by environment by management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IRI	International Research Institute for Climate and Societies
NARs	National Agricultural Research
NASA	National Aeronautics and Space Administration
NASFAM	National Smallholder Farmer Association of Malawi
SSA	Sub Saharan Africa
YG	Yield Gap
OPV	Open Pollination varieties

3 Executive summary

Worldwide hunger is concentrated in the east and southern regions of Africa (FAO, Hunger Map), where maize is a major component of food security. Due to its high potential productivity, maize is considered a strategic crop to mitigate recurring hunger and poverty. Maize is mostly grown by resource-poor farmers in complex risky farming-systems alongside legumes, oilseeds and livestock. With growth of population and incomes, the demand for maize is projected to increase by 50% over the next ten years. It is critical therefore to: (i) in the medium to longer terms, increase the sustainable production of maize in the context of expected global changes in climate and food demand and quality, driven by population and wealth growth; and (ii) in the short to medium terms, eliminate food shortages during poor seasons while maximising production and farmers profits during the good seasons.

The task is complex due to the constraints of increasingly degraded natural resource base, shortages of labour, agronomic skills, poor value chains i.e. access to inputs and output markets, and significant cultural and communication limitations. In this scoping study the report will describe the fundamental elements and background information needed to:

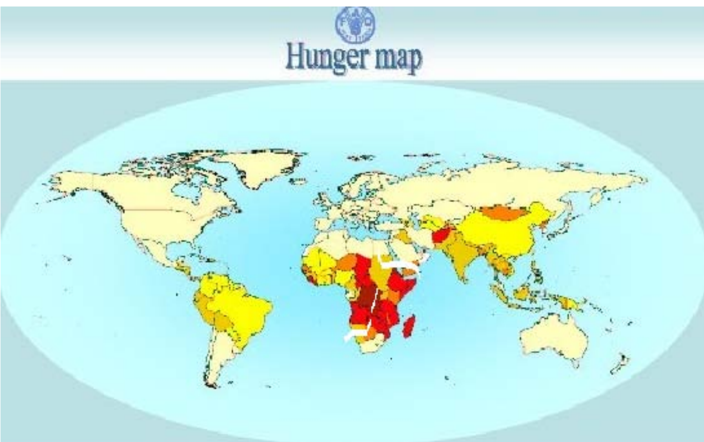
1. Improve understanding about present sources of resilience and adaptability in maize-legume farming systems across eastern Africa;
2. Improve understanding of the limitations of the current practices and strategies;
3. Identify opportunities for significant and sustainable improvements in the resilience, adaptability and productivity of maize-legume production systems;
4. Identify the need for transformational changes for those situations in which existing systems are failing or are expected to fail in the face of increased climate variability and climate change.

This research will be conducted in the context of a household livelihood approach and focus on maize-legume farms. The report will be developed based on the analysis of existing layers of spatial information, published technical papers, and unpublished R&D reports sourced from ACIAR, CIMMYT, Harvest Choice, NASA, IRI and the IFPRI data bases.

4 Introduction

As one of the most vulnerable regions in the world to the projected impacts of climate change, Africa faces many challenges. Most important, uncertain rainfall and the exposure to unmitigated climate risks and rapid population growth are major obstacles for the sustainable intensification of agricultural production and the enhancement of the livelihoods of rural households. In Africa, approximately 1 billion people live in chronic hunger and more than 1 billon live in extreme poverty. Africans, together with the developed world, have already started taking actions in the region and a number of important investments are being made to help small farmers access farming supplies, training, and develop markets for their produce. However given the constraints on soil fertility, shortages of labour, agronomic skills, the drying environment and cultural and societal issues, the task is complex. Australia and Queensland in particular (via the APSRU group) have an extensive record of successes at providing interdisciplinary systems solutions to complex problems. Previous work by the APSRU group in Zimbabwe, Malawi and Kenya in collaboration with ICRISAT (ACIAR, LWR2/1996/049) produced important advances in Africa's farming systems research capability, including (i) an increased availability of quality data sets; (ii) an enhanced capacity of APSIM to simulate African farming systems; (iii) improved methodologies for participatory research projects; (iv) and an important number of scientific publications and reports that are highly valuable to support future R,D&E in the region. However, before further R,D&E investment is realised, it will be important to identify the most vulnerable regions, and relevant and actionable issues where limited investment would have the potential to significantly improve crop yields, increase food production, and minimise the risk of harvest failure. The objective of this short research activity will be to develop a baseline analysis to identify (i) highly vulnerable regions across Ethiopia, Tanzania, Malawi, Kenya, and Mozambique; and (ii) a list of relevant and actionable issues of potentially high impact for research, development and increased investment.

Hunger is concentrated in the east, central and southern regions of Africa (see red-zones of FAO hunger map). Across Eastern and Southern Africa (ESA) maize is the major component of food security for the region and for a majority of the rural households. As the most important staple crop, maize is mostly grown by resource-poor farmers in complex risky farming systems alongside legumes, oilseeds and livestock – and is also the basic staple food for the majority of urban poor. The population of the region exceeds 300 million, of whom over 75% depend on farming. With growth of population and incomes, the demand for maize is projected to increase approximately 3–4% annually over the next ten years, leading to a requirement of 50% more maize by 2018. Cereal grains constitute the largest share of eastern Africa's imported goods, often in the form of emergency food aid. While it may appear that the



food crisis has receded somewhat at an international level, within the region maize grain prices have remained stubbornly high – aggravating the supply risks to food security. In a recent IFPRI report Smith, et al. (2006) reported that the percent of people food energy deficient across SSA varies from 76.4% in Ethiopia, 73.3% in Malawi, 60.3% in Mozambique, and 43.9% in Tanzania and Kenya. Countries where staple food is an 83.2, 69.4, 77.3, 70.6, and 61.8%, respectively, of the total energy consumed (National level figures).

Therefore, further agricultural research is urgently needed to devise solutions for farmers who produce maize under these risky semi arid conditions – for maize itself, but also to determine more clearly when and how legumes can be incorporated into the system, and to devise sustainable management approaches that increase soil fertility and soil moisture. Such research needs to be designed and conducted in the context of household livelihood systems and local institutional settings. In particular the value chains for input supply and produce marketing are crucial; and they also convey knowledge and buffer risk. Such research should be oriented to whole farm-household systems and needs to be undertaken in close cooperation with male and female farmers as well as local input supply and marketing institutions, in order to produce technologies that are relevant to the social context of households and particularly meet the needs of female farmers.

5 SRA outputs

The key outputs from this SRA will be:

1. A report describing the characteristics of maize-legume production systems and typical households across eastern and southern Africa including:
    - existing sources and availability of point, regional and spatial data sets of value for household livelihood and vulnerability analyses;
    - a description of typical maize-legume cropping systems and practices; proportion of single cross hybrids and open pollination varieties used; sources of improved seeds; market share of private seed companies.
    - a description of existing modelling tools for whole farm and household analysis frameworks, and needs for further improvement;
    - a description of typical farm types in the maize-legume production regions of ESA including: resource constraints for increased production, indices of human and social capitals, present risk management strategies and production objectives, and a compilation of ideas on opportunities for significant improvement in yields, production and risk management.
2. A field trip across countries from eastern Africa with the objective of gaining further understanding of R,D&E needs, engaging with local NARs and African researchers.
3. Presentation at the ACIAR workshop that will take place in Malawi during September 2009, highlighting the opportunities for collaborative research between Australia and African countries.

6 SRA activities

5.1 Collection and compilation of spatial information. Spatial data bases from IFPRI, Harvest Choice, CIMMYT, and NASA will be explored to extract relevant layers of information that will be used and/or combined using GIS techniques to derive maps of vulnerability, yield gaps, and high impact from intervention and investment.

5.2 Gaps in information. A literature review will be conducted to identify sources of relevant point, and regional information across the main maize-producing regions, with the objective of identifying valuable data sets for model validation and gaps in technical, genetic, agronomic, biophysical and socio-economic information.

5.3 Systems modelling tools. A revision of the literature on recent advances in the development and application of more integrative (whole farm) systems modelling tools (at a range of complexity levels) and needs for further improvements relevant to the African situation.

5.4 Report on field trip. A brief report will be produced summarising learnings from a field trip to research facilities and farmers across a number of countries from eastern Africa.

5.5 Participation at the ACIAR workshop. Initial results from the analysis of spatial information and identification of opportunities to achieve a 30% increase in yields and production, and a significant reduction in the risk of crop failure will be presented at the GCP Annual Research Meeting at Mali in September 2009.

7 Report on SRA activities

7.1 Collection and compilation of spatial information

7.1.1 Data compilation (by Alex Hoffman)

The following data sets and graphs were compiled, prepared and submitted to ACIAR between September and October 2009.

- Relationship between international vs. Kenya maize prices from 2000-2009.
- Number of research FTE's per million ha cropped at regional and sub-regional levels across eastern Africa.
- Changes in total production, area planted and yields of grain legumes across African regions and other developing regions (Central and South America, South and South-East Asia) between 1980 and 2007.
- Production and Net imports of grain legumes between 1980-2007 in Kenya and Uganda
- Changes in total production and yield of livestock in African regions and other developing regions (Central and South America, South and South-East Asia) between 1980 and 2007.
- Total livestock production in Kenya and Uganda between 1970 and 2007.
- Breakdown of protein sources (maize, rice, wheat, meat, pulses) on a regional, sub-regional and national level 1994 – 2003.
- Total protein consumption (grams) on a regional, sub-regional and national level between 1970 and 2003.
- Breakdown of daily calorie consumption (KCals) by crop on regional, sub regional and national level (1994-2003).
- Trends in daily calorie consumption between 1970 and 2003 by developing region (Asia, Latin America, Oceania, Africa).

7.1.2 Spatial analysis of hot spots (by Andries Potgieter and Peter Davis)

The objective of this work was to identify "hot spots" in south eastern Africa where SIMLESA is likely to have the highest impact in terms of relieving food security and poverty issues.

Spatial data bases from IFPRI, Harvest Choice, CIMMYT, and NASA were explored to extract relevant layers of information. A number of data sets were then combined using GIS techniques to derive maps of high likely impact from intervention and investment. The study region encompassed the following Sub-Saharan countries: Ethiopia, Tanzania, Kenya, Malawi and Mozambique.

Data and methods

In this work we used a number of indices to spatially characterise the present severity of food shortages across eastern Africa. This was done using the most current natural, agricultural (1999,2000,2001) and population statistics (2000) that are available at a gridded level within each of these countries (www.harvestchoice.org). More up to date data was available but only at a national level which did not suffice for the purposes of this study.

We created hot spots by integrating a theoretical measure of food shortages and the potential yield gap. Estimates of yield gap (YG) was used as a measure of potential for improvement in cropping systems, and the number of people without food, as a measure of potential impact of improvement in food security. Here people without food were defined as food insecurity index (FII). The most critical regions would be those having the biggest (negative) number of FII and the highest YG. Thus hotspots can be expressed as:

$$\text{Hot Spots} = f[\text{FII}, \text{YG}] \qquad [1]$$

In addition, the capacity of people to access markets i.e. to access inputs (seeds, fertiliser etc.) and sell their produce, was used to narrow down the analysis to regions were market access (MA) wouldn't provide a severe limitation (Table 1). Market sheds were derived based on the time in hours required travelling from a given single point (1x1km pixel) to the nearest market hub. Here, market hubs were defined as cities with a population of 20,000 or more (2000 year estimate), based on CIESIN's GRUMP alpha data. The travel time approach is estimated based on the combination of different global spatial data layers. These dataset included: elevation, slope in degrees, GLC2000 land cover, urban areas, roads, railways, rivers, borders, major water bodies and major sea routes (Harvest-Choice, 2009).

Gridded production allocation totals (1999 to 2001) for maize, sorghum, rice, wheat, cassava, soybeans, beans, millet were downloaded from the Harvest Choice website (www.harvestchoice.org). Collectively these are the most important crops in SSA contributing between 80 and 60% of the total calorie intake (Lobell et al, 2008; FAO 2007). No data on Teff were available.

