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Spatial Patterns of Food Staple Production and Marketing in South East Africa: Implications for Trade Policy and Emergency Response

by

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EXECUTIVE SUMMARY

This paper aims to develop and test methods for spatial mapping of population, food production, consumption, and marketed quantities in Africa. As an initial, exploratory exercise, the paper examines the spatial pattern of population, food production, consumption, and trade in the three countries of Zambia, Malawi and Mozambique. This largely descriptive initial work will lay the empirical foundations for future analytical work modeling regional trade flows of food staples.

By mapping population, food production, and trade flows, the paper aims to help policy makers better understand and anticipate spatial interactions in staple food markets. Through visual presentation of market information, these spatial mapping tools offer prospects for animating an ongoing dialogue among public and private stakeholders on key market flows, key bottlenecks, and key opportunities for improving food security in good and bad harvest years.

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ACRONYMS

CATISA	Cassava Transformation in Southern Africa
CFS	Crop Forecast Survey
CIESIN	Center for International Earth Science Information Network
DCW	Digital Chart of the World’s Populated Places
DMA	U.S. Defense Mapping Agency
DRC	Democratic Republic of Congo
FEWSNET	Famine Early Warning Systems Network
GIS	geographic information system
GPW	Gridded Population of the World
GRUMP	Global Rural-Urban Mapping Project
GRUMPe	Global Rural Urban Mapping Programme
IHS	Integrated Household Survey
MSU	Michigan State University
TIA	Trabalho de Inquérito Agricola
NASA	National Aeronautics and Space Administration
NGA	National Geospatial Intelligence Agency
NOAAUS	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
ORNL	Oak Ridge National Laboratory
PHS	Post Harvest Survey
TPC	Tactical Pilotage Charts

1. INTRODUCTION

1.1. Motivation

Food staples move spatially within Africa, from surplus production areas to deficit markets. Production concentrates in geographic areas where favorable soils, water, road access, input supply, and government policy regimes permit reliably profitable production and trade. Major markets, in turn, cluster in large population centers, district headquarters, mining towns, capital cities, and assembly markets located at key transport, communications, and financial hubs. When unencumbered by infrastructural or policy constraints, trade flows link surplus producing zones with the deficit markets they can most profitably serve.

Yet across Africa, political borders frequently separate surplus food production zones from the deficit markets they would normally serve. Drawn in Berlin in 1885, the continent's arbitrary political boundaries cut across natural market sheds, impeding the free flow of people and goods. They separate food surplus northern Mozambique from deficit markets in Malawi and eastern Zambia; food surplus zones in Uganda and northern Tanzania from deficit markets in eastern and northern Kenya, and surplus cassava and maize producing areas of northern Zambia and southern Tanzania from the deficit mining towns of Katanga and Kasai provinces in the Democratic Republic of Congo (DRC).

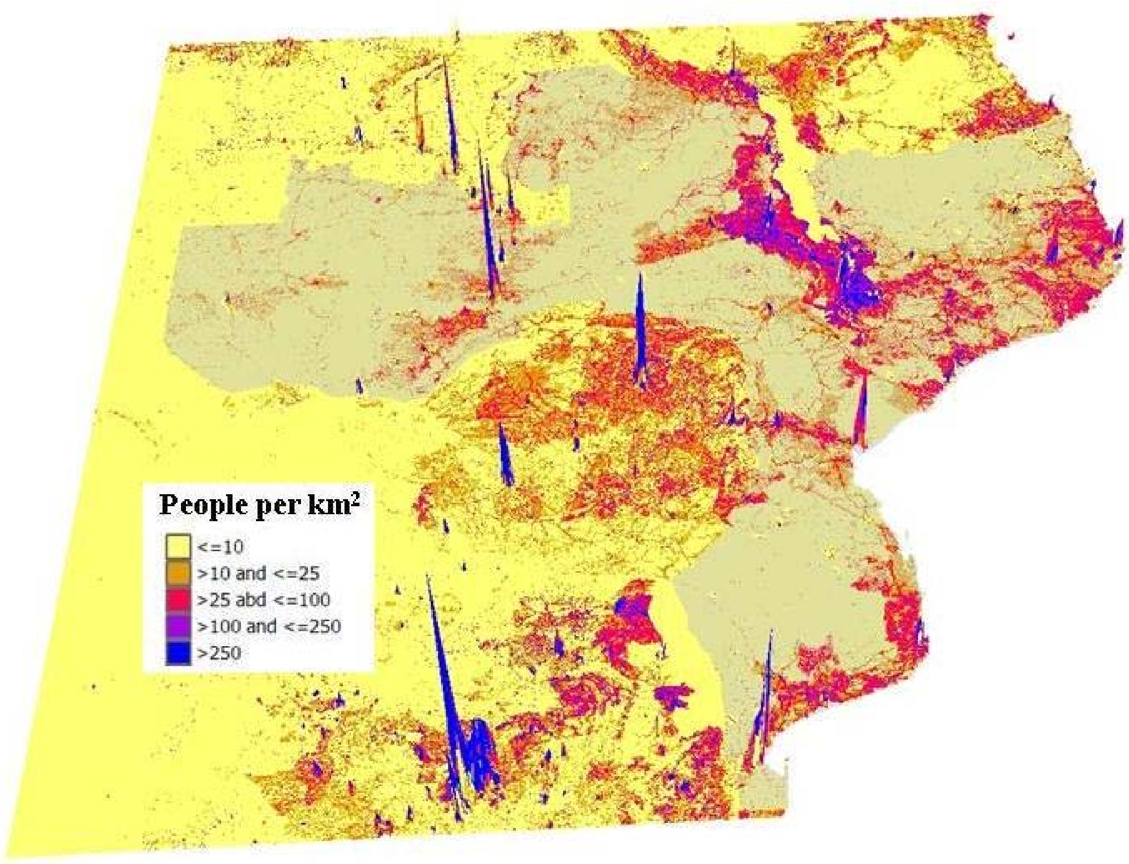
For traders and farmers, political borders translate into a welter of tariff and non-tariff barriers, which together constrain cross-border trade in food staples. These artificial impediments to trade, in turn, raise costs and lower incentives to farmers and traders while simultaneously raising consumer food prices in cross-border deficit zones. Because surplus food production zones often lie across international borders from the deficit markets they would most naturally serve, the most profitable trade flows often transect national borders. Fluid cross-border flows, therefore, become critical for maintaining regional food security, for maintaining incentives for farmer investment in the surplus zones, and for avoiding the extreme price volatility and consequent boom-and-bust production cycles that result when production shocks reverberate within the confines of small individual country boundaries.

Africa's arbitrary, inherited political boundaries frequently divide common cultures, linguistic groups, social networks, and economic partners. As a result, closely linked population groups frequently cluster on opposite sides of international borders (Figure 1). The Nyanja-speaking people, of the so-called Chinyanja Triangle, straddle the borders of northern Mozambique, Malawi and eastern Zambia. Bemba speakers spill across northern Zambia, southern Tanzania and southern Democratic Republic of the Congo, which because of its historic links and geographic encirclement on three sides the Zambians refer to as the *tenth province of Zambia.*

1.2. Objectives

Mapping population, food production, and trade flows can help policy makers to understand these spatial interactions in staple food markets. By presenting market information visually, spatial representation of key food security analysis can provide information to a variety of stakeholders — national governments, food aid and emergency response programs, regional economic fora, private sector trade groups, and farmer representatives — thereby helping to animate an ongoing dialogue on key market flows, key bottlenecks, and key opportunities for improving food security in good and bad harvest years.

Figure 1. Population Density in South Eastern Africa

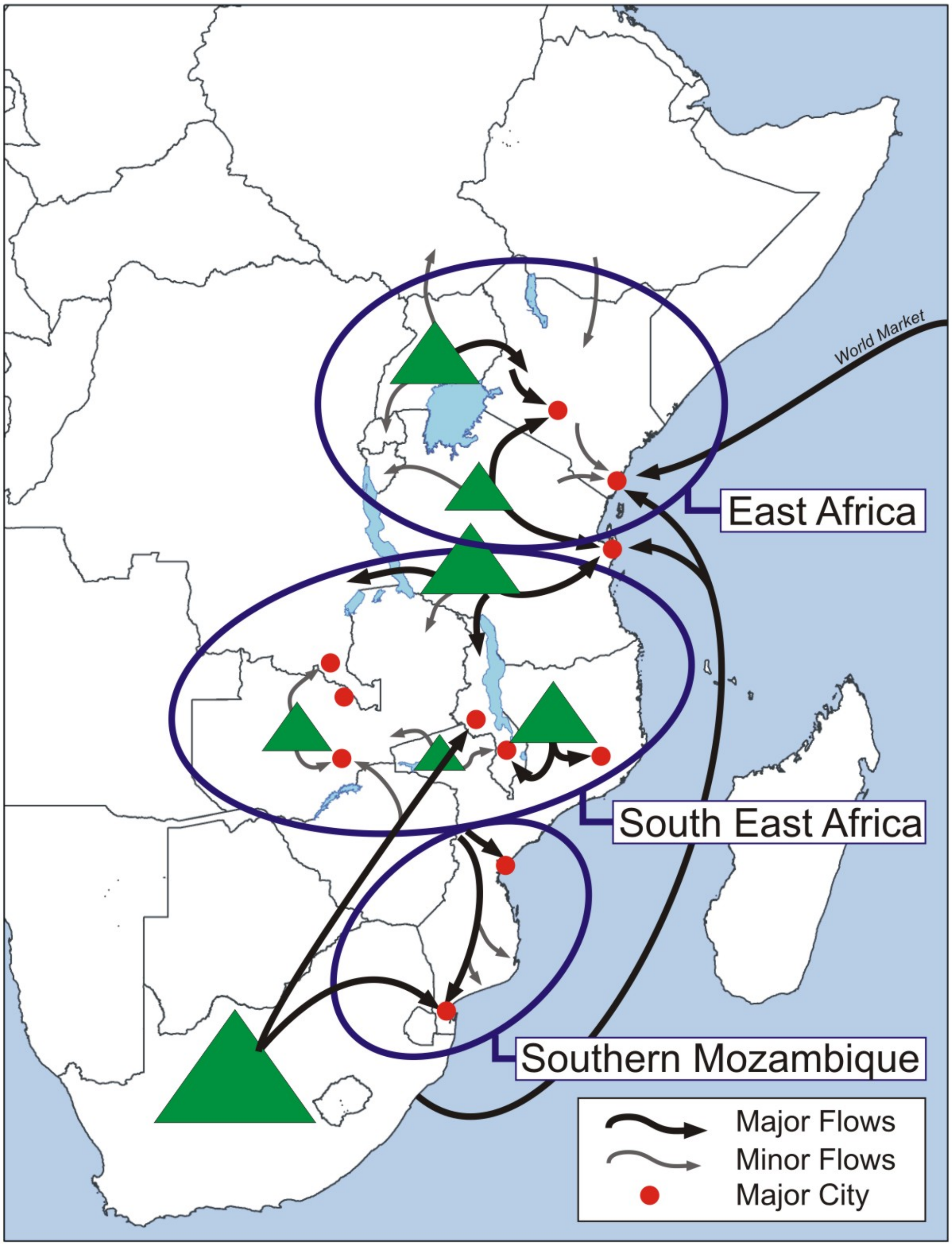


Source: Landscan 2007.

This paper aims to develop and test methods for spatial mapping of population, food production, consumption, and marketed quantities in Africa. This largely descriptive initial work will lay the empirical foundations for future analytical work modeling regional trade flows of food staples. Operationally, it will provide a means of visually presenting analytical material to policy makers and private sector stakeholders in ways that we hope will be easily understood and effective in advancing ongoing dialogues on policy options for improving national and regional food security.

In the short run, this work will focus on Zambia, Malawi, and Mozambique, the three countries forming the core of the South East Africa Market Shed (Figure 2). Over time, we hope to apply these methods to all of Sub-Saharan Africa.

Figure 2. Maize Market Sheds in Eastern and Southern Africa



Source: Govereh et al. 2008.

Part I. Methods of Spatial Analysis

2. POPULATION

Population clusters — in cities and in densely populated rural areas — help to spatially locate and quantify the magnitude staple food consumption across a given geographic domain. By mapping the quantities consumed, together with the spatial location of farm population and food staple production, it becomes possible to estimate the volumes of key staple food trade flows within a regional market shed. The spatial distribution of urban and rural population thus provides the backbone for building spatial maps of staple food consumption, production, and trade flows. Two publicly available data sources provide spatial maps of global population potentially suitable for this purpose.

2.1. GRUMP

The Global Rural-Urban Mapping Project (GRUMP) provides a spatial mapping of urban and rural populations across the globe. Distributed by Columbia University's Center for International Earth Science Information Network (CIESIN), the GRUMP builds on earlier GIS work that produced the first Gridded Population of the World (GPW1) in 1995. In 2005, CIESIN distributed the third and latest population grid (GPW3) providing geo-referenced population distributions for 1990, 1995 and 2000. The GPW, which maps census population into sub-national administrative boundaries, has become increasingly spatially disaggregated over time. As more digitized data have become available, the number of sub-national units has increased dramatically, from 19,000 worldwide in GPW1 to 400,000 in GPW3. Although the GPW provides output resolution at 2.5 arc minutes (about 5 kilometers square at the equator), it does not model the spatial distribution of population within these administrative units. Instead, the GPW distributes population evenly inside subnational administrative units.

GRUMP refines the GPW data in two principal ways. First, GRUMP generates higher resolution output than GPW, 30 arc seconds resolution (about 1 kilometer squared at the equator).[1] Second, it defines the geographic extent of "urban" areas and partitions population spatially into rural and urban areas. Because official definitions of "urban" vary considerably across countries, the GRUMP has developed a standardized procedure merging night time lights with city-level census data to estimate the geographic extent and population of "urban" areas across the globe. Primary data sets used to produce the GRUMP population grid and the physical area occupied by urban settlements include measures of night time lights and a standard list of world cities.[2] Because night time lights fail to identify and to illuminate the full extent of many small settlements, particularly in Africa and Latin America, GRUMP supplements these data by using a variety of spatial indicators of terrain, vegetation, roads, and powerlines to infer the location and size of these small settlements. The GRUMPe (Global Rural Urban Mapping Programme) algorithm assigns population spatially to urban and rural areas using census population data for each administrative unit together with the

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[1] Both GRUMP and LandScan report data in grids of 30 arc seconds. At the equator, this results in roughly 1 square kilometer grids. As distance from the equator (latitude) increases, the physical size of each cell decreases, leading to higher grid resolution.

[2] The mapping of night time lights come from the U.S. National Oceanic and Atmospheric Administration (NOAA),while the Digital Chart of the World's Populated Places (DCW) is produced by ESRI for the U.S. Defense Mapping Agency (DMA), and the spatial indicators of terrain, vegetation, roads and powerlines come from the Tactical Pilotage Charts (TPC) produced by the Australian Defense Imagery and Geospatial Organization (Balk et al. 2004).

physical extent of urban areas, as estimated primarily by the presence of night lights, supplemented in Africa by these other spatial indicators. In allocating population within each administrative unit (province or district) into rural and urban areas, the algorithm maintains the national rural and urban population percentages as estimated by the United Nations. Thus, at the national level, the GRUMP mirrors the UN population distribution between rural and urban areas.

The GRUMP makes three related digital outputs available to the public:

- a point file mapping all world cities of 1,000 people or more;
- a shape file[3] mapping the physical extent of urban areas in an "urban mask"; and
- a population grid allocating population to rural administrative areas and urban extents.

2.2. LandScan

The LandScan data base provides a spatial population grid intended for use in preparing responses to natural and manmade disasters. In the event of a hurricane, a terrorist attack, an epidemiological outbreak, or a leaky nuclear reactor, a detailed gridded estimate of the number of people present at each location enables planners to estimate the potentially at-risk population and plan responses accordingly. On contract to the U.S. Defense Department, the Department of Energy's Oak Ridge National Laboratory produces the LandScan data base of world population distributed on a 30 arc second grid.

LandScan aims to measure where people are (ambient population), as opposed to where they reside (residential population). During the day, some proportion of a rural population will be working in their fields or herding cattle, rather than in their census-enumerated dwelling. At some time of the month or week, some household members will be travelling to market towns, health clinics, or schools. Similarly, depending on the time of day or week, some people will be found in airports, factories, or even on roads running through unpopulated areas. Though they do not reside in those locations, people may be there and hence affected by a fire or other emergency occurring at that location. Within the U.S., LandScan data can be use to differentiate between daytime and night-time population distribution (Figure 3).

World-wide, the LandScan data base applies a 24-hour average of movement patterns that assigns a small percentage of rural inhabitants to crop fields, grasslands, and commercial establishments in order to estimate average *ambient* population in a given location.

LandScan projections begin with census data for each country, using subnational statistics maintained by the U.S. Bureau of Census, including the locations and population of all urban agglomerations of 25,000 or more. Along with these spatially referenced demographic data, LandScan applies information on road networks, slope of the terrain, land cover, night time lights, exclusion areas (such as national parks), and coastlines.[4]

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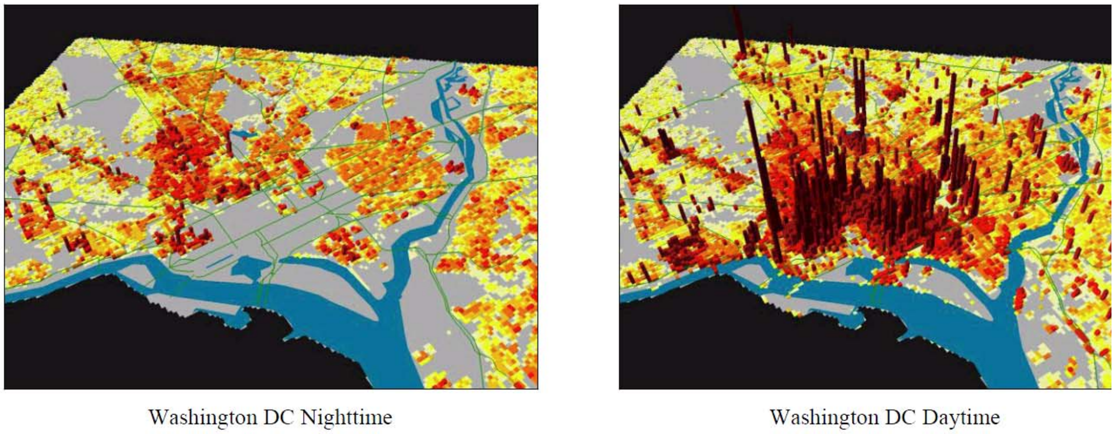
[3] A shape file is a georeferenced digital file that maps polygons onto the earth's surface to delineate administrative or natural boundaries.

[4] Data on road networks comes from the National Imagery and Mapping Agency (NIMA). Data on slope of the terrain comes from NIMA's Digital Terrain Elevation Data. That on land cover originally came from the U.S. Geological Survey's Global Land Cover Characteristics data base, but in recent years LandScan has replaced this with high resolution data from the National Geospatial Intelligence Agency (NGA). Data on exclusion areas, such as national parks come from the U.S. Census Bureau, while information on coastlines comes from NIMA's World Vector Shoreline data base. Data on night time lights, from NOAA, are gradually being phased out in favor of very high resolution imagery (one meter or less) used for detecting rooftops and other human constructions (Bright 2002; Brown 2008).

Figure 3. LandScan Model of Changes in the Ambient Population of Washington D.C.


Washington DC Nighttime

Washington DC Daytime

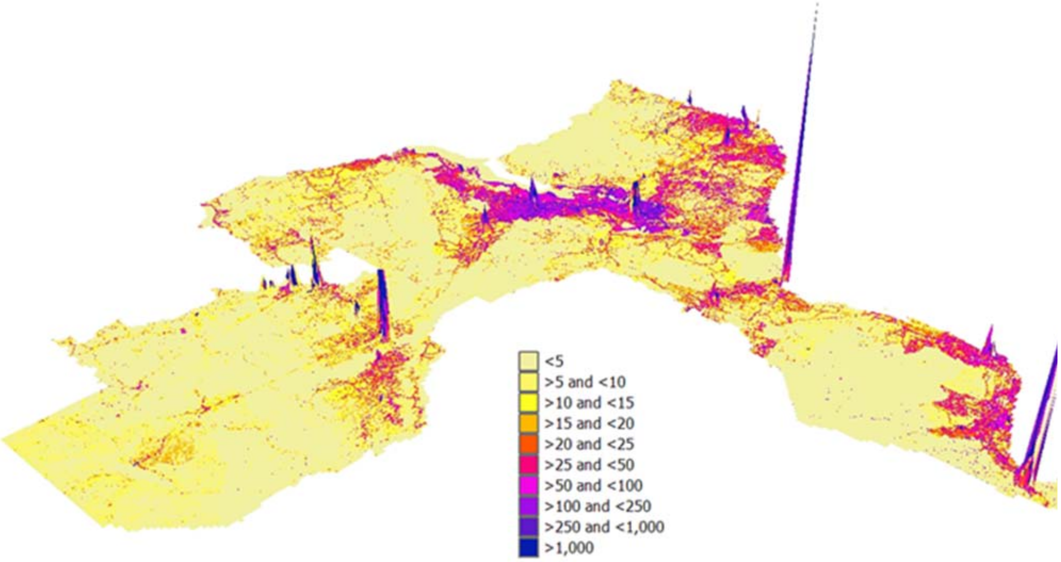
Source: Bhaduri 2009.

The LandScan spatial allocation algorithm estimates population in each 1 square kilometer grid cell by allocating sub-national census data based on the relative likelikhood of population occurring at different proximities to a road, along terrains of differing slope, under different categories of land cover, and according to the location of nighttime lights. In regions such as Africa and Central America, where access to night time electricity remains limited, LandScan replaces the night time lights measure with very high-resolution imagery (1 meter) that can detect variations in land cover, including rooftops and constructed buildings (Brown 2008). The prevalence and location of these human constructions provide spatial data for allocating population geographically. The weighting coefficients used for each of these explanatory factors vary from country to country. As in GRUMP, the LandScan algorithm normalizes total population to equal census control totals.

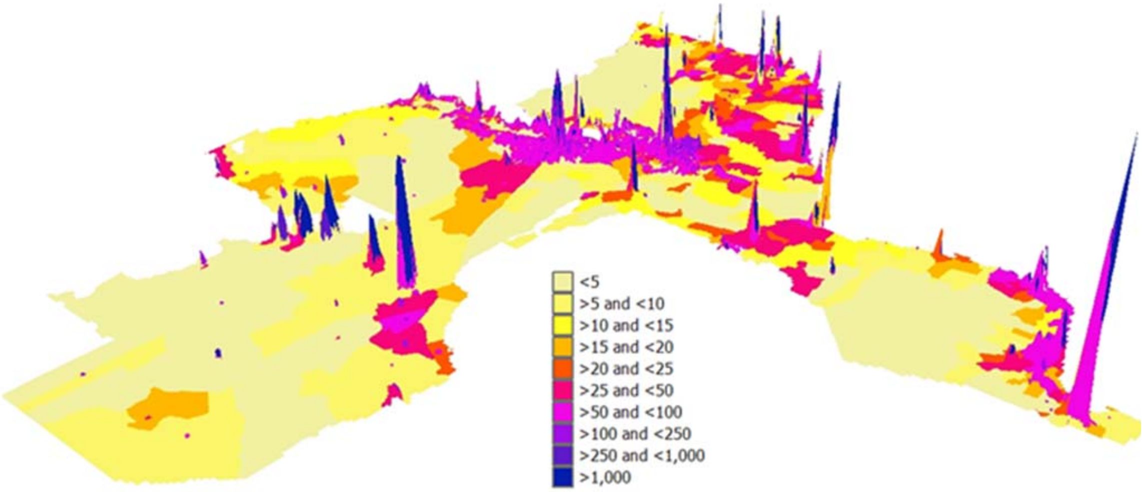
2.3. Comparisons

Both spatial data sets build on best-available sub-national census data and on the population of known urban settlements. The two differ primarily in how they distribute rural and urban populations across space. In rural areas, GRUMP does not model population distribution. Instead, it allocates population uniformly across a given rural administrative unit (usually a province or a district), giving the GRUMP maps a characteristic blocky look in rural areas (Figure 4). In contrast, the LandScan algorithm estimates rural population dispersal as a function of roads networks, land cover, slope, and other factors. As a result, the LandScan pattern resembles a neural network along which key nodes (cities) are connected by strands of connective tissue (roads). Rural population is arrayed across the countryside, with density increasing in favorable terrains and in proximity to transport corridors. This difference emerges most clearly in places such as western Zambia (Figure 4). When administrative units are small in size, as in most OECD countries and in the Republic of South Africa, GRUMP provides a more discriminating representation of population distribution than it does in countries where administrative units are larger, as in much of Sub-Saharan Africa where the GRUMP maps in rural areas take on a less realistic, blocky look.

Figure 4. Raster (Grid) Data Comparisons of the Spatial Distribution of Population in the GRUMP and LandScan Data Bases



a. LandScan Population Density (Population per km2)



b. GRUMP Population Density (Population per km2)

Sources: LandScan: http://www.ornl.gov/gist; GRUMP: http://sedac.ciesin.columbia.edu/gpw/.

In urban areas, the two differ as well. In the three countries we have examined, GRUMP estimates a higher population density within the confines of physically smaller urban extents. The difference arises because GRUMP maps urban physical extents primarily based on night time lights, supplemented in Africa with the ancilliary spatial data discussed earlier. In contrast, Lanscan in Africa depends primarily on high resolution imagery that identifies buildings and other man-made structures, rather than relying on night lights. Given low levels of electrification in many African cities and suburbs, the resulting GRUMP urban extents are physically smaller than the inhabited areas identified by LandScan.

When mapping these data in grid format[5], the two representations differ noticeably. However, when summing population into polygons (shape files), by urban extent and by district, the two look very similar (Figure 5). Given the high population density in major urban centers, particularly in Maputo (Mozambique), an enlarged urban extent buffer is necessary to accommodate the number of dots required to represent the city's true population weight. However, in densely populated, highly rural countries like Malawi, with very detailed administrative units (over 9,000 in a country the size of Mississippi), the addition of urban extent buffers does not add much additional information on population distribution (Figure 5).

National population totals do not differ appreciably between the two methods, because both use official census data as their point of departure (Table 1). However, the GRUMP estimates a larger urban population, particularly in Zambia and Mozambique, than a summation of the LandScan population within the spatial confines of the GRUMP urban extents.

2.4. Conclusions

For the food security mapping and analytical work we intend to pursue, we have elected to use the LandScan population data base because its modeling approach provides the more detailed rendering of both rural and urban population.

In rural areas LandScan models the distribution of rural population, while GRUMP does not. Given that smallholder farmers live within walking distance of their fields, locating population across geographic space becomes critical to locating crop production. The LandScan data base provides a plausible model for distributing population — and hence crop production — across space, while the GRUMP data base does not. Likewise, given our interest in helping to inform emergency response efforts, spatial allocation of rural becomes particularly important. Designed to assist in emergency planning, the LandScan data base is clearly preferred for our purposes.

Similarly in urban areas, the LandScan data base provides what we consider to be a more detailed estimate of the physical distribution of urban and suburban population. The key, in our view, is LandScan's use of high resolution imaging to identify man-made structures in contrast to GRUMP's reliance on coarser data on night lights. Given the unavailability and

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[5] Gridded data provide digitized images of a surface. They divide a surface into squares of the desired level of resolution. Each cell corresponds to a spot on the earth's surface. It contains a single value representing elevation, population, terrain or some other quantifiable variable. These digitized, gridded data are referred to as "raster" data. In contrast, shape files divide the surface area of the globe into polygons representing continents, islands and interior administrative or natural boundaries. For each polygon (a district, a country or even a lake), the GIS software can store relevant data required by the user. In this paper, for example, we have stored information on population, surface area, and food production.

unreliability of electrification in much of Sub-Saharan Africa, the GRUMP reliance on night lights seems likely to understate the numbers of small urban settlements as well as the physical extent of urban and suburban areas.

Figure 5. Dot Density Representation of the GRUMP and LandScan Population Data at the District Level

a. Landscan, Rural, and Urban Area Data **b. Grump, Rural, and Urban Area Data**

c. Landscan, Urban Buffers* **d. GRUMP, Urban Buffers***

* This map enlarges the display area in urban centers by applying a.1 decimal degree (12 km) buffer to all GRUMP-defined urban extents and a 0.2 decimal degree (24 km) buffer to cities over 500,000 (50 dots) in population.

Source: LandScan: http://www.ornl.gov/gist; GRUMP: http://sedac.ciesin.columbia.edu/gpw/.

Table 1. Rural and Urban Population Distribution within the GRUMP-Defined Urban Extents

Country	Population		Difference	
Location	GRUMP, 2000	LandScan, 2007	GRUMP-LandScan	%
Malawi				
rural	11,432,573	11,404,399	28,174	0%
urban	2,308,434	2,185,288	123,146	6%
total	13,741,007	13,589,687	151,320	1%
Mozambique				
rural	15,394,382	16,535,071	-1,140,689	-7%
urban	6,600,267	4,095,581	2,504,686	61%
total	21,994,649	20,630,652	1,363,997	7%
Zambia				
rural	7,671,370	7,759,718	-88,348	-1%
urban	4,432,386	3,708,143	724,243	20%
total	12,103,756	11,467,861	635,895	6%
Three country total				
rural	34,498,325	35,699,188	-1,200,863	-3%
urban	13,341,087	9,989,012	3,352,075	34%
total	47,839,412	45,688,200	2,151,212	5%

Source: GRUMP and Landscan data bases.

3. FOOD PRODUCTION

3.1. Key Food Staples

The two most important food staples in Sub-Saharan Africa are maize and cassava. Continent wide, maize accounts for 15% of total calorie consumption, with cassava supplying a further 12%. Maize typically dominates in the semi-arid and temperate zones, while cassava predominates in the warmer, tropical parts of the continent.

In South East Africa, these two primary food staples assume even greater importance, accounting for 60% of total calorie consumption. Therefore, as the first step in a broader mapping exercise, this spatial review of food staple production, consumption and trade focuses on maize and cassava. While maize predominates in Malawi and Zambia, cassava provides the greater calorie contribution in Mozambique. Over all three countries, maize supplies about 40% of local calorie consumption, while cassava provides another 20% (Table 2).

3.2. National Production Estimates

Ministries of agriculture throughout Africa produce annual crop production estimates. These vary in quality and precision, depending on the resources available and the methods used. In

Table 2. Food Staple Consumption in South East Africa, 1995 to 2003 Averages

	Consumption		
	kg/capita	cal/ cap/day	% calories
Malawi			
maize	134	1,170	55%
cassava (fresh)	69	127	6%
cassava (dried equivalent)	22		
Mozambique			
maize	56	457	22%
cassava (fresh)	227	679	33%
cassava (dried equivalent)	71		
Zambia			
maize	129	1,099	54%
cassava (fresh)	79	238	12%
cassava (dried equivalent)	25		
Three Country Total			
maize	99	846	40%
cassava (fresh)	139	392	19%
cassava (dried equivalent)	44		

Source: FAOSTAT.

Zambia, the ministry of agriculture commissions the Central Statistical Office to conduct an annual Crop Forecast Survey (CFS) of 13,000 large and small farms, before harvest, to estimate production to help government and private traders anticipate prospects for export or requirements for food imports. In contrast, in Malawi and Mozambique, the ministries of agriculture do not conduct a nationally representative production survey. Rather, they request crop area estimates from national extension staff. In the case of Malawi, extension officers conduct crop cuts. In Mozambique, field staff estimate both area and production. In both cases, ministry headquarters prepare national production figures by aggregating the district-level estimates from their regional field staff.

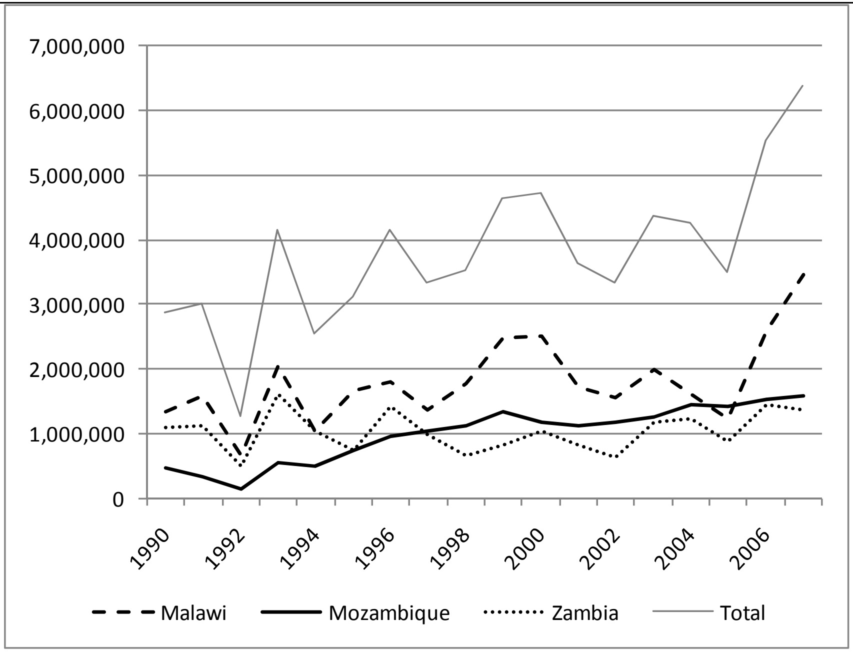
Maize production is typically easier to assess than the annual harvest of perennial crops such as cassava. Because most of the region relies on rainfed maize production, most farmers harvest once a year, at the end of the rainy season. As a result, they can readily recall how many bags they harvest from each field, and so recall data on maize quantities harvested is generally reliable. Nonetheless, maize remains a politically sensitive crop, and so production estimates may be, advertently or inadvertently, prone to subjective adjustments. In 2008, for example, despite official estimates of a record maize crop in Malawi, prices reached record highs, far in excess of those prevailing in neighboring countries. Most trade observers believe that official production figures overstated the 2008 Malawian maize harvest by 25% to 30%.

With cassava, greater imprecision arises in estimating quantities harvested. Because cassava is a perennial crop, with a 2-4 year productive life span, farmers harvest cassava year round, over a period of years, in small quantities, mainly for household consumption. This makes estimates based on recall data very difficult. Farmers, in many places, rely on this safety valve, adjusting their cassava harvest upwards in years when the maize crop fails and downwards when the maize crop does well (see, for example, Collinson 1985, p.26). While this flexibility provides an important food security benefit to farm households, it makes estimating harvested production in any given year very difficult. In practice, ministry staff apply a rough yield rate to the estimated hectarage under mature cassava.

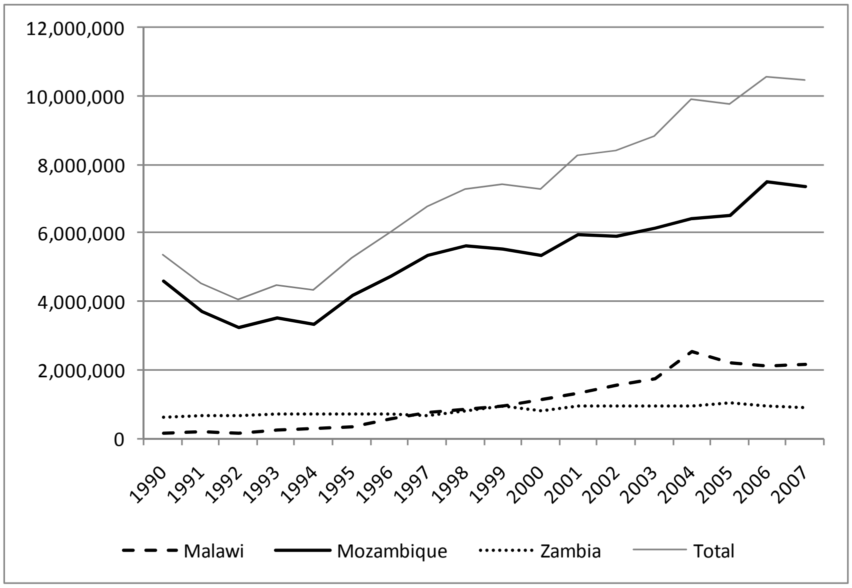
Over time, regional production data suggest two principal trends. First, cassava production has increased steadily across the region. Since the mid-1990's, output has roughly doubled. Several factors account for this growth: successful control of cassava mealybug infestation, multiple releases of improved varieties (bred from the IITA Tropical Manioc Selection series), and reduced maize subsidies in Malawi and Zambia, which have induced farmer diversification out of maize and into alternative food staples such as cassava, sweet potatoes, sorghum, and millet.

Maize production has grown more slowly than cassava and with considerably greater volatility (Figure 6). Erratic rainfall in Zambia and Malawi accounts for most of the volatility in regional maize production, though intermittent fertilizer and input subsidies also contribute. Differing weather patterns in northern Mozambique, driven by monsoon rains rather than by the inland convection currents that drive weather in Zambia and Malawi, have produced steady growth in Mozambican maize production along with considerably less volatility than among its inland neighbors. In aggregate, from the mid-1990's to the mid-2000's, maize production has increased by about 25% in the three countries. The apparent spike in 2007 was driven by the officially reported doubling of Malawian maize production compared to 2006.

Figure 6. Trends in Maize and Cassava Production in South East Africa



a. Maize Production



b. Cassava Production

Source: FAOSTAT

3.3. Baseline Aggregate Production Levels

Volatility in maize production drives food insecurity in South East Africa. Cassava, because of its drought resistance, provides a smaller but more reliable annual contribution to basic staple food consumption.

To map staple food availability and consumption, we first need to define a baseline "normal" production year. We then examine how the spatial distribution of food availability changes during good and bad years. Given the volatility of maize supply in Malawi and Zambia, a "bad" year in the region occurs when maize production in those two countries falls abruptly. Conversely, a "good" year occurs when the maize harvest in Malawi and Zambia exceeds normal levels.

To construct a *normal* baseline, we have taken average annual production from 1995 through 2006. This 12-year span begins after the major regional drought of 1992 and before the recent surge in estimated maize production in Malawi. As a *bad* year, we have taken production levels prevailing in 2005, when per capita maize production in Malawi and Zambia fell 40% and 16%, respectively, below the 12-year baseline. The following harvest, of 2006, constitutes a *good* year, with maize production in both countries rising 25% to 36% above the 12-year baseline (Table 3). Note that because of differing weather patterns in Mozambique, compared to its inland neighbors, reported maize production there remained strong even during bad production years in Malawi and Zambia.

3.4. Farm-level Survey Data

3.4.1. Smallholder Production

Smallholder farmers account for the bulk of maize and cassava production in all three countries. To understand how smallholder production varies spatially, we rely on analysis of nationally representative household surveys in each of the three countries. In Malawi, we have used the second Integrated Household Survey (IHS) of 2004/2005. These data provide cropping information from 9,800 households in all 26 rural districts of Malawi. In Mozambique, we have used the most recent Trabalho de Inquérito Agricola (TIA) survey of 2006. This survey covers 6,200 rural households in 21 rural districts spread across Mozambique. Each of these surveys covers the harvest during calendar year 2005. And in Zambia, we have analyzed household-level data from the second supplemental Post Harvest Survey (PHS) of 2004, covering the harvest of calendar year 2003. The PHS survey includes data on 5,400 households farming in all 71 rural districts of Zambia.

3.4.2. Large-scale Commercial Farms

Only in Zambia do large-scale commercial farmers produce a significant share of the national maize crop. Data from Zambia's annual Crop Forecast Survey provides a provincial and sometimes district-level breakdown of crop production for large farmers (defined as those farming more than 20 hectares) and for small and medium farms (defined as those cultivating less than 20 hectares). These data suggest that large farms produce roughly 30% of Zambia's national maize harvest and over 50% of marketed volumes (Table 4).

3.4.3. Comparing Farm-level Survey Data with Aggregate National Estimates

Farm-level surveys do not always match national production estimates. In part, detailed farm surveys often have many objectives other than estimating total production. They often aim, instead, to understand farmer decision-making, input use and a range of demographic and household welfare measures. Sampling frames and weights may not enable reliable national estimates, particularly for minor crops and livestock enterprises. Indeed, Zambia specifically runs a separate CFS of 13,000 farm households before the harvest each season for the express purpose of estimating production. Then, after the harvest, they execute a much smaller PHS to evaluate farmer input use, land allocation and behavioral issues.

Table 3. Staple Food Production during Stylized Normal, Bad, and Good Maize Production Years

	Normal	Bad	Good	Change from "normal"	
				to "bad"	to "good"
National production data					
Maize ('000 tons)	1995-2006	2005	2006		
Malawi	1,852	1,225	2,577	-34%	39%
Mozambique*	1,468	1,403	1,534	-4%	4%
Zambia	973	866	1,424	-11%	46%
total	4,293	3,494	5,535	-19%	29%
Cassava ('000 tons fresh)	2005-06				
Malawi	2,149	2,198	2,100	2%	-2%
Mozambique*	7,000	7,264	6,736	4%	-4%
Zambia	1,003	1,056	950	5%	-5%
total	10,152	10,518	9,786	4%	-4%
Cassava ('000 tons dry weight)	0.31	0.31	0.31		
Malawi	672	688	657	2%	-2%
Mozambique	2,190	2,273	2,107	4%	-4%
Zambia	314	330	297	5%	-5%
total	3,176	3,291	3,061	4%	-4%
Per capita national production					
Maize production per capita (kg/person/year)					
Malawi	161	97	202	-40%	25%
Mozambique	73	71	76	-3%	3%
Zambia	93	78	127	-16%	36%
total	102	80	125	-21%	22%
Dried cassava production per capital (kg/person/year)					
Malawi	53	54	52	2%	-2%
Mozambique	109	113	105	4%	-4%
Zambia	28	30	27	5%	-5%
total	72	75	70	4%	-4%
Projected aggregate production using 2007 Landscan population totals					
Maize ('000 tons)					
Malawi	2,194	1,324	2,739	-40%	25%
Mozambique	1,507	1,456	1,558	-3%	3%
Zambia	1,070	896	1,458	-16%	36%
total	4,770	3,676	5,755	-23%	21%
Cassava ('000 tons dry weight)					
Malawi	721	737	704	2%	-2%
Mozambique	2,248	2,333	2,163	4%	-4%
Zambia	323	340	306	5%	-5%
total	3,292	3,410	3,173	4%	-4%

* Because of the long-term upward trends in cassava and in Mozambican maize production (see Figure 6), all cassava and Mozambican maize computes "normal" averages from 2005 and 2006.
Source: FAOSTAT.

Table 4. Maize Production and Sales by Farm Size in Zambia

	Normal 1995-2006	Bad 2005	Good 2006	Change from "normal" bad	 good
National production and sales data					
Maize production ('000 tons)					
small farms (under 20 ha)	691	598	1,107	-13%	60%
large farms (over 20 ha)	282	268	318	-5%	13%
total	973	866	1,424	-11%	46%
Share of maize production					
small farms (under 20 ha)	71%	69%	78%	-3%	9%
large farms (over 20 ha)	29%	31%	22%	7%	-23%
total	100%	100%	100%		
Maize sales ('000 tons)					
small farms (under 20 ha)	207	115	358	-45%	73%
large farms (over 20 ha)	240	235	270	-2%	13%
total	447	350	628	-22%	40%
Share of maize sales					
small farms (under 20 ha)	46%	33%	57%	-29%	23%
large farms (over 20 ha)	54%	67%	43%	25%	-20%
total	100%	100%	100%		
Share of production sold					
small farms (under 20 ha)	30%	19%	32%		
large farms (over 20 ha)	85%	88%	85%		
total	46%	40%	44%		
Projected aggregates using 2007 production estimates from Table 4					
Maize production					
small farms (under 20 ha)	759	619	1,133	-18%	49%
large farms (over 20 ha)	310	277	325	-11%	5%
total	1,070	896	1,458	-16%	36%
Maize sales ('000 tons)*					
small farms (under 20 ha)	228	119	367	-48%	61%
large farms (over 20 ha)	264	243	276	-8%	5%
total	491	362	643	-26%	31%

* Projected aggregate production times share of production sold by each farm group.
Source: Zambia Crop Forecast Survey and Table 3.

Table 5 compares the most recent farm household surveys with national production estimates for those same years. In three out of six instances, the farm household survey estimates track aggregate production estimates within plus or minus 10%. Mozambican cassava production estimates track to within 30%. The two large outliers are Zambia’s maize production estimate, for which the post-harvest household survey estimates 80% more smallholder production than does the national estimate produced by the much larger pre-harvest CFS. Conversely, Malawi’s IHS survey estimates cassava production only 7% as high as the official production figures. These disparities suggest that additional investment in basic production estimates will be necessary to firm up our understanding of basic food staple positions.

Table 5. Differences between Aggregate and Survey Estimates of Maize and Cassava Production

				Maize			Cassava		
Country	Harvest Year	Maize Harvest	Survey	FAO	HH Survey	HH survey/ FAO	FAO	HH Survey	HH/FAO
Malawi									
	2004 & 05	normal/bad	IHS2	1,225	1,100	**0.90**	2,198	151	**0.07**
Mozambique									
	2002	normal	TIA 02	1,179			5,925		
	2005	good	TIA 05	1,403			6,500		
	2006	good	TIA 06	1,534	1400	**0.91**	7,500	5480	**0.73**
Zambia									
	2000	normal	PHS S#1	1,040					
	2003	normal	PHS S#2						
	small			771.4216	1370	**1.78**	815		
	large			386.4384					
	total			1,158			957	836	**0.87**

Sources: FAOSTAT, Malawi Integrated Household Survey 2004/05, Mozambique TIA surveys of 2002, 2005 and 2006; Zambia Post-Harvest Surveys of 2000 and 2003.

3.5. Allocating Production across Space

3.5.1. District-level Production

Where district-level production estimates are available, these enable allocation of production across administrative boundaries. Both the Malawi and Zambia farm household surveys include data from all districts, though sampling frames make them statistically valid only at the provincial level. In Mozambique, the national agricultural survey includes only a sampling of districts, which are grouped into *estrato*, a geographical unit smaller than a province and larger than a district that is created by breaking provinces into common agro-ecological zones. By mapping districts into *estrato*, and using the relative rural population of each district within a single *estrato*, it is possible to allocate production across districts.

From the district-level production estimates, we compute the share of maize and cassava produced in each district. Since farm household survey aggregates do not match national production estimates exactly (Table 5), we take the official national production estimates as given (Table 3) and then multiply these totals by the production share of each district to compute the smallholder tonnage harvested in each district.

In sum, we estimate smallholder production at district level as follows, by:

1. Allocating production to districts using household survey data;
2. Calculating district production shares using these data; and
3. Applying these shares to national smallholder production data to estimate the production level in each district.

To these smallholder totals, we must add maize produced on the commercial farms. While production data are available for Zambia's large-scale farms, digitized spatial maps of the major commercial farm blocks are not, to our knowledge, available. Therefore, we have used the CFS district-level production data for large farms, together with sketch maps of the commercial farm blocks to prepare hand-drawn, stylized shape files identifying the general areas where the large-scale maize production occurs. The resulting maps sum together maize production by both large and small farms.

At the district level, Figure 7 displays the distribution of maize and cassava production using a simple dot density map. Each dot represents 5,000 tons of maize or 5,000 tons of dried (calorie equivalent) cassava.[6] Figure 8 provides a three-dimensional version of these data. By mapping production per square kilometer within each district, these extruded volumes provide a visual representation of the volumes of food produced in each district. The height of the figures (the production per square kilometer) times the area under production (the surface area of the polygon) equals the total volume of food produced. Think of these three-dimensional representations as piles of bags stacked on the ground. The bigger the surface area and the higher the pile, the greater the volume of maize and cassava produced.

3.5.2. Gridded (Pixel-level) Production Allocation

As an alternative to the blocky representation of the extrusion map, Figures 9 to 11 display the production data by grid cell. To create these grid map allocations of production, we compute district-level per capita production of maize and cassava (from household survey data) and then use the Landscan population raster to allocate per capita smallholder production across space. Because smallholders typically live within walking distance of their fields, the distribution of rural population across geographic space provides a good indication of where smallholder crop production takes place. In contrast, in the commercial farm blocks we apply a uniform production per square kilometer to allocate commercial farm production spatially. Summing smallholder and large farm production results in the raster file grids displayed in Figures 9 to 11.

In general, spatial dispersion of production depends on two sets of variables: agroclimatic and market-related. Agroclimatic variables such as rainfall, soil type and temperature clearly affect production potential and cropping patterns at any given location. Access to markets (distance to roads, road quality, transport availability) similarly influence input prices, output prices, and hence incentives to produce food surpluses for sale. In a next round of spatial analytical work, we hope to test out spatial regression and related allocation techniques (analogous to those used by Landscan to allocate population across space) to see if they can help to discriminate among production and marketing densities within a single district and to assess their accuracy for possible use in countries where district-level household data are not available.[7] For purposes of this paper, we rely on the district-level per capita production as a proxy incorporating both agroclimatic and market access variables.

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[6] To convert fresh cassava, which is two-thirds water, to a calorie-equivalent dry weight, we multiply fresh cassava tonnage by 0.31, the average cassava-to-maize calorie conversion in the FAO food balance sheets for these three countries.

[7] This next round of mapping efforts will build on spatial regression techniques, such as those used in the Landscan population allocation algorithm (Landscan 2002) and in poverty mapping exercises (Elbers, Lanjouw, and Lanjouw 2003; Bedi, Coudouel, and Simler 2007) as well as on recent maximum entropy work modeling the spatial allocation of crop production (You and Wood 2006; You et al. 2007a and 2007b).

Figure 7. Dot Density Map of Staple Food Production in South East Africa, Normal Year

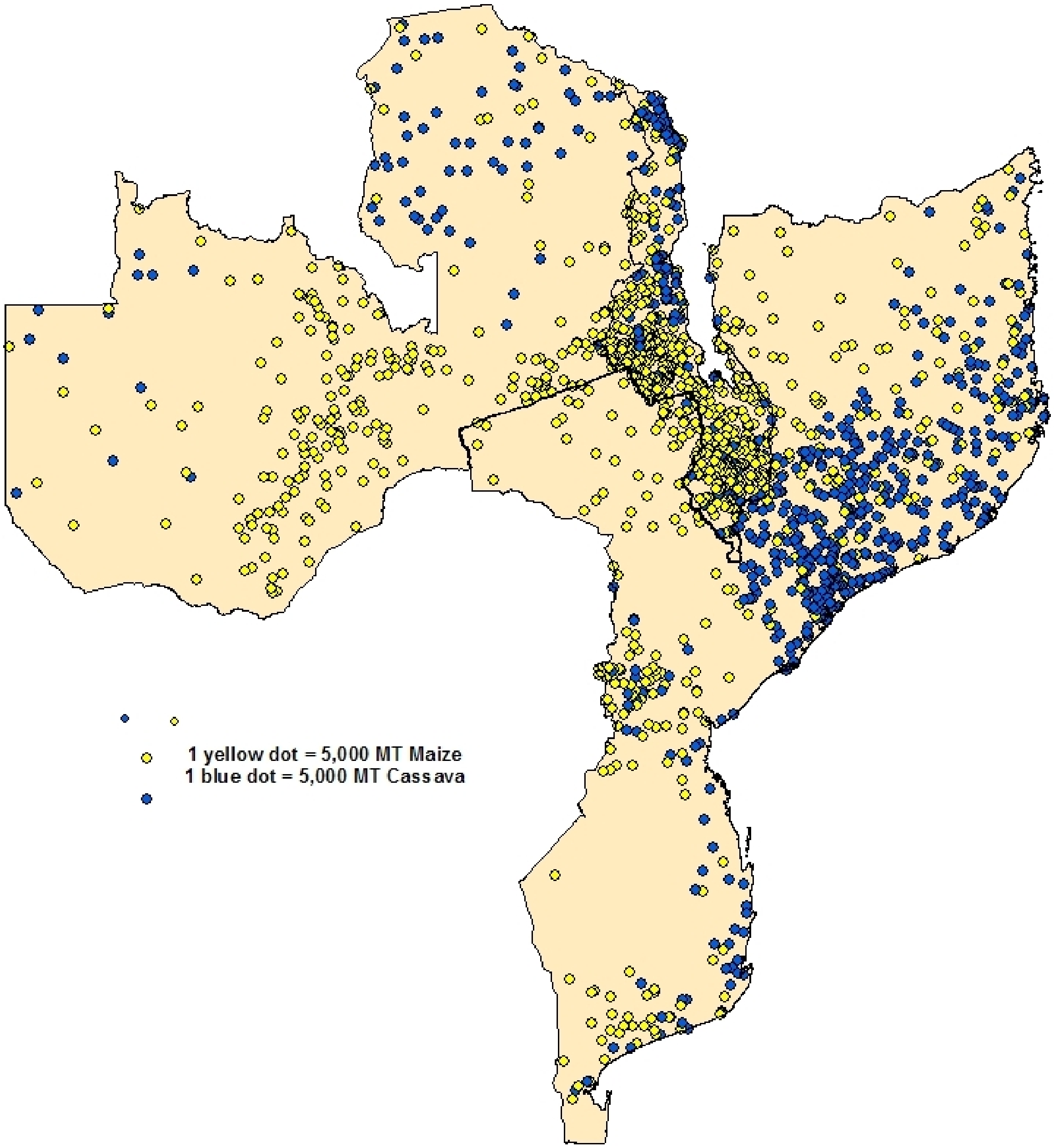
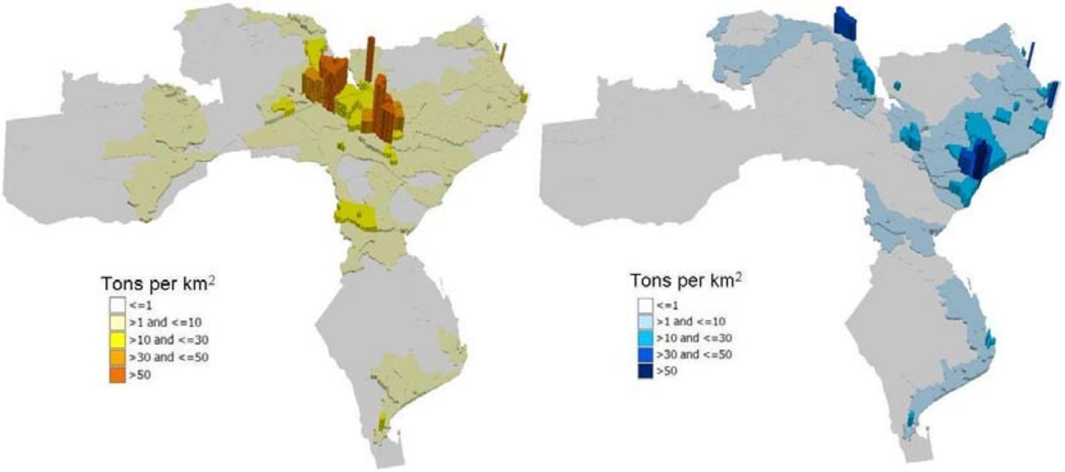


Figure 8. District-Level Extrusion Map of Staple Food Production in South East Africa

a. Maize Production **b. Cassava Production**



c. Maize Plus Cassava Production

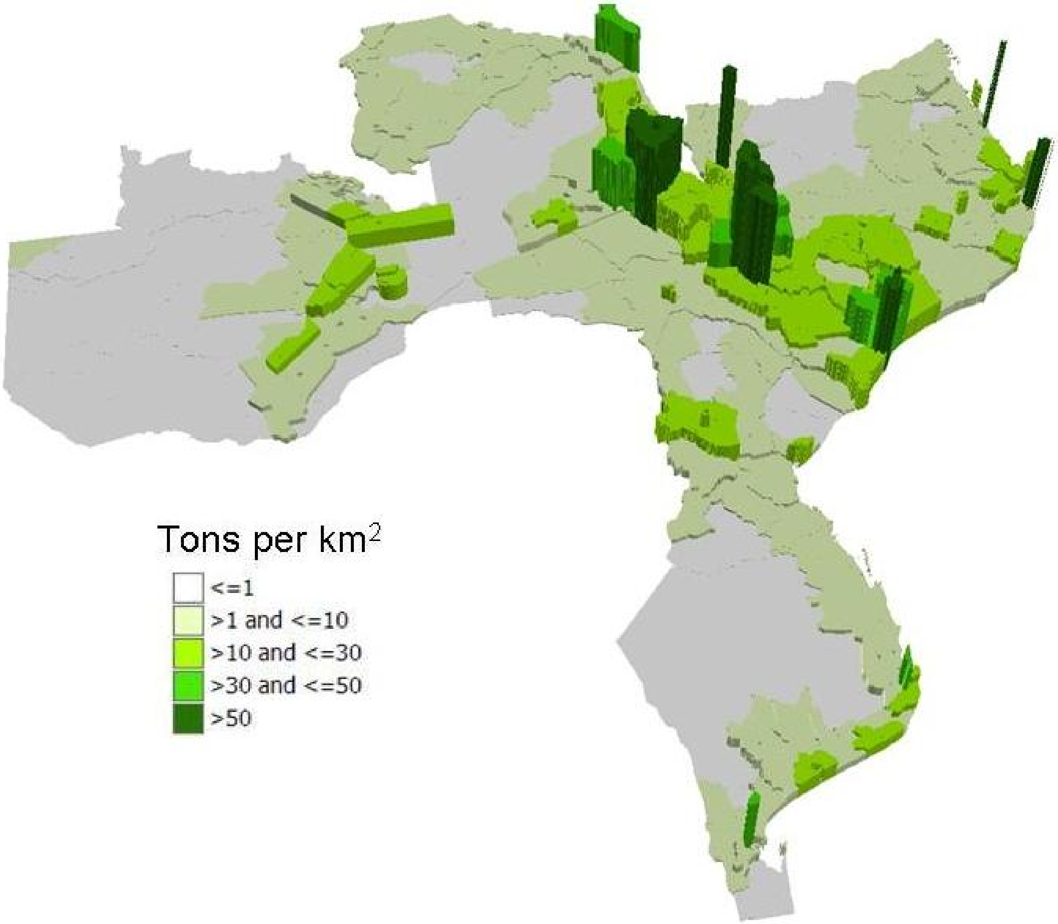
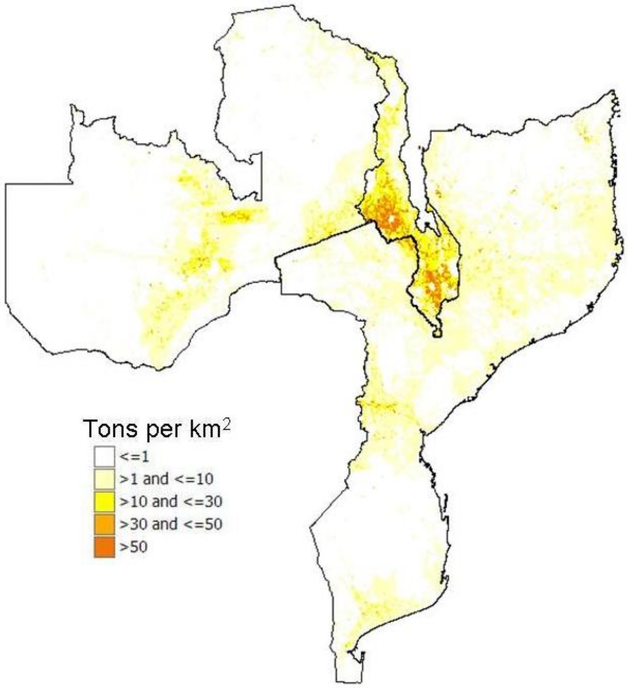


Figure 9. Grid Map of Maize Production in South East Africa, Normal Year

a. Two-dimensional Density (Raster) Grid



b. Three-dimensional Density (Raster) Grid

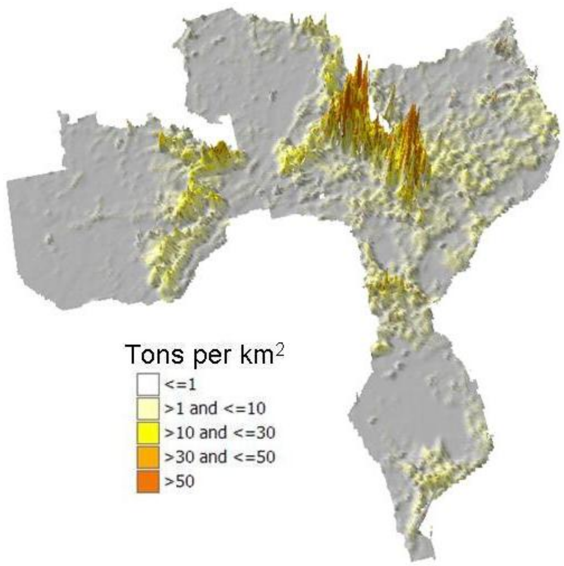
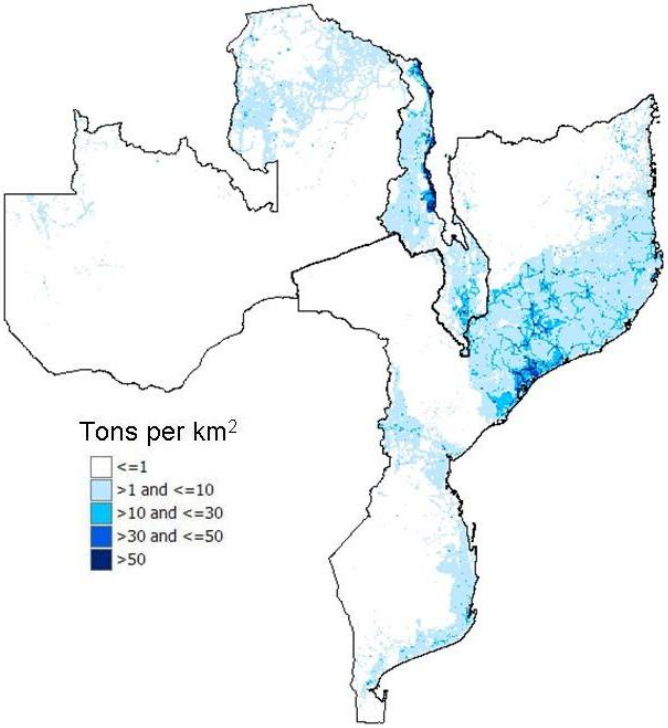


Figure 10. Grid Map of Cassava Production in South East Africa, Normal Year

a. Two-dimensional Density (Raster) Grid



b. Three-dimensional Density (Raster) Grid

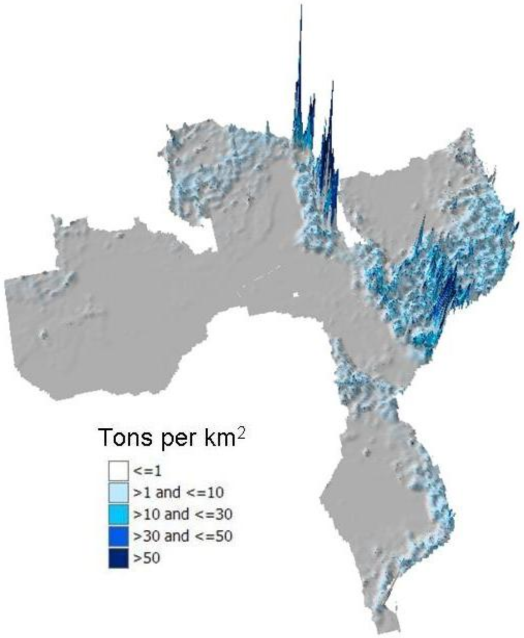
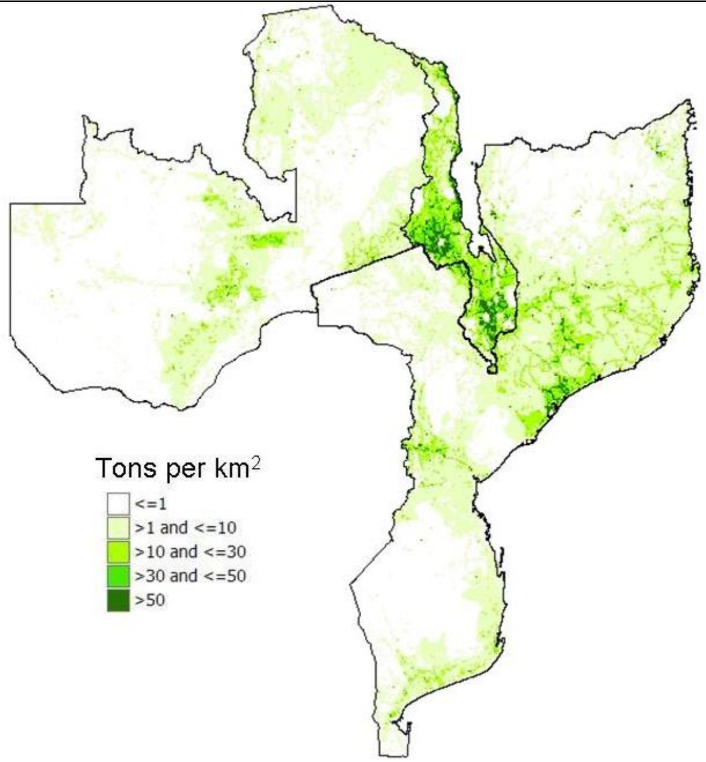
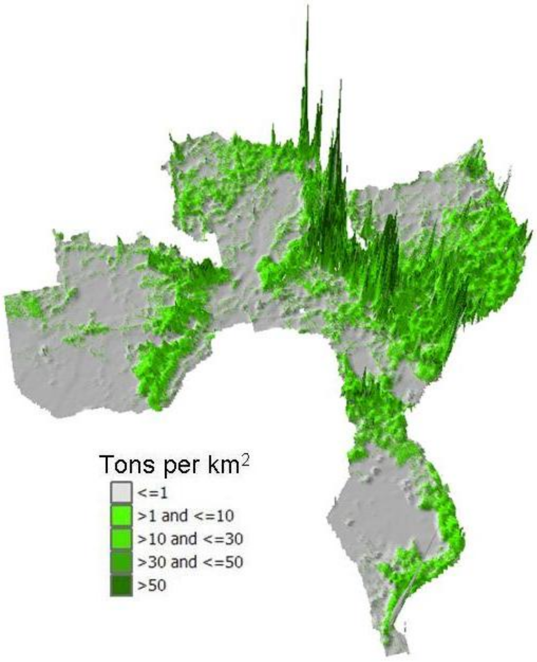


Figure 11. Grid Map of Staple Maize & Cassava Production in South East Africa, Normal Year

a. Two-dimensional Density (Raster) Grid



b. Three-dimensional Density (Raster) Grid



4. CONSUMPTION

4.1. Food Staple Zones

African governments estimate aggregate staple food production annually, and they typically conduct detailed national farm household surveys regularly enough to generate production shares across districts. However for consumption estimates, district-level data are rarely, if ever, available. Therefore, in order to allocate consumption spatially we need to find an alternate means of generalizing spatially about consumption behavior. For purposes of this paper, we rely on the concept of a *food staple zone*. Because the mix of staple foods produced, relative food prices and consumption preferences differ markedly across regions, so, too, do spatial patterns of staple food consumption. The spatially detailed food production data, available from farm household surveys, offer a window into those geographic differences in staple food production and consumption patterns.

In general, maize production predominates in the southern latitudes and interior portions of the region (Figure 12). In these areas, where night-time temperatures occasionally fall below freezing, cassava cannot grow. Hence, these areas depend primarily on maize and drought-tolerant cereals such as sorghum and millet. Cassava production, in contrast, predominates in the northern tropical belt and along the Mozambican coast. Because the bulk of the cassava growing regions also produce maize, a large proportion of food production in South East Africa takes place in dual staple zones where farmers produce both crops.

Mapping these differences in production intensity, we have used available production data to classify the region into three different food staple zones (Figure 13). In doing so, many different classification systems are possible. The most simple, imposing the least data demands, would classify zones using the relative percentage of households growing each crop. Area- or production-based crop measures are also possible. These have the advantage of taking into account estimates of the relative volumes of production of each staple food. Table 6 compares four different definitions and evaluates the differences in population, area and production arising from each.[8]

Ultimately, we have opted for a three-way classification using relative cropped area as the discriminating variable (definition Area 3 in Table 6). Under this classification system, the *cassava belt* refers to zones where farmers plant more than three times as much hectarage to cassava as to maize (that is, where they devote over 75% of the area allocated to these two crops to cassava). The *maize belt*, conversely, refers to areas where farmers plant more than three times as much area in maize as in cassava. We refer to the remaining areas, where farmers plant 25% to 75% in both staples, as *dual staple zones*. The dual staple zones, which cover large swaths of northern and coastal Mozambique as well as northern parts of Malawi and Zambia, house about half of the region's rural population and account for over 30% of total maize production and 90% of cassava production (Table 6). Because households in the dual staple zones (and in the cassava belt) produce and consume both staples, substitution possibilities here offer prospects for releasing large quantities of maize during deficit years, as households choose to harvest and eat more cassava and sell the more valuable maize.

Before mapping food consumption across these food staple zones, we require consistent estimates of total maize and cassava consumption. This requires a reconciliation of the basic supply-demand balances for each food commodity.

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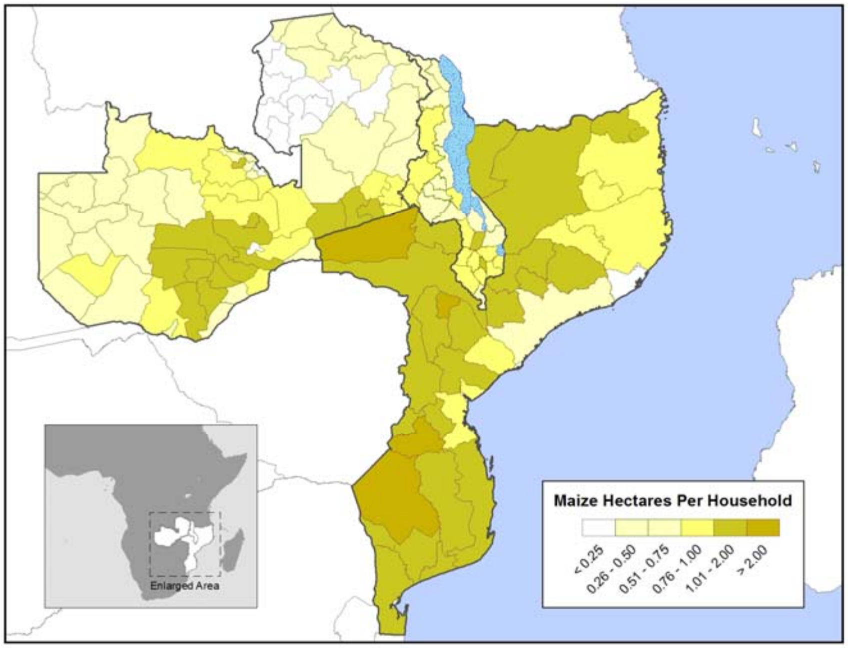
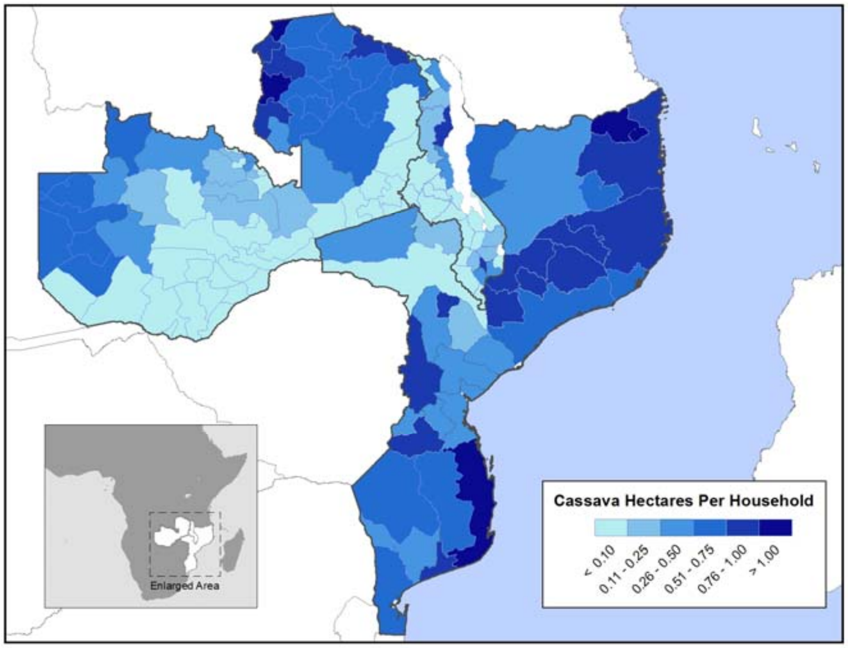
[8] See Haggblade and Nielson (2007) for a side-by-side comparison of household and area-based definitions.

Figure 12. Spatial Distribution of Area Planted per Household in Maize and Cassava



a. Maize Area Planted



b. Cassava Area Planted

Source: Haggblade and Nielsen 2007.

Figure 13. Food Staples Zones

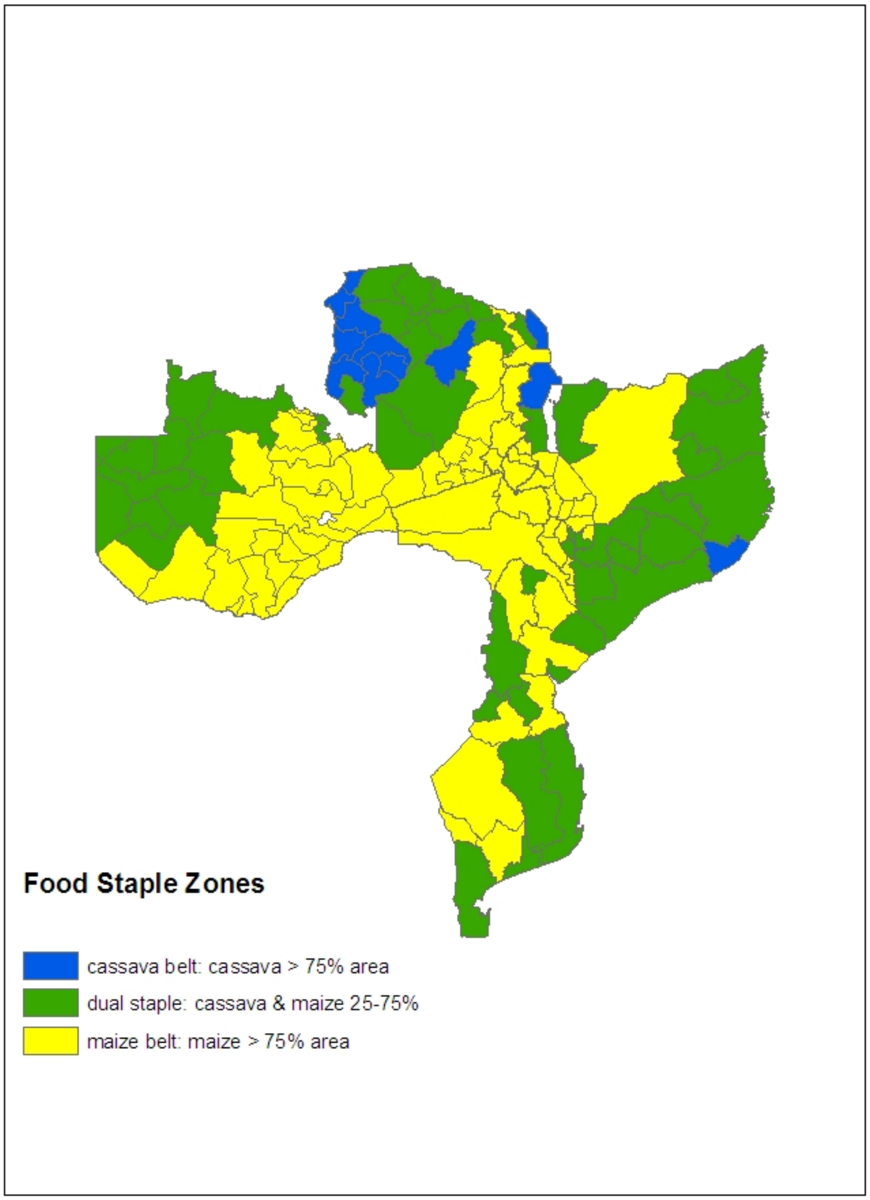


Table 6. Alternate Definitions of Food Staple Zones

Alternate definitions	Definition		Ratio maize/ cassava	Rural household distribution	Percent of Households Growing each crop		Production kg per household		Distribution of regional production	
	maize	cassava			maize	cassava	maize	cassava*	maize	cassava
	Percent of households growing each crop									
HH1										
cassava belt	< 25%	> 75%	0.33	0%						
dual staple zones	> 25%			65%	86%	67%	558	340	46%	99%
maize belt	> 75%	< 25%	3	35%	98%	7%	1,097	8	54%	1%
				100%						
	Area of cassava plus maize planted to each crop									
Area 1										
cassava belt	< 10%	> 90%	10	1%	56%	99%	112	637	0%	2%
dual staple zones	10-90%			69%	87%	64%	565	321	51%	97%
maize belt	> 90%	< 10%	0.1	31%	98%	8%	1,136	7	49%	1%
				100%					100%	100%
Area 2										
cassava belt	< 20%	> 80%	0.25	4%	59%	97%	175	588	1%	6%
dual staple zones	20-80%			55%	87%	70%	498	368	38%	93%
maize belt	> 80%	< 20%	4	42%	97%	12%	1,100	14	62%	2%
				100%					100%	100%
Area 3										
cassava belt	< 25%	> 75%	0.33	5%	60%	95%	215	525	1%	7%
dual staple zones	25-75%			50%	88%	72%	491	397	31%	91%
maize belt	> 75%	< 25%	3	45%	97%	14%	1,069	19	68%	3%
				100%					100%	100%

* Fresh cassava converted to dry weight at 0.31 times fresh weight.
Sources: Malawi IHS Survey 2005; Mozambique TIA Survey 2005; Zambia Supplemental PHS Survey 2004.

4.2. Supply-demand Balances

The total supply of staple foods available at any particular location in any given year comes from one of three possible sources: local production (Q), stock draw downs (dK), or imports (M). Total utilization includes human consumption (C), exports (X), seeds, feeds, industrial uses, and losses (SFIL).

Equation 4.1. Supply = Demand

$$Q + dK + M = C + X + SFIL$$

At the national and subnational level, exports refer to net outflows and imports to net inflows of staple foods. At the household level, purchases are equivalent to imports, while sales are equivalent to exports. These equalities thus hold at the national, regional, district, and household levels (Table 7).

These supply-demand balances become important because direct measurement of food consumption (C) and net marketed volumes (X-M) is generally not available annually. So interested policy makers must estimate unknown components from known variables using some variant of Equation 4.1.

In constructing annual food balance sheets, for example, it is possible to estimate human food consumption as a residual, as in Equation 4.2., starting with total availability (Q + dK + M) and then deducting exports (X) and non-human uses (SFIL). Similarly, at the household level, production (Q) plus purchases (M) and stock changes (dK) minus sales (X), seeds, feeds and losses (SFIL) enables an estimate of human consumption using the so-called *disappearance method* (Equation 4.2.).

Equation 4.2. Consumption = Total Supply Minus non-Human Uses

$$C = Q + dK + M - X - SFIL$$

For marketed volumes, direct data may sometimes be available from household or trader surveys. In those cases, it is possible to compute net sales directly as sales (X) minus purchases (M). In many instances, however, purchases and sales data are not available. In these cases, it is possible to estimate net sales as total local supply minus local uses, as in Equation 4.3.

Equation 4.3. Net Sales = Supply Minus Local Uses
$X - M = Q + dK - C - SFIL$

Equation 4.4. provides an alternative formulation used, in some cases, to equilibrate staple food balance sheets. This version of the basic supply/demand balance computes stock drawdowns as a residual equal to the difference between domestic uses of a food and available apparent supply. This formulation appears to be the one adopted by FAOSTAT in computing maize consumption in Zambia, as the following discussion will amplify.

Equation 4.4. Stock drawdowns = Consumption Requirements Minus Available Supply
$dK = C + X + SFIL - Q - M$

Table 7. Commodity Balances in Rural and Urban Areas

	Rural	Rural	Rural	Urban	National
	Deficit districts	Surplus districts	Total	Total	Total
Production	Q	Q	Qr	Qu	Q
Imports (purchases)	+Mrr +Mir		+ Mir	+Mru +Miu	+Miu +Mir
Stock drawdowns	+ dK	+ dK	+ dKr	+ dKu	+ dK
Exports (sales)		- Xrr - Xru - Xri	-Xru -Xri		-Xri
Seeds, feeds, industrial uses, and losses	- SFILr	- SFILr	- SFILr	- SFILu	-SLIF
Human Consumption	C	C	Cr	Cu	C

<u>Variables</u>
Q = production
M = imports (purchases)
dK = stock draw downs
X = exports (sales)
SFIL = seeds, feeds, industrial uses and losses
C = human consumption

<u>Indices</u>
r = rural
u = urban
i = international

Mjk = imports from j location to k location
Mrr = Xrr
Xru = Mru

4.3. Aggregate Food Balance Sheet Estimates of Consumption

At the macro level, most countries produce annual food balance sheets (Table 8). In many instances, food policy analysts apply Equation 4.2. to estimate food consumption as a residual based on estimated production and trade data. For some foods, such as wheat, which is primarily imported or produced by a handful of large commercial farms, national estimates of production, sales, and imports may be very precise. However, primary staples such as maize are grown by millions of small farms and consumed by millions of independent urban consumers, traded through a wide range of supply channels and often prepared by hand or by service milling at local hammer mills. Thus, fewer large-scale key informants are available for estimating aggregate volumes of maize production, consumption, and trade flows. Cassava presents additional difficulties because it is typically harvested piecemeal over a period as long as several years. As a result, collecting accurate recall data on cassava production is more difficult and subject to greater error than for maize. These factors lead to imprecision and often to inconsistencies between production and consumption aggregates.

Table 8. Food Balance Sheets for Malawi, Mozambique and Zambia

	Maize				Cassava (dry weight)			
	Malawi	Mozambiqu	Zambia	Total	Malawi	Mozambiqu	Zambia	Total
Average FAO food balance sheet quantities, 1995 to 2003 ('000 tons of maize equivalents)								
Production (Q)	1,840	1,059	868	3,768	436	1,676	263	2,375
Stock drawdowns (dK)	-27	3	458	434	0	0	0	0
Formal imports (M)	131	189	131	452	0	0	0	0
Formal exports (X)	9	1	7	17	0	0	0	0
Seeds and losses (SL)	234	87	61	382	48	262	13	323
Feeds and industrial uses (FI)	217	164	67	449	145	181	0	326
Consumption (C) food balance sheet	1,485	999	1,321	3,804	242	1,233	250	1,725
Projected "normal" aggregates for 2007**								
Production (Q)	2,194	1,507	1,070	4,770	721	2,248	323	3,292
Stock drawdowns (dK)	-32	4	458	549	0	0	0	0
Formal imports (M)	156	189	162	572	0	0	0	0
Formal exports (X)	11	1	9	22	0	0	0	0
Seeds and losses (SL)	279	124	75	484	80	351	16	448
Feeds and industrial uses (FI)	259	234	83	568	240	243	0	452
Consumption (C) food balance sheet	1,770	1,341	1,521	4,817	400	1,654	307	2,391
Informal net imports (M-X)	70	-50	-20	0	0	0	0	0
Consumption (C)*	1,840	1,291	1,501	4,817	400	1,654	307	2,391
Quantities (kilograms per capita)								
Production (Q)	161	73	93	104	53	109	28	72
Stock drawdowns (dK)	-2	0	40	12	0	0	0	0
Formal imports (M)	12	9	14	13	0	0	0	0
Formal exports (X)	1	0	1	0	0	0	0	0
Seeds and losses (SL)	21	6	7	11	6	17	1	10
Feeds and industrial uses (FI)	19	11	7	12	18	12	0	10
Consumption (C) food balance sheet	130	65	133	105	29	80	27	52
Informal net imports (M-X)	5	-2	-2	0	0	0	0	0
Consumption (C)*	135	63	131	105	29	80	27	52
Caloric consumption C* (Kcal/person/day)	1,183	547	1,144	921	257	700	234	457
As Share of National Production								
Production (Q)	100%	100%	100%	100%	100%	100%	100%	100%
Imports (M)	7%	18%	15%	12%	0%	0%	0%	0%
Exports (X)	0%	0%	1%	0%	0%	0%	0%	0%
Seeds, feed, industrial uses, losses (SFIL)	25%	24%	15%	22%	44%	26%	5%	27%
Consumption (C)*	81%	94%	152%	101%	56%	74%	95%	73%

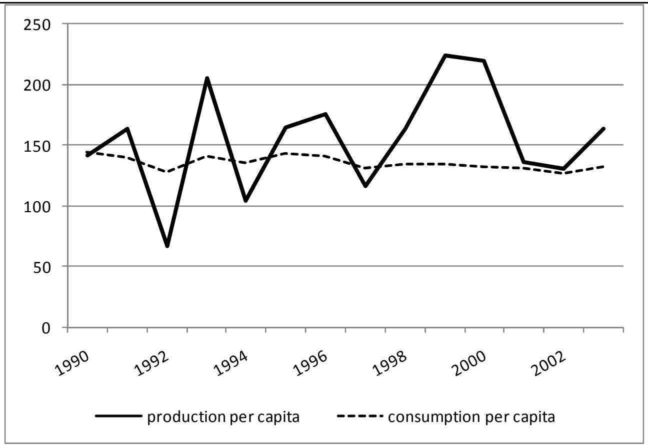
* Informal cross-border trade included.

** As in Table 3, these calculcations retain the per capita totals from the FAO food balance sheets and adjust to 2007 aggregates using Landscan population totals.

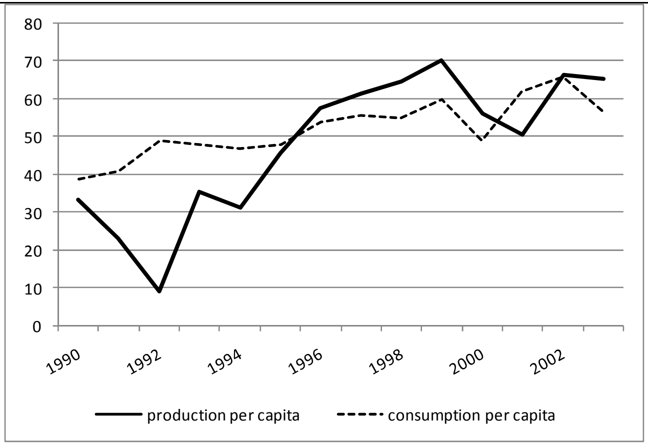
Source: FAOSTAT, Table 3.

For maize consumption, at least in Zambia, the FAO appears to apply Equation 4.4. instead of Equation 4.2. to estimate stock drawdowns, rather than consumption, as a residual item balancing food supply and demand. According to FAO food balance sheets, maize consumption remains largely static, even in the presence of wide fluctuations in production and prices (Figure 14). In Malawi, for example, the FAO food balance sheets projected per

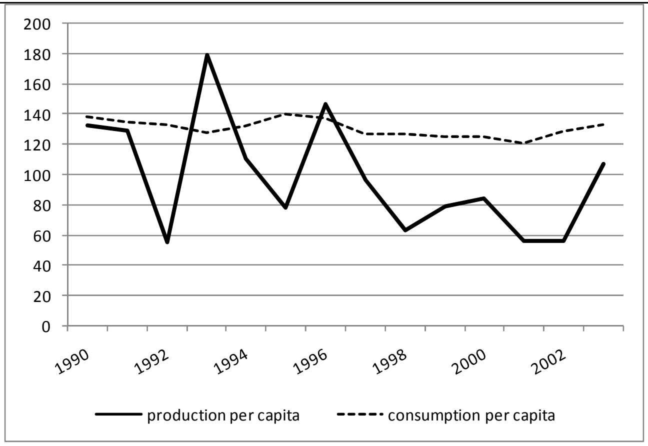
Figure 14. Trends in Estimated Maize Production and Consumption Per capita



a. Malawi



b. Mozambique



c. Zambia

Source: FAOSTAT Food Balance Sheets.

capita maize consumption within a tight range, between 130 and 140 kilograms per person per year, while production fluctuated far more widely, between 70 and 220 kg per person. In Mozambique, the FAO projects smoothly rising maize consumption as production increased over the past decade and a half. In Zambia, as in Malawi, maize consumption has remained largely constant, according to the FAO food balance sheets, despite wide swings in production. In the case of Zambia, consumption has remained substantially higher than apparent availability (Q + M – X). Possibly production or informal imports have been underestimated. Rather than adjusting these items, presumably in order to respect official trade and production statistics, the FAO appears to use stock drawdowns as a balancing item, resulting in largely stable per capita maize consumption. But this requires consistent, large-scale stock drawdowns in eight of the nine latest years reported since 1995 (Annex Table A.2.). Clearly, the production, consumption and trade data need to be reconciled, particularly in Zambia. Here, again, a call for more careful data collection — of production, trade (formal and informal), and consumption quantities — becomes necessary.

4.4. Consumption Data

Data on food consumption are subject to even greater levels of imprecision than production statistics. Most African countries survey food consumption only intermittently, certainly not annually as they do with farm production. When household consumption surveys do take place, statistical agencies typically estimate food consumption based on respondent recall information over a prior reference period, usually a day or a week.[9] Responses differ depending on the person interviewed in the households. They generally underestimate meals consumed outside the home. Snack foods and seasonal fruits, vegetables, and meats are typically undercounted. Inaccuracies inherent in recall data, for a wide range food products, are compounded by seasonal variations in food availability, pricing, and consumption patterns. Moreover, some surveys collect responses in value terms only. Given widely differing unit prices, depending on quantities purchased, this makes estimation of quantities consumed very difficult.

Given the uncertainties in estimates of both production and consumption, it is not surprising that the consumption estimates built from Equation 4.2. or 4.4. may differ substantially from the consumption figures measured through household surveys. In the three countries examined here, consumer recall data from household surveys lead to estimated maize consumption per capita 25% to 30% higher than national food balance sheets in Malawi and Mozambique and 10% lower in Zambia. With cassava, the two consumption estimates track closely in Zambia. But in Malawi and Mozambique, cassava consumption estimated from household survey data comes in 30% to 40% lower than the food balance sheet estimates (Table 9).

4.5. Reconciliation

To reconcile differences between national production estimates and household-level consumption figures, we start with national production figures and a national food balance sheet (Table 8). We then compare food balance sheet estimates of per capita and total consumption with those coming from household-level survey data.

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[9] Some very detailed nutritional studies weigh actual food quantities used in household meal preparation. Though more accurate than recall data, these studies are very expensive and remain unavailable in most African countries.

Table 9. Contrasting Per capita Consumption Estimates

	Maize			Cassava (dry weight)		
	rural	urban	national	rural	urban	national
Consumption survey estimates of per capita consumption (kg/person/year)						
Malawi						
cassava belt	50	100		110	60	
dual staple zone	109	163		62	35	
maize belt	179	177		11	7	
total	168	172	168	19	11	18
Mozambique						
cassava belt	50	55		66	115	
dual staple zone	75	85		50	80	
maize belt	100	160		30	1	
total	80	92	82	46	79	53
Zambia						
cassava belt	50	104		82	35	
dual staple zone	80	102		60	24	
maize belt	140	136		2	3	
total	108	128	114	32	8	25
Food balance sheet estimate of per capita consumption (kg/person/year)*						
Malawi			135			29
Mozambique			63			80
Zambia			131			27
Ratio of consumption survey to food balance sheet estimates of per capita consumption						
Malawi			1.24			0.61
Mozambique			1.31			0.66
Zambia			0.87			0.92
Projected total 2007 consumption ('000 tons)**						
Malawi						
cassava belt	9	10	19	40	12	52
dual staple zone	125	15	141	144	7	151
maize belt	1,403	277	1,680	175	22	197
total	1,537	302	1,840	359	41	400
Mozambique						
cassava belt	21	2	24	56	10	66
dual staple zone	709	258	967	941	484	1,425
maize belt	273	28	300	163	0	163
total	1,003	288	1,291	1,160	494	1,654
Zambia						
cassava belt	62	7	69	96	2	98
dual staple zone	235	101	336	168	23	190
maize belt	662	434	1,096	9	9	18
total	959	543	1,501	273	34	307

* See Table 8 estimate of 2007 consumption per capita (C*).

** Per capita totals adjusted to match food balance sheet totals in Table 8. Note that the shaded cells correspond to the C* totals in Table 8.

Note: shaded cells represent estimated national consumption in rural and urban areas.

Sources: Malawi IHS 2005; Mozambique IAF 2002/03; Zambia FSRP Urban Survey 2006, Table 8.

In Zambia, roughly one-third of national maize consumption comes from stock drawdowns, according to the FAO food balance sheets which impute annual stock drawdowns of over 450,000 tons per year over nearly a decade (Table 8). While large stock offtakes may be possible in any given year, these figures are implausible over the long period suggested by the official FAO food balance sheets (see Annex Table A.2). Possibly production data have been understated; estimates from large commercial farms are notoriously difficult to obtain in Zambia. This would explain the large gap between farm survey and reported national production figures in Table 5.

For the present, given these uncertainties, we have opted to use the FAO food balance sheets as our baseline in estimating annual food consumption of maize and cassava. However, given the availability of cross-border monitoring of informal maize trade flows, we have adjusted the FAO estimates by including cross-border informal maize trade in normal, bad and good years (FEWSNET 2008; Dradri 2007). A series of recent studies suggest that in normal years, northern Mozambique exports about 50,000 tons of maize to Malawi, while southern Tanzania supplies an additional 20,000 tons. Northern Zambia likewise exports about 20,000 tons of maize to its "tenth province" of Katanga Province, DRC. During major supply shortfalls in Malawi, the informal inflows from northern Mozambique and southern Tanzania increase substantially, to as much as 250,000 tons and 40,000 tons, respectively (Whiteside 2003; Govereh et al. 2008). The adjusted consumption figures used in the ensuing mapping are indicated with C* in Table 9.

4.6. Spatial Representation of Food Consumption

District-level consumption data are not generally available in most African countries. So, unlike production data, we must rely on alternate means for imputing spatial distribution of staple food consumption. Rather than district-level shares, we instead compute per capita consumption by food staple zone.

These data indicate that maize and cassava consumption clearly vary across the three food staple zones (Table 10). On average, the total consumption of these two foods ranges between 145 and 165 kilograms of dry weight per capita, with maize supplying about two-thirds of total calories from these two major staples. But across food staple zones, the proportion of maize to cassava varies markedly. In the cassava belt, residents consume about 100 kilograms of cassava and 50 kilograms of maize per year. Yet in the maize belt, these proportions reverse. In the dual staple zones, although results vary slightly across the three countries, the data suggest roughly equal shares of maize and cassava consumption (Table 10). In general, across all zones, urban residents consume more maize (also more wheat and prepared foods) than rural dwellers.

Therefore, we partition the population in each country into six categories: rural and urban areas within each of the three food staple zones (Table 10). Using our adjusted best-estimate of food balances for a normal crop year, we follow a five-step process to allocate rural and urban consumption across countries and food staple zones. First, within each of the six categories and three countries, we use available household survey data to compute per capita consumption of maize and cassava, by direct recall where possible and using the disappearance method in other instances (Table 9). Second, we multiply reported per capita consumption by Landscan population totals to estimate total tons consumed in each of the six categories. From this, we compute the share of each category in total national consumption. Third, we multiply these consumption shares by our best estimate of total national consumption (C*) in Table 8 to impute *normalized* total consumption in each category. As with production, we use this procedure to ensure that total consumption, when summed nationally, matches our aggregate food balance sheet figures.

Table 10. Normal Year Consumption, by Food Staple Zone (Kg Per capita)

	Maize			Cassava (dry weight)			Maize plus cassava		
	rural	urban	national	rural	urban	national	rural	urban	national
Cassava belt									
Malawi	40	80	54	179	98	150	219	178	205
Mozambique	38	42	38	100	175	107	138	217	146
Zambia	57	119	61	89	38	87	147	157	147
three-country total	50	81	53	103	101	103	153	182	156
Dual staple zone									
Malawi	88	131	91	101	57	98	189	188	189
Mozambique	57	65	59	76	121	87	133	186	146
Zambia	92	117	98	65	26	56	157	143	154
three-country total	65	75	68	76	103	83	142	179	150
Maize belt									
Malawi	144	142	144	18	11	17	162	154	160
Mozambique	76	122	79	46	2	43	122	124	122
Zambia	161	156	159	2	3	3	163	159	161
three-country total	134	149	137	20	6	17	154	155	154
National totals									
Malawi	135	138	135	31	19	29	166	157	165
Mozambique	61	70	63	70	121	80	133	182	143
Zambia	124	146	131	35	9	27	159	155	158
three-country total	98	113	101	50	57	52	149	166	153

Source: National consumption surveys, adjusted to match food balance sheet aggregate consumption in Table 8.

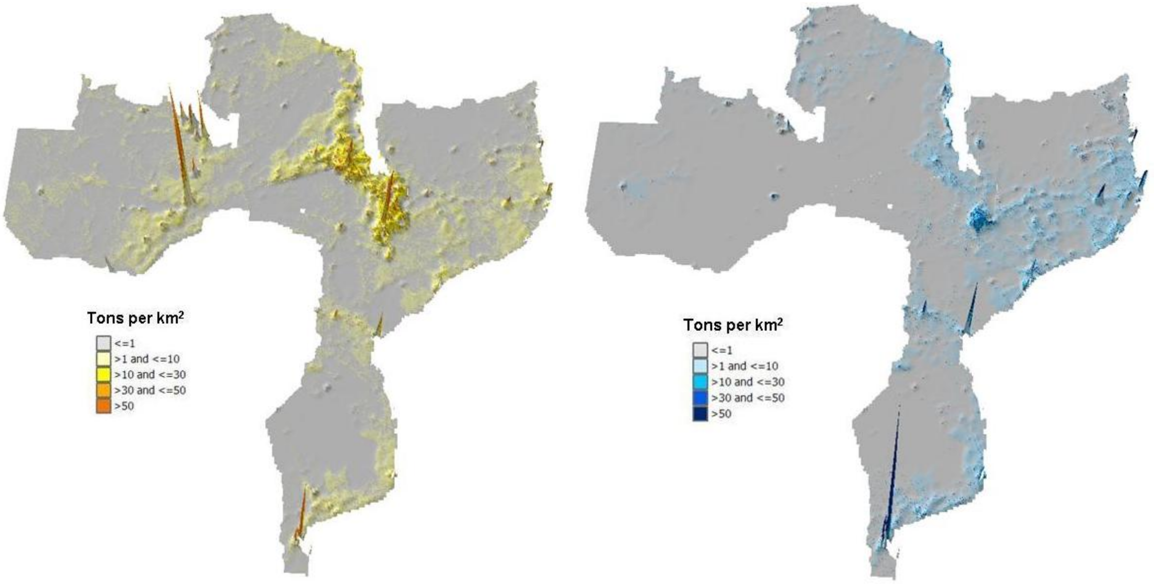
Fourth, in order to allocate consumption spatially across each of the six rural-urban food staple zone areas, we compute normalized per capita consumption by dividing the zonal consumption totals by the Landscan population totals for each category. Finally, we multiply these normalized per capita figures for each of the six categories by the *pixel-level* Landscan population, generating a pixel-level spatial distribution of total consumption of both crops.

In summary, our procedure for estimating consumption involves five steps:

1. Compute per capita consumption in each of the six rural-urban food staple zone categories using household survey data;
2. Multiply these figures by Landscan population data to get total consumption in each category, then express each as a share of total national consumption;
3. Generate “normalized” total consumption in each category by multiplying these shares by our best estimate of total national consumption;
4. Compute normalized per capita consumption by dividing figures from step 3 by Landscan population totals in each category; and
5. Allocate total consumption spatially by multiplying these normalized per capita figures by pixel level Landscan population data.

Figure 15 maps the resulting spatial allocation of maize and cassava consumption. The aim of this exercise is to produce a spatial representation of national staple food consumption while respecting the consumption totals from the national food balance sheets.

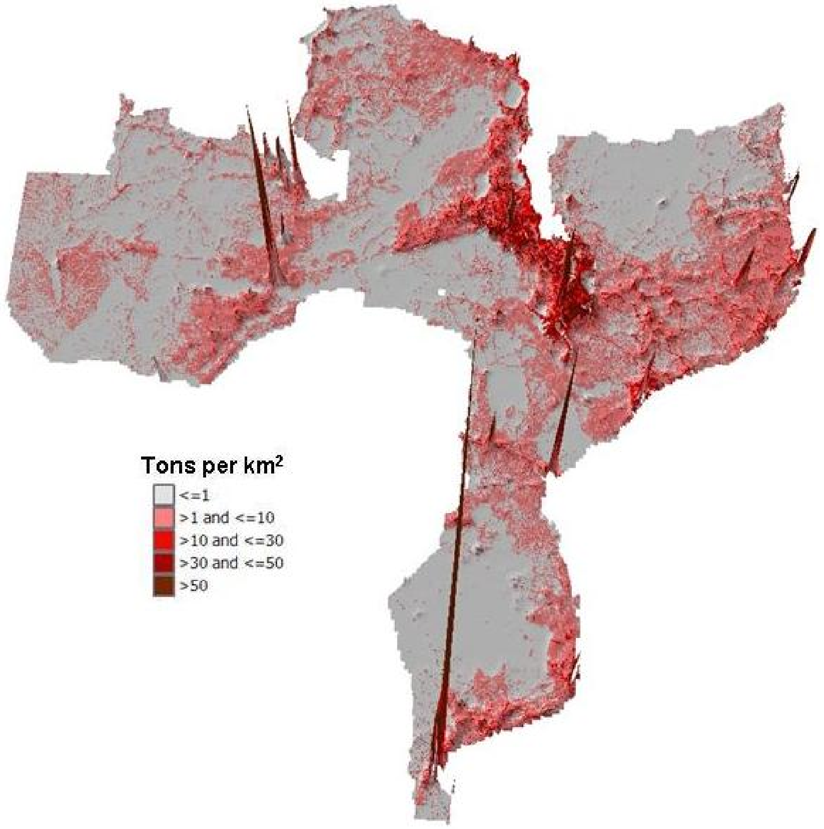
Figure 15. Grid Map of Maize and Cassava Consumption, Normal Year



a. Maize Consumption

b. Cassava Consumption

c. Maize Plus Cassava Consumption



5. SALES AND PURCHASES

5.1. Data Sources

In urban areas, households purchase the majority of the food they consume. Therefore, household consumption surveys provide estimates of urban purchases. Urban households buy from retailers who procure stocks supplied by domestic producers and by importers.

For rural areas, most farm household surveys include questions on crop sales. The results from these surveys typically suggest that a minority of farm households sell large surpluses to the market, while a majority relies on own production supplemented by net purchases (Jayne et al. 2006). In some instances, farm household surveys also collect data on rural household purchases. In general, however, sales data are more reliable than estimates of total purchases in rural surveys, for several reasons. First of all, a few large farms account for the great bulk of marketed volumes, and these emergent commercial growers keep good track of production and sales. Secondly, even smaller commercial farms harvest at one time and sell at only a few points in time. Purchases, in contrast, take place more frequently, in smaller increments, and in highly variable amounts across seasons. Thus, the timing of a survey and the errors involved in aggregating multiple purchases of variable sizes, amplify the prospects for errors in data collection, recall, or appropriate seasonal weightings required to compute annual total purchases. For these reasons, we consider survey-based estimates of rural food *sales* more reliable than survey-based estimates of total rural food *purchases*.

5.2. Aggregate Sales and Purchases

To estimate total volumes of cassava and maize marketed, we begin with import and export data from the food balance sheet (Table 8). Urban consumption figures provide estimates of urban purchases (Table 9). Volumes marketed by smallholders we compute from survey-based estimates of the share of total production they market. We then multiply these marketed shares by total national production (from Table 8) to generate estimates of smallholder sales. To this we add the commercial farmer sales (Table 4). Rural household purchases then become the item balancing total sales and purchases in Table 11.

5.3. Spatial Allocation of Sales

Sales, like purchases, are spatially concentrated where favorable production conditions coincide with good market access. Ultimately, as with production, we would like to estimate spatial regression models to help us situate maize and cassava sales over space. In the short run, as with production, we have opted to use the most granular spatial data available to us — district-level sales shares — to approximate the spatial clustering of these two driving forces. Therefore, as with production data, we compute per capita sales by district, then multiply by rural population to estimate total sales by district. From this, we can compute the share of each district in total sales. Using the aggregate national estimate of total sales, from Table 11, we then estimate normalized sales volumes per district by multiplying total sales by each district share. In the district-level extrusion maps, we map these sales totals directly (Figure 16).

Table 11. Total Marketed Volumes of Maize and Cassava ('000 Tons)

	Maize			Cassava (dry weight)		
	Malawi	Mozambique	Zambia	Malawi	Mozambique	Zambia
Total Sales (market supply)						
From domestic production						
small farms	267	198	228	113	563	46
large farms	0	0	264	0	0	0
From imports						
informal	70	0	0	0	0	0
formal	156	189	162	0	0	0
total sales	494	387	653	113	563	46
Total Purchases (market demand)						
Domestic						
rural households*	181	47	81	72	69	12
urban households	302	288	543	41	494	34
Exports						
informal	0	50	20	0	0	0
formal	11	1	9	0	0	0
total purchases	494	387	653	113	563	46

* Rural household purchases computed as a residual balancing total sales and total purchases.
Sources: Tables 3, 4, 8, 9 and 10.

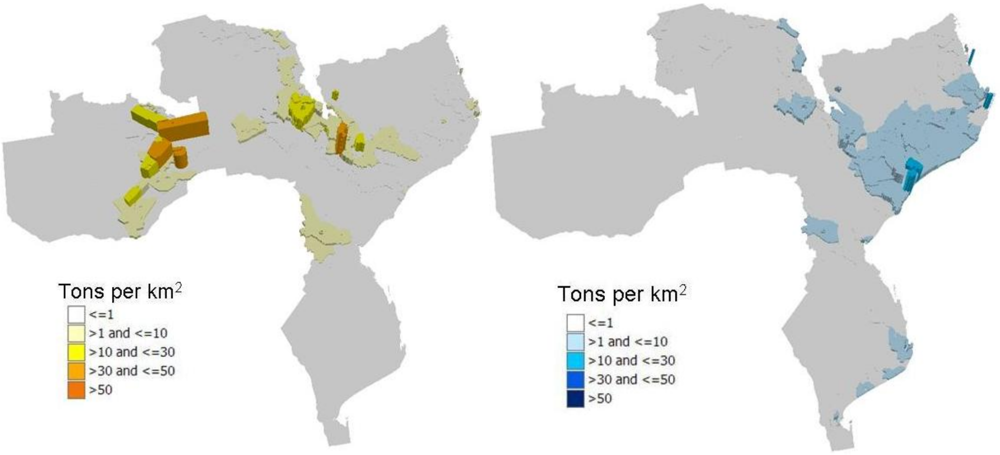
To generate the more detailed gridded (raster) sales surface, we compute per capita normalized sales for each district and allocate these to raster cells (pixels) by multiplying per capita sales times the number of people per cell. Given roughly 1 kilometer square pixels, these pixel-level sales data approximate a digitized spatial estimate of sales per square kilometer, which we map in Figure 17.

5.4. Spatial Allocation of Purchases

Because we do not have good district-level data on consumption or food purchases, for rural and urban consumers, we allocate food purchases in the same way as we did consumption — using standard per capita purchases by food staple zone, separately for rural and urban areas within each country. As with consumption data, above, we use household survey data to compute per capita purchases of maize and cassava in each of the six geographic areas in each country — rural and urban areas within each of the three food staple zones (Table 12). Multiplying by Landscan population for each of these six areas generates an estimate of total purchases in each. From these estimates, we compute shares of total rural and urban purchase in each food staple zone. In order to ensure that total purchases agree with the aggregate national totals for rural and urban areas, we multiply the zonal shares by the total rural and urban purchases computed in Table 11. Dividing again by population generates per capita purchases for each area. To produce district-level extrusion maps, we then multiply these per capita purchases by population in each rural and urban district area.

To produce digital, gridded (raster) maps of food purchases, we multiply the adjusted per capita purchases for each of the six zones by population in that zone, thereby assigning a purchase quantity to each 1 kilometer square cell. Figure 18 provides a three-dimensional summary of the spatial location of maize and cassava purchases.

Figure 16. District-level Extrusion Map of Food Staple Sales in South East Africa, Normal Year



a. Maize Sales **b. Cassava Sales**

c. Maize Plus Cassava Sales

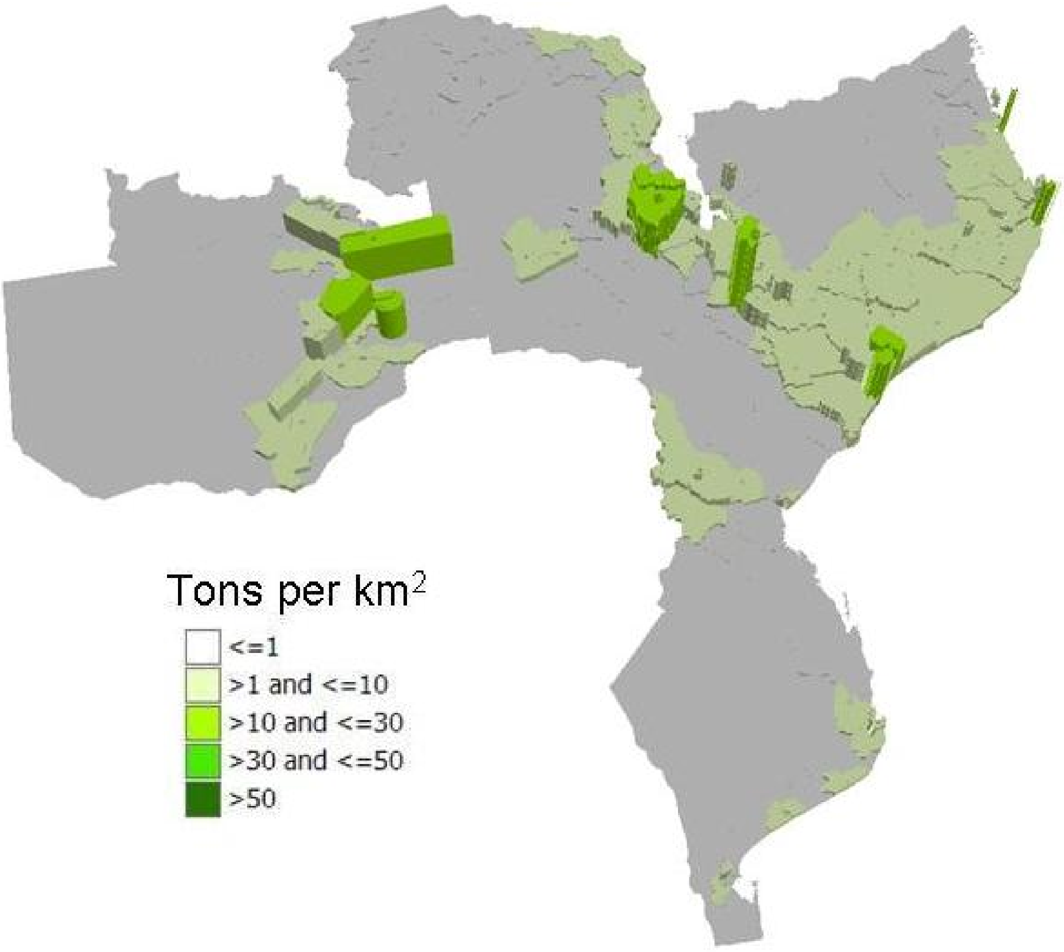
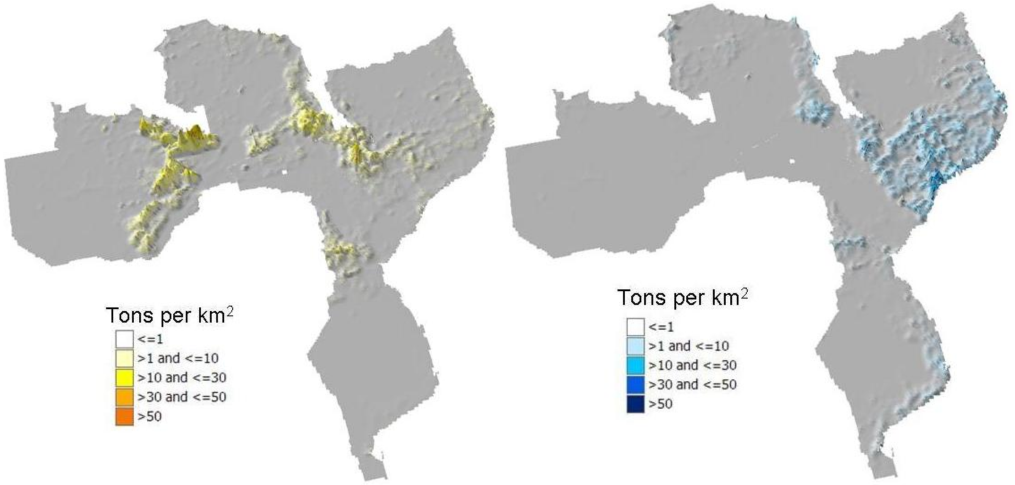


Figure 17. Grid Map Sales of Staple Food Sales in South East Africa, Normal Year



a. Maize Sales

b. Cassava Sales

c. Maize Plus Cassava Sales

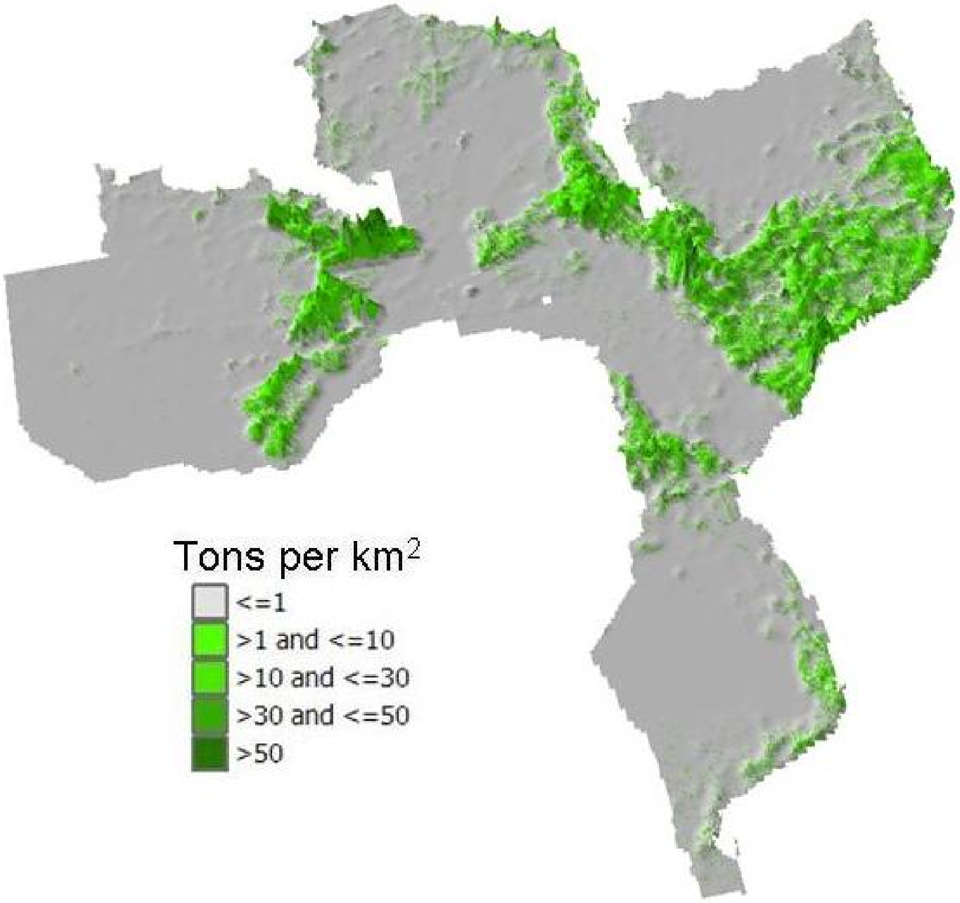


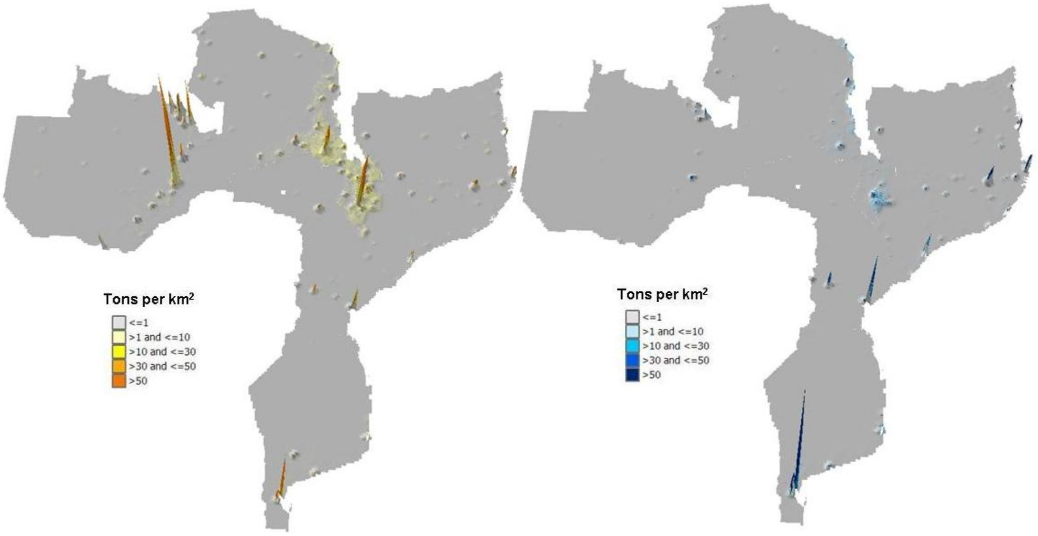
Table 12. Normal Year Smalholder Selling and Household Purchasing Patterns, by Food Staple Zone

	Smallholder Sales						Purchases					
	Maize			Cassava (dry weight)			Maize			Cassava (dry weight)		
	rural	urban	national	rural	urban	national	rural	urban	national	rural	urban	national
Total Sales and Purchases ('000 tons)												
Malawi												
cassava belt	4	-	4	13	-	13	1	10	11	8	12	20
dual staple zone	16	-	16	18	-	18	15	15	30	29	7	36
maize belt	247	-	247	82	-	82	165	277	442	35	22	57
total	267	-	267	113	-	113	181	302	483	72	41	113
Mozambique												
cassava belt	2	-	2	39	-	39	1	2	3	3	10	13
dual staple zone	152	-	152	489	-	489	34	258	292	56	484	540
maize belt	44	-	44	35	-	35	13	28	41	10	0	10
total	198	-	198	563	-	563	47	288	336	69	494	563
Zambia												
cassava belt	8	-	8	14	-	14	5	7	12	4	2	7
dual staple zone	55	-	55	26	-	26	20	101	121	8	23	30
maize belt	165	-	165	6	-	6	56	434	491	0	9	10
total	228	-	228	46	-	46	81	543	624	12	34	46
Per Capita Sales and Purchases (kg/capita)												
Malawi												
cassava belt	19	-	12	59	-	38	5	80	31	36	98	58
dual staple zone	11	-	10	13	-	12	10	131	19	20	57	23
maize belt	25	-	21	8	-	7	17	142	38	4	11	5
total	23	-	20	10	-	8	16	138	36	6	19	8
Mozambique												
cassava belt	3	-	3	69	-	63	2	42	6	6	175	22
dual staple zone	12	-	9	39	-	30	3	65	18	5	121	33
maize belt	12	-	12	10	-	9	4	122	11	3	2	3
total	12	-	10	34	-	27	3	70	16	4	121	27
Zambia												
cassava belt	7	-	7	13	-	12	5	119	11	4	38	6
dual staple zone	22	-	16	10	-	8	8	117	35	3	26	9
maize belt	40	-	24	1	-	1	14	156	71	0	3	1
total	29	-	20	6	-	4	10	146	54	2	9	4

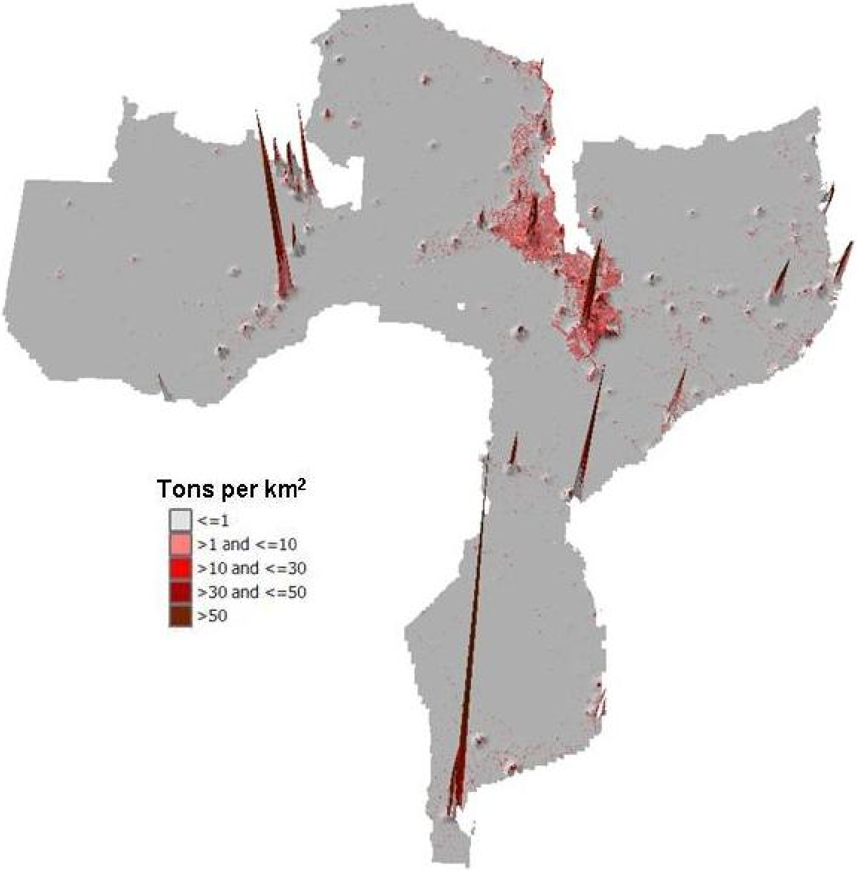
Source: National consumption surveys; FAO food balance sheets.

Figure 18. Grid Map of Staple Food Purchases in South East Africa, Normal Year

a. Maize Purchases **b. Cassava Purchases**



c. Maize Plus Cassava Purchases



Part II. Implications for Regional Trade and Emergency Responses

6. NORMAL YEAR

6.1. Spatial Dimensions of Food Production and Consumption

Production of maize and cassava clusters in zones of favorable agro-ecological conditions, heavy population, and market proximity. The dominant food production zones in this three-country region lie in Malawi, northerm Mozambique and central Zambia (Figure 19a). While maize dominates food production in Malawi and central Zambia, cassava and maize together contribute to the emergence of a large regional bread-basket in the dual-staple zones of northern Mozambique (Figures 9 and 10).

As a source of marketed sales, the commercial farms of central Zambia dominate the region along with the food-surplus zones of northern Mozambique (Figure 19b). Malawi, despite its high population density and consequently high food production, requires large quantities for rural consumption, leaving proportionally less combined volumes of maize and cassava available for sale than in Zambia and northern Mozambique (Tables 13 and 14). Thus, the topography of marketed sales differs substantially from that of overall production (compare Figures 19a and 19b). The highlands of Malawian production recede into foothills in the face of domestic consumption requirements, leaving the commercial farms of central Zambia and the small farms of northern Mozambique as key sources of marketed food surplus during normal harvest years.

Food consumption and purchases closely track urban population centers and land-scarce rural areas. These food-deficit populations predominate in central and southern Malawi, in the Copperbelt cities of Zambia (and the DRC), and in Mozambique’s coastal cities, particularly Maputo in the south and Beira in the center (Figures 20a and 20b).

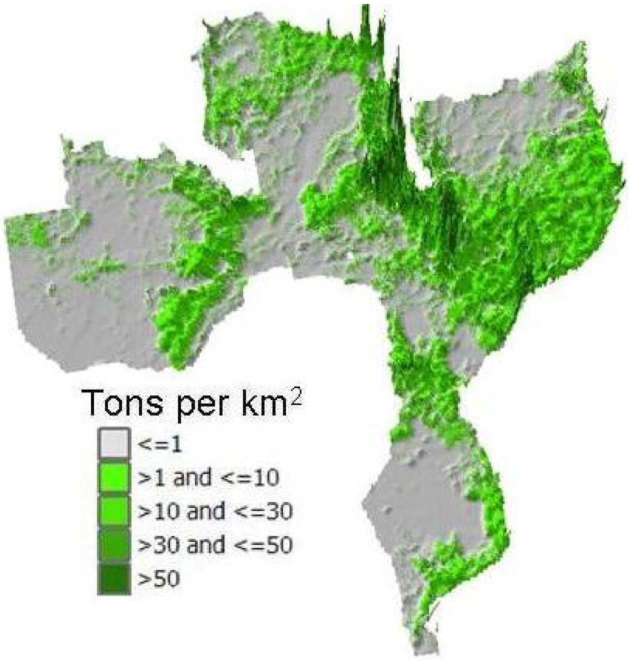
6.2. Implications for Regional Trade

Marketed flows within the region travel from the surplus zones (Figure 19b) to the cities and deficit rural markets (Figure 20b). In normal years, the largest flows of net food sales (defined as food sales out of domestic production minus food purchases) come from Zambia’s commercial farm blocks, the dual-staple zones of northern Mozambique and surplus farms in the densely populated central and southern Malawi (Figure 21).

The deficit markets they serve lie in both rural and urban areas. Deficit rural areas predominate in the southern interior maize belt zones of Zambia, Malawi, and Mozambique (pink zones in Figure 21). Urban markets predominate in the Copperbelt mining towns of Zambia and DRC, in central and southern Malawi and in the coastal cities of Mozambique (red zones in Figure 21). Though urban markets occupy a much smaller geographic area than the deficit rural areas, the vastly greater population density in urban areas results in purchased volumes roughly two to six times as large as rural markets in normal years (computed from Table 14). Hence the two-dimensional representation of food surplus and deficit areas (Figure 21) contrasts quite starkly with the three-dimensional representation (Figure 22), which shows the relative scale of the net food inflows to urban areas (the red spikes plunging below sea level).

Figure 19. Grid Map of Staple Food Production and Sales, Normal Year

a. Production of Maize Plus Cassava



b. Sales of Maize Plus Cassava

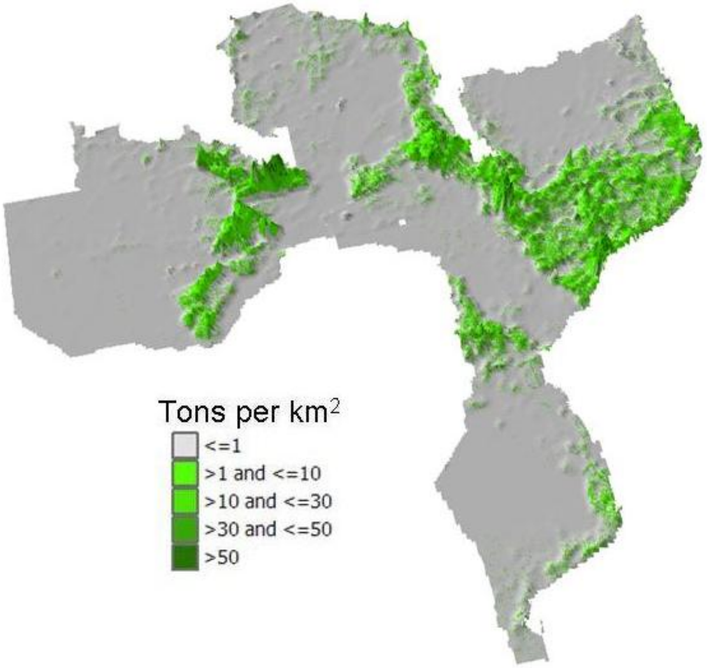


Table 13. Maize and Cassava Balances in Normal, Bad and Good Years

a. Maize balances

	Malawi			Mozambique			Zambia		
	Normal	Bad*	Good*	Normal	Bad*	Good*	Normal	Bad*	Good*
Quantities ('000 tons of maize equivalents)									
Production (Q)	2,194	1,324	2,739	1,507	1,456	1,558	1,070	896	1,458
Stock drawdowns (dK)	-32	0	-350	4	0	0	458	260	220
Formal Imports (M)	156	385	22	189	373	183	162	444	0
Formal Exports (X)	11	2	6	1	7	1	9	8	5
Seeds and losses (SL)	279	337	217	124	125	128	75	100	68
Feeds and industrial uses (FI)	259	190	288	234	312	242	83	110	57
Consumption (C) food balance sheet	1,770	1,467	1,644	1,341	1,451	1,386	1,521	2,046	1,548
Informal net imports (M-X)	70	286	0	-50	-250	0	-20	0	-20
Consumption (C)*	1,840	1,467	1,900	1,291	1,135	1,370	1,501	1,383	1,528
Quantities (kilograms per capita)									
Production (Q)	161	97	202	73	71	76	93	78	127
Imports (M)	12	28	2	9	18	9	14	39	0
Exports (X)	1	0	0	0	0	0	1	1	0
Seeds, feed, industrial uses, losses (SFIL)	40	39	37	17	21	18	14	18	11
Consumption (C)*	135	108	140	63	55	66	131	121	133
Maize calories (Kcal/person/day)	1,279	1,020	1,321	592	520	628	1,238	1,140	1,259

b. Cassava Balances

	Malawi			Mozambique			Zambia		
	Normal	Bad*	Good*	Normal	Bad*	Good*	Normal	Bad*	Good*
Quantities ('000 tons of maize equivalents)									
Production (Q)	721	737	704	2,248	2,333	2,163	323	340	306
Stock drawdowns (dK)	0	0	0	0	0	0	0	0	0
Formal Imports (M)	0	0	0	0	0	0	0	0	0
Formal Exports (X)	0	0	0	0	0	0	0	0	0
Seeds and losses (SL)	80	82	78	351	364	338	16	17	15
Feeds and industrial uses (FI)	240	246	235	243	252	234	0	0	0
Consumption (C) food balance sheet	400	409	391	1,654	1,717	1,592	307	323	291
Informal net imports (M-X)	0	0	0	0	0	0	0	0	0
Consumption (C)*	400	409	391	1,654	1,717	1,592	307	323	291
Quantities (kilograms per capita)									
Production (Q)	53	54	52	109	113	105	28	30	27
Imports (M)	0	0	0	0	0	0	0	0	0
Exports (X)	0	0	0	0	0	0	0	0	0
Seeds, feed, industrial uses, losses (SFIL)	24	24	23	29	30	28	1	1	1
Consumption (C)*	29	30	29	80	83	77	27	28	25
Cassava calories (Kcal/person/day)	278	284	272	758	787	729	253	266	240

* Bad years refer to seasons when the Malawian maize harvest falls 40% below normal levels. Conversely, good years refer to seasons when produces a very good maize harvest, 25% above normal levels. See Table 3 for details.

Source: FAOSTAT food balance sheets, adjusted to *normal*, *bad* and *good* total production figures. Baseline balance sheets used in these computations include: Malawi – bad years (1994, 2002), good years (1999, 2000); Mozambique – 1999; Zambia – bad years (1999, 2000), good years (1993, 1996).

Table 14. Marketed Volumes of Maize and Cassava in Band Good Years* (‘000 Tons)

a. Maize Purchases and Sales

	Malawi			Mozambique			Zambia		
	Normal	Bad*	Good*	Normal	Bad*	Good*	Normal	Bad*	Good*
Total Sales (market supply)									
From domestic production									
small farms	267	161	334	198	274	204	228	119	367
large farms	0	0	0	0	0	0	264	243	276
From imports									
informal	70	286	0	0	0	0	0	0	0
formal	156	385	22	189	373	183	162	444	0
total sales	494	832	356	387	647	388	653	806	643
Total Purchases (market demand)									
Domestic									
rural households**	181	590	38	47	137	80	81	299	65
urban households	302	241	312	288	253	306	543	500	552
Exports									
informal	0	0	0	50	250	0	20	0	20
formal	11	2	6	1	7	1	9	8	5
total purchases	494	832	356	387	647	388	653	806	643

b. Cassava Purchases and Sales (Dried Equivalents)

	Malawi			Mozambique			Zambia		
	Normal	Bad*	Good*	Normal	Bad*	Good*	Normal	Bad*	Good*
Total Sales (market supply)									
From domestic production									
small farms	113	114	112	563	581	475	46	62	32
large farms	0	0	0	0	0	0	0	0	0
From imports									
informal	0	0	0	0	0	0	0	0	0
formal	0	0	0	0	0	0	0	0	0
total sales	113	114	112	563	581	475	46	62	32
Total Purchases (market demand)									
Domestic									
rural households**	72	72	72	69	69	0	12	26	0
urban households	41	42	40	494	513	475	34	36	32
Exports									
informal	0	0	0	0	0	0	0	0	0
formal	0	0	0	0	0	0	0	0	0
total purchases	113	114	112	563	581	475	46	62	32

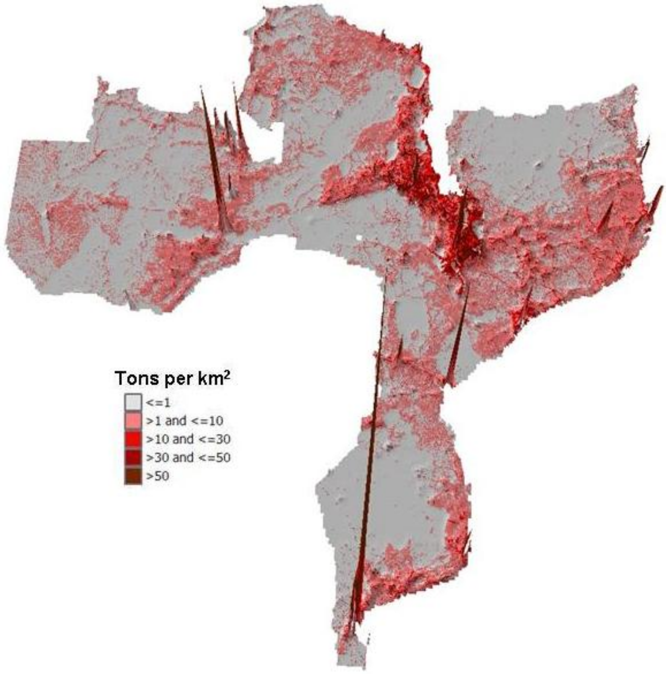
* Computed as a residual balancing total sales and total purchases, except for maize in Mozambique, where small farm sales balance supply and demand, and Zambian maize, where large farm sales equilibrate supply and demand.
Source:

In normal years, net imports — from South Africa into the cities of southern Mozambique and Malawi and to a lesser extent from southern Tanzania into Malawi — supplement domestic production. This suggests that the region, as a whole, requires open external borders to enable these inflows to prevent episodic consumption shortfalls. Likewise, in normal years, Zambian farmers supply maize and cassava to the DRC Copperbelt cities of Lubumbashi and Kasai (Table 14).

These spatial configurations suggest that cross-border flows from northern Mozambique to Malawi, from Zambia to DRC, from southern Tanzania to Malawi and from South Africa into southern Mozambique constitute important commercial corridors whose smooth functioning remains essential for maintaining farmer incentives and food security within South East Africa.

Figure 20. Grid Map of Staple Food Consumption and Purchases, Normal Year

a. Consumption of Maize plus Cassava



b. Purchases of Maize plus Cassava

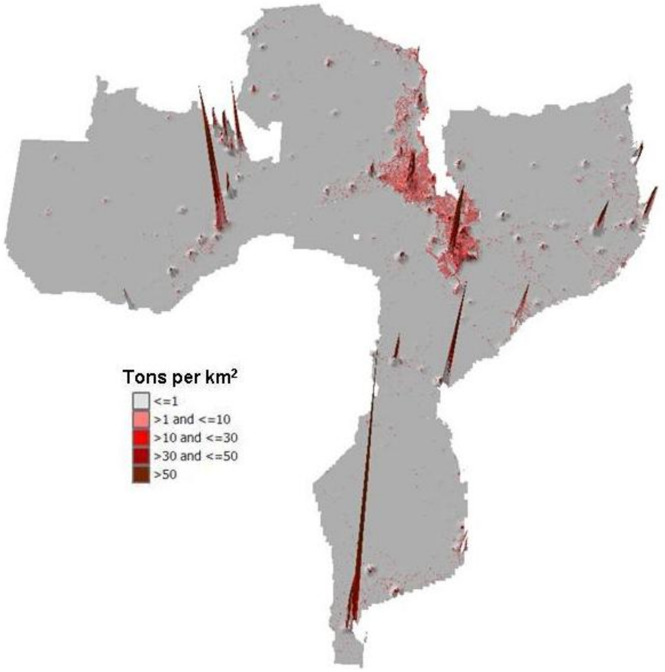


Figure 21. District-Level Map of Net Sales (Sales minus Purchases) of Food Staples, Normal Year

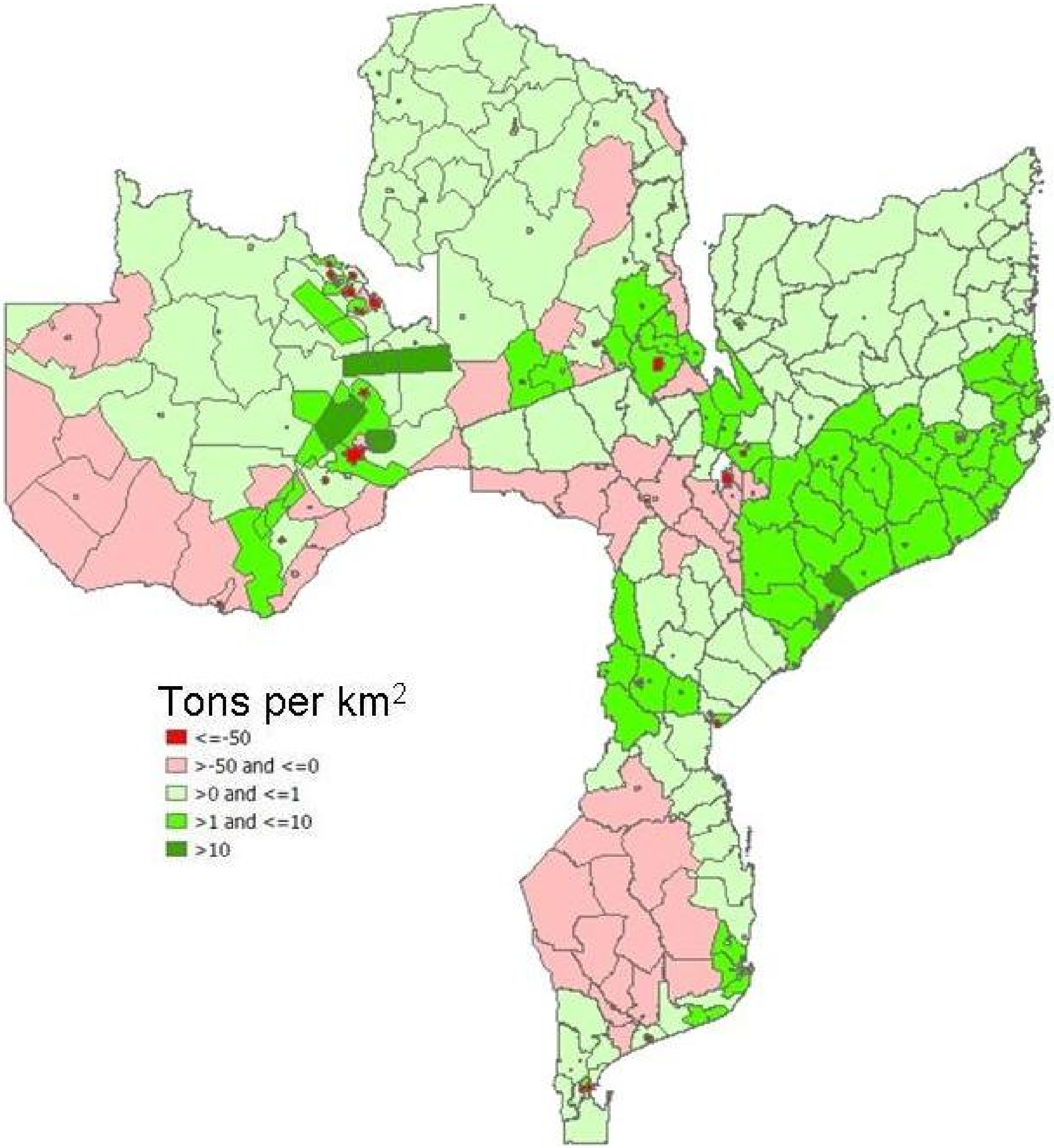
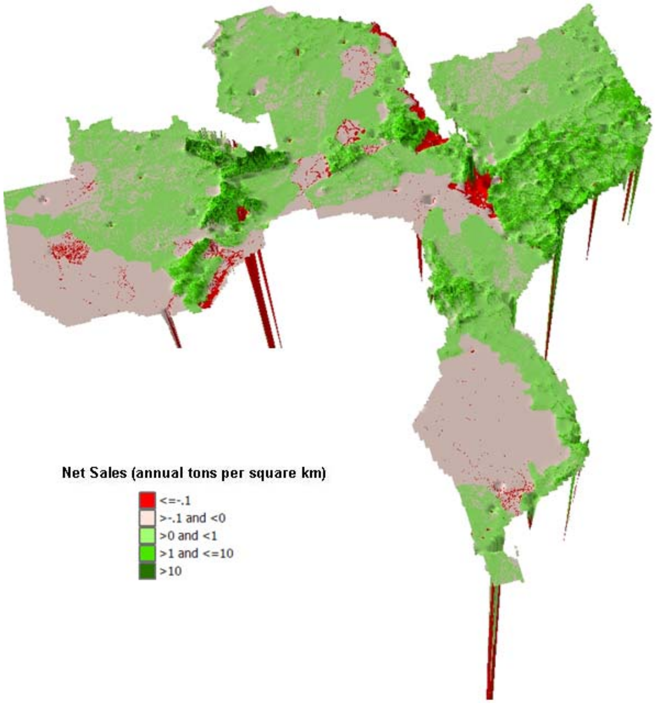
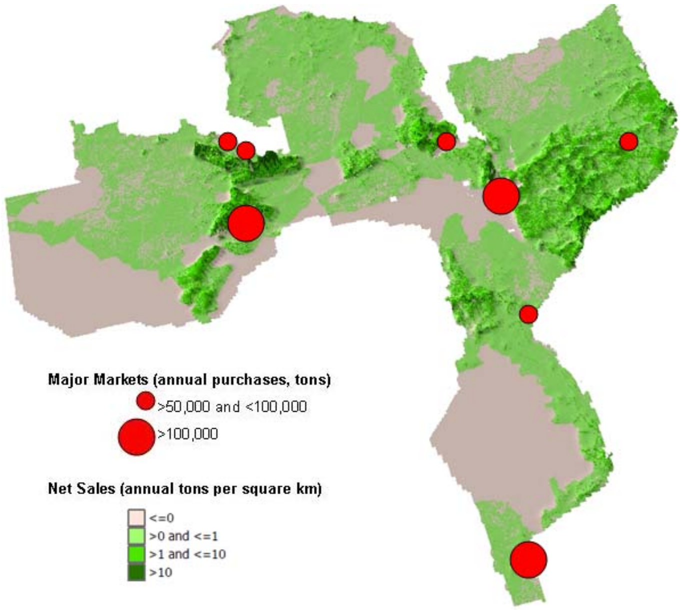


Figure 22. Grid Maps of Net Staple Food Sales (Sales minus Purchases), Normal Year

a. Three-dimensional in Both Positive and Negative Dimensions



b. Three-dimensional in the Positive Dimension Only

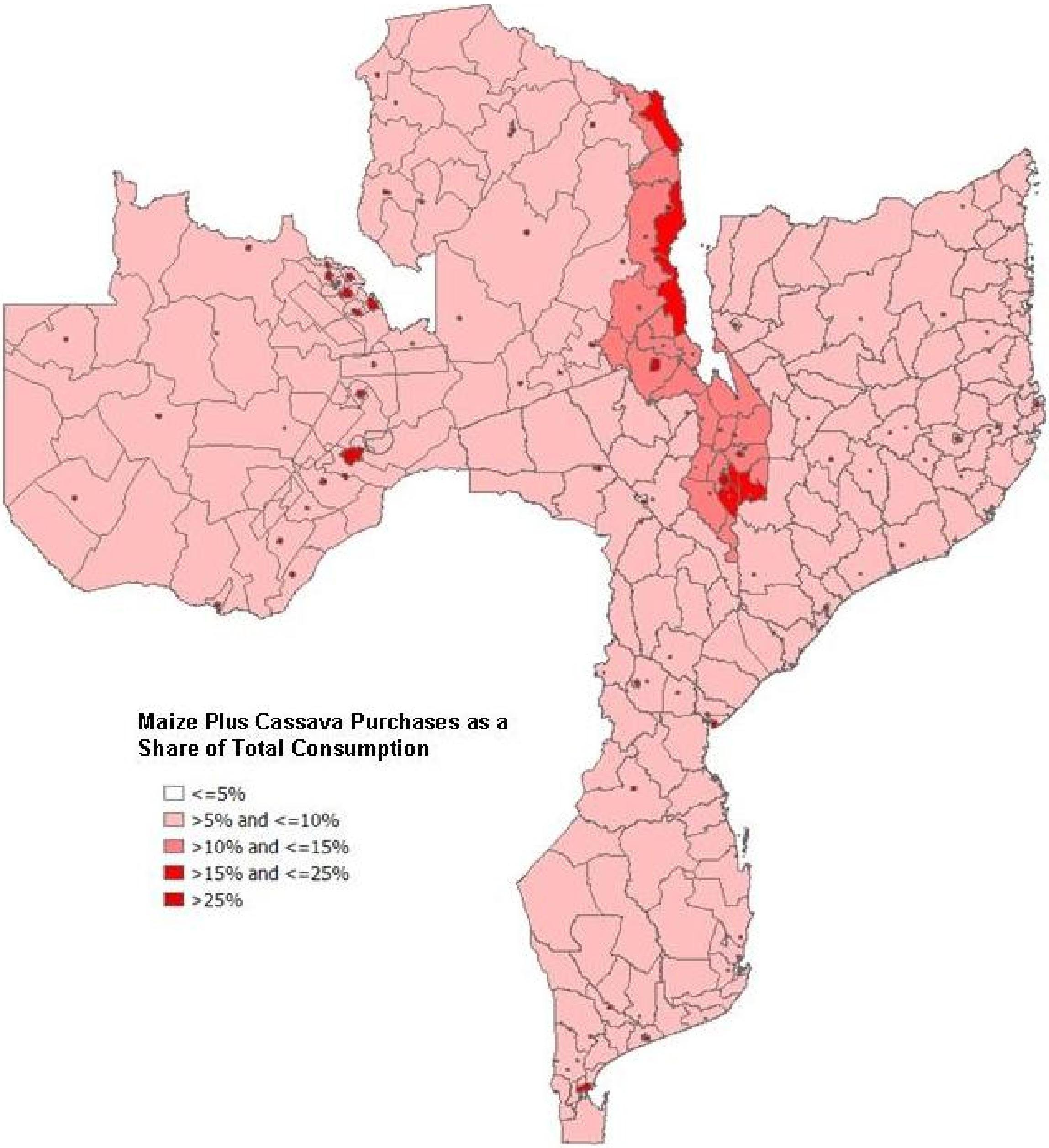


6.3. Implications for Emergency Response

Even during normal production years, large portions of the rural countryside in this three-country region purchase more maize than they sell (Figure 21). These areas – the interior of southern Mozambique, lowland areas of the Zambezi valley in Mozambique, southern and western Zambia, and spotty areas in central and northern Malawi – coincide with the geographical areas most likely to receive food aid or other emergency assistance when production is poor. While the volumes purchased in these areas may be small (typically 5% to 10% of total maize consumption in normal years), these figures are based on averages over all types of households across each food staple zone (Figure 23). Because even food-deficit areas include some net selling households, the extent of reliance on the market among net food buying households can be much higher than 10%. For example, in southern province of Zambia, over 50% of households were net buyers of maize during the 2003 harvest year (a normal harvest in our categorization) and they spent on average more than 10% of total household income on maize purchases. Market reliance becomes even heavier when we break households down by income: the poorest 20% of net buying households in Zambia during that harvest year spent about 40% of their total household income on maize purchases (Tschirley 2007).

The key implication of this analysis is that it is precisely those households most likely to require emergency assistance who are most accustomed to obtaining food from markets even during normal production years. To the extent that relief programs can supply these households with cash in lieu of in-kind food during such emergencies, the households will be more able to maintain their typical livelihood strategies and, according to most research, will be able to obtain more food for a given value of transfer (Magen, Donovan, and Kelly 2009).

Figure 23. Total Maize plus Cassava Purchases as a Share of Total Consumption



7. BAD HARVEST YEAR IN MALAWI

7.1. How Does the Map Change?

Malawi serves as the food security barometer for the South East African market shed. It's production is highly volatile (Figure 14) due to reliance on rainfed smallholder production and inconsistent input and output marketing policies. During a typical drought year, production falls 40% below normal and the mountains of food production shrink commensurately, primarily due to the fall in maize production (Table 13 and Figure 24). The rural surpluses that supply Malawi's cities consequently recede as deficit rural areas expand, requiring roughly 650,000 tons of maize imports from surrounding countries (Table 14). Rural areas account for two-thirds of this deficit, opening up attractive commercial opportunities throughout central and southern Malawi for informal traders from northern Mozambique, southern Tanzania, and sometimes from eastern Zambia. Rural deficit areas similarly expand in western and southern Zambia and to a lesser extent in southern Mozambique (tables 15-17).

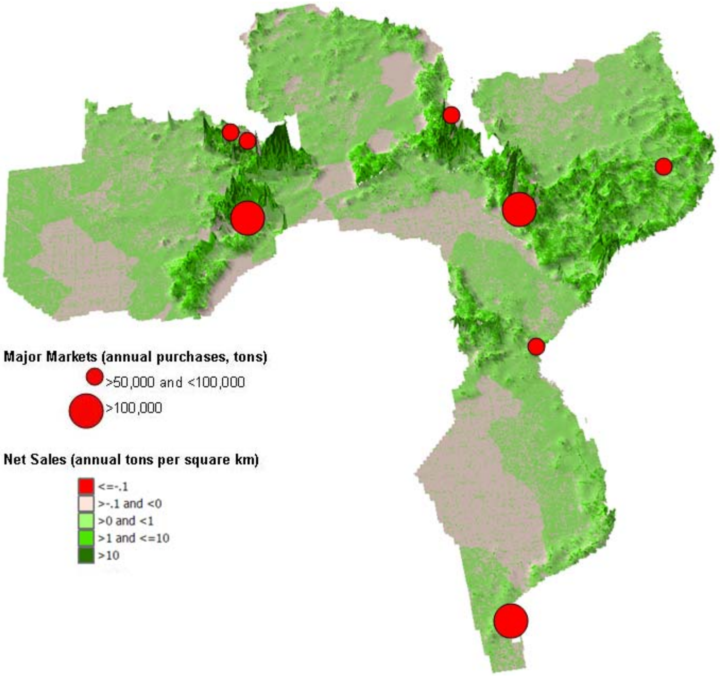
7.2. Implications for Regional Trade

Because food production in northern Mozambique and north-central Zambia is frequently less affected during regional drought years than the predominantly maize-producing zones of central and southern Malawi and southern Zambia, these northern zones become critical suppliers of maize to deficit areas within the region (Figure 24). Quantitatively, northern Mozambique looms largest. During a drought year, northern Mozambique provides as much as 250,000 additional tons of maize for export to Malawi, via a network of informal traders linked to large regional wholesalers, as well as roughly double that amount in marketed cassava for domestic consumption (see Table 14, Whiteside 2003 and Tschirley et al. 2005). This supply response most likely depends on the large size of Mozambique's dual staple zones and on consumers' ability to shift consumption temporarily in favor of cassava in order to free up maize for export at attractive prices in Malawi. Although the commercial farming block in central and north-central Zambia supplies more marketed maize, roughly 350,000 tons, Zambia's cassava-belt farms market far less cassava, roughly 50,000 tons annually. Unlike northern Mozambique, Zambia's maize sales fall slightly during drought years (Table 14). Regionally, South Africa and the maize-surplus highlands of southern Tanzania likewise provide critical supplementary maize supplies during regional drought years.

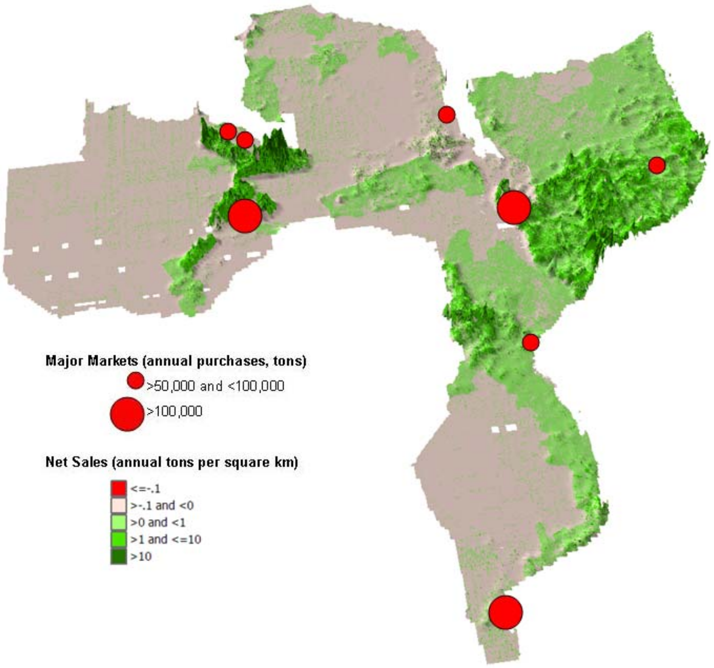
Surprisingly, Malawi and Zambia — the key beneficiaries of open borders during drought years — retain the tightest controls on maize imports and exports (see Tschirley et al. 2005; Jayne et al. 2006; Dorosh, Dradri, and Haggblade 2009). To encourage farmers in surplus areas to invest in food production (farm equipment, inputs, water control, and soil fertility), the region's intermittently food-deficit zones will need to assure them reliable access to their markets during drought years. Otherwise, these farmers will switch from foodcrops to cotton or other cash crops, a move that may already have begun in northern Mozambique in response to the Malawian government's border controls following the 2002/03 food shortages (Whiteside 2003). Looking forward, reliably open borders will be critical for ensuring farmer incentives in surplus zones and for ensuring food security in deficit zones.

Figure 24. Changes in Net Sales of Cassava and Maize in Good and Bad Years

a. Good Year



b. Bad Year



7.3. Implications for Emergency Response

During a stylized poor production year, the geography of net buying status changes dramatically in Zambia and Malawi. Nearly the entire geographical extent of Zambia and the northern half of Malawi move to net buying status. In Zambia, only parts of the cassava belt, along with commercial farming areas in the maize belt, remain net sellers. Net buying areas in the Zambezi valley and southern areas of Mozambique also expand, though this change is not as dramatic (Figure 24).

Even in deficit years, as in a normal year, some households will have a saleable surplus. But net purchasing households usually become even more dependent on markets during drought years – if food is available in those markets. Here again, cash transfer programs, complemented by needed commercial imports and in all likelihood some food aid distribution, would go a long way towards meeting household needs while allowing them to maintain their typical livelihood strategies.

It is also noteworthy that even during this stylized bad production year, sizeable net sales take place throughout northern Mozambique. While this part of Mozambique can and does have poor harvests, their rainfall tends not to be highly correlated with that in the rest of the region. For example, during the devastating regional droughts in 1992 and 1995, Mozambique north of the Zambezi was little affected. This asynchronous rainfall pattern opens the possibility for some local procurement of needed food aid even during years or poor regional production, though on-the-ground verification in northern Mozambique would be important to confirm harvest levels and avoid local procurement in an already short market. Because much of the commercial farming area of Zambia has irrigation, its surpluses hold up relatively well during otherwise poor production years.

Table 15. Shifts in Maize Production Shares during Bad Harvest Years in Zambia

Agro-ecological		Maize production share	
zones	rainfall	normal*	bad**
AEZ3	> 1,000 mm	4%	6%
AEZ2	800 - 1,000 mm	70%	60%
AEZ1	< 800 mm	26%	34%
total		100%	100%

* 2002/03, ** 2004/05
Source: Post Harvest Surveys of 2002/03 and 2004/05.

Table 16. Consumption per Capita during Bad and Good Harvest Years* (kg/person)

a. Bad Year

	Maize			Cassava (dry weight)			Maize plus cassava		
	rural	urban	national	rural	urban	national	rural	urban	national
Cassava belt									
Malawi	32	64	43	183	100	154	215	164	197
Mozambique	34	37	34	104	181	111	138	218	145
Zambia	53	110	56	94	40	91	147	150	147
three-country total	45	69	47	108	104	107	152	173	155
Dual staple zone									
Malawi	70	105	73	103	58	100	173	163	172
Mozambique	50	57	52	79	126	90	129	183	142
Zambia	85	108	90	69	28	58	153	135	149
three-country total	57	67	60	79	107	86	137	174	145
Maize belt									
Malawi	115	113	115	18	12	17	133	125	132
Mozambique	67	107	69	47	2	45	114	109	114
Zambia	148	144	146	2	3	3	150	147	149
three-country total	84	100	87	52	59	54	136	159	141
National totals									
Malawi	108	110	108	32	19	30	140	129	138
Mozambique	53	62	55	73	125	83	126	187	138
Zambia	114	135	121	37	10	28	151	144	149
three-country total	84	100	87	52	59	54	136	159	141

b. Good Year

	Maize			Cassava (dry weight)			Maize plus cassava		
	rural	urban	national	rural	urban	national	rural	urban	national
Cassava belt									
Malawi	42	83	56	175	95	147	216	178	203
Mozambique	40	44	41	96	168	103	137	212	144
Zambia	58	121	62	85	36	82	143	158	144
three-country total	51	84	55	99	98	99	150	181	154
Dual staple zone									
Malawi	90	135	94	99	56	95	189	191	189
Mozambique	61	69	63	73	117	84	134	186	146
Zambia	93	119	100	62	25	53	155	144	152
three-country total	68	79	71	74	99	80	142	178	150
Maize belt									
Malawi	149	147	148	17	11	16	166	158	165
Mozambique	81	129	84	44	1	41	125	131	125
Zambia	163	159	162	2	3	2	165	162	164
three-country total	138	153	141	19	6	16	157	159	158
National totals									
Malawi	139	143	140	31	18	29	170	161	169
Mozambique	64	75	66	68	116	77	132	191	144
Zambia	126	149	133	33	9	25	159	158	159
three-country total	102	117	105	48	55	50	150	172	155

* Bad and good years as defined in Table 3.

Table 17. Food Marketing during Bad Production Years

	Smallholder sales						Purchases					
	Maize			Cassava (dry weight)			Maize			Cassava (dry weight)		
	rural	urban	national	rural	urban	national	rural	urban	national	rural	urban	national
Total Sales and Purchases ('000 tons)												
Malawi												
cassava belt	3	-	3	13	-	13	3	8	11	8	12	20
dual staple zone	10	-	10	18	-	18	48	12	60	29	7	36
maize belt	149	-	149	82	-	82	538	221	759	35	23	58
total	161	-	161	114	-	114	590	241	831	72	42	114
Mozambique												
cassava belt	2	-	2	40	-	40	3	2	5	3	10	14
dual staple zone	211	-	211	505	-	505	97	227	324	56	502	558
maize belt	61	-	61	36	-	36	37	24	62	10	0	10
total	274	-	274	581	-	581	137	253	391	69	513	581
Zambia												
cassava belt	4	-	4	19	-	19	19	7	26	9	2	12
dual staple zone	29	-	29	35	-	35	73	93	166	16	24	40
maize belt	86	-	86	8	-	8	206	400	606	1	10	10
total	119	-	119	62	-	62	299	500	798	26	36	62
Per Capita Sales and Purchases (kg/capita)												
Malawi												
cassava belt	11	-	7	59	-	38	15	64	33	36	100	58
dual staple zone	7	-	6	13	-	12	34	105	39	20	58	23
maize belt	15	-	13	8	-	7	55	113	65	4	12	5
total	14	-	12	10	-	8	52	110	61	6	19	8
Mozambique												
cassava belt	4	-	4	71	-	65	5	37	8	6	181	22
dual staple zone	17	-	13	41	-	31	8	57	20	5	126	34
maize belt	17	-	16	10	-	10	10	107	16	3	2	3
total	17	-	13	35	-	28	8	62	19	4	125	28
Zambia												
cassava belt	4	-	4	18	-	17	18	110	23	8	40	10
dual staple zone	11	-	8	14	-	10	29	108	49	6	28	12
maize belt	21	-	12	2	-	1	50	144	88	0	3	2
total	15	-	10	8	-	5	38	135	70	3	10	5

8. GOOD HARVEST YEAR

8.1. How Does the Map Change?

In good harvest years, maize production increases by roughly 40% in Malawi and Zambia, while holding steady in Mozambique (Table 3). Cassava production, largely unaffected by drought, remains stable and, if anything, falls slightly, possibly because consumers in dual-staple zones profit from low maize prices to increase maize consumption and rebuild in-ground cassava stocks (Collinson 1985; Nielson 2009). The favorable rainfall patterns and input subsidy programs that drive these production shifts visibly affect food output, prices, and net marketed surpluses (Figure 24).

The large jump in maize harvest turns Malawi and Zambia from food-deficit to food self-sufficient. Rural net surpluses (sales minus purchases) in Malawi increase from 80,000 tons in normal years (and negative 430,000 tons in bad years) to about 300,000 tons in a good harvest year (Table 14 and Table 18) This covers urban household demand, and Malawi does not require significant commercial food imports. Similarly in Zambia, rural net surpluses increase perceptibly. While commercial farm maize sales remain roughly constant at 260,000 to 280,000 tons, small farm maize surpluses increase dramatically from 150,000 tons in normal year (and minus 180,000 tons in bad years) to about 300,000 tons in a good year. As in Malawi, this small farm surge becomes sufficient to service domestic urban requirements, and Zambia, too, becomes self-sufficient. In very good years, both are able to export maize.

8.2. Implications for Regional Trade

Trade volumes, and even sometimes trade patterns, vary from one year to the next. These changes affect both the normally surplus and the normally deficit zones.

While the food surplus areas of northern Mozambique and southern Tanzania export small quantities of maize into Malawi during normal years, the amounts demanded jump significantly during drought years and then fall to negligible levels during good production years in Malawi. This means that farmers in the cross-border surplus zones require some buffering system that enables them to release large quantities of food during bad harvest years in Malawi but stock food during the good harvest years. Consumer substitution among food staples may provide this flexibility in northern Mozambique, although the magnitude of the elasticity requires empirical investigation.

In the normally deficit national markets of Malawi and Zambia, good harvest years present opportunities for maize export. Although DRC remains a reliable long-term market for Zambian (and southern Tanzanian) farmers, short-run surges in domestic production may exceed the demand of these traditional export markets. In the short-run, Zimbabwe serves as a reliable market for episodic food surpluses from Zambia and Malawi. But over the long-run, Zimbabwe will presumably return to its status as a reliable surplus producer. This means that Zambia and Malawi will need to develop reliable markets elsewhere, possible in DRC or Angola. Alternatively, they will need to develop food storage or buffering systems that enable them to expand and contract domestic consumption counter-cyclically. Cassava substitution for maize — in human foods, cattle feed, and industrial processing — offers one promising means for moderating shocks in annual maize availability.

Table 18. Food Marketing during Good Production Years

	Smallholder sales						Purchases					
	Maize			Cassava (dry weight)			Maize			Cassava (dry weight)		
	rural	urban	national	rural	urban	national	rural	urban	national	rural	urban	national
Total Sales and Purchases ('000 tons)												
Malawi												
cassava belt	5	-	5	13	-	13	0	10	10	8	12	20
dual staple zone	20	-	20	18	-	18	3	16	19	29	7	36
maize belt	308	-	308	81	-	81	34	286	320	35	22	57
total	334	-	334	112	-	112	38	312	349	72	40	112
Mozambique												
cassava belt	2	-	2	33	-	33	2	3	4	-	10	10
dual staple zone	157	-	157	413	-	413	57	274	331	-	465	465
maize belt	45	-	45	30	-	30	22	29	51	-	0	0
total	204	-	204	475	-	475	80	306	386	-	475	475
Zambia												
cassava belt	12	-	12	10	-	10	4	7	12	-	2	2
dual staple zone	89	-	89	18	-	18	16	103	119	-	21	21
maize belt	265	-	265	4	-	4	45	442	487	-	9	9
total	367	-	367	32	-	32	65	552	618	-	32	32
Per Capita Sales and Purchases (kg/capita)												
Malawi												
cassava belt	24	-	15	58	-	38	1	83	30	36	95	57
dual staple zone	14	-	13	12	-	12	2	135	12	20	56	23
maize belt	32	-	26	8	-	7	4	147	27	4	11	5
total	29	-	25	10	-	8	3	143	26	6	18	8
Mozambique												
cassava belt	3	-	3	58	-	53	3	44	7	-	168	15
dual staple zone	13	-	10	33	-	25	5	69	20	-	117	28
maize belt	13	-	12	8	-	8	6	129	14	-	1	0
total	12	-	10	29	-	23	5	75	19	-	116	23
Zambia												
cassava belt	12	-	11	9	-	9	4	121	10	-	36	2
dual staple zone	35	-	26	7	-	5	6	119	35	-	25	6
maize belt	64	-	38	1	-	1	11	159	71	-	3	1
total	47	-	32	4	-	3	8	149	54	-	9	3

Trade policy, too, needs to change. In some years, Zambia and Malawi are able to export food. In other years, they require substantial imports. In both cases, they benefit from open borders. Yet, Zambian and Malawian policy makers retain quantitative controls on both imports and exports in good and bad harvest years. The unpredictability of access to export (and import) markets clearly discourages investment in food production and trading infrastructure. In contrast, Mozambican policy makers have long recognized the benefits of regional trade. The historically maize-deficit cities of southern Mozambique can import food more cheaply from nearby South Africa than from the far-distant surplus zones in northern Mozambique. Hence Mozambique clearly benefits from open borders that enable maize imports into the south and maize exports out of the north.

8.3. Implications for Emergency Response

Emergency response would not be required during good regional production years. Yet some households throughout these countries will remain net buyers, and the typically food deficit areas remain so, though now smaller in geographical extent. Within these areas, many of the poorer households will continue to rely heavily on market purchases to complement their still inadequate production. Safety net programs serving these households would be able to significantly expand the impact of their limited budgets by using cash as a first option in place of in-kind food aid; any in-kind food aid that is needed could almost certainly come from local or regional procurement during these years, rather than being shipped internationally at much higher cost.

9. CONCLUSIONS

9.1. Spatial Mapping

We emerge from this exercise persuaded that spatial mapping of staple food production, consumption, net market position, and related trade flows is both revealing and feasible. Spatial maps reveal the strong geographic clustering of food production and purchases as well as the heavy concentration of marketed surpluses and net consumption. The proximity of surplus food producing zones to cross-border deficit markets emerges clearly from the maps as does the consequent case for opening borders to enable key regional marketing corridors to function.

To be feasible, we conclude that spatial mapping of staple food market sheds will need to rely on grid maps (raster files) rather than administrative boundaries. Not only are administrative boundaries difficult to assemble for many Africa countries, they also camouflage the considerable intra-district variation in population, food production, consumption, and sales densities. For both of these reasons, we find the grid maps more revealing and more feasible to produce.

To produce grid maps of staple food market sheds in Africa, we recommend building on the Landscan population data base, which offers high resolution and complete coverage, even in war-torn parts of the continent. By mapping the distribution of population over space, it provides essential information required for spatially locating volumes of food consumption as well as smallholder production. To estimate aggregate production and consumption, we see no alternative to the FAOSTAT data base. Despite its weaknesses, it provides the only broadly available consistent data source in the region. In situations where national household survey data are available, Chapters 3-6 describe our preferred method for building spatial grid maps using the Landscan population and FAO food aggregates to develop national aggregates for population, food production, and consumption, then spatially allocating production, sales, consumption, and purchases using available household surveys together with measured differences across food staple zones. In other parts of Africa, where detailed household survey data are unavailable, modification of these methods or development of alternate algorithms for the spatial allocation of food production and consumption will be required.

Looking forward, we have identified several areas for future analysis. The first, and most important, involves testing, modification, and application of alternate spatial allocation models in settings where household survey data on food production, consumption and sales remain sparse or non-existent[10]. Second is the use of urban buffers to expand the Landscan urban population totals (particularly in Mozambique) and enable imputation of urban consumption patterns to these peri-urban populations (see Table 1). Third, it will be useful to generate more detailed spatial maps of net buying status and combine these with spatial information on receipt of food aid during various years, to show more clearly the extent and geographical location of heavy market reliance for staple foods and how this relates to historical patterns of food aid distribution.

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[10] Several prototypes are available from which to build. These include the spatial regression techniques such as those used in Landscan population allocation algorithm (Landscan 2002), similar efforts applied in poverty mapping (Elbers, Lanjouw, and Lanjouw 2003; Bedi, Coudouel, and Simler 2007), and maximum entropy methods such as those used in SPAM (spatial allocation model) model (You and Wood 2006; You et al. 2007).

9.2. Empirical Issues

Data deficiencies pose serious problems for policy makers, farmers, and traders. Food production data remain uncertain, while consumption and marketing data are often non-existent. By juxtaposing production, consumption, import, sales, and purchase data, the mapping exercise helps to highlight inconsistencies and weaknesses in data quality. In this initial three-country undertaking, we have noted serious inconsistencies between Zambia's national maize production and consumption data, between Malawi's official and survey-based estimates of national cassava production, and between food balance sheet and household survey estimates of cassava consumption in both Malawi and Mozambique (see Tables 5 and 9).

Volatility in maize *production* triggers most of the food supply pressures in this region. Yet our knowledge of the ensuing impact on maize and other food *consumption* remains sketchy. Indeed, FAO food balance sheets largely assume away inter-annual variations in staple food consumption (Figure 14). In practice, consumption of food staples must vary significantly between bad, normal, and good maize production years, particularly among vulnerable household groups. Yet available consumption and nutritional studies generally fail to provide a solid empirical basis for evaluating quantitative changes in caloric intake and in consumer substitution among food staples, both seasonally and during drought years. Future work on regional food markets and food security will require empirical investigation of consumer and industrial users' responsiveness to changing relative food prices and on prospects for substitution between maize and a whole host of secondary food crops, including cassava, coarse grains, wheat, sweet potatoes, Irish potatoes, and seasonal wild foods.

9.3. Policy Conclusions

Population, food consumption, and food production remain highly concentrated geographically. Urban population spikes translate into large deficits markets (the red circles in Figures 2 and 23) sucking in staple food supplies from nearby mountains of surplus (green triangles in Figures 2 and 23) food production zones. This clustering frequently occurs in proximity to international borders. In South East Africa, major surplus food production zones — in northern Mozambique, north-central Zambia and southern Tanzania — lie in close proximity to deficit markets in other countries — in Malawi and in southern DRC. These geographic realities suggest that cross-border trade in food staples will occur along specific regional marketing corridors. Open borders enable deficit markets to moderate food shortages during deficit years, while at the same time offering markets to farmers who have invested in productive capacity in cross-border surplus food producing zones. As a region, South East Africa requires reliably open borders in order to encourage surplus food production in favorable zones and to ensure food security in intermittently deficit markets.

ANNEX TABLES

Annex Table A.1. Trends in Staple Food Production in South East Africa

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Maize production ('000 tons)																		
Malawi	1,343	1,589	657	2,034	1,040	1,661	1,793	1,352	1,772	2,479	2,501	1,713	1,557	1,983	1,608	1,225	2,577	3,445
Mozambic	453	327	132	533	489	734	947	1,042	1,124	1,336	1,180	1,115	1,179	1,248	1,437	1,403	1,534	1,579
Zambia	1,093	1,096	483	1,598	1,021	738	1,409	960	638	822	1,040	802	606	1,158	1,214	866	1,424	1,366
Total	2,888	3,012	1,273	4,165	2,550	3,133	4,150	3,354	3,535	4,638	4,722	3,630	3,342	4,389	4,259	3,494	5,535	6,390
Cassava production, raw data ('000 tons)																		
Malawi	145	168	129	216	250	328	535	720	835	906	2,795	3,362	1,540	1,735	2,532	2,198	2,100	2,150
Mozambic	4,590	3,690	3,239	3,511	3,352	4,178	4,734	5,337	5,639	5,553	5,362	5,975	5,925	6,150	6,413	6,500	7,500	7,350
Zambia	640	682	682	744	744	744	744	702	817	971	815	950	950	957	957	1,056	950	940
Total	5,375	4,540	4,050	4,471	4,346	5,250	6,013	6,759	7,291	7,430	8,972	10,287	8,415	8,842	9,902	9,754	10,550	10,440
Cassava production, adjusted data ('000 tons)*																		
Malawi	145	168	129	216	250	328	535	720	835	906	1,118	1,329	1,540	1,735	2,532	2,198	2,100	2,150
Mozambic	4,590	3,690	3,239	3,511	3,352	4,178	4,734	5,337	5,639	5,553	5,362	5,975	5,925	6,150	6,413	6,500	7,500	7,350
Zambia	640	682	682	744	744	744	744	702	817	971	815	950	950	957	957	1,056	950	940
Total	5,375	4,540	4,050	4,471	4,346	5,250	6,013	6,759	7,291	7,430	7,295	8,254	8,415	8,842	9,902	9,754	10,550	10,440

* Shaded cells adjusted to trend.
Source: FAOSTAT.

Annex Table A.2. Trends in Zambia's Maize Balances

Year	Production	Imports	Stock changes	Exports	Domestic supply	Industrial uses	Feeds	Seeds	Losses and other	Food consumption
2,003	1,161	163	268	1	1,590	36	40	23	49	1,442
2,002	602	300	630	5	1,527	35	40	23	46	1,384
2,001	602	24	810	20	1,416	33	40	13	44	1,286
2,000	882	8	570	17	1,442	34	40	12	45	1,311
1,999	822	22	580	9	1,415	33	30	18	44	1,290
1,998	638	444	320	0	1,402	31	30	18	42	1,281
1,997	960	53	370	9	1,374	30	30	15	43	1,256
1,996	1,409	54	-20	2	1,442	31	30	19	44	1,317
1,995	738	113	590	3	1,438	30	30	20	44	1,313
1,994	1,598	316	-630	10	1,274	25	30	20	58	1,141
1,993	1,598	316	-630	10	1,274	25	30	20	58	1,141
1,992	483	680	110	0	1,274	28	30	19	39	1,158
1,991	1,096	44	120	1	1,259	30	30	20	38	1,141
1,990	1,093	100	70	17	1,246	24	30	19	38	1,134
Average										
2000 to 2003	812	124	569	11	1,494	35	40	18	46	1,355
1990 to 2003	977	188	226	7	1,384	31	33	19	45	1,257

Source: FAOSTAT.

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