GREEN MINI-GRID HELP DESK

Mapping of Cereals, Fisheries and other Productive Use Businesses for Village Mini-grids

A Review of 15 African Countries

Report by Energy 4 Impact and Inensus

February 2019

ENERGY4IMPACT ACCELERATING ACCESS TO ENERGY · INENSUS · SUSTAINABLE ENERGY FUND FOR AFRICA · AFRICAN DEVELOPMENT BANK · AFRICAN DEVELOPMENT FUND

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Photo courtesy of Energy 4 Impact

List of Abbreviations

Technical:

AC	Alternating current
DC	Direct current
MG	Green Mini-Grid
PV	Photovoltaic

Economic/financial:

GDP	Gross domestic product
ICBT	Informal cross-border trade
PU	Productive use/user
PUE	Productive use of energy
VAR	Value addition ratio
VC	Value chain

Political/geographic:

CEN-SAD	Community of Sahel-Saharan States
COMESA	Common Market for Eastern and Southern Africa
EAC	East African Community
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organisation of the United Nations
SADC	Southern African Development Community
SSA	Sub-Saharan Africa

EXECUTIVE SUMMARY

Light industry and small businesses – so-called 'productive users' (PUs) – are a key factor in the success of village-based, green mini-grids (MGs) in Sub Saharan Africa (SSA). In most cases MGs are not able to reach a sufficient level of sales from private households to secure their financial viability and so have to sell to PUs. However, without linkage to and support for PUs, MGs are likely to struggle to increase local commercial uptake of electricity to achieve the critical mass of sales required. This report aims to start addressing this problem by mapping potential PU businesses for MGs in 15 African countries.

There is no "one size fits all" model for PUs and MGs. However, the most successful models are usually centred upon the business needs of local PUs and foster the development of new PUs around existing value chains (VCs), in order to increase productivity or the value of goods sold. This report focuses on those parts of the VC for village-based businesses, namely local production, local processing and local or regional end user markets.

The kinds of productive activity that are of most interest to MGs fall into the following broad areas:

- Agricultural production, such as irrigation pumping and post-harvest storage;
- Aquaculture production, such as fish breeding;
- Agricultural processing, such as milling, husking, cooling, pasteurisation, drying, juicing, pressing, grinding, pulping and roasting;
- Light manufacturing, such as saw milling, carpentry, welding, brick-making, tailoring and looming; and
- Access to end-user markets, enabled by ice-making and cold storage.

A Scope of the Report

The report focuses on PU activities in 15 African countries, namely: Burkina Faso, Cameroon, the Republic of Congo, Côte d'Ivoire, the Democratic Republic of Congo (DRC), Ethiopia, Madagascar, Mali, Mozambique, Niger, Nigeria, Senegal, Uganda, Zambia and Zimbabwe.

It identifies 43 different types of off-grid PU activity that are relevant for village-based MGs (see Table 1). It provides in-depth analysis on those sectors which offer the greatest opportunities for MGs to electrify PU activities, namely cereals (maize, sorghum and millet, and rice) and fisheries (fish capture and aquaculture).

The report is divided into four main sections:

- Methodology: sets out the criteria for selecting VCs and methods of analysis.
- Gaps in knowledge and data: identifies challenges in data gathering and recommends how to address gaps.
- Value chain and PU analysis: describes the key actors, drivers, trends and challenges for rural VCs within the cereals and fisheries sectors, including possible entry points for MGs.
- Country mapping: shows economic data, energy data and PU VCs for each country, with maps indicating off-grid areas that might be suitable for MG development.

It should be noted that the report is focused on PU activities for village-based mini-grids, rather than utility-scale mini-grids, which sell to larger manufacturing, processing and consumer businesses, and are likely to target regional, national or even international markets.

B Analysis and data inefficiencies

Much of the research for this report is based on literature on rural VCs and productive use of energy (PUE). One of the biggest challenges in this research has been the lack and inaccuracy of data such as:

- Limited economic information on PU VCs at a local level e.g. costs and revenues of typical PU businesses, up-to-date information on product prices or processing or service charges, and points of competition along the VC.

- Inadequate information on technical and economic implications of electrification of PUs by MGs e.g. technical and cost implications for MGs in mechanising manually operated activities or replacing diesel-powered machinery, potential for introduction of value-addition activities to improve the quality of existing products or diversify outputs from local processing, and broader business model considerations.
- Lack of up-to-date national electrification maps showing existing grid networks, off-grid areas with MGs and areas not yet electrified.

The report can only provide a high level overview on what is happening in each country. Developers will still need to carry out their own due diligence on the ground on local PU activities. They will also probably need to develop targeted business development services for local entrepreneurs and make grants or micro-finance available to stimulate investments in income-generating equipment.

C Value chain activities for cereals and fisheries

Local production of cereals and fishing in rural communities in Africa is typically dominated by smallholders. Their businesses tend to rely on rain-fed production and are very vulnerable to weather, leading to variable supplies and volatile prices. Inefficiencies in production and post-harvest handling, combined with a lack of proper storage and preservation facilities, often lead to losses in product quantity and quality.

Local processing is typically done in small quantities, either carried out manually or using artisanal, diesel-powered machinery, which is expensive to run and often unreliable. It is often hindered by a lack of appropriate electrical equipment and reliable sources of power. Furthermore, many small businesses simply cannot afford the cost of the equipment or access local financing for it.

Most products are sold to private households and local markets. Some maize and fish products are targeted at larger consumers and more distant markets. The scope for trade outside the local area is hampered by many factors such as: the poor road infrastructure; the poor quality of local products and lack of standards; uncertainty around local trade practices and volatility of product prices; and the poor integration of rural actors in the national value chain. Opportunities to broaden end user markets are emerging through: changing consumption trends; increases in urban population and household purchasing power; demand from cross-cutting sectors such as the animal feed and beverage markets; and growing cross-border trade.

D How MGs can add value to cereals and fisheries

Electrification by mini-grids can add value to production of cereals and fisheries, both on cultivation through irrigation of crops or fish aquaculture, and on post-harvest activities such as the drying of cereals and fish, and the threshing and winnowing of cereals. One of the challenges is that such services are typically needed in field locations which may be some distance from the villages, so developers have to decide whether to extend the mini-grids or use portable equipment.

Electrification can support local processing activities such as the cleaning of cereals and fish, and the de-hulling and milling of cereals. Most machinery used for such activities has a high energy requirement and this needs to be considered when designing the mini-grid and the operation and maintenance strategy. Post-processing activities that may be supported through electrification include local packaging, energy production from agricultural residues and local production of animal feed from the by-products of processing. Depending on local markets, electricity may also be used for the production of baked, cooked or fortified products.

MGs can add value through non-electric activities such as centralised storage activities (the lack of which contributes significantly to post-harvest losses), the provision of business development support (including basic business and financial advice, dissemination of market information and help addressing sector risks such as droughts, pests and diseases), and supply and financing of PU appliances. In some cases the MGs may themselves decide to directly enter the PU business and offer services such as milling or fish to the local community.

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1 INTRODUCTION

1.1 Background

Productive use of energy (PUE) plays a critical role in the development of many village-based green mini-grids (MGs) in rural communities in Sub-Saharan Africa (SSA). Private households in these areas typically consume low amounts of energy, so MGs may not be financially viable without connecting to income-generating users of energy. These so-called "productive users" (PUs) mainly comprise small-scale, local manufacturing, commercial or retail businesses.

This report maps the opportunities for PUE for MGs in 15 African countries – Burkina Faso, Cameroon, the Republic of Congo, Côte d'Ivoire, the Democratic Republic of Congo (DRC), Ethiopia, Madagascar, Mali, Mozambique, Niger, Nigeria, Senegal, Uganda, Zambia and Zimbabwe. It identifies the most important PU value chains (VCs) for MGs and describes the main production, processing and end user market activities where electrification through the MGs can add value.

Energy 4 Impact and Inensus (together the "Help Desk") were contracted by the African Development Bank ("AfDB") to produce the report under the Business Development Services Line of the Green Mini-Grid Market Development Programme. The report is one of a series being produced by the Help Desk. Other relevant reports currently in production include one on demand side management best practice and another on billing strategies.

1.2 Report structure

Chapter 2 explains the methodologies used for: identifying the most common rural VCs across the 15 countries; analysis of the value chain activities; and mapping out areas and activities suitable for integration into MGs.

Chapter 3 reviews available literature on VC analysis and PUE in the relevant countries, identifying knowledge gaps.

Chapter 4 analyses four of the most important VCs for MGs across the 15 countries, namely maize, sorghum/millet, rice and fisheries. It highlights activities along those VCs which represent opportunities for MGs. It includes key technical and economic considerations and identifies gaps in data.

Chapter 5 provides macro-economic and electricity data and maps on the 15 countries and identifies potential opportunities for PUE from mini-grids, focusing on the cereals and fisheries sectors covered in Chapter 4.

2 METHODOLOGY

This chapter outlines the tools and methods used to analyse the different PUs and VCs and to identify value-addition opportunities for village-based MGs.

2.1 Scope

The report focusses on opportunities for small-scale PU businesses with isolated rural village-based MGs in 15 selected African countries.

It is targeted at developers of small to medium-sized solar MGs, with a capacity of a few hundred kilowatts or less. These MGs are generally able to handle appliances with a capacity of 10 kilowatts or less.[1]

Due to the broad geographical remit of the report and the heavy reliance on publically available data, most of the country information relates to the administrative regions or counties of the selected countries, rather than smaller districts or villages. The report is therefore not a substitute for developers carrying out their own due diligence at a local level.

In order to make the report as relevant as possible for MG developers, we have focused on PU VCs that meet two tests. First, they already exist in off-grid areas or can easily be introduced. They are likely to primarily serve local markets, but may also serve more distant markets. Second, they have high potential for value-addition through access to electricity and are likely to have a broad range of electrical load requirements.

In this report, we have identified 43 commodities where value can potentially be created through electrification by rural MGs in the 15 selected countries – see Table 1. We have carried out a detailed analysis on the potential for value addition with five of these commodities, namely four cereals (maize, sorghum and millet, and rice) and fish (including fish capture and aquaculture). These five commodities were selected because they are relevant for most of the selected countries. If we had more time, we probably would have included other commodities in this analysis such as shea nuts, ground nuts, and cassava. We have classified the crops using the FAO[2] system – see Appendix D.

Table 1: Commodities with potential for PUE from rural, village-based mini-grids by country

	Commodity/PU Business	Countries (see notes below)
Cereals	**Maize**	COG, DRC, MOZ, NGA, UGA, SEN, ZMB, ZWE
	Sorghum	BFA, DRC, ETH, MDG, MLI, MOZ, NER, NGA
	Millet	BFA , MLI, MOZ, NER, NGA, SEN
	Rice	BFA, DRC, CIV, CMR, COG, MDG, MLI, NER, NGA, SEN
	Wheat	BFA, ETH, ZWE
Vegetables and Melons	**Tomatoes**	SEN
	Pineapples	CIV, DRC, UGA
	Mangoes	CIV, SEN
	Bananas / Plantain	CIV, COG, CMR, DRC, MDG
	Dates	BFA
	Figs	BFA
	Cashew nuts	BFA, CIV
Oilseed Crops	**Coconuts**	BFA, CIV, DRC
	Oil palm	BFA, CIV, COG, DRC
	Groundnuts	BFA, COG, DRC, MDG, MLI, MOZ, NER, SEN

[1] Most PUE activities covered in this report work with single-phase or three-phase AC-type connections, and a few would also be suitable for DC connections on a small scale. NREL & Energy 4 Impact (2018, 18-23) provide more information on MG system sizing and design for PUs.