Table 1. Aggregated statistics for each country

Country	**Population 2000 & (2006) (M)**	**Total Area (km^2)**	**Number of Market Sheds**	**Average Area of Market Sheds (km^2)**
Ethiopia	69 (81)	1,130,723	63	18,839
Kenia	31 (36.5)	582,020	30	21,046
Malawi	11.6 (13.6)	111,838	21	14,478
Mozambique	18 (21)	786,150	49	20,257
Tanzania	34 (39.5)	947,908	61	16,638

Gridded population statistics were extracted for the year 2000 census (GRUMP, CIESIN www. sedac.ciesin.columbia.edu) (Table 1). Only grid cells (~9km x 9km) with more than 2 people/km^2 and less than 1000 people /km^2 were selected. Grid cells with less than 2 people/km^2 were considered to be self reliant, and cells with more than 1000 people /km^2 were classified as highly dense populated areas (Lobell et al, 2008; FAO 2007).

Grain requirement ranged between 115 to 400 kg grain /annum per person (Figure 1). In case of missing data we used a minimum grain requirement per person of 190 kg/grain/annum assuming a caloric requirement of 1,900 calories/day and a typical caloric content of 3,600 calories per kilogram of grain (Liu et al, 2008).

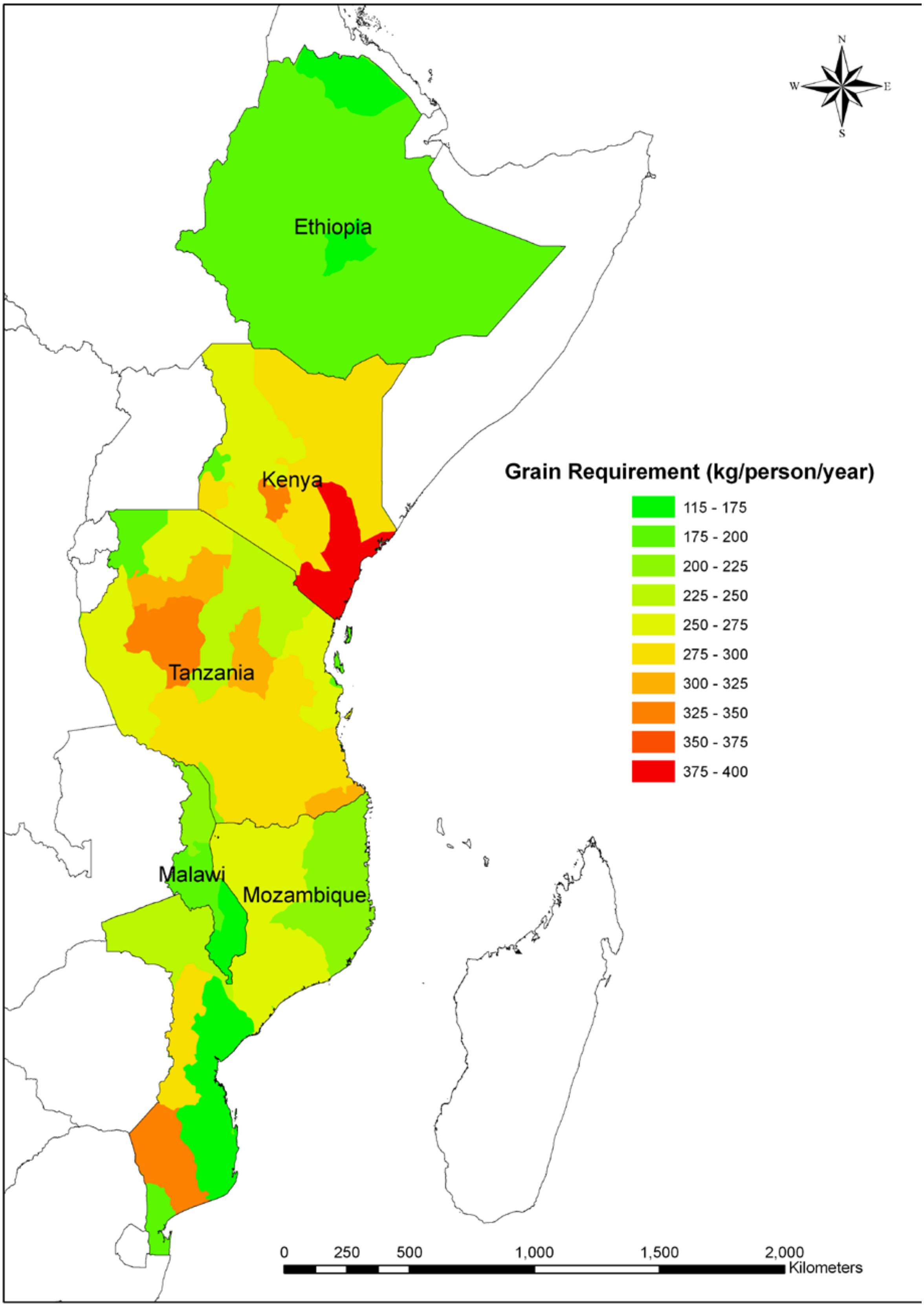


Figure 1: Grain requirement (kg/person/year) for each country (source: Harvest Choice).

Measuring the human impact of shifting relationships between production and population consumption encompasses the FII. This is a theoretical formula and is given in eq. [2] (Funk and Brown, 2009):

$$FII = [P - PoP*GR]/GR \qquad [2]$$

where, P is grain production (yield x area), PoP is population, GR represents the grain requirement/person/annum. Negative values represent areas where demand for food consumption is higher than actual availability (supply), while positive values are the opposite. FII is a function of population, grain requirement and production at a specific location and time.

As maize is the main staple in the region, the yield gap for the maize crop was used as an index of YG. YG was calculated as the difference between simulated low technology inputs (LI) (manure, manual labour etc.) maize yields, and high technology inputs (HI) (fertiliser, machinery etc.) maize yields, expressed as a percentage ratio (Harvest Choice, www.harvestchoice.org). Negative values depict areas, which are likely to improve in maize production.

A traditional *kmeans* clustering analysis was then run on the standardised data set to divide the region into ten classes. Ten classes were selected for simplicity purposes. Each class was grouped based on minimising the variance within groups and maximising the variance between groups using FII and YG . Since these data varies between countries this analysis was done for each country separately. The data for all clusters and was then mapped in ArcMap for each country and all together.

All data layers were imported into ArcGIS and overlayed (masked) with the suitable cropping areas for maize, sorghum, millet and the five country polygon boundaries. This resulted in a data layer, which consisted of polygons that had a single value for each of FII, YG and MA within the selected masked region for each country.

Results & Discussion

In this analysis the cropping areas, which show the biggest gains in crop improvement, were assumed to be those regions that have the highest differences between low input technology and high input technologies (i.e. simulated high yield gaps, see Fig. 2).

YG ranged from -225% to +20% across all 5 countries. This range was evident in all countries except Malawi where the YGs were mainly negative (shades of red). Such areas were mainly in the agricultural land use regions in all countries. Those regions with little or no scope to improve on current production levels are indicated in shades of yellow and falls between -15% to zero.

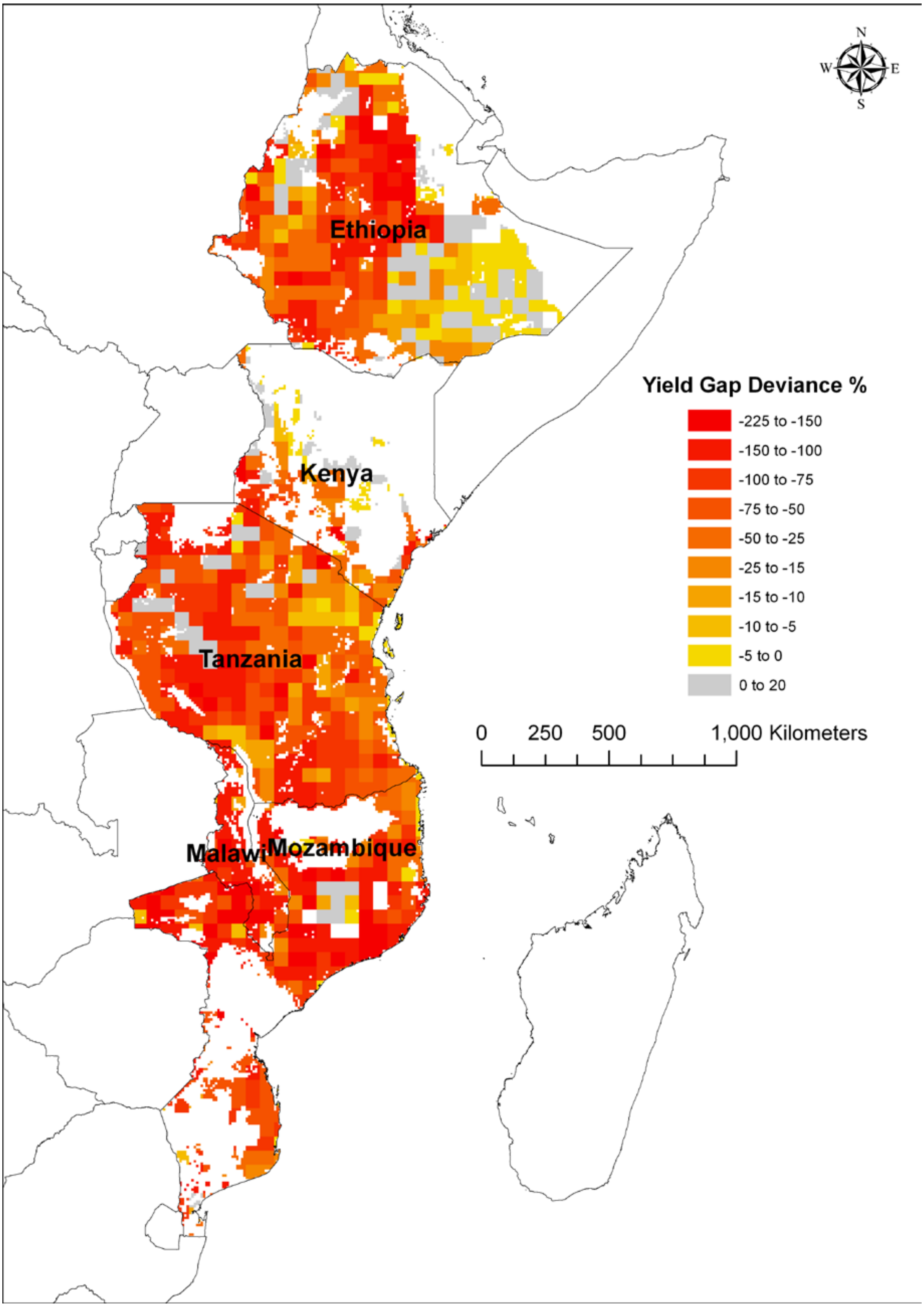


Figure 2: Simulated yield gap deviation percentage. Negative values showing those areas with the largest difference between maize yields assuming high technology inputs and low technology inputs.

The impact of human shifts in the relationship between production and food consumption is showed in Figure 3. The largest negative FII index were observed in

Ethiopia and Kenia while Malawi, Tanzania and Mozambique had less areas of values less than a -100. The variability in FII was the smallest in Malawi with most areas falling in the grey class i.e. very little or no food shortages and thus a secure food supply.

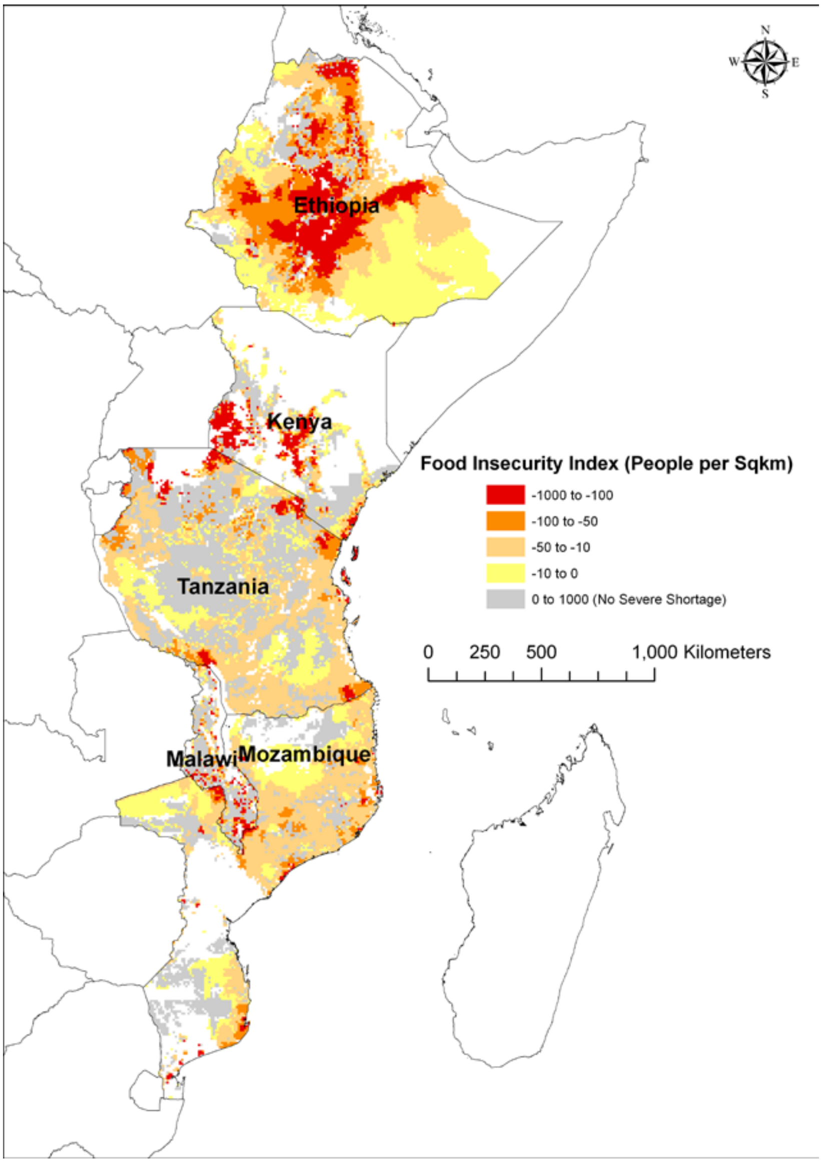


Figure 3: Food insecurity index for all 5 countries. Yellow to red represents areas with most people that are likely to have a food shortage (per km^2). Derived form Eq [2] using gridded data from 1999 to 2001 (www.harvestchoice.org).

Combining the data of Figure 2 (YG) and 3 (FII) and utilising the k-means clustering analysis resulted in 10 groups (pre-selected cut-off) per country (Figure 4 and Table 2). For MA data was included as an additional layer of information but not included in creating the hot spots or clusters. Distribution of these classes varied spatially not only within each country but across countries.

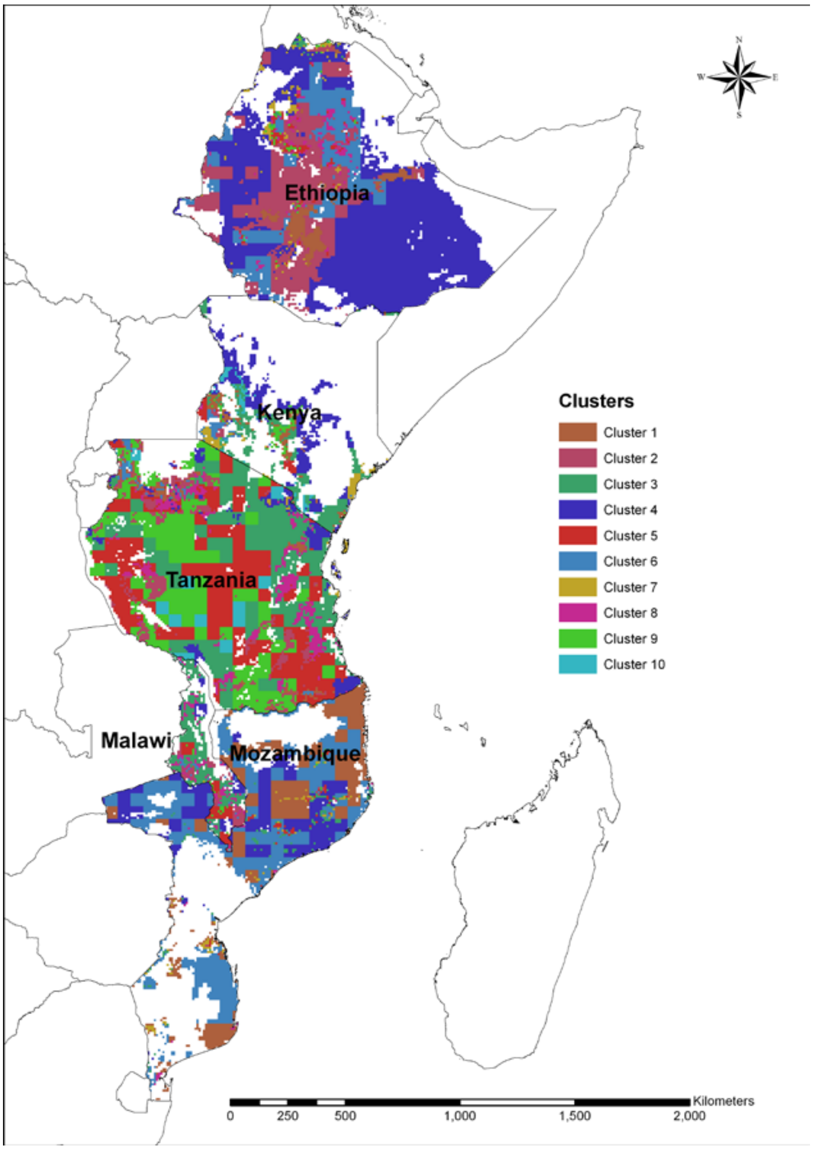
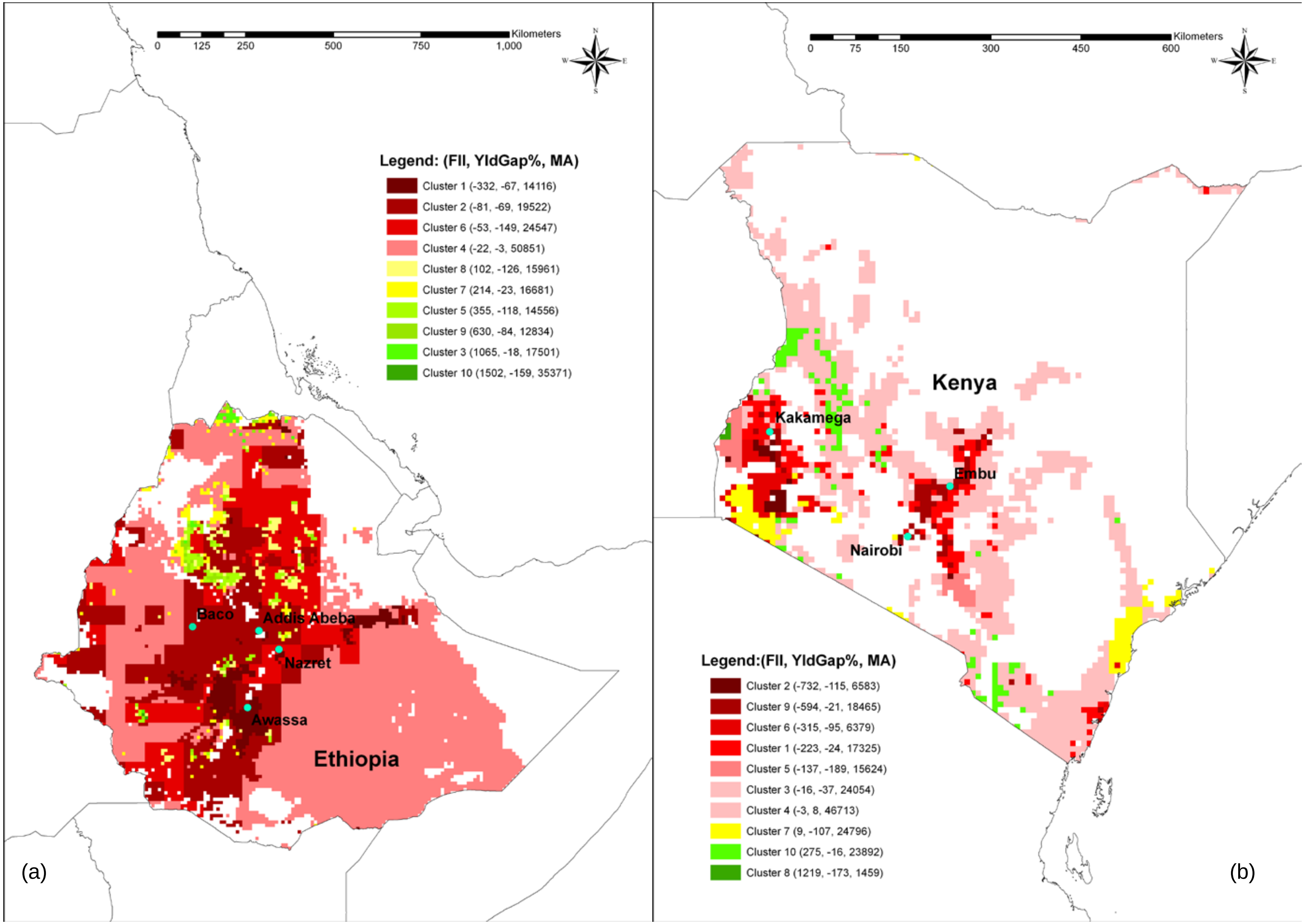


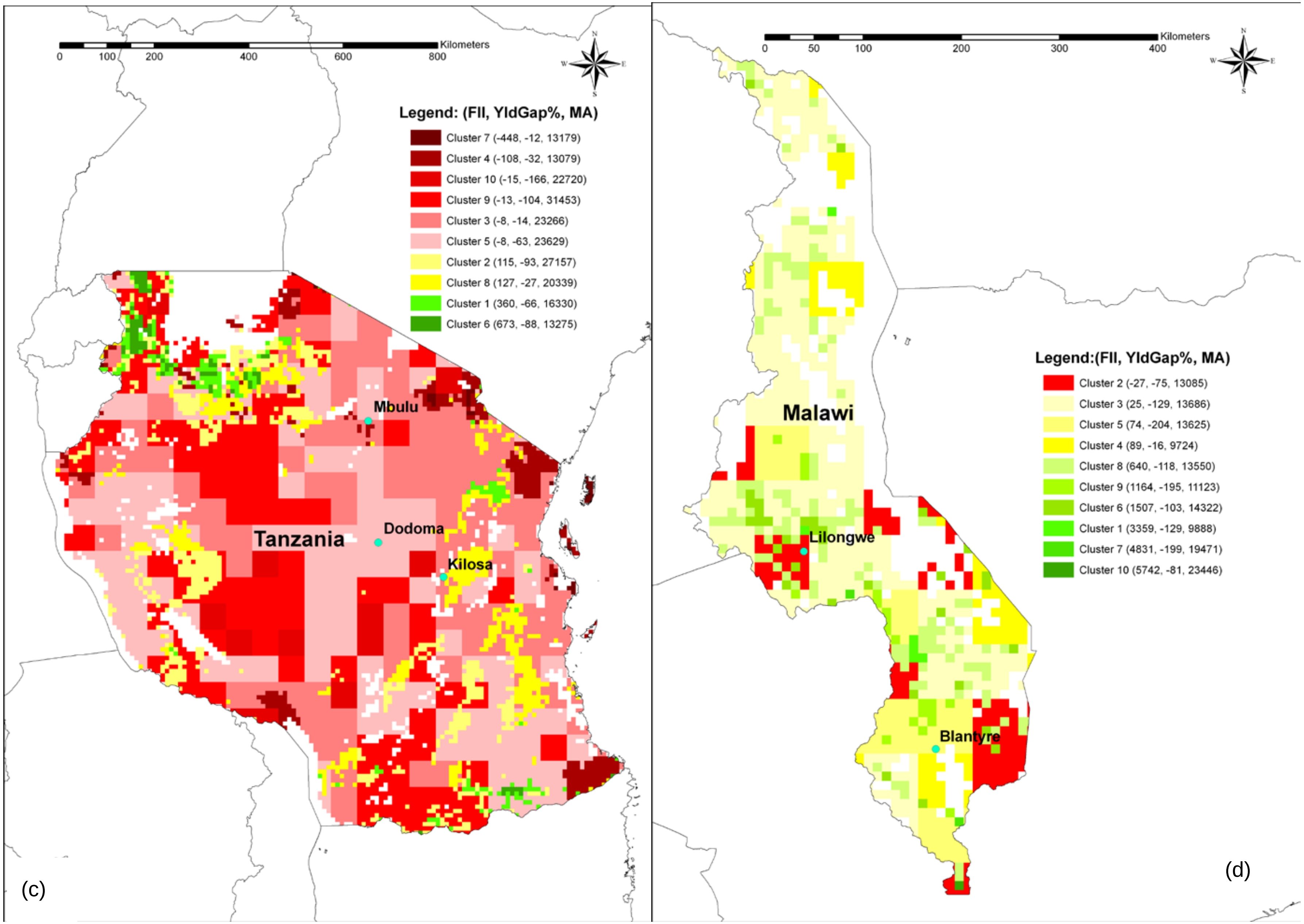
Figure 4: Cluster distribution across all countries.

Cluster averages ranged from -732 to 5742 and -244 to 8 for FII and YG respectively across all countries (Figure 5a to 5e and Appendix 1, Table 1). More specifically, Kenya showed 5 clusters to have FII values < 100 (clusters: 2, 9, 6, 1 and 5), while 3 areas (clusters: 2, 5 and 7) showed YG of more than 100% (<-100%). The smallest MA area (6,379) also coincided with large negative FII (-315) and a YG% value of -95%.

For Tanzania only two clusters showed FII values less than -100 (clusters: 7 and 4). These areas however, did not have the largest room for improvement in YG with values of -12% and -31%, respectively. MA in these two regions were the smallest of all the groups in Tanzania (13,179 and 13,079 km^2). The largest YGs were evident in groups 10 and 9 with -166% and -104%, respectively.

Ethiopia showed three clusters (1, 2 and 6) with FII less than -50 and YGs of more than 50% (< -50%). The largest YG was evident in cluster 10 (-159%) although it showed no imminent food shortage with a large positive FII value (1,502). Spatially this area represents a very small region in Kenya (cluster 10, Fig. 5b).


Kilometers
0
125
250
500
750
1,000
Legend: (FII, YldGap%, MA)
Cluster 1 (-332, -67, 14116)
Cluster 2 (-81, -69, 19522)
Cluster 6 (-53, -149, 24547)
Cluster 4 (-22, -3, 50851)
Cluster 8 (102, -126, 15961)
Cluster 7 (214, -23, 16681)
Cluster 5 (355, -118, 14556)
Cluster 9 (630, -84, 12834)
Cluster 3 (1065, -18, 17501)
Cluster 10 (1502, -159, 35371)
Baco
Addis Abeba
Nazret
Awassa
Ethiopia
(a)
Kilometers
0
75
150
300
450
600
Kenya
Kakamega
Embu
Nairobi
Legend:(FII, YldGap%, MA)
Cluster 2 (-732, -115, 6583)
Cluster 9 (-594, -21, 18465)
Cluster 6 (-315, -95, 6379)
Cluster 1 (-223, -24, 17325)
Cluster 5 (-137, -189, 15624)
Cluster 3 (-16, -37, 24054)
Cluster 4 (-3, 8, 46713)
Cluster 7 (9, -107, 24796)
Cluster 10 (275, -16, 23892)
Cluster 8 (1219, -173, 1459)
(b)


Kilometers
0 100 200 400 600 800
Legend: (FII, YldGap%, MA)
Cluster 7 (-448, -12, 13179)
Cluster 4 (-108, -32, 13079)
Cluster 10 (-15, -166, 22720)
Cluster 9 (-13, -104, 31453)
Cluster 3 (-8, -14, 23266)
Cluster 5 (-8, -63, 23629)
Cluster 2 (115, -93, 27157)
Cluster 8 (127, -27, 20339)
Cluster 1 (360, -66, 16330)
Cluster 6 (673, -88, 13275)
Mbulu
Tanzania
Dodoma
Kilosa
(c)
Kilometers
0 50 100 200 300 400
Malawi
Lilongwe
Blantyre
Legend:(FII, YldGap%, MA)
Cluster 2 (-27, -75, 13085)
Cluster 3 (25, -129, 13686)
Cluster 5 (74, -204, 13625)
Cluster 4 (89, -16, 9724)
Cluster 8 (640, -118, 13550)
Cluster 9 (1164, -195, 11123)
Cluster 6 (1507, -103, 14322)
Cluster 1 (3359, -129, 9888)
Cluster 7 (4831, -199, 19471)
Cluster 10 (5742, -81, 23446)
(d)

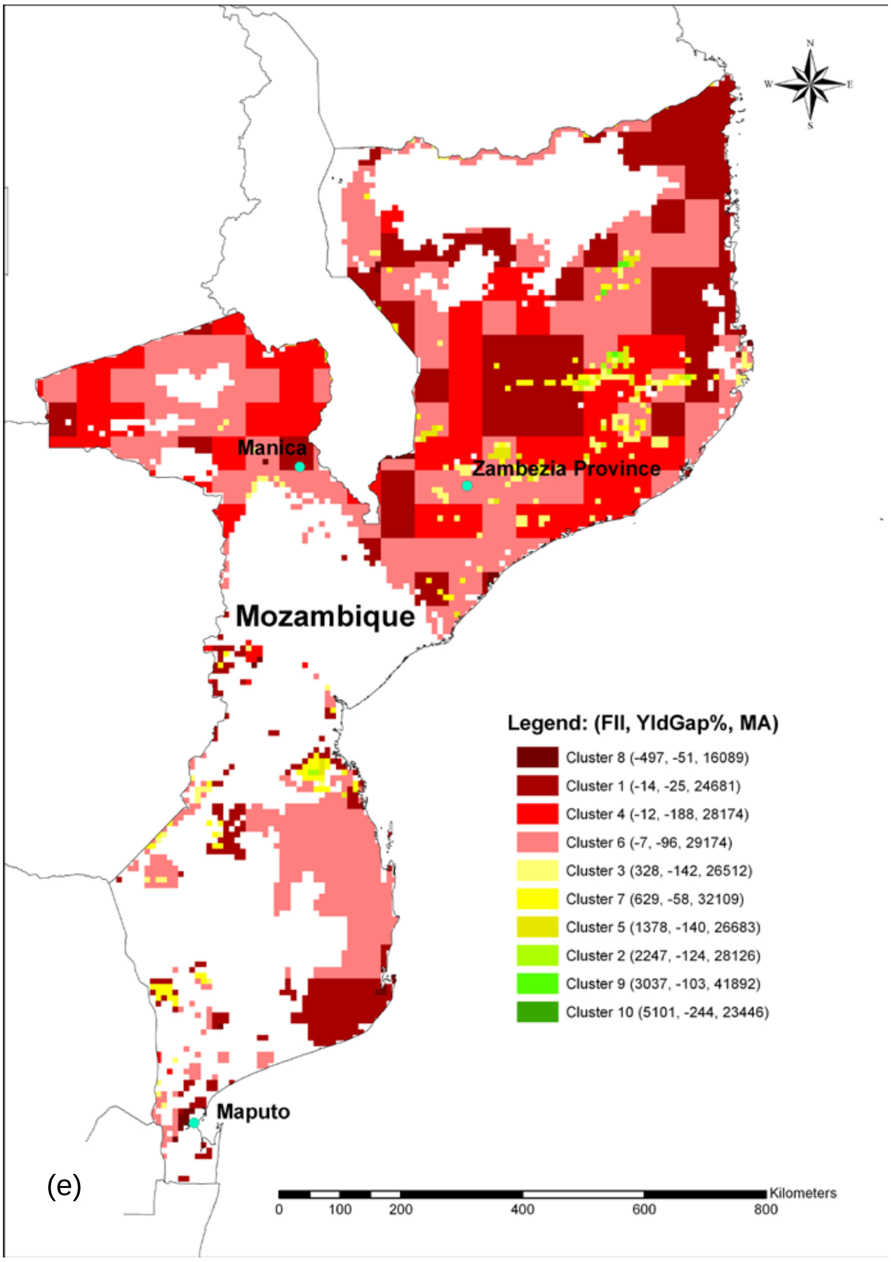


Figure 5: Hot spots for each country with cluster averages shown in brackets (FII, YG, MA). Market access was not included in the creating of the clusters or hot spots. (a) Ethiopia, (b) Kenia, (c) Tanzania, (d) Malawi and (e) Mozambique. The colours in the maps range from red (negative FII) through yellow to green (positive FII values). Capital cities as well as likely study location are super-imposed on all countries.

MA areas for these three regions were above the average (see Table 1) in two of the three regions i.e. for cluster 2 and cluster 6.

In Mozambique cluster 8 showed the largest negative magnitude in FII with a value of -497. All regions, except cluster 1, however showed YG values more than 50% (<-50). MA was above the average (20,257 km^2 in Table 1) for all those regions except for cluster 8 suggesting that this region is highly populated and very close to market hubs greater than 20,000 people. However, this region does have a large spatial presence compare to the other regions in Mozambique (Fig. 5e).

All regions in Malawi showed negative YG values with all of them more than 50% (<-50%) except cluster 4 which had a YG value of 16% (-16%). Cluster 2 was the only region with a negative FII value. Although this size of this region is relatively small compare to the other clusters it is still significant in terms of project implication and likely impact. MA area for almost all regions where similar to the average except for clusters 7 and 10 (> 14,478 km^2).

Super-imposing the likely study locations (Table 2) on the hot spot maps (Fig. 5a to e) resulted in almost all location falling within the dark red to red clusters in all countries, except for Blantyre in Malawi, which was located within the yellow area (cluster 3). However, there is a huge hot spot just east of this location which could be targeted.

Table 2: Location names of likely regions to be targeted in the SIMLESA project (Bekele, 2010, pers. comm.)

Ethiopia	Kenya	Malawi	Mozambique	Tanzania
Baco	Kakamega	Blantyre	Manica	Mbulu
Nazret	Embu		Zambezia Province	Kilosa
Awassa				

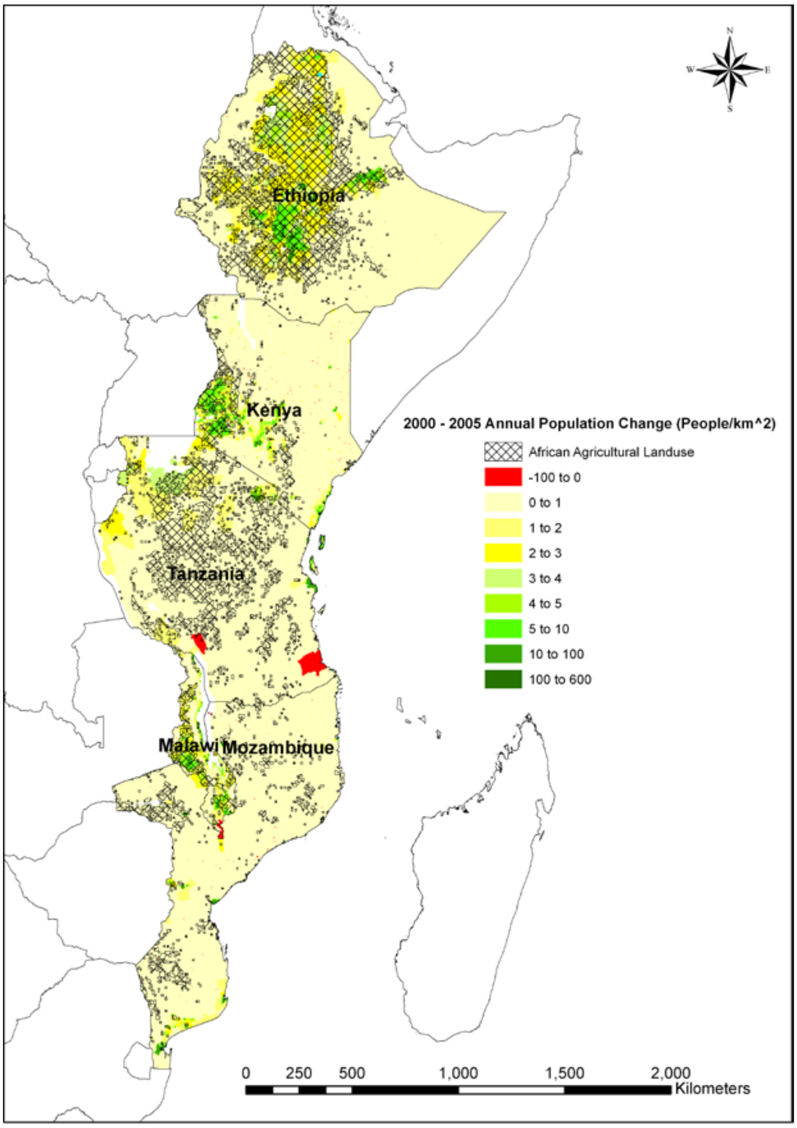


Figure 6: Population change (people/km2/year) from 2000 to 2005. Agricultural land use is overlayed (hatched)

Globally, increases in cropped area are at a slower rate than population growth thus resulting in a decrease in harvested area per capita (Funk and Brown, 2009). This is even more so for Africa and specifically, the five SIMLESA countries where most of the population growth over the last decade has occurred in the agricultural land use areas (Figure 6). In addition, with future food security progressively threatened by climate change (IPCC, 2007). Therefore, the hot spot regions derived here are likely underestimating the magnitude of impact and the spatial extend of the current food security situation.

Conclusions

This analysis showed that the integration of population, production, simulated yield gap, and grain requirement per person with traditional cluster analysis can successfully be used as a diagnostic tool to aid in indentifying areas of potentially food shortages across eastern Africa. The large variability in market access within and between countries confounded the impact of the other variables. In addition, the market sheds of 20,000 people or more – only data available at this spatial scale - are insufficient in capturing the dimensions of more locally operating and owned markets within these countries. Therefore it is suggested that market access be excluded in future hot spot analyses. Clustering of population, grain requirement and yield gap layers within each country showed areas where food security are most likely to be a problem.

It is anticipated that future changes in climate will progressively exacerbate their vulnerability and is likely to lead to an increase in the number of people without food. Constraints from our method at answering, Where are the SSA's hungriest? How many people are hungry?, How is hunger changing over time?, and What are the underlying causes of hunger? are several. Two important ones have been addressed in Smith et al., (2006), and they are diet quality and vulnerability (e.g. proportion of the calorie intake purchased from outside the household). Alternative methodologies to the local quantity as used here include analyses of household expenditure surveys (Smith et al., 2006).

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7.1.3 Expected project impact in Africa: People without food

Based on the data sets described above we estimated the expected impact of a 30% increase in maize yields (as indicated in the SIMLESA project) on the number of people with out food for the participating countries, i.e. Ethiopia, Kenya, Malawi, Mozambique and Tanzania.

We based these calculations on aggregated (National) production data from each country for the following staple foods; beans, cassava, maize, millet, rice, sorghum, soybeans and wheat for the period 1997-2007, national population 1997-2007, energy requirements for moderate physical activity (average of men and woman), and energy content of the agricultural produce (Ref.1 and Ref.2). Therefore,

Kilocalories produced by each Country per year = [(Beans production in kg)*(Number of kilocalories in 1kg of Beans)] + [(Cassava production in kg)*(Number of kilocalories in 1kg of Cassava)] + [(Maize production in kg)*(Number of kilocalories in 1kg of Maize)] + [(Millet production in kg)*(Number of kilocalories in 1kg of Millet)] + [(Rice production in kg)*(Number of kilocalories in 1kg of Rice)] + [(Sorghum production in kg)*(Number of kilocalories in 1kg of Sorghum)] + [(Soybeans production in kg)*(Number of kilocalories in 1kg of Soybeans)] + [(Wheat production in kg)*(Number of kilocalories in 1kg of Wheat)]

This gave an estimate of how much energy (kcal) that was produced within each country for each year between 1997 and 2007. The next step was to calculate how much energy (kcal) was required to provide the entire population of each country (Ref.1) with enough energy to meet the average daily energy requirement for moderate activity (i.e. including population grow). This was calculated by taking the average of the listed kilocalorie/day/person values for men and women aged 30-60 for moderate activity (Ref. 3) (921,625 kilocalories/year/person between 1997 and 2007), then,

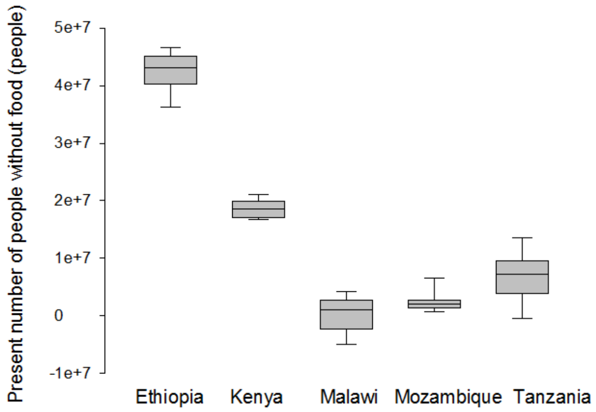
Kilocalories required by each Country per year = (Population of Country) * (921,625 kilocalories)

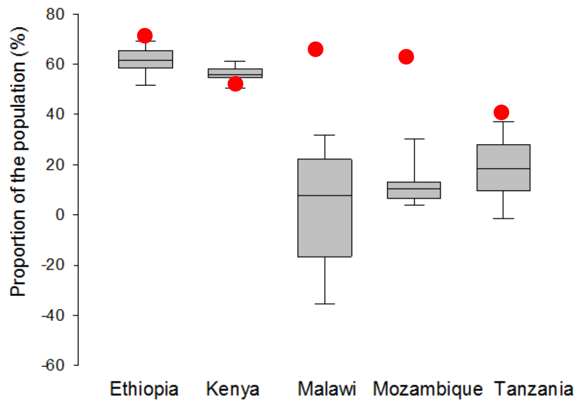
Now that the kilocalories produced by each Country per year, and the kilocalories required by each Country per year had been calculated, the number of people without food within each country could be calculated by taking the difference between the kilocalories produced and the kilocalories required, and then dividing this figure by the number of kilocalories required per year per person (921,625 kcal). Hence,

The number of People without food within each Country = [(kilocalories produced by each Country per year) – (kilocalories required by each Country per year)] / (921,625 kilocalories)

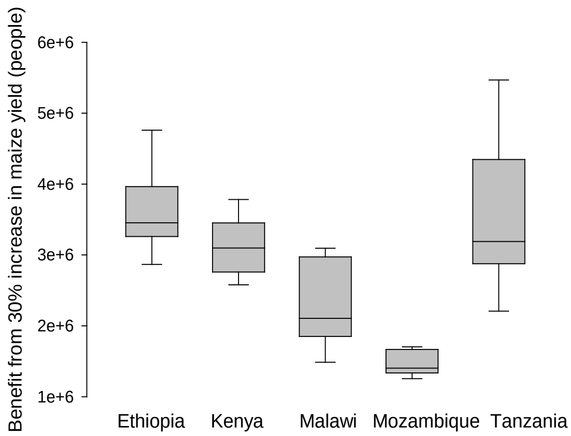
This method was applied for three different scenarios. The first scenario was conducted on present production levels as in CIMMYT (Ref.1). A second scenario was calculated assuming an increase in maize yields by 30% at the National level; and a the third was conducted assuming an increase in the yields of maize, soybean and beans yields at National levels (not shown here).

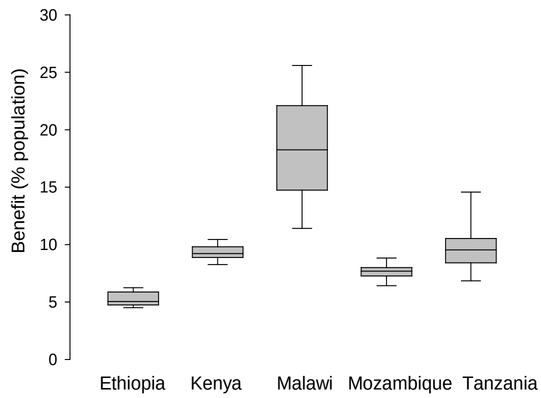
Initial results are presented below for the first and second scenarios. Results are aggregated at the National level and presented in box plots to capture variability in production and increase in population within the period 1997-2007. The box plots show the 5th, 25th, 50th, 75th and 95th percentiles for number of people without food (left), and (right) expressed as a proportion of the total population (1997-2007 period). Negative values indicate that during some years between the years 1997 and 2007, at the National level, there was surplus of food production. The red circles in the right graph are results of food insecurity as calculated by Smith et al., (2006) using a data set on Household Expenditure (IFPRI, 2006).





The box plots below represent the 5th, 25th, 50th, 75th and 95th percentiles (1997-2007 period) of the number of people without food after assuming a 30% increase in maize yields (left), and the proportion of the benefit expressed as a percentage of the total population (right).





References

Ref. 1: http://www.cimmyt.org/agricdb/fao/Default.aspx
Ref. 2: http://www.nal.usda.gov/fnic/foodcomp/search/
Ref. 3: Page 25, Table 3.4 of http://www.ifpri.org/sites/default/files/publications/rr146.pdf

7.1.4 Gaps in information.

<u>Data sets for regional analyses</u>
A number of spatial datasets were sourced from the spatial data bases of IFPRI, Harvest Choice, CIMMYT, and NASA. The data was then combined to produce the analysis of hot-spots for food security across the main maize-producing regions (as described in 6.1.2). The objective of this analysis was to identify potential landing points where ACIAR investment would have important returns on investment i.e. in terms of food security and poverty alleviation.

<u>Data sets for model validation.</u>
APSRU already has in its data archive valuable data sets for model validation consisting of soil descriptions, historical climate records and validated APSIM modules for the following crops and pastures: maize (Shamudzarira and Robertson, 2002; Whitbread and Ayisi, 2004), mungbean, sorghum, pearl millet (vanOosterom et al., 2001), velvet bean (Robertson et al., 2005; Whitebread et al., 2004), pigeon pea (Robertson et al., 2001), and ground nut (Dimes et al., 2003). Important changes have been made to APSIM to be able to reproduce the use of small amounts of fertilisers and different qualities of manures on nitrogen mineralization (Probert, et al., 2005).

Despite the availability of important data sets that could help the project commence, they are only available for a number of limited countries and regions within these countries. For example, there is very limited information for farming systems in Mozambique and Tanzania, as well as from some areas in Ethiopia and Malawi. These gaps in information include the compilation of climate records and soil properties in an APSIM ready format, together with data sets for the validation of the most relevant crop models within each of the regions including, genetic, agronomic, biophysical and socio-economic information.

7.1.5 Systems modelling tools.

Nowadays, most research, development and extension projects incorporate systems analysis and systems modelling as an irreplaceable methodology to support co-learning and practical management decision-making at all levels of scale; to quantify complex systems interactions and to provide ex-ante analyses that identify best bet options for likely scenarios; to better understand potential impacts from new technology packages and allocation of resources. Below these points are developed further.

<u>The role of systems modelling tools to improve decision making in farming systems.</u>
Irrespective of the levels of wealth/poverty or the scale of the agricultural practice, farmers intuitively adapt their management in response to perceived changes in their operational environment; a process that requires access to relevant experiential information (Schwartz and Sharpe, 2006). The decision making processes that underlie decision making has been described as the combined operation of two systems: a fast, automatic, effortless, unconscious system resembling a neural network; and a slow, deliberate, effortful, conscious system better described as being organised by rules (Kahneman, 2003). Operation of the former (intuition or practical wisdom – after Schwartz and Sharpe, 2006) is mandatory; operation of the second one (conscious, rules based) is optional. Practical wisdom, requires the right goals, the right motives, and builds over time - with practice, as it requires practical knowledge for the decision maker to

change old habits – 'it takes an enormous amount of practice to change your intuition' (Kahneman, 2009). It also requires enough flexibility, autonomy, and confidence in the available options e.g. technological or managerial, for the decision maker to respond appropriately to a given situation. An interesting problem therefore arises in the absence of relevant experiential practice (e.g. in the face of unprecedented change such as climate change, or when new technologies are presented to traditional farmers). This is because practical wisdom can not be taught as it is context sensitive (Schwartz and Sharpe, 2006). For example, for the case of adapting to climate change, little or no experience might be available to farmers to relate to and identify possible actions. This means that medium and long term farm planning in the face of likely change scenarios will require far greater levels of attention and support than received so far. Yet, farmers often find long-term climate projections of limited relevance while under pressure to resolve more immediate day-to-day and season-to-season decisions (Howden et al., 2007). For traditional farmers from the developing world new technologies e.g. conservation agriculture principles or risk management strategies, have the potential to present similar challenges, as they might be perceived too difficult, too risky, and even culturally wrong. To address some of these issues, participatory discussions and computer-aided farming systems design have proved useful at gaining insights into complex systems, developing intervention strategies, and generating awareness on the potential impacts of incremental or transformational changes to adapt to change when applied in real-world situations e.g. commercial farms (Carberry et al., 2009), or smallholder farming systems (Tittonell et al., 2009; vanWijk, 2009; Whitbread et al., 2009).

Examples of applications of systems modelling tools that aim at increasing the adaptive capacity of farm managers include (i) helping decision makers develop new and relevant practical wisdom, hoping that this will increase their capacity to make better decisions when facing unprecedented change or choosing to adopt new technologies (Schwartz and Sharpe, 2006); and (ii) to design farm practices, tactics and strategies that are more resilient to change and better able to profit on emerging opportunities (Nelson et al., 2007; Adger et al., 2009). In addition other important applications of systems models in the developed and developing world have included, (iii) the evaluation of trade-offs between competing objectives in the farm e.g. profit – food security – risk management – environmental outputs (ex-ante); (iv) adding value to experimentation and demonstration (ex-ante and ex-post); exploration of systems constraints (ex-ante); and (v) generation of information or systems understanding for policy, banking and insurance institutions, agribusinesses and value chain assessments (ex-ante). The Agricultural Production Systems Research Unit (APSRU) has a long history (20 years) of developing and applying, in collaboration with practitioners, a range of systems modelling tools of different levels of complexity and scale i.e. the field, the farm, the region, the country. The two most relevant tools to this project are the Agricultural Production Systems Simulator (APSIM) and its multi field whole farm configuration (APSFarm).

<u>The APSIM model:</u> APSIM is a modular modelling framework that has been developed by APSRU in Australia. APSIM was developed to simulate biophysical process in farming systems, in particular where there is interest in the economic and ecological outcomes of management practice in the face of climatic risk. APSIM's structure consists of different plant, soil and management modules. These modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil

pH, erosion and a full range of management controls. APSIM has been tested in a diverse range of systems and environments including many small house holder systems from Africa (Wafula, 1995; Probert, et al., 1995; Robertson et al., 2005; Shamudzairira and Robertson, 2002; Twomlow et al., 2008; Whitbread et al., 2004). APSIM has been used in a broad range of applications, including support for on-farm decision making, farming systems design for production or resource management objectives, assessment of the value of seasonal climate forecasting, analysis of supply chain issues in agribusiness activities, development of waste management guidelines, risk assessment for government policy making and as a guide to research and education activities. APSIM is a modelling framework that allows individual modules of key components of the farming system (defined by model developer and selected by model user) to be ‘plugged in’ (McCown et al., 1996). APSIM has been developed by the Agricultural Production Systems Research Unit (APSRU), a collaborative group made up from CSIRO and Queensland State Government agencies. Development started with the formation of APSRU in 1991 and the effort has grown from an initial team of 2 programmers and 6 scientists (actively engaged in model design and elaboration). Presently there is a team of 6 programmers and software engineers and 60 scientists based in Toowoomba, Queensland, and more than 100 programmers, modellers and users across Australia. In addition, since the new licensing agreement for the use of APSIM was established in 2004, 650 licenses have been issued to users across the globe. From a simple internet search (Google) on the main cropping systems models, APSIM (128,000 hits), DSSAT (42,700) hits, and CROPSYST (8,240 hits), APSIM shows a market share of 71% globally. Some of the key reports that include model testing results are listed in the table below.

Study	Major focus	Key references
Test data sets for SOILWAT and SOILN modules	Soil water balance and soil nitrogen balance in the absence of crops	Probert et al. (1998c)
Hermitage long-term trial, southern Qld	Tillage and residue retention effects on continuous what systems with differing levels on N fertiliser inputs	Probert et al. (1995), Turpin et al. (1996)
Warra long-term trial, southern Qld	Crop growth, yield, N uptake, soil water and soil nitrogen balance for continuous wheat, wheat/grain legume and wheat/lucerne rotations on a run-down heavy clay soil	Probert and McCown (2000)
Test data sets for the NWheat module	Wheat growth, yield, N uptake and protein in relation to soil water and soil N supply, as influence by fertiliser inputs and residue inputs	Keating et al. (2001)
Runoff plot studies in southern Qld	Agronomic/runoff studies at 4 sites (Fairlands, Billa Billa, Goodger and Greenmount) in southern Queensland were used to test APSIM-SWIM's prediction of runoff, soil water, and crop growth in a cropping system context at the large plot or contour bay scale	Connolly et al. (2001)
Cropping systems at Katherine, NT	Crop and soil dimensions of legume-cereal systems on a red-earth soil in a semi-arid tropical environment	Probert et al. (1998b), Jones et al. (1996)
Liverpool Plains, NSW	Water balance and crop/forage production in different rotations on a heavy black cracking clay	Paydar et al. (1999)
Lucerne modelling in Qld, WA and NZ	Lucerne dry matter, N content and water balance in different environments	Probert et al. (1998a), Moot et al. (2001), Dolling et al. (2001)
Wheat systems in WA	Wheat growth and yield and soil water and nitrogen balance for sands and duplex soils in the WA wheat belt	Asseng et al. (1995, 1997, 1998a,b, 2000, 2001)
Effluent irrigation trials in southern Australia	Water and nitrogen balance in forest systems in southern Australia irrigated with effluent	Snow and Dillon (1998), Snow et al. (1998, 1999a,b)
Sugarcane systems	Sugarcane growth and yield and water and N balance at various locations within the sugar industry	Keating et al. (1997, 1999a), Inman-Bamber and Muchow (2001)
International studies: Africa	Maize and grain legumes in low input farming systems in Zimbabwe	Robertson et al. (2000a), Shamudzarira and Robertson (2000), Shamudzarira et al. (2000)
International studies: Netherlands	High input wheat systems in Netherlands	Asseng et al. (2000)

The APSFarm model: More recently the need to adjust the scale of economic activity of farm businesses to fit within the boundaries set by shifts in resource availability (e.g. water, climate, finances), environmental change (e.g. emissions, land degradation), and farmer preference, required the development and application of more integrative and interdisciplinary modelling tools. In response to this demand APSRU (Rodriguez et al., 2007) developed a participatory framework capable of mimicking the rules and decision making processes farmers undergo when managing complicated farm businesses. The framework involves interviews and discussions with farmers and their consultants to identify, quantify and translate rules, preferences, practices and strategies into a whole farm systems model (APSFarm), becoming a virtual representation of their farm business. Once model outputs for the baseline scenario (i.e. climatology) are accepted as realistic by the participating farmer case studies, the model is then used to address specific questions from the farmers, researchers, extension officers or agribusinesses via What if? scenario analyses. The final outcome being farmers, extension officers, researchers and local agribusinesses more confident that the new available technologies will successfully achieve their objective and fit with in the existing farming systems, bio-physical, social, cultural constraints.

APSFarm is a dynamic simulation model that extends the APSIM model (version 5.4) (Keating et al., 2003) to simulate economic, financial, environmental impacts of alternative allocations of land, labour, time, irrigation water, livestock, machinery, and finance resources at the whole farm level.

In APSFarm the management of the farming system is modelled as a set of state and transition networks. Each field has a current state e.g. fallow, wheat, sorghum, etc., and 'rules' that allow transition to adjacent states. These rules represent both the capacity (e.g. availability of machinery, land, labour); capability (e.g. agronomic and technical skills); and attitudes (e.g. farm business strategies, risk attitude) of the farm manager. These rules are usually expressed as a Boolean value (true for feasible, false otherwise), but can also be real values where higher values represent the increased desirability of a particular action. Each day, the model examines all paths leading away from the current state to adjacent states, and if the mathematical product of all rules associated with a path is non-zero, it becomes a candidate for action. Should one or more candidates present, the highest valued path is taken, and the process repeats until all options for that day are exhausted. Rules can represent farm level criteria, such as sowing windows for each crop, fields cropping history, definitions of "break of the season" such as mm of rainfall over a defined period of time required to commence sowing, the maximum farm area the farmer would plant to each crop, availability of labour and machinery, etc. Examples of field level criteria include: minimum extractable soil water required for sowing a crop, soil type restrictions e.g. plant available water capacity, level of ground cover, etc. Other inputs include prices, production costs, available labour, alternative sources of off farm income, assets and farm debt level, etc. Outputs from APSFarm include but are not limited to production measures (e.g. yields and crop areas); economic measures (i.e. production costs, crop gross margins, economic risk, and farm annual profit); efficiency measures (i.e. crop and whole farm water use efficiency); and environmental measures (i.e. deep drainage, runoff, and erosion).

Other modelling approaches (NUANCES-FARMSIM) have been developed by other groups (vanWijk, et al., 2009). The NUANCES framework stands for: Nutrient Use in Animal and Cropping systems – Efficiencies and Scales). FARMSIM is a simplistic whole farm calculator integrating a number of sub-models that deal with crops, soils, livestock and the management of manure. Idem to APSIM, many of the FARMSIM model components had important input from experimentation carried out in Africa over the last few years. The main difference between the two models is that APSFarm is a dynamic systems model allowing for more detail in the number of interactions that occur at the whole farm level.

7.1.6 A systems analysis approach for farm typologies

Livelihood analysis is a common method in development projects; it is usually applied to identify impacts and vulnerabilities to hazards, and potential adaptive response strategies to increase adaptive capacity and reduce vulnerabilities. The purpose of the typology is to classify households into a limited number of types for which models can be developed to describe / mimic and investigate: (i) household behaviours in response to changes in key drivers affecting resources and opportunities for adaptation and improvement; and (ii) how the collective responses of the different households might impact upon their informal economies, e.g. local and regional markets. Typologies can be based on a range of different household characteristics; based on the objective of our project we suggest basing the typological classification on household’s resource endowment, socio-economic and environmental variables, to allow a full description of the household livelihoods and behaviours e.g. attitude to risk, level of motivation for the adoption of improved technologies aiming at intensifying maize and legume production.

Household livelihoods can be defined as the sum of activities and resources through which households fulfil their needs (Cecchi et al., 2010). Livelihood analyses include household resources, productive activities, practices and strategies, capacities and capabilities, consumption patterns, expenditure, trade and exchange activities. In a livelihood analysis this information is usually gathered via rapid rural appraisals i.e. interviews with farmers, focus groups and community representatives; or existing data bases such as the surveys conducted by IFPRI, or the Integrated Household Survey as conducted by NEC and NSO with technical support from IFPRI.

The livelihoods of smallholder households in sub-Saharan Africa are highly diverse (Tittonell et al., 2009), including their agro-ecology, bio-physics, socio economics, and behavioural-cultural characteristics. Even within villages household livelihoods can vary significantly in response to their resource endowment, availability of labour, access to resources and markets, production objectives, attitude to risk, practical experience (practical wisdom) (Dorward, 2006). Livelihood typologies are usually developed as a mean of communicating and understanding complex relationships between multiple factors affecting farmer’s behaviours (Emtage, et al., 2007). In this project, livelihood typologies will also be used to help in the development of representative household models (Dorward, 2002; Tittonell et al., 2009) - capable of replicating their behaviour - to evaluate tradeoffs and interactions between: household decision behaviours, local drivers of change and technological and institutional innovations, and the impact on the farm household resource use, agro-ecosystem sustainability and its welfare.

This approach will allow (a) a better understanding to be gained on the relationships and interactions between competing household activities and issues within rural livelihoods; (b) the development of analytical and ex-ante evaluations of potential impacts of different practices, tactics and strategies on the household livelihoods (Dorward, 2006), before they are tested or implemented in the field; and (c) to scale up results to capture interactions between alternative household designs and their local and regional economies in which they operate through models of the local/regional informal economies.

Examples of household typology analyses

There have been a number of household typology analyses across several regions and SSA countries. Dorward (2006), used a cluster analysis using data from the 1997/98 Integrated Household Survey (IFPRI and NSO 2002) from Malawi, to identify groupings or types of households first with regard to agroecological zones, and second with regard to socio-economic characteristics within each zone (Dorward, 2002). Dorward (2002) used farm employment, remittances, value of productive asset holdings, estimated retained maize per household member, holding size per household member, access to credit, and gender of household head, to create seven household types for each of three agro-ecological zones. The seven farm typologies accounted for 60% of the national number of rural households and included: Large farmers; Medium farmers with assets; Borrowers; Poor male headed; Poor female headed; Employed; and Remittance.

More recently Tittonell (2009) developed consistent typologies of farms and rural households to help them understand and categorise the diversity of livelihood strategies among smallholder farmers in mid- to high-potential agricultural systems of the east African highlands. The objective of their work was to fine-tune the targeting of innovations to address problems of poor soil fertility. In their work the typologies needed to be able to differentiate patterns of soil fertility management and status among the farm types. In their work they surveyed a total of 250 farms across Kenya and Uganda, using farmers' participatory self ranking surveys. Questions included biophysical, socio-economic and managerial aspects of each farm, and operationally they were run by trained national teams. Socio-economic and farm management information included characteristics of the household head (name, age, gender and marital status) and family structure, labour availability, sources of income, a map of the farm, land use patterns, use of/access to agricultural inputs, food security, livestock system, links to nearby markets, and production orientation. The different fields of each farm were identified with the aid of a map drawn by the farmers and the centre and perimeter of each field geo-references by means of a GPS. Bio-physical information was collected for each individual field and included, slope, landscape position, flooding, erosion, hard-settings, rock/stone cover, etc.), and management (e.g. the practice of fallow, nutrient input use, soil conservation measures, farmer soil fertility assessment, etc.). Wealth rankings and resource flow mapping were implemented to identify wealth classes, indentify livelihood strategies and categorise household diversity.

Community workshops were used to discuss with the participating farmers resource endowment plus criteria representing orientation of production activities (market, self-consumption), main type of constraints to agricultural production (as determined by land:labour ratios and cash availability), position of the household in the farm developmental cycle, and main sources of income for the household. Some of the key variables selected by the farmers, as indicative of resource endowment were: food security, labour availability, cash crops, livestock, use of fertilisers, timing of farm operations, land availability, use of quality seeds, income, soil conservation measures, access to information, weeding frequency, type of house, transport means, planting method, veterinary services, household nutrition, family size, education level and post harvest storage.

Surveyed data sets were analysed using principal component analysis (PCA) to identify non-correlated socio-economic indicators to use as proxies for the household categorisation criteria, to identify homogeneous classes through cluster analysis. Variables included in the PCA analysis were: Total area owned by the household, total area farmed by the household, total area with cash crops, family size per household, family members working temporarily / permanently off farm, age of the household head, % household income from off/non-farm activities, number of years receiving off-farm income, production orientation (% production for the market), total number of livestock, number of improved (improved breed) cattle, number of oxen and ox-ploughs, months of food self-sufficiency.

Based on this analysis, five farm typologies were defined for regions studied: (i) farms that rely mainly on permanent off-farm employment; (ii) larger, wealthier farms growing cash crops; (iii) medium resource endowment relying partly on non-farm activities; (iv) medium to low resource endowment relying partly on non-farm activities; and (v) poor households with family members employed locally as agricultural labourers by wealthier farmers.

Constraints and challenges in the development of typologies

Even though a number of important attempts at classifying households in SSA countries (Dorward, 2002; Tittonell et al., 2009), there are no homogeneous typologies for all the SIMLESA participating countries. In addition, important differences between countries and regions within countries - agro-ecological potential, infrastructural, and cultural -, might conspire against identifying relevant typologies when using existing classifications. A new analysis based on a homogeneous data base across all five participating countries is highly recommended.

We expect that two main constraints will need to be overcome in the development of livelihood typologies across the five different project countries.

Firstly: the extent of the heterogeneity across countries, across agro-ecological zones within the countries, and within villages in each of the targeted environments.

Secondly: the availability of homogeneous data on which to base the development of the typologies.

It will be essential to the success of the exercise to identify early in the project consistent patterns differentiating between households across the targeted locations. The selected variables describing productive resources (i.e. quality and quantity), agro-ecological potential; and market access variables, should allow capture essential differences between households in both household decisions about activities and household welfare. Cluster analysis will then need to be used to investigate patterns of variation to construct the typology. According to Dorward (2002) the analysis will require:

1. Identify variables for use in cluster analysis; in collaboration with CIMMYT's Socio-Economics Program.
2. Construct, standardise and weight selected variables;
3. Investigate patterns of variation with different numbers of clusters and different variables;
4. Construct a classification system.

The role of informal rural economy models

Modelling the informal rural economy involves simulating the way that individual household's behaviour, income and expenditure are modified through interaction both with each other- within the (aggregated) informal economy- and with the rest of the world - i.e. other agents and activities not explicitly allowed for in the household models, (Dorward, 2006). The importance of this scale of modelling relies on the existing trade offs on the allocation of limited resources between on farm and off farm activities. Examples of between-household interactions modelled within the informal rural economy might include sales and purchases of maize or legumes within the community; hiring in and out labours; purchase of local services and products. The interactions with the rest of the world might include sales of cash crops, purchase of inputs, purchase of tradable commodities for consumption, receipt of remittances, beyond the boundaries of the local community that might affect local prices, flow of nutrients, and availability of labour.

7.1.7 Report on field trip.

7.1.7.1 Participation at the third annual Drought Tolerant Maize for Africa (DTMA) workshop (by Solomon Fekybelu)

The objective of this meeting was to coordinate international activities and efforts across various CGIAR centres, public, and non-government organizations, working in the development of maize varieties of improved tolerance to drought conditions.

DTMA Vision: "Within 10 years, generate maize germplasm with 1 ton ha-1 yield increase under drought stress conditions, increase average maize productivity under smallholder farmer conditions by 20-30% on adopting farms; and reach 30-40 million people in sub-Saharan Africa, potentially adding an annual average of US$160-200 million of grain in drought-affected areas."

The meeting involved the participations of 13 different countries from different regions of Sub Saharan Africa. Participants include Angola, Benin, Ghana, Ethiopia, Kenya, Malawi, Mali, Mozambique, Nigeria, Tanzania, Uganda, Zambia and Zimbabwe. This, therefore, provides diverse representation of agro-ecologies and socio economic conditions.

During the meeting, progress reports from different disciplines and activities from various regions of Africa were presented. Presentations were made in two groups. In the first group, reports on planning on association mapping and phenotyping protocol, molecular breeding, breeding progress, double haploids and web portal as well as Mechanization and data integration. In the second group, reports on the socio-economics aspect mainly in the areas of variety release, seed production, seed sector study, etc were presented. Moreover, plenary sessions were held at the end of the presentations. It was possible to learn that there are wider area of collaborations between Australia and Africa. This is because of:

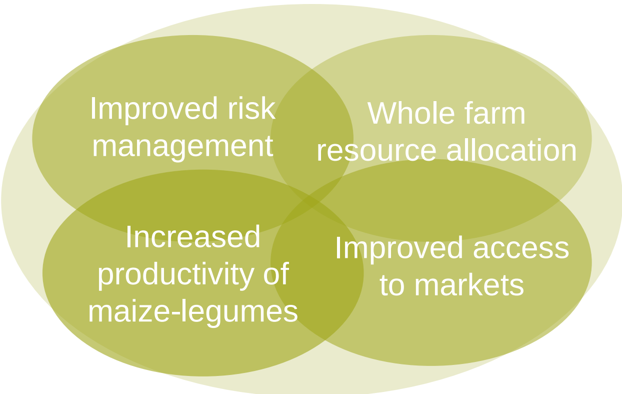
- a similarity in agro-climatic conditions;
- an increased focus to improve drought tolerance in maize.

Key learnings included the major area of collaboration between Australia and Africa/CIMMYT i.e. exchange of germplasm, and development of a strategy to test genotypes across Africa and Australia so that reliable information will be generated about the genetic potential of elite breeding lines.

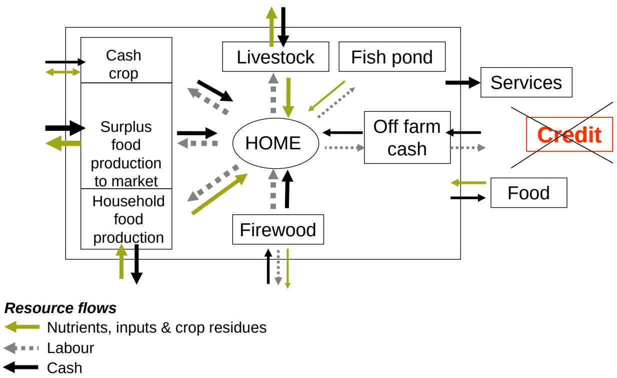
It was also learnt that strong expertise in the areas of GXE analyses and crop simulation modelling from Australia can be tapped in to speed up the release of new varieties, and to better match environments to physiological traits. Rich germplasm resources and extensive data set can be used to diversity the gene pool of the Australian breeding program and speed up the genetic progress of identifying materials that are suitable to Australian growing conditions. The ACIAR supported project will therefore create a perfect opportunity to liaise the Queensland maize breeding program to various projects in Africa, including DTMA.

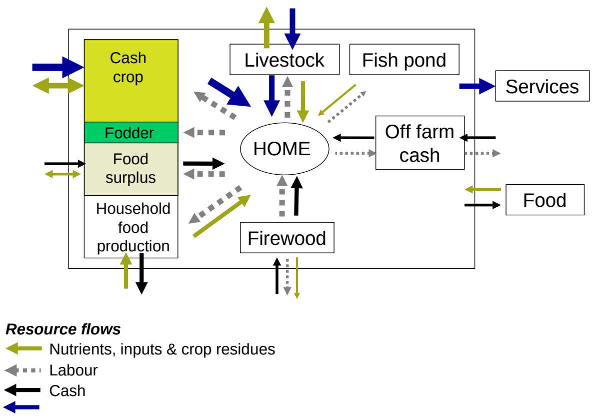
7.1.7.2 Discussion with farmers from central, east Malawi (by Daniel Rodriguez and Andrew Ward)

The objective of this trip was to gain understanding of the production environment and existing farming systems in the region. During this trip, four farms were visited where conservation agriculture is being practiced. Initial observations indicated clear benefits of the practice, in particular in those farming systems having very limited competition for crop residues (no or very few livestock – goats), and there is available labour. Though, key problems still to be addressed seem to be related to the difficulty of weed control in conservation agriculture fields, in particular when there is a high cost of opportunity for hand labour, lack of herbicides and the required knowledge for their effective application, and lack of incentives to increase land and water productivity due to lack of markets for the surplus produced food.



African farming systems are complex and highly heterogeneous i.e. in terms of their agro ecology, their socioeconomics, and in their access to inputs, finance and markets. In general, food security concerns and low maize yields prevent farmers from investing in other crops (legumes, cash crops) due to cash, labour and land shortages. However, important opportunities for improvement on land, nutrients and water productivity can be identified. For example, in the Vihiga district, Kenya (Tittonell et al., 2009) the authors indicate that food self-sufficiency could be achieved from intensifying the use of fertilisers to increase maize yields, and transferring resources (land) from maize (main staple production), to alternative cash producing enterprises, in a more diversified and risk-robust farming system. Similar observations were made by this project team during a visit to a farm in the district of Salima, Malawi. Presently the farmer primarily cultivates maize in 70% of the farm (main staple crop), and a limited area of cash crops (remaining 30%) applying conservation agriculture practices. It is envisaged that after the productivity of the main staple crop (maize) is increased and stabilised, household resource allocation across more profitable and less risky enterprises could be improved. This could include the integration of cropping and livestock activities, the adoption of risk management and seasonal climate information, together with the inclusion of value adding enterprises (chickens, pigs, fish). In the diagram below (left) we show a conceptual representation of the present allocation of household resources across number of enterprises. Notice the surplus of food production and the limited allocation of resources to cash crops and livestock, i.e. cash producing enterprises. The diagram on the right shows a hypothetical-improved allocation of resources that allows the farmer to generate more cash after improving the productivity and reliability of the staple crops, allowing for more land resources to be used in cash crop activities or to introduce nutrient concentrating enterprises such as livestock. Obviously, the keys to success would be related to an intensification of the production of the staple crop, together with improved risk management strategies and the introduction of value adding and nutrient concentrating enterprises such as poultry, or goats.





7.1.8 Participation at the ACIAR workshop (by Daniel Rodriguez, Solomon Fekybelu and Andrew Ward)

The purpose of this travel was to participate in the project formulation workshop for ACIAR-Africa collaborative initiative. The specific objectives include:

1. identify needs, priorities and capacities of the collaborative partners;
2. identify possible areas of cooperation in the project

During the meeting, representative from NARs in Ethiopia, Kenya, Tanzania, Malawi and Mozambique presented their needs and potential areas where Australian support may facilitate their effort to promote sustainable and profitable maize-legume production systems in their respective countries. Most of them stressed the need to strengthen capacity building. In the areas of germplasm development, they indicated their interest to work with Australian partners to strengthen their capacity in GXE(M) and environmental characterization techniques and data interpretations. We presented our strength and its potential benefits to our partners in Africa/ CIMMYT. We also participated in the development of logframe to integrate the germplasm development components among participating NARs and non-government organizations.

The second major objective of this trip was to gather information regarding the maize production systems in Africa. Some of the information, such as the type of varieties grown in Africa and the role of private seed sectors in seed production and dissemination of improved varieties provide useful baseline information for the new ACIAR initiative.

Table 2 show approximate number of varieties, both open pollinated varieties (OPVs) and hybrids released in the year 2002-2006. The table also summarizes the approximate proportion of varieties released by public and private sectors in the five ACIAR project participant countries.

Table 2. Total number of improved maize varieties released by public and private sectors in five ACIAR project participant countries in 2002-2006.

		Approximate percentage	
Country	No variety	Private	Public
Ethiopia	18	28	72
Kenya	82	78	22
Tanzania	9	72	28
Malawi	17	72	28
Mozambique	6	0	100

Source variety testing and release approaches in DTMA project countries in sub-Saharan African, 2009.

Table 2 shows the type of maize varieties released in the five participant countries.
In all of the five countries only white maize is released. Except for Mozambique, hybrids are the dominant forms of varieties grown by farmers. Most of hybrids are marketed by private seed companies while OPVs are supplied mostly by public breeding programs. However, emerging seed companies are also increasingly involved in the multiplication and dissemination of improved OPVs and three way hybrids. A number of big seed companies including Pioneer, Monsanto, Seed co, Pristine seeds, Kamano Seeds, Pannar etc are involved in seed business in Africa.

Table 3. The type of improved maize varieties released in five project participant African countries.

Country	OPVs		Hybrids		Total
	White	Yellow	White	Yellow	
Ethiopia	6	0	12	0	18
Kenya	6	0	49	0	55
Tanzania	1	0	6	0	7
Malawi	0	0	7	0	7
Mozambique	4	0	0	0	4

Source variety testing and release approaches in DTMA project countries in sub-Saharan African, 2009.

8 Conclusions and recommendations

8.1 Conclusions

Often the most important decisions farm households make are those related to the interactions between the different components of the farm household; and that in many cases, what might seem to be a good new idea or technology (because of the conventional wisdom), when transferred / imposed on a new farm manager, can result in a practice that doesn't fit the existing system, expectations, values or culture - factors that will finally determine whether the practice is accepted and adopted, or discarded as soon as the external pressure from the project subsides.

- Across eastern Africa, the intensification of maize-legume farming systems, the availability of input and output markets, as well as the existence of value adding activities, underpins the capacity of most households to achieve an improved allocation of limited resources i.e. cash, land, labour across alternative enterprises, to develop more diversified and resilient farming systems.
- It is the view of the authors in this review that the integration of cropping and livestock enterprises needs to be carefully evaluated in terms of potential benefits to diversity and increase income and to concentrate the existing limited availability of nutrients in the system.
- Capabilities to help mimic (simulate) the behaviour of typical smallholder farms, is fundamental to our capacity to marry best fit technologies, practices, tactics and strategies, to markets and key drivers of change, in the search of farming systems designs of increased productivity and resilience.
- Australian and African farmers are similar in the way that they make decisions on the allocation of limited resources to maximise profits/food production and minimise risks. Furthermore, important differences relate to access to input and output markets, and climate risk management skills and available information and tools. There are good opportunities to improve the risk management capacity of the highly risk averse African farmers. Much of the rainfall in eastern and southern Africa is influenced by ENSO (SST in the Indian Ocean), and there is high predictability in a region around Lake Victoria, and moderate predictability in southern Ethiopia. There are good opportunities for exploring the use of index-based weather insurance for small holders originally developed by IRI, NASFAM, World Bank, and the Insurance Association of Malawi. The problem with the use of climate information in Africa seems to be of "market" atrophy: negligible demand coupled with inadequate supply of climate services for development decisions…" (IRI, 2008).
- Building resilience in the farming system is a good strategy when facing uncertainty. Here we argue for the need to develop and apply more integrative assessments that combine whole farm systems models with deliberative processes that involve the decision maker and scientists in a co-learning process, leading to the development of more profitable and resilient farm businesses. Due to the number of interacting factors it is highly recommended that future impact

assessments and opportunities for adaptation to climate change are pursued at the scale that is most relevant to the decision maker. We propose that in the case of adapting farming to climate change, the minimum level of integration should be the farm household level.

- The agro-ecologies of Africa are highly variable, and so are the social, cultural and economical conditions of its people. Variety selection criteria vary from one country to the other and from one region to the other even within a country. Currently, there is very limited choice of improved maize varieties. The germplasm development efforts therefore needs to be consolidated and geared towards the development of varieties that are not only resilient to changing environmental conditions but also suitable to the needs of small scale farmers. National breeding efforts need to be supplemented with technical support to rapidly identify and deploy improved germplasm.
- There is strong demand for better varieties. However, poor development of the private seed industries and/or unfavourable government policy in some of these countries resulted in slow dissemination of improved varieties. This has to be addressed with the necessary policy adjustment to encourage the increased participations of the private sectors in the seed business. We suggest partnering with organizations that are trying to support the development of viable seed sectors.

8.2 Recommendations

Increasing the adaptive capacity of small holder farmers to climate variability and change

It is clear now that climate change will add stress and uncertainty to farming systems in Africa, where many regions are already vulnerable to climate variability. Climate change in Africa is expected to increase the frequency of those stresses (unexpected events), seasonal variations (variations in periodicity and amount of rainfall), and long term trends (such as increases in prices, and long term changes in temperatures and rainfall). A key to the capacity of small holder farmers to adapt to a harder i.e. dryer, warmer and more variable production environment will rely on their access to relevant knowledge and actionable information. However, climate change is surrounded by many uncertainties, acting at many different scales, i.e. uncertainties on future global emissions; uncertainties on climate sensitivities to increased atmospheric greenhouse gases; uncertainties on feedbacks in the climate system; uncertainties on regional impacts on rainfall and temperatures; and finally, uncertainties on how human systems, including agriculture, will be able to react to these changes, and how these changes will interact with mitigation policies, prices and markets. When uncertainty is rife, building resilience and robustness to change in a system has been proposed as a good strategy to reduce vulnerability while allowing for flexibility to benefit from the good opportunities. In addition to addressing how yields may differ as a result of adaptive measures (as usually farmers intuitively know), and how changes in production i.e. changes in planted areas, are likely to affect food supply, food quality and food security, there is increasing need for more integrative assessments that combine crop yield changes with socio-economic-value chain scenarios to account for many of the uncertainties above. A participatory analysis of systems characteristics that introduce resilience and robustness to change, for a range of representative farm typologies, seems to be a good starting point to generate relevant and discussable information that could be used to generate knowledge while lifting barriers to understanding and action.

Improved small holder and value chain climate risk management strategies
There is an important gap at integrating climate information into practice. Important advances could be achieved with small investments in the areas of:

- Capacity building, training and making information available in a useful format;
- Reaching community-level stakeholders and supporting best fit-practice including:
    - Developing demand-lead climate science, methods, tools & products;
    - Communicating relevant and actionable climate risk information to rural communities;
    - Assessing the quality of available and new climate information products;
    - Monitoring and evaluating progress in the development and adoption of information and the generation of knowledge in the farming communities and value chains;
    - Adding value to climate information using modelling to translate rainfall into relevant measures of economic profit – economic risk – and food security indices.

The role of systems modelling technologies
Simulation modelling has proved beneficial in commercial farming in Australia when applied within a participatory action research approach. In the developing world, Africa, and Asia, modelling assisted discussions with farmers are providing an opportunity for learning using the simulation to gain a "virtual experience" on new technologies, practices or management options; or rekindle the farming system with the objective of exploring options for the intensification of production in smallholder farms.

In this project it is recommended that systems modelling is applied to:

- facilitate co-learning (i.e. researchers, extension officers, farmers and policy) about "best fit" technologies and the way they could be best combined at farm level to maximise productivity and reduce risks, in farming systems having high seasonal and spatial variability.
- quantify complex interactions, and provide ex-ante and ex-post analyses that identify best bet options for likely future scenarios (e.g. expected impacts and adaptation options fin face of increased climate variability and climate change);
- understand the potential impact of new technology packages (e.g. conservation agriculture), improved allocations of limited resources (e.g. nutrients, water, labour, finances, land), and to identify best fit genotypes for particular managements and environments).

Speed up the development and deployment of improved germplasm
Increased regional integration of regional breeding programs through exchange of germplasm and information is very important to speed up the development and deployment of improved varieties. There is a need to employ detailed analyses of GXEXM to identify genotypes for specific agro-ecologies and management conditions. This will

also help in identifying recommendation domains of improved varieties. Experience and expertise from Australia and Queensland can greatly support this effort.

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10 Appendixes

10.1 Appendix 1:

Table 1: Variable averages (Food Insecurity Index (FII) and Yield Gap percentage deviation (YG) and Market Access (MA) for each class utilising cluster analysis for each country. Market access was excluded om the clustering procedure.

Cluster	Region	FII	YG	MA
1	Ethiopia	-332	-67	14,116
2	Ethiopia	-81	-69	19,522
6	Ethiopia	-53	-149	24,547
4	Ethiopia	-22	-3	50,851
8	Ethiopia	102	-126	15,961
7	Ethiopia	214	-23	16,681
5	Ethiopia	355	-118	14,556
9	Ethiopia	630	-84	12,834
3	Ethiopia	1,065	-18	17,501
10	Ethiopia	1,502	-159	35,371
2	Kenya	-732	-115	6,583
9	Kenya	-594	-21	18,465
6	Kenya	-315	-95	6,379
1	Kenya	-223	-24	17,325
5	Kenya	-137	-189	15,624
3	Kenya	-16	-37	24,054
4	Kenya	-3	8	46,713
7	Kenya	9	-107	24,796
10	Kenya	275	-16	23,892
8	Kenya	1,219	-173	1,459
2	Malawi	-27	-75	13,085
3	Malawi	25	-129	13,686
5	Malawi	74	-204	13,625
4	Malawi	89	-16	9,724
8	Malawi	640	-118	13,550
9	Malawi	1,164	-195	11,123
6	Malawi	1,507	-103	14,322
1	Malawi	3,359	-129	9,888
7	Malawi	4,831	-199	19,471
10	Malawi	5,742	-81	23,446
8	Mozambique	-497	-51	16,069
1	Mozambique	-14	-25	24,681
4	Mozambique	-12	-188	28,174
6	Mozambique	-7	-96	29,274
3	Mozambique	328	-142	26,512
7	Mozambique	629	-58	32,109
5	Mozambique	1,378	-140	26,683
2	Mozambique	2,247	-124	28,126
9	Mozambique	3,037	-103	41,892
10	Mozambique	5,101	-244	23,446
7	Tanzania	-448	-12	13,179
4	Tanzania	-108	-32	13,079
10	Tanzania	-15	-166	22,720
9	Tanzania	-13	-104	31,453
3	Tanzania	-8	-14	23,266
5	Tanzania	-8	-63	23,629
2	Tanzania	115	-93	27,157
8	Tanzania	127	-27	20,339
1	Tanzania	360	-66	16,330
6	Tanzania	673	-88	13,275