[2] Food and Agriculture Organisation of the United Nations

	Commodity/PU Business	Countries (see notes below)
	Shea nuts	BFA, CIV, CMR, ETH, MLI, NER, NGA, UGA, SEN
	Sesame seeds	BFA, ETH, NGA
	Sunflower	UGA
	Soya beans	ZMB, ZWE
Root/ Tuber Crops	**Irish potatoes**	MDG, MLI
	Yam	CIV, COG, NGA
	Cassava	BFA, CIV, COG, DRC, MDG, MLI, MOZ, NER, NGA, ZMB
Beverage and Spice Crops	**Cocoa beans**	CIV, COG, MDG, NGA
	Coffee beans	CIV, COG, DRC, ETH, MDG, UGA
	Tea	DRC
	Cola nuts	BFA, CIV, DRC
	Vanilla	MDG, UGA
Leguminous crops	**Beans**	CIV, COG, DRC, MDG, SEN
	Cowpea	BFA
Sugar Crops	**Sugarcane**	BFA, COG, DRC, MLI, MDG, SEN
Other Crops	**Cotton**	BFA, CIV, MDG, MLI, NER, SEN, ZMB, ZWE
	Rubber plant	CIV, COG, DRC
	Tobacco	BFA, COG, ZWE
Livestock - Products from Slaughtered Animals	**Cattle meat**	CIV, ETH, MLI, NER, SEN, UGA, ZWE
	Goat meat	MDG, MLI, NER, SEN
	Pig meat/ Pork	SEN
	Chicken meat	MDG, NER, SEN
	Hides and Skins	ETH, MDG, ZWE
Livestock - Products from Live Animals	**Dairy (milk, cheese, yoghurt, butter)**	ETH, UGA
Fisheries	**Fish capture**	CIV, CMR, DRC, MLI, MOZ, NGA, SEN, UGA
	Aquaculture	MDG, NGA, UGA, ZMB, ZWE
Quarry and Mining	**Cement and bricks**	COG, MDG, NER
	Metalwork	MDG
Timber	**Woodwork**	COG, MDG, UGA, ZMB
Note 1	**Country abbreviations (World Atlas):** BFA – Burkina Faso; CMR – Cameroon; COG – Republic of Congo; DRC - Democratic Republic of Congo; CIV – Côte d'Ivoire; ETH – Ethiopia; MDG – Madagascar; MLI – Mali; MOZ – Mozambique; NER – Niger; NGA – Nigeria; SEN – Senegal; UGA – Uganda; ZMB – Zambia; ZWE – Zimbabwe	
Note 2	This list is not exhaustive. It is based on public information on commodities/PU businesses already existing in rural, off-grid areas in the relevant country. Clearly, there may be potential to introduce new commodities/PU businesses to such areas.	

Source: Authors, various literature

While the information in this report is useful in determining the high level viability of a MG project, it should not be looked at in isolation. To assess the viability of MG sites at the village level, developers also have to consider local electric connectivity and distance to the main grid, competitiveness versus alternative energy sources (diesel engines or solar home systems), the level of existing entrepreneurship and value addition activities, the logistics for access to appliances, the quality, affordability and power rating of those appliances, access to markets for the existing VCs, access to local finance for PUs, and the availability of local business development service providers.

2.2 Definitions

For the purposes of this report:

A MG is a set of small-scale renewable or hybrid electricity generators and possibly energy storage systems connected to a distribution network that supplies electricity to a small, localised group of customers and operates independently from the national transmission grid.

PUs are small or micro local businesses, typically active in agriculture, fishing, light manufacturing, or small commercial and retail trading.

PUE is use of energy by those businesses and other consumers to increase income, productivity and quality of life[3].

A VC refers to all activities that add value to a commodity or service from production through processing to marketing and end-user markets[4].

2.3 Sources of information

The data for this report comes from two main sources:

- Publicly available information: We have carried out a literature review and desktop research using public information sources. The main sources were government ministries (e.g. of agriculture, trade and energy), rural electrification agencies, trade associations, chambers of commerce, private companies, private sector development directories, financial access organisations, universities, research institutes, NGOs and development organisations[5].
- On-the-ground experience: We have drawn on the on-the-ground experience of Energy 4 Impact and Inensus who have provided technical assistance to over 100 developers across 36 countries in SSA, both directly through the Help Desk and other programmes. The Help Desk has supported developers in all but one of the 15 selected countries, the exception being the Republic of Congo.

2.4 Mapping process

We have followed a three-step process for mapping the most interesting PU businesses for MGs in the 15 selected African countries – see Figure 1 below.

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[3] This covers both the narrow definition of PUE under which electricity is used as a direct input for income generation and productivity (Contejean and Verin 2017, GIZ and EUEI PDF 2011, European Commission 2011) and the broader definition under which electricity is used to improve the socio-economic wellbeing of a community (NREL & Energy 4 Impact 2018, Lecoque and Wiemann 2015, Webber and Labaste 2010, NRECA International n.d.).

[4] For information on different types of VC, see https://www.ids.ac.uk/ids/global/pdfs/VchNov01.pdf.

[5] Some development organisations have been actively involved in facilitating the development of rural agricultural VCs in SSA. Examples include: USAID's COMPETE programme which has focused on staple foods in Kenya, Uganda, Tanzania, Ethiopia, Burundi and Malawi (https://www.eatradehub.org/old_project_compete?page=1); USAID's Global Food Response programme which has analysed the rice value chains in Senegal, Nigeria, Liberia, Mali and Ghana (http://www.fao.org/sustainable-food-value-chains/library/non-learning-packages/details/en/c/274711); USAID's FEWS NET programme which provides updates on agricultural production and markets in SSA that are vulnerable to severe climatic conditions such as drought (http://fews.net/); and UNDP's DIMAT programme which has analysed rice, beans and cassava value chains in Uganda (https://www.kilimotrust.org/DIMAT.pdf).

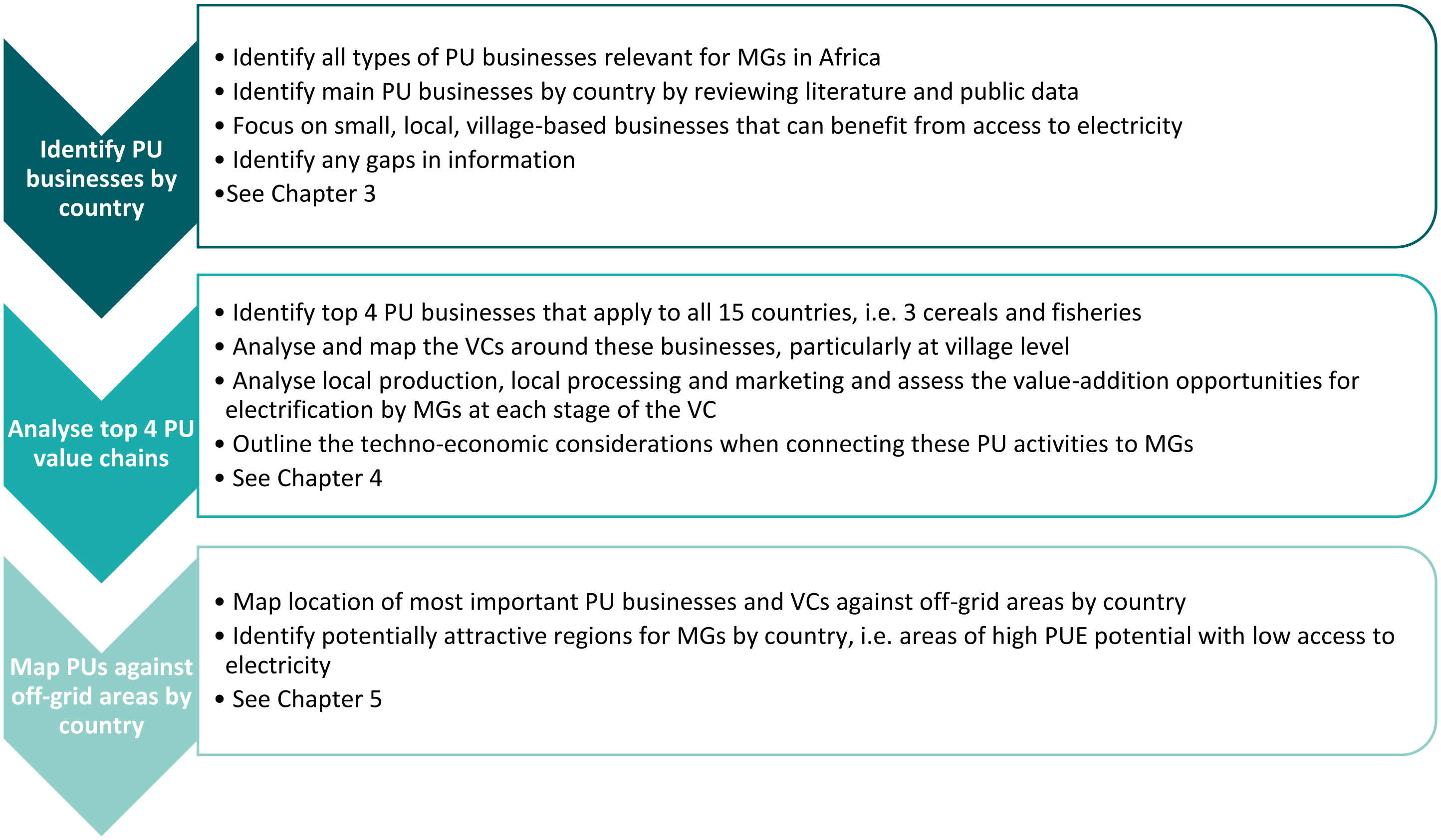


Figure 1: PU mapping process

2.5 Value chain analysis

In this report, we have analysed the VCs for five commodities, namely maize, sorghum, millet, rice and fish. For each of these commodities, we look at the main activities, players and equipment along the VC and the key business drivers e.g. weather, local infrastructure, and local trading arrangements. We break the VCs down into three main stages i.e. production, processing and marketing or end user markets[6]:

- **Local production** includes cultivation of cereals, fish capture or aquaculture and post-harvest or post-capture handling.
- **Local processing** includes all activities that transform basic commodities into more valuable products. We have broken these down under two main headings:
  - i) Primary processing transforms raw commodities into primary products (e.g. milling cereals into flour, drying or smoking of fish)
  - ii) Secondary processing transforms primary products into higher value and more marketable products (e.g. baked products made from cereal flour, or fillets created from gutted fish)
- **Marketing** includes all activities carried out to sell end user products.

Some players operate across the entire VC or are involved in multiple businesses. For example, many local traders of maize, sorghum and millet are involved in the production, processing and marketing of the cereals, selling them directly

[6] For a more in-depth look at VCs and the main stages of value addition, please refer to GIZ's "*ValueLinks*" manuals, KIT, Faida MaLi and IIRR's "*Chain Empowerment*" report, the European Commission's "*Analysis and Development of Inclusive Value Chains*" information note, and the International Labour Organisation's "*Rough Guide to Value Chain Development*". These are all listed in the Bibliography.

from the farm in grain form or as flour after local processing. Given the similarities in the processing methods, traders can potentially also use the same equipment for all three cereals.

2.6 Value addition opportunities for MGs

We have identified four ways in which electrification by MGs can potentially add value to PU businesses:

- Increasing productivity by replacing manual labour with electric equipment;
- Lowering costs and improving efficiency by replacing diesel-based equipment with electric ones;
- Increasing the value and improving the quality of existing products e.g. finer quality flour and less broken rice; and
- Diversification of end user products e.g. baked and fried goods from cereal flour.

MGs can add value through non-electric activities such as centralised storage activities (the lack of which contributes significantly to post-harvest losses), the provision of business development support (including basic business and financial advice, dissemination of market information and help addressing sector risks such as droughts, pests and diseases), and supply and financing of PU appliances. In some cases the MGs may themselves decide to directly enter the PU business and offer services such as milling or fish to the local community.

One of the key questions in relation to value addition is the choice of electrical equipment. This report therefore considers the technical considerations and economic implications of using different types of equipment and their suitability for connection to MGs. Appendix C summarises the technical considerations for small-scale off-grid cereal processing equipment.

For a full list of the questions related to VCs, please refer to Table 2.

Table 2: Value chain questions

Analytical Focus	Questions
Market size and activities across the VC	• How large is the market of the value chain in SSA and the 15 selected countries? • What are the main activities and characteristics across the VC i.e. production, local processing and marketing? • Where are these activities located in each country? • Who are the key actors across the VC? • What knowledge gaps exist and how can they be filled?
Market trends and drivers across the VC	• What are the major drivers of supply and demand? • What are the main trends and challenges across the VC? • What knowledge gaps exist and how can they be filled?
Opportunities for MG value-addition	• What PU activities are mechanised and/or dependent on electricity for operation? • What are the general load requirements for these activities? • How can MGs add value across the VC? • How do the PU activities fit in with the needs of a MG? • Are there any new PU activities that could be introduced into the VC, and what is the rationale for introducing them? • What PU activities can be taken up by the MG developers themselves as a new source of revenue? • What knowledge gaps exist and how can they be filled?

Analytical Focus	Questions
Technical and economic considerations	• What are the technical factors that MG developers need to consider before electrifying identified PU activities? • What are the costs, revenues and value-addition considerations for PU businesses and MGs? • What knowledge gaps exist and how can they be filled?

3 GAPS IN KNOWLEDGE AND DATA

There is plenty of high level literature on small PU businesses in SSA, explaining how to promote them, what challenges they face, and how they contribute to rural development. However, apart from a few case studies, there is very little detailed information on rural PU businesses or village-based PUE at the country level.

This chapter summarises the main gaps in the knowledge and data. In the first section, we look at the information gaps on rural VCs for cereals and fisheries, including PUE. In the second section, we consider the difficulties in mapping PU businesses at a country level, and the limited information on the opportunities for PUE at village level.

3.1 Gaps in analysis of cereals and fisheries value chains

Lack of detail at village level. Most public data is compiled at a national or regional level, with limited information on local village-based economics. For example, there is little documented information on local demand and consumption of sorghum and millet, perhaps because the production and processing is carried out mainly by private households and very little is marketed outside the local area. There are also few concrete examples of small rural businesses pursuing value-addition activities for rice beyond milling, even if theoretically there is potential for secondary processing activities around baking and beverages.

Lack of detailed and up-to-date economic data on rural VCs. There is limited data available on the costs and revenues of local production, processing and marketing of small-scale businesses in cereals and fisheries. The problem is particularly acute for informally traded products and services and it is hard to find documented information on local trade practices and points of competition in the VC. In addition, these costs and revenues tend to differ in different regions within the country.

Lack of price transparency, particularly for cereals. There is little transparency on farm gate prices for unprocessed cereals, the wholesale and retail prices of final products, and service or processing fees (e.g. toll milling). The same is true for fisheries, although the level of price transparency is higher than for cereals. The problem is exacerbated by the seasonality of pricing. Some MG developers have partly addressed this problem by setting up information and communication technology centres which provide online information on local pricing.[7]

Lack of information and analysis on the interaction between markets. There are many interesting aspects of the cereal and fishery VCs that require further research. One is the dynamics of informal trade, both local and international (e.g. the informal maize trade between Mozambique and Malawi, or between Zambia and the DRC, and the informal rice trade between Côte d'Ivoire and Guinea). Another is the impact of other sectors (e.g. how does the supply and demand of poultry and the related animal feed market affect the utilisation of maize, sorghum and fish?) Local and regional food policies can also affect demand and supply of cereal products. Some countries class certain cereals as strategically important and introduce local incentives and special rules on cross-border trade which directly impact the local businesses.

3.2 Gaps in analysis of PUE within the cereals and fisheries VCs

There has been very little detailed analysis published on the cereals and fisheries VCs which looks at PUE activities for MGs. What little has been published has tended to focus on the wider context of rural electrification (grid and off-grid) rather than MGs[8]. Below are examples of some of the most important information gaps:

[7] Renewable World has developed a number of community-owned and managed micro-grids around Lake Victoria in Kenya which have ICT centres that provide information on local fish prices.

[8] GIZ's PRODUSE manual (GIZ and EUEI PDF 2011) provides a framework for planning, promoting and implementing PU components in rural electrification programs. It explores economic and value chain effects of PUE in an off-grid setting e.g. in production, value addition, market channels and consumers. ESMAP's 2008 paper considers two approaches to developing VCs in rural areas. The systematic approach involves analysing technologies along the VCs, identifying bottlenecks and determining areas where electricity can be of benefit. The pragmatic approach involves leveraging on existing or planned projects in other development sectors located in the same areas and identifying ways that electricity could benefit these sectors.

Limited information on energy use in the agricultural sector. We found little information on the typical electricity needs of rural PU businesses operating along the cereal and fishery VCs in SSA and the business cases for electrifying such businesses.

Limited information on using MGs to power value-addition activities. We were unable to find much public information in the selected countries on the performance of PU businesses as MG customers, how these businesses fitted into the MG business model, and practical examples of MGs taking on PU activities as a business[9]. Most of the information provided in this report is based on E4I's and Inensus' own experience working with MG developers.

Lack of detailed information on locally fabricated electrical equipment for use along VCs. There is little public information on the costs, load requirements and operating performance of locally fabricated electrical machinery used in the cereals and fishery VCs.

3.3 Gaps in overall country analysis and PU mapping

Most of the information on major production areas is based on administrative regions in a country (e.g. provinces, districts, etc.), rather than on specific areas within these regions (e.g. villages, towns etc.) where small-scale VC activities are most prominent. In addition, the information that we did find was too high level and often several years out-of-date.

[9] One exception is Mandulis Energy in Uganda which offers milling services to local farmers.

4 VALUE CHAIN AND PRODUCTIVE USE ANALYSIS IN CEREALS AND FISHERIES

This chapter takes an in-depth look at the some of the most important PU VCs for MGs in the selected African countries – namely cereals (maize, sorghum and millet, and rice) and fisheries (fish capture and aquaculture). These PUs were chosen because of their presence in many rural village communities and the opportunities for value-addition activities for small-scale businesses using power from MGs.

4.1 Overview

This section discusses common characteristics of the cereals and fisheries businesses and the potential for value addition from MGs across the VC i.e. production, processing and end user markets. These are summarised in Table 3 below. The rest of this section looks at the main supply and demand drivers for these businesses and the key technical and economic considerations for these PU business. More detailed analyses of the individual VCs are provided later on in this chapter. For a more detailed overview of the potential for these PU businesses in the 15 selected countries, please see Chapter 5 and Appendix A.

Table 3: Common characteristics of cereals and fisheries businesses and opportunities for MG value addition

	Characteristics	MG Value-Addition Opportunities
Production	• Dominated by smallholder farmers with typical land holdings of less than 10 hectares per household for cereals, and small-scale low quality equipment for fishing. • Production is highly dependent on weather (e.g. rain-fed cultivation of cereals and inland or marine fish capture). • For cereals, any increase in productivity is mainly driven by an increase in the cultivated area, rather than improved inputs. • Post-harvest/post-capture activities (e.g. cleaning and drying of cereals or fish, or threshing and winnowing of cereals) are often done manually.	• Utilisation of electricity to improve production (e.g. water pumping services for irrigation of cereals like rice, or for fish breeding in aquaculture). • Mechanisation of manual, post-harvest activities such as cleaning and drying for both cereals and fish. • Replacing diesel-based or manually-operated machinery used in post-harvest activities, such as threshing and winnowing of cereals, and ice-making to preserve fish.
Local Processing	• Processing is done manually at a household level or using diesel-powered machinery at small- to medium-scale levels. There is a strong correlation between the high amount spent on fuel and the prices of processed products. • Common processing activities for cereals include de-hulling and milling. Fish is commonly processed through drying, smoking, salting and filleting.	• Replacing manual and diesel-based activities in commonly practised processing. • MGs to provide electricity to existing small local service businesses, or provide services directly themselves where they do not exist.

	Characteristics	MG Value-Addition Opportunities
End user markets	• Consumed at household level as staple foods. • Growing demand for good quality, ready-to-cook products, particularly from urban households. • Growing demand for animal feed, providing a potential market for by-products of processed commodities.	• Further value-addition through introduction of less commonly practised activities such as grading and packaging of products. • Introduction of new products such as locally produced animal feed and products from secondary processing activities such as baking and frying.

4.1.1 Market drivers

Supply-side drivers

1. Weather and seasonality

The cereals and fishery businesses are vulnerable to local weather conditions, which often leads to variable supplies and volatile pricing. They tend to rely on rain-fed production, rather than irrigation or aquaculture, and suffer from inadequate storage facilities and preservation services. They are also vulnerable to annual variations in growing seasons and climate change more generally. This in turn affects local prices of raw and processed products, so that they are lower during harvest, when there is a surplus, and higher during the rest of the year due to a decreased supply and an increase in storage costs.

In Zambia, for example, local prices for maize grain fluctuate by up to 60% between the harvest and lean seasons, while maize meal prices fluctuate by about 10%, owing to fluctuations in grain availability and storage costs (Keyser 2007, Chapoto, et al. 2010). Zimbabwe has historically experienced crop losses three years out of five due to uncertain weather conditions (USAID 2014, 28).

In the fisheries sector, countries such as Madagascar and Mozambique are prone to tropical storms and cyclones, which affect water levels and water salinity for aquaculture production (Satia 2017). Fish prices therefore often fluctuate with rainfall variability. Poor storage and preservation at village level in Uganda and Tanzania compel farmers to sell fish at low prices during peak fishing seasons in order to reduce losses (Akande and Diei-Ouadi 2010). This is also the case in rainy seasons when there is less sunshine to preserve certain types of fish through drying.

2. Agricultural and trade policies

Cereal and fish products are mostly sold locally within countries or across neighbouring countries. Some SSA regions[10] have liberalised trade for locally produced commodities and put in place common external tariffs for the export and import of these commodities.

Governments, however, tend to monitor movements of agricultural products for reasons of food security and can place ad hoc or long-term restrictions on imports, processing and exports. Countries such as Ethiopia, Nigeria, Zambia and Zimbabwe have occasionally imposed import and export bans for maize and other staple foods in order to encourage local production and trading. In Zambia, there have been frequent changes in the government-controlled maize market – for example the Food Reserve Agency's (FRA) buying and selling strategy and also export controls - leading to increased price

[10] Examples include: CEN-SAD: Community of Sahel-Saharan States; COMESA: Common Market for Eastern and Southern Africa; EAC: East African Community; ECCAS: Economic Community of Central African States; ECOWAS: Economic Community of West African States; SADC: Southern African Development Community. UNCTAD's report (UNCTAD 2012, 20-46) has more information on trading agreements in these regions.

volatility, higher marketing costs and uncertainty (USAID 2017). Government-imposed trade barriers on fish feed or restrictions on local fishing can lead to higher costs in aquaculture production and locally traded fish.

Demand-side market drivers

1. End-use

Products that serve multiple end user markets are likely to be more desirable due to the diversification of risk. Cereals, for example, can be consumed in both grain and processed form in households, providing PU opportunities in local processing and packaging. The value of some cereals such as maize and rice may vary depending on the quality or grade of the processed product. Other forms of demand include production of local beverages from cereals, and animal feed production from the by-products of cereal and fish processing. It may also be possible to use agricultural waste products and residues for energy production, but this is beyond the scope of this report.

2. Population growth

Population growth, particularly urban growth, is likely to increase demand for fish and cereal products. For example, fish consumption in SSA is expected to increase 65-89% by 2030 due to population growth (Gordon et al. 2013). Increases in urban household incomes and related dietary changes are also likely to increase fish and cereal consumption. Urban growth has driven up demand for ready-to-cook sorghum and millet products such as flour mixes and certain street foods. In Mozambique, urban growth is expected to increase demand for poultry by up to 300% in the coming years, which will have a knock-on effect on demand for poultry feed and demand for cereals (USAID 2018).

Common challenges

1. Poor infrastructure

Poor quality infrastructure in the rural areas has a negative impact on the availability of cereals and fish, and on the quality of processing and end use products. This problem can take many forms, including low quality road networks and high transportation costs, lack of storage and preservation facilities, poor quality processing equipment, and lack of access to and unreliability of electricity supply.

Take the example of rice. In Cameroon, rice is mostly sold in its unprocessed and natural paddy form to local and regional markets due to low quality processing equipment. In Côte d'Ivoire, paddy rice is often exported to Guinea for hulling and parboiling, due to the poor equipment and unreliable electricity. In Senegal, poor transport links isolate the southern, rice-producing regions of the country from the surrounding, urban consumer markets.

Similar problems apply to fisheries. Fish losses in SSA are estimated to be over 25% of total catch in SSA (Gordon, Finegold, et al. 2013, WorldFish Center 2009, Satia 2017, Kolding, et al. 2016), partly because of problems with storage and preservation, packaging, drying, processing, transportation and electricity[11]. This affects fish quality, making it difficult to market fish and fish products outside the local area. According to the WorldFish Center (2009), improved processing technologies and marketing could reduce post-harvest losses by over 50%.

2. Lack of quality standards and supply chain regulations

Product prices in rural markets are often determined by quality spot-checks conducted by local actors at points of sale. Formal quality standards for raw and processed local products are rare, particularly for cereals. The lack of formal standards and supply chain regulations for local products make regional trading of products such as rice and fish more difficult. Fishing regulations are also important to avoid over-catching of fish and typically include registration and licensing

[11] Akande and Diei-Ouadi (2010) provide an interesting overview of fish losses in Mali, Uganda, Ghana, Kenya and Tanzania and their micro economic impacts on each country.

of fishermen and fish farmers, plus rules on fish capture equipment, the use of chemicals, and the minimum permitted size of fish for capture and sale.

3. Limited access to finance

Many small, rural businesses cannot afford the high upfront cost of purchasing equipment required to produce higher quality products due to the low volume of products handled and the relatively low margins available. They are also often unable to access local finance to buy equipment and some MGs are trying to get round this problem by offering appliance financing schemes.

Akande and Diei-Ouadi 2010 highlight the financial challenges preventing local fishermen in Uganda, Ghana and Tanzania taking advantage of new post-harvest and post-capture handling techniques such as ice-making, off-grid refrigeration, on-board use of ice and appropriate drying methods. Similar challenges are faced by smallholder farmers carrying out rice processing in Cameroon and Côte d'Ivoire.

4.1.2 Technical and economic considerations

Technical considerations that may affect the viability of a PU or MG business include:

- Seasonal demand variations: Demand for some machinery, such as mechanical driers, shelling and winnowing machines, tends to vary seasonally, with higher demand experienced during harvest seasons. It is important to take account of this fluctuation in demand when designing the MG system.
- Load scheduling and shedding: Load management is important to ensure reliable power supply and minimise technical issues. It is particularly important for MGs supplying power to machinery with relatively high power ratings and spiky usage patterns such as milling and ice making machines. Such machines draw a lot of power from the grid and can disrupt supply to other MG loads, particularly during peak demand hours or when there is lower availability of renewable resources e.g. night time on a solar MG. To prevent such events from happening, MG operators can schedule specific times in the day for operation of these machines (load scheduling) or disconnect them during peak hours of demand (load shedding)[12].
- Mini-grid design to match machinery requirements: The choice between a single-phase or three-phase MG system depends on the types of machinery to be connected. Three-phase systems are generally better suited for motor-driven machinery such as milling machines and water pumps for irrigation or for supplying water to ice making machines[13], while single-phase systems can work for smaller loads such as mechanical dryers. Three-phase systems can cost up to 20% more to build than single-phase systems, due to the additional parts needed for transmission and distribution (e.g. cables, poles, inverters and meters) and the higher cost of connecting individual customers. However, three-phase systems allow for growth in demand because they can accommodate larger machinery from the same customers without needing to change the entire transmission and distribution network. Three-phase power also reduces power losses along the distribution network.
- Machinery replacement: Following on from the two points above, there may be a case for replacing existing PU machines with more energy efficient ones. Most small-scale cereal and fish feed millers, for example, use diesel-powered milling machines. To connect these mills to a MG system, they would either have to be converted to motor-driven mills or replaced with electric mills. Although the costs of conversion are lower than replacement, it is important for motor-driven mills to select the right type and size of motor to avoid damaging the milling

[12] These strategies are examples of demand side management, which aims to achieve a balance in demand and supply of power in the MG system. For more information on this, please refer to Energy 4 Impact and NREL's paper on productive use (NREL & Energy 4 Impact 2018, 14)

[13] It is advisable to consider three-phase power supply for machinery requiring large motors of over 5 horse power (NREL & Energy 4 Impact 2018).

machines and, to some extent, affecting the MG system[14]. In addition, there already exist electrical milling machines suitable for use in off-grid rural areas in SSA and capable of working efficiently with MG power.

- Site-specific energy requirements: Some activities, such as drying of grains or fish and shelling of grains, often take place at or close to the point of production/harvest. Battery-backed, portable machines may be a more attractive option where electricity distribution from the MG to the sites is not technically or economically practical. Care should however be taken to avoid exposing the batteries to frequent deep discharges, which could potentially reduce their life cycle. A charge controller could help in this regard. Users must also be trained to switch off machinery whenever a deep discharge occurs. In addition, scheduled maintenance of equipment is required, especially to replace parts such as batteries or DC brushes where DC machinery is being used.
- High start-up current: Irrigation pumps, milling, shredding, shelling and winnowing machines, and other large loads typically have high start-up current requirements[15]. A manual starter or a starting current limiter can help minimise the effects of this on the MG system.

[14] It costs about $500 to convert a diesel-powered milling machine into an electric motor-driven machine, compared to about $2,000 to replace the milling machine with an electric one. NREL & Energy 4 Impact (2018, 28) provides a technical and economic comparison between these two options for a maize milling machine.

[15] For more information, see Tables 3 to 5 in NREL & Energy 4 Impact (2018).

4.2 Maize

Maize is the most commonly produced cereal in SSA, taking up over 16% of the approximately 200 million hectares of cultivated land on the continent (Macauley 2015). It can grow under diverse ecological conditions and is consumed in many forms, making it adaptable to household diets across a range of cultural settings. Figure 2 shows the main activities in the rural maize VC in SSA, including production, local processing and marketing.

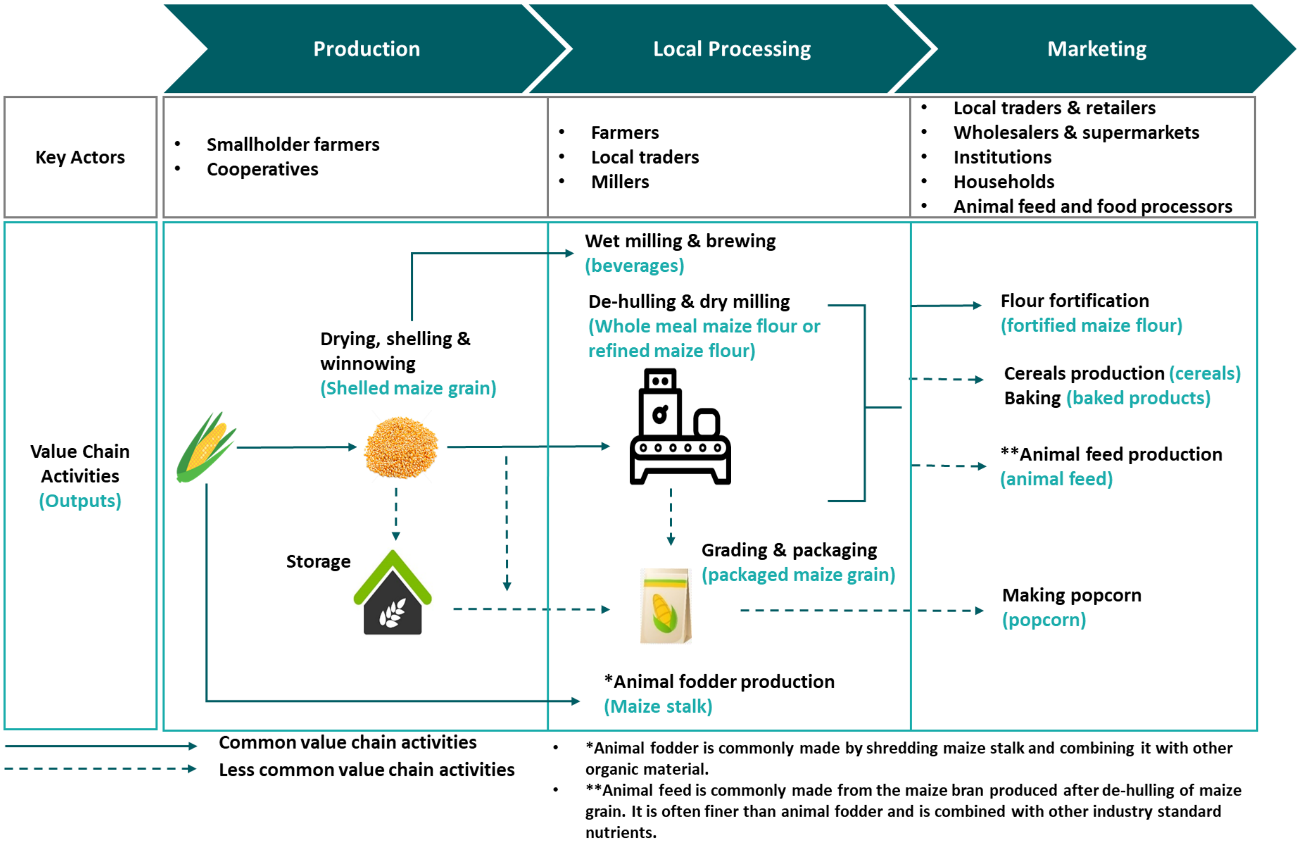


Figure 2: Maize value chain in Sub-Saharan Africa

4.2.1 Production

Most of the maize produced in SSA comes from smallholder farmers. Total production of maize in 2015 was about 64 million tonnes, with yields ranging from 1.2 to 3.5 tonnes per hectare. Maize is often grown in close proximity to other crops, either other cereals (mostly in Eastern and Southern Africa) or roots and tubers (mostly in Western Africa). Most of the maize is rain-fed (i.e not irrigated) and produced using manual inputs. Production is higher in Eastern Africa and Southern Africa compared to Central Africa and Western Africa, with the first two regions accounting for about 75% of production in SSA – see Figure 3 and Figure 4 below.

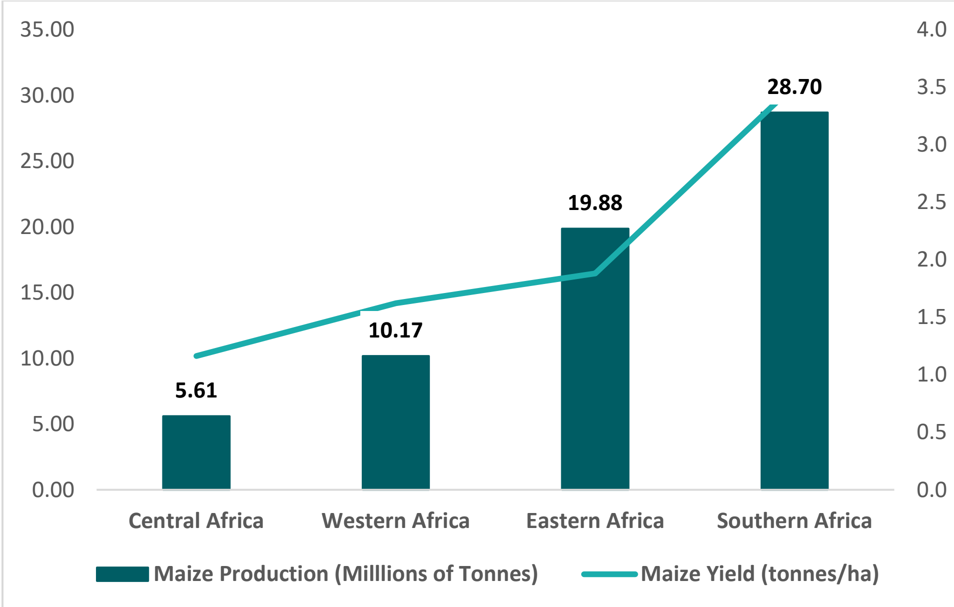


Figure 3: Maize production and yield in SSA regions (2015)

Source: FAOSTAT 2015

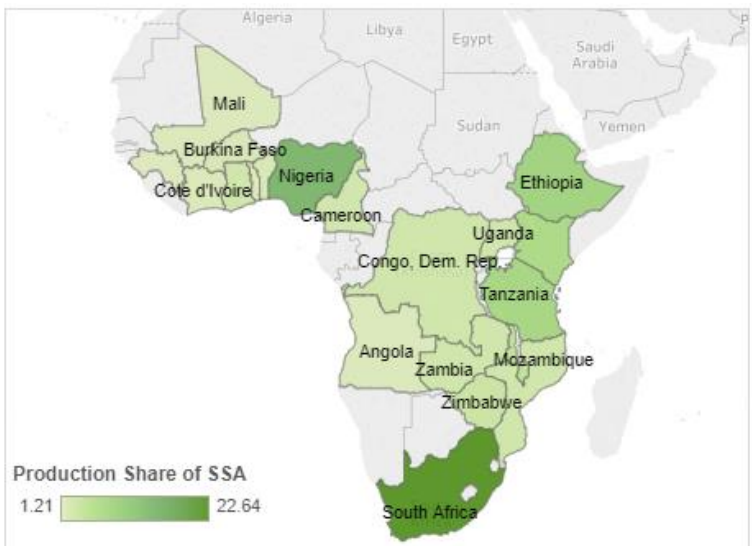


Figure 4: Major maize producing countries in Sub-Saharan Africa

Source: Harvest Choice

Ethiopia, Nigeria, Zambia, Uganda, Mozambique, Cameroon, Mali, Burkina Faso, the DRC, Zimbabwe and Côte d'Ivoire are in the top 20 major maize producing countries in SSA (Macauley 2015). Ethiopia, Nigeria and Zambia are traditionally surplus maize producers, exporting maize to neighbouring countries within their respective regions. Figure 5 shows maize production in our focus countries.

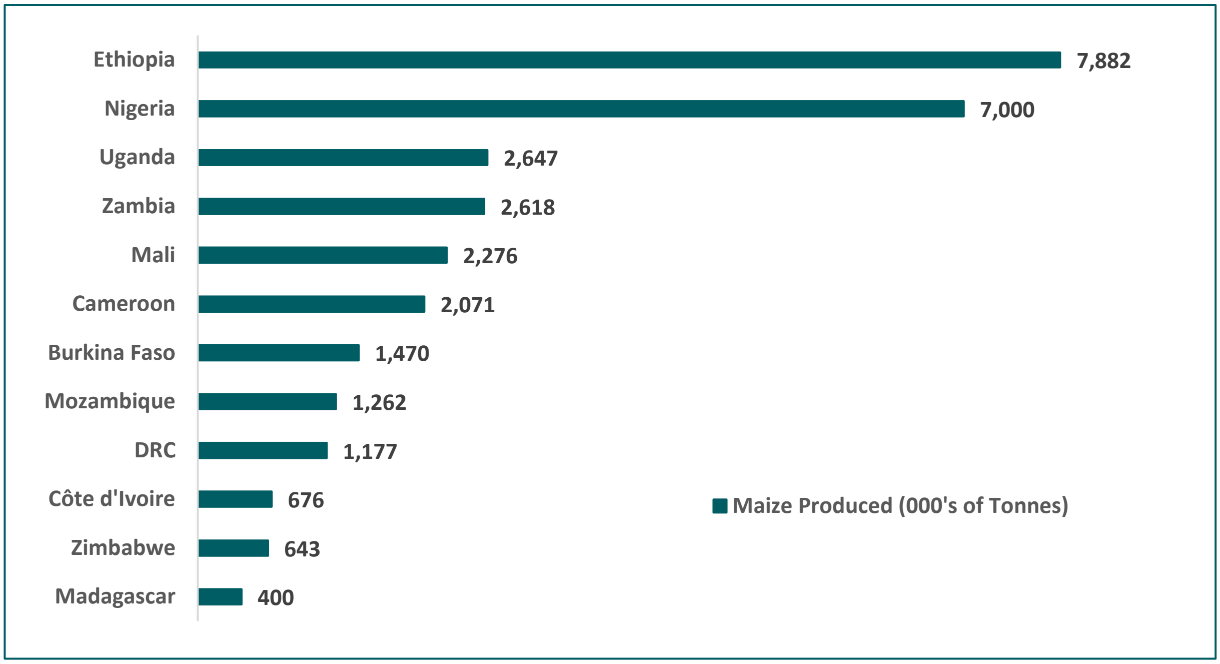


Figure 5: Maize production in target countries (2015)[16]

Sources: FAOSTAT 2015, Nzeka and Taylor 2017, USAID 2017

Cultivation and harvesting of maize is still mainly done manually, due to the small size of most farmers' land holdings. We have not found any documented information on small-scale irrigation for maize, although it is used by larger-scale commercial farmers and cooperatives.

Once harvested, maize is sun-dried on the ground for a few days before it can be shelled. This method can lead to over- or under-drying due to lack of grain moisture control[17], and losses when packing and unpacking the grain. It also exposes the grain to dirt and foreign materials which can potentially degrade the quality of processed goods[18]. Shelling, which involves removing the maize grain from its cob, is also done manually[19] while the maize is still on the ground. However, this is very labour-intensive, especially for larger amounts of harvested maize. The grain is then manually winnowed[20] to remove any chaff or straw, and dried once more before it is packed into 50kg – 100kg bags. Maize stalks are shredded manually for use as fodder for livestock, especially dairy animals.

Inadequate storage facilities are a major challenge for maize farmers. Only 15% of farmers in Mozambique have access to proper storage facilities (The Monitor Group 2012) while poor storage contributes to 47% of losses in Nigeria (Oguntade 2013, 44). Similar challenges are faced by farmers in Uganda and Zambia.

4.2.2 Local processing

The most important primary processing activities for maize are milling of grain into flour, and grading and packaging of flour or maize grain. Local, small-scale millers either purchase maize grain from local traders and mill it for sale to end users or wholesalers, or provide milling services to household consumers or small-scale cottage industries such as local

[16] Senegal 2013 maize production, 233, 234.28 tonnes (FAO); Niger 2012 maize production, 8,413 tonnes (FAO); no information found on maize production in the Republic of Congo.
[17] FAO recommends drying cereals to moisture levels of 10%-15% before storage (FAO n.d.)
[18] FAO's maize post-harvest publication (Mejía 2003, 30) highlights maximum tolerable limits for maize quality.
[19] The most popular method is using a sharp object to tug the grain from the cob.
[20] This involves lifting and tossing the maize grains using hand-held winnowing baskets to allow for the wind to blow away the lighter chaff or straw. The seeds then fall vertically without any chaff (FAO n.d.).

restaurants. Maize bran, a by-product of the milling process, is usually sold to animal feed processors for onward sale to poultry or fish farmers.

There are two main types of maize milling techniques used in SSA: dry milling and wet milling. Dry milling processes maize into flour or bran for food consumption and animal feed respectively, while wet milling is mainly used for production of beverages and tends to be done on a larger scale. This report focuses on dry milling.

Local small-scale millers produce an average of up to 300kg of flour per day (Kapuya, et al. n.d.). They usually mill the grain whole without removing the outer shell (de-hulling), the result of which is whole grain flour, preferred by rural households due to its low price and high nutritional value. Most medium-scale millers produce an average of up to 8 tonnes an hour. They typically de-hull the maize before processing it to produce refined maize flour, which is preferred by larger consumers such as schools, hospitals, and prisons, and higher income households. Food aid organisations such as the World Food Programme also have a high demand for maize. Refined flour is finer and easier to prepare, but is pricier and has lower nutritional value than whole grain flour. In countries such as Nigeria, maize is also de-hulled to produce maize grits commonly used for production of breakfast cereals. Maize bran can be sold to animal feed manufacturers, mostly in the poultry and fisheries sectors, for further processing and fortification. Some medium-scale millers also process the animal feed themselves.

Hammer mills and plate mills are widely used by rural communities for dry milling, due to their low capital and maintenance costs and their ability to process dry maize grain into fine flour for human consumption. Roller mills are mainly used for animal feed production, wet milling, and production of maize grits, since they crush the grain rather than grinding it, thus producing larger particles suitable for animal digestion, fermentation and cereal production (FAO n.d.). They require higher levels of maintenance than hammer and plate mills.

4.2.3 Marketing

Maize is mainly produced for subsistence use at household level, with the exception of some countries such as Uganda and parts of Mozambique, where maize is produced primarily for income generation. Over 300 million people in Africa use maize as a staple in their diet, making it one of the most important foods in Africa. About 95% of maize is utilised as food (VIB 2017). Maize can be consumed as fresh or dried grain or in processed form, either on its own or mixed with other products[21]. Maize consumption in Southern Africa is higher than other regions – see Figure 6.

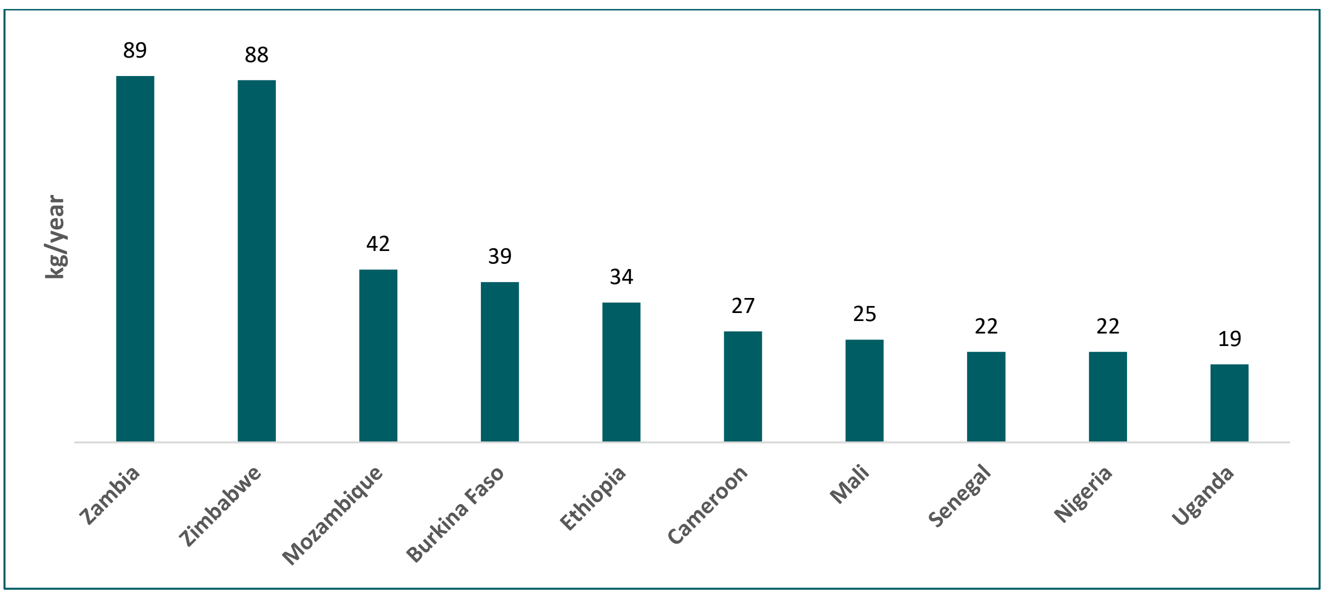


Figure 6: Annual per capita maize consumption in Sub-Saharan Africa

Source: VIB (2017, Table 1.1)

[21] Table 1 in Ekpa et.al.'s publication (Ekpa, et al. 2018) contains detailed information on various maize-based foods across SSA.

Apart from household food consumption, maize is the most popular source of animal feed worldwide, owing to its nutritional benefits and wide availability. Maize is one of the main sources of feed for poultry and aquaculture in SSA. For example, about 50% of maize produced between 2005 and 2010 in Nigeria was supplied to the animal feed sector, with poultry accounting for 98% of the market and the rest going to fisheries (SAHEL 2017). FAO projects a 73% growth in per capita consumption of poultry and poultry products in SSA between 2000 and 2030 (FAO 2011). Figure 7 shows the growing demand for maize for human and animal consumption since 2013.

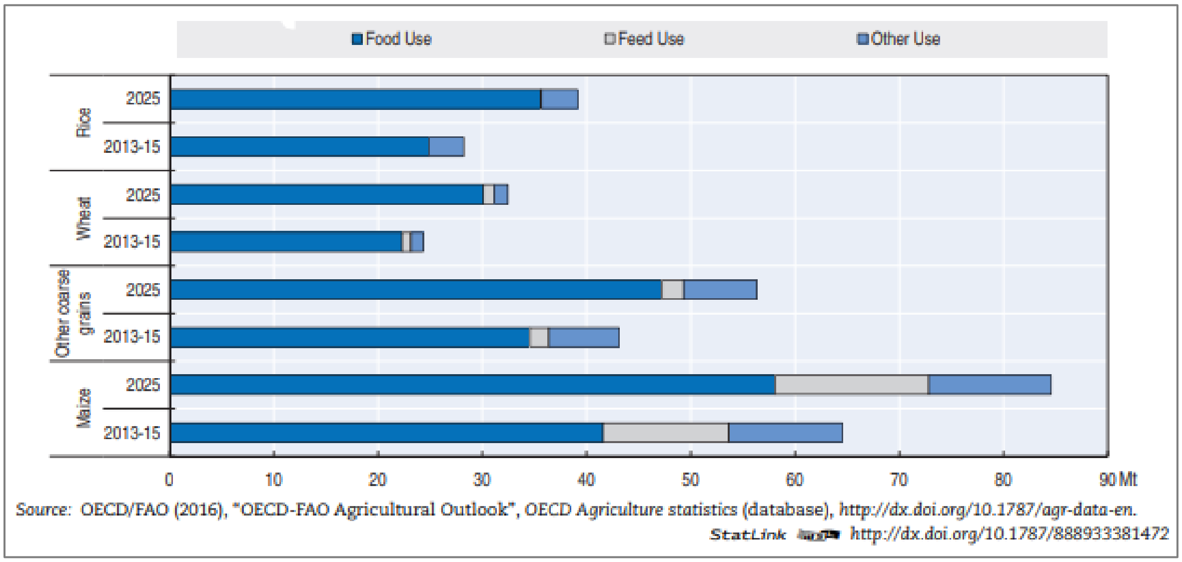


Figure 7: Comparison of cereal demand in Sub-Saharan Africa

Source: (OECD/FAO 2016, 76)

Local traders and millers are at the centre of the rural maize VC in SSA. In most countries, traders collect maize from farmers and sell the grain and/or the flour to the local rural and urban market. Millers add value to the maize through processing and in some countries such as the DRC, Mozambique, Uganda, Zambia, and Zimbabwe, they act as a central distributor for maize and flour to local rural and neighbouring urban markets. Some medium-scale millers package and brand their own products. This activity, however, requires a steady supply of good quality maize grain which can be challenging in an environment where production is largely dependent on the weather. Proper storage facilities at this level can help to smooth out the supply of maize all year round.

Maize products that have been through primary processing can be sold to end users in their current form or further processed to make other maize-based products. The most common secondary processing activity in SSA is fortification of maize flour. Flour is mixed with flour from other foods, usually sorghum, millet and cassava, to produce flour mixes for porridge and weaning food. This is done by either mixing all the ingredients and milling them together, or milling them separately and mixing them afterwards. Other common secondary products include baked goods, brewed beverages, breakfast cereals and popcorn, but these tend to be regional and cultural-specific[22].

4.2.4 Drivers and challenges

The following points highlight common drivers and challenges affecting the maize industry in SSA:

- Maize prices are highly seasonal, going up during dry seasons and planting periods. Governments in countries such as Ethiopia, Zambia and Zimbabwe have set up large-scale storage facilities in a bid to stabilise supply of grain over the year. Staple crop prices are also regulated occasionally, especially during periods when there is a deficit in production.

[22] Ekpa, et al.(2018) provides a comprehensive list of maize-based foods and their methods of processing/preparation.

- Cross-border trade seems to be strictly intra-regional. Surplus maize producers such as Uganda and Zambia only export maize and maize products within Eastern Africa and Southern Africa, respectively. This could be driven by different consumption preferences. Poor processing technologies also affect the quality of maize products, so that they cannot be traded on international markets.
- Trading of maize grain is more formalised than trade for processed maize products, probably due to established local and international systems for quality control of maize grain. Maize flour in contrast tends to be based on local quality standards.
- Government strategies to support certain crops help both local and regional crop businesses. For example, in 2016 the government of Uganda released a policy statement[23] regarding value addition in maize and other commodities such as coffee, fish, dairy, beef, beans, cotton, tea, and horticultural crops. On the other hand, the Zambian government has explored the potential of cassava as a supplement to maize, owing to its resilience in drought and other adverse weather conditions (JAICAF 2008, 14).

4.2.5 Opportunities for MG value-addition

Figure 8 shows the main energy-dependent activities along the rural maize VC, together with the electric machinery required at each stage of the VC and their power specifications.

	Production	Local Processing	Marketing
PUE Activities	• Irrigation • Animal fodder production • Drying • Shelling • Winnowing • Storage	• De-hulling • Dry milling • Wet Milling • Cleaning and packaging (whole grain /maize flour/maize bran)	• Flour fortification • Animal feed production • Cereal production • Baking • Brewing beverages • Making popcorn • Packaging
Machinery	• Irrigation pump (0.2kW) • Electric motor (up to 7.5 kW) • Shredder (0.2 kW) • Dryer (0.2 kW) • Sheller (0.2 – 1 kW) • Winnowing and sorting machine	• Huller (3 kW) • Plate mill / Hammer mill (0.75 kW - 7 kW) • Electric motor (up to 7.5 kW) • Packaging machine (2 kW)	• Flour mixer (1.1 kW – 3 kW) • Electric oven (6kW) • Brewing machines (up to 10 kW) • Packaging machine (2 kW)

Figure 8: Energy-dependent activities along the maize value chain in Sub-Saharan Africa

Opportunities in maize production

There are many opportunities for power from MGs to add value to maize production, particularly around the mechanisation and electrification of manual, post-harvest handling activities. As mentioned above, cultivation is often rain-fed, while post-handling activities are carried out manually. We have not found documentation on maize irrigation at a small-scale level, but MGs could potentially power water pumps for irrigation. Examples of mechanised activities that use electrically powered machinery include:

- Electric driers of grain can reduce moisture to the right levels before shelling, milling or storage;
- Electric shelling and winnowing machines can replace manual labour and speed up the process. Some winnowing machines come with sieves and screens to sort and grade the maize grain, and can be connected directly to milling machines. The utilisation of shelling machines typically fluctuates through the year, being higher during harvest and dry seasons when there is a high supply of maize grain, and lower during the rest of the year, owing to the reliance on rainfall for cultivation; and

[23] See policy statement from March 2016 by Uganda's Ministry of Agriculture, Animal Industry and Fisheries on http://csbag.org/wp-content/uploads/2016/05/POLICY-STATEMENT-FOR-THE-MINISTRY-OF-AGRICULTURE-ANIMAL-INDUSTRY-AND-FISHERIES-FOR-THE-FINANCIAL-YEAR-2016-17.pdf

- Electric shredding machines can improve the quality of animal fodder produced from maize stalk. The shredders can cut the stalk into finer pieces, making it easier to mix in other food substances for production of animal fodder.

Driers, shelling machines and winnowing machines could help farmers and local traders to improve the quality of maize grain. Millers can also use winnowing machines to screen maize grain before milling.

Opportunities in local processing and marketing of maize

There are numerous opportunities for MGs to add value to local processing and marketing of maize:

- Replace existing diesel-powered mills with electric ones. Examples of solar-powered mills available in the SSA market are provided in Appendix C.
- MG operators can offer milling services directly themselves in areas where these activities are not present. One MG in Uganda called Mandulis Energy buys maize grain and processes it into flour for sale to local communities (NREL & Energy 4 Impact 2018, 10). They also provide toll milling services to local households.
- Supply power to millers and local traders to package and brand their own products for the local market. A constant supply of maize grain is required for this to work.
- Provide non-electric value-addition opportunities such as central facilities for large-scale drying and storage of maize grain in order to allow supply of maize grain all year round.
- Introduce secondary processing activities for new maize products based on local dietary preferences and consumption trends. For instance, maize in East Africa is mainly consumed either in grain form or as flour, while in Nigeria it is more commonly consumed in the form of breakfast cereals. Corn bread is popular in Ethiopia, Nigeria and most parts of Southern Africa[24].

Other value-addition opportunities

By-products of maize, such as maize stalk and maize bran, can be utilised as animal feed or as feedstock for the generation of electricity and other energy products such as biofuels. Mandulis in northern Uganda, for example, sells maize bran to local businesses which produce bio-gasified briquettes for use in cooking stoves (NREL & Energy 4 Impact 2018). Using maize products as feedstock for energy production should only be done if they are not required as feed for livestock, and if there is a constant supply of the feedstock all year round.

4.2.6 Technical and economic considerations

Technical considerations

In addition to the points raised in Section 4.1.2, it is worth noting that machines used for milling maize can also be used for milling other cereals such as wheat, sorghum and millet. This can create economies of scale for the PU businesses and the MG operators because the same processing equipment can be used for multiple crops. Other equipment, such as hullers, are designed to be operated alongside milling machines. It is important to select the right size and specification for the hullers to match those of the milling machines.

Economic considerations

As noted in Chapter 3, there are no documented, site-specific studies that look at the business case for adding value to maize production and processing through power from MGs. To do this properly, it would be necessary to model the upfront capital costs of the milling equipment, the operational costs of the mill such as electricity, labour, local taxes, and storage costs, and map the local competition.

We do have some high level data. Figure 9 compares two business models for local, small-scale millers operating electric mills in East Africa. It shows that millers that offer both milling services and sell maize flour are likely to be more profitable

[24] Known as *dabo* in Ethiopia, *donkwa* in Nigeria and *chimodho* in Zimbabwe (Ekpa, et al. 2018, 49)

than those that just offer milling services. The breakeven MG tariffs for the more profitable milling and flour businesses are likely to be over double those for pure milling businesses.

Micro-Grid-Powered Electric Mill (Milling Services Only)

VARIABLES	VALUES	UNITS
Size of equivalent electric motor	10	kW
Amount of power consumed per day	20	kWh/day
Revenue from milling per day	10.80	$/day
Labor cost	3.12	$/day
Net profit to be maintained (diesel-based case)	1.34	$/day
Desired cost of power	6.34	$/day
Breakeven Tariff for Diesel Cost Equivalence	**0.32**	**$/kWh**
Breakeven Tarif for Profitability	**0.38**	**$/kWh**

Micro-Grid-Powered Electric Mill (Milling Services and Selling Flour)

VARIABLES	VALUES	UNITS
Size of equivalent electric motor	10	kW
Average daily operation	2	hours
Amount of power consumed per day	20	kWh
Revenue from milling per day	21.6	$/day
Labor cost	3.12	$/day
Net profit to be maintained (as per business as usual)	12.14	$/day
Desired cost of power	6	$/day
Breakeven Tariff for Diesel Cost Equivalence	**0.32**	**$/kWh**
Breakeven Tariff for Profitability	**0.92**	**$/kWh**

Figure 9: Break-even tariffs for millers

Source: (NREL & Energy 4 Impact 2018, 29)

Figure 10 shows how the value of maize per kilo increases by 35% from the farm gate to the processed maize flour and maize bran in Amuru district in Northern Uganda.

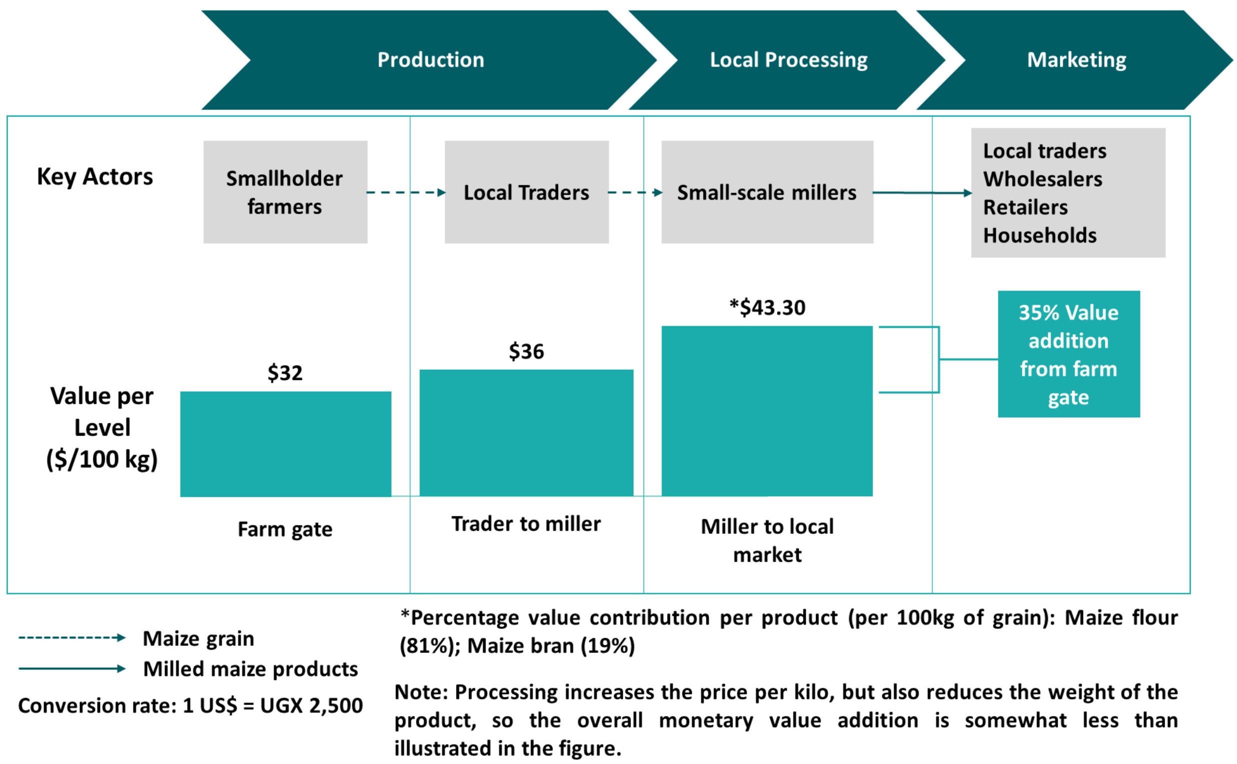


Figure 10: Value-addition of maize and maize products in northern Uganda in 2010

Adapted from (Dalipagic and Elepu 2014, 13-16)

Access to electricity can potentially reduce the operational costs of mills versus the diesel-powered equivalent. According to a TechnoServe study in northern Mozambique, millers with an electricity connection[25] charged about $0.08 per kilo of

[25] The study does not distinguish between grid and off-grid connections.

grain for de-hulling and milling, while those using diesel generators charged about $0.1 per kilo for the same services (TechnoServe 2009).

4.3 Sorghum and millet

Figure 11 shows the main activities in the rural sorghum and millet VC in SSA, including production, local processing and marketing.

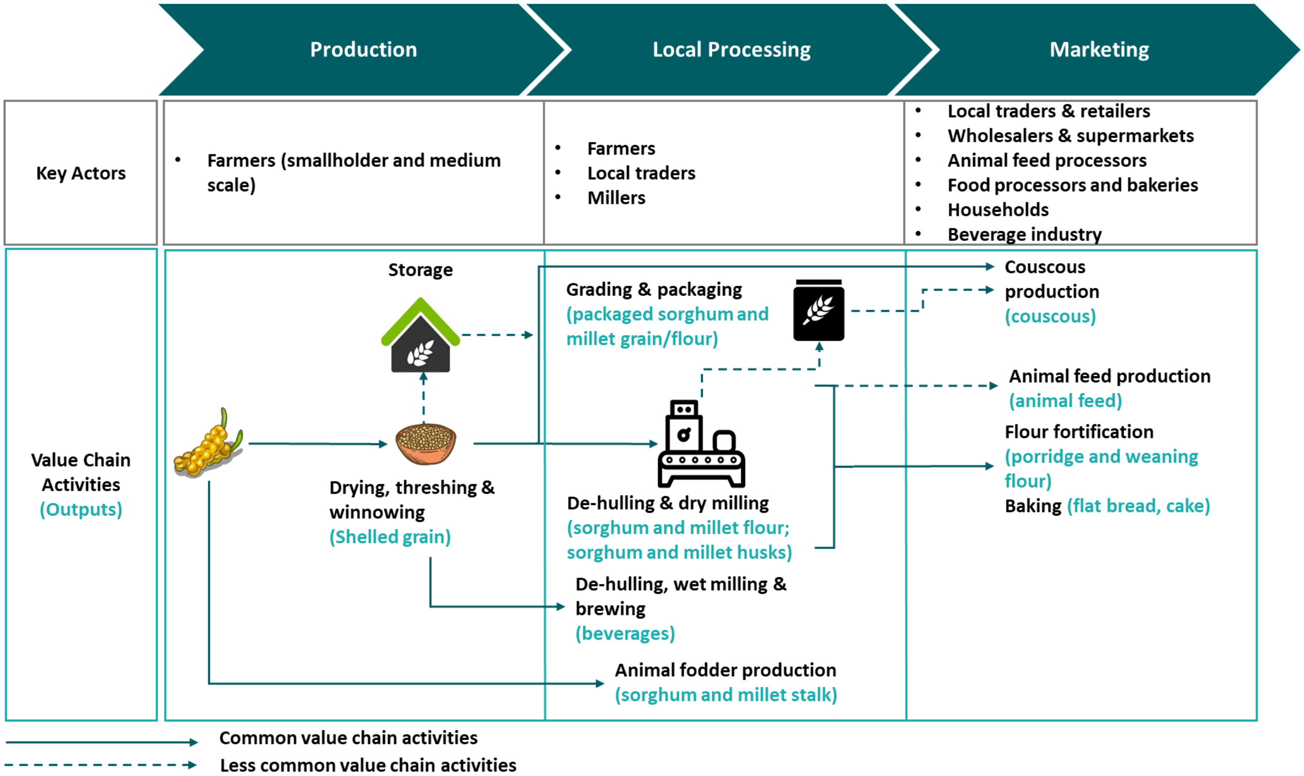


Figure 11: Sorghum and millet VC in Sub-Saharan Africa

4.3.1 Production

Sorghum and millet have been important staples in the semi-arid tropics of Africa for centuries. The two grains account for 56% of the area planted with cereals on the continent, and 41% of the region's cereal grain production – more than maize (36%) and rice and wheat combined (23%) (Rohrbach n.d.). Africa produces an average of 18 million metric tonnes of sorghum and 13 million metric tonnes of millet per year. Ethiopia and Burkina Faso are two of the highest sorghum producers in SSA and the world.

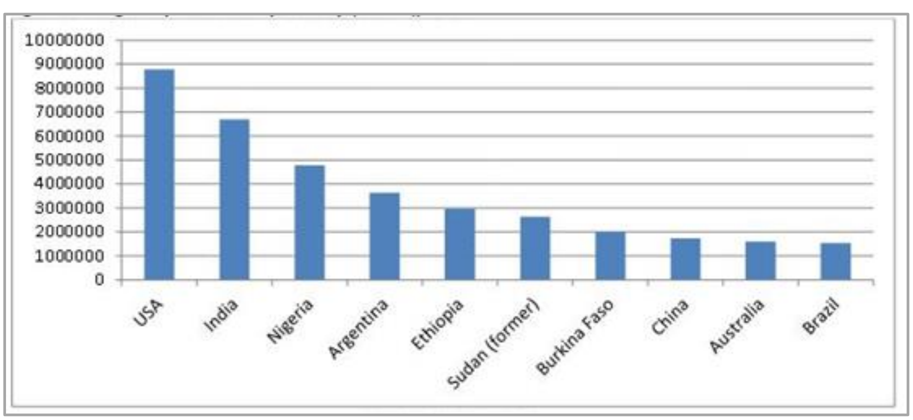


Figure 12: Sorghum production by country in tonnes (2012)

Source: FAOSTAT, 2012

Sorghum and millet are resilient to drier environments and are relatively nutritious, making them popular staple crops for the very poor (they are sometimes referred to as 'coarse grain' or 'poor people's crops' (FAO 1995)). Production is mainly carried out by smallholder farmers for subsistence use, using rain-fed means and using manual inputs. Less than 5% of locally produced sorghum and millet is commercially processed (Rohrbach n.d.). Local and international trade is also limited. Some countries such as Botswana, Nigeria, South Africa and Zimbabwe process sorghum and millet commercially for the beverage and animal feed industries.

Sorghum is the second largest crop produced across Africa after maize. Nigeria, Sudan, Ethiopia, Burkina Faso and Tanzania are the largest producers, accounting for about 75% of the region's production. Out of nine species of millet produced in Africa, pearl millet is the most popular making up 78% of total production[26]. The largest producers of pearl millet in SSA are Nigeria (41%), Niger (16%), Burkina Faso (7%), Mali (6.4%), and Senegal and Sudan (4.8% each) – see Figure 13 below.

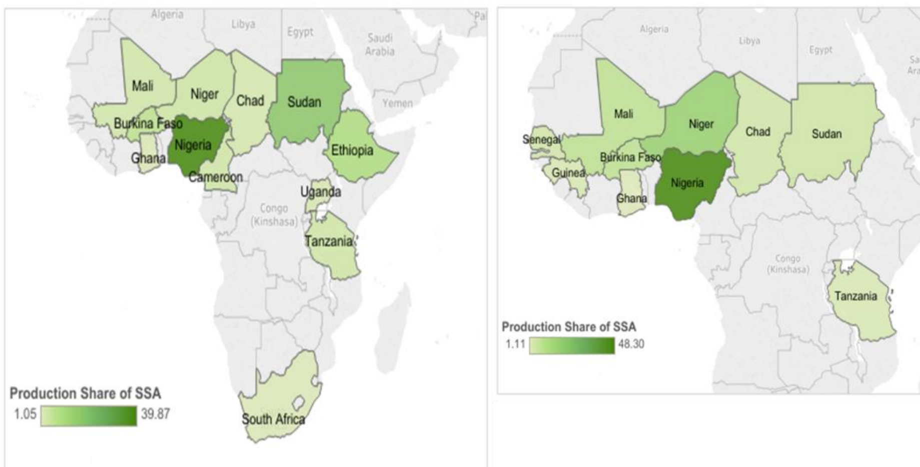


Figure 13: Major producers in Sub-Saharan Africa -– sorghum (left) and pearl millet (right)

Source: Harvest Choice

Western Africa produces the highest tonnage of sorghum in in SSA. In 2015 alone, the region accounted for 58% of total sorghum produced in SSA – see Figure 14 below. Western and Eastern Africa together accounted for 90% of sorghum produced that same year. Western Africa, however, had lower yields with 0.9 tonnes/hectare compared to Eastern Africa with 1.5 tonnes/hectare.

Production of millet follows a similar pattern to sorghum with Western Africa taking the lead followed by Eastern Africa. These two regions together contributed 93% of total millet produced in SSA in 2015 – see Figure 14 below. Eastern Africa had yields of 1.3 tonnes/hectare compared to 0.7 tonnes/hectare in Western Africa.

[26] Pearl millet is closely followed by finger millet (19% of total production), tef (9%) and fonio (4%). Finger millet is produced mainly in East and Southern Africa.

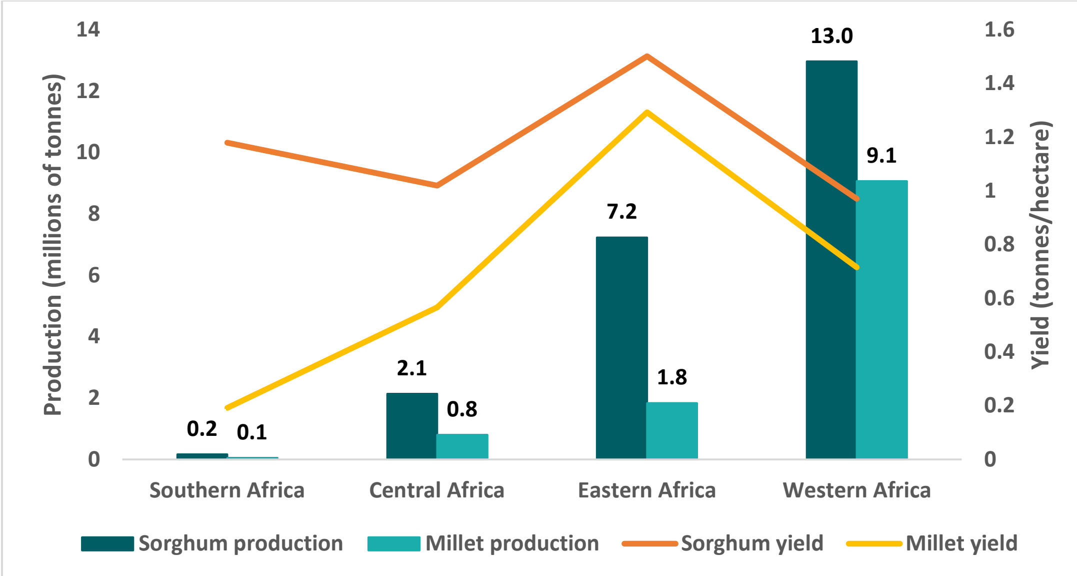


Figure 14: Sorghum and millet – production and yield in SSA regions (2015)

Source: FAOSTAT, 2015

Out of the 15 focus countries, Burkina Faso, Ethiopia, Mali, Niger and Nigeria are the largest producers of both sorghum and millet. Cameroon is a major producer of sorghum while Senegal and Uganda are major producers of millet. Figure 15 below shows sorghum and millet production in all 15 countries.

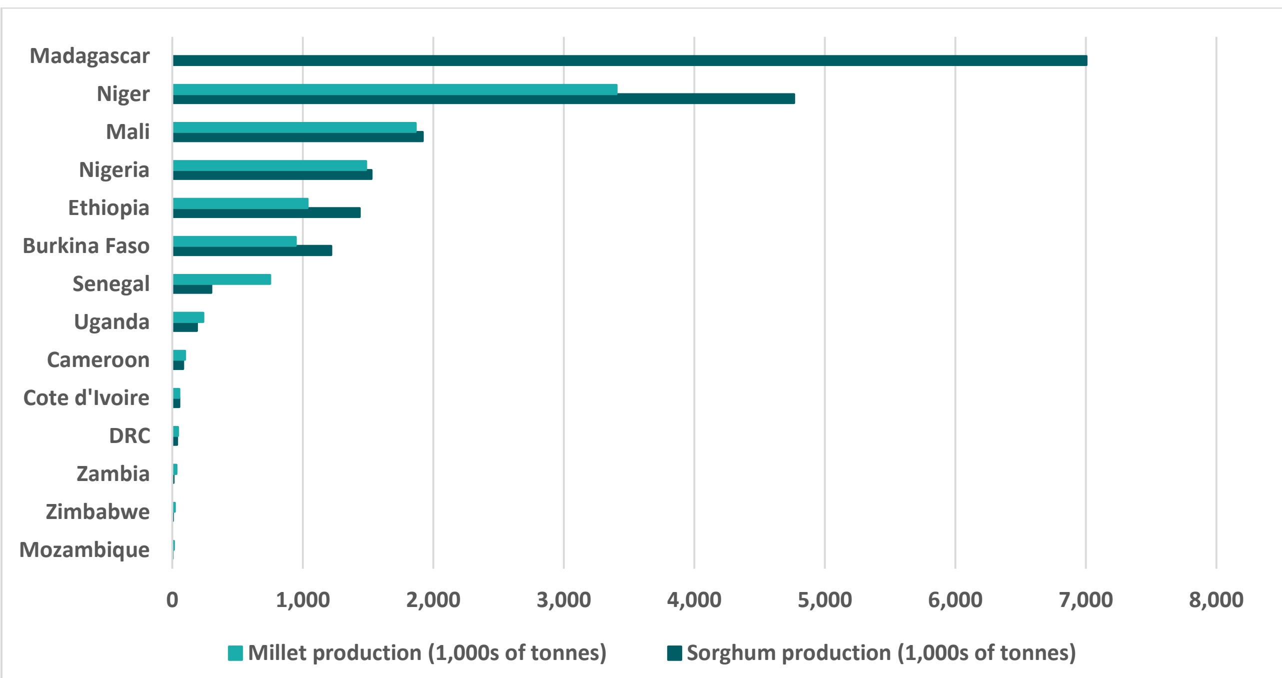


Figure 15: Sorghum and millet – production in target countries (2015)

Source: FAOSTAT, 2015[27]

As mentioned already, production of sorghum and millet is dominated by smallholder farmers relying on rain-fed means, with little irrigation or use of fertiliser and improved seeds. After harvest, the grains are dried by spreading them under

[27] No information can be found on sorghum or millet production in the Republic of Congo.

the sun for several days before they are threshed, cleaned [28] and stored or processed. This inefficient method of drying leads to post-harvest losses and low quality products. The stalks from the sorghum and millet crops are utilised as building materials for houses (roofs and walls) or as forage for animals.

Demand for clean millet is on the rise, from customers as well as processors. Threshing is usually carried out manually by using heavy sticks to beat the grains and separate them from their panicles. This is both time- and labour-intensive and can be a challenge when handling large quantities. The grains also get contaminated by foreign objects such as sand and stones during manual threshing. Cleaning the grains ensures a better quality product for the customers and prevents damage to processing machinery from the impurities. Though not common in most countries, cleaning is considered a critical step in countries such as Mali.

Drying is required before threshing, storage and milling of sorghum and millet, in addition to making couscous from millet[29]. The preparation of couscous can be labour-intensive. The millet goes through manual granulation before being steam-cooked and dried in open air. Using a mechanical dryer helps speed up the process, increasing productivity. Storage mostly takes place at the household level in enclosed silos or granaries with no temperature control. So far, we have not found documented information on large-scale, village level storage.

4.3.2 Local processing

Like maize, local processing of sorghum and millet can be done both at a primary and secondary level. The most common primary processing activities are de-hulling and milling of the grains. This is usually done in households by manually pounding with a mortar and pestle, or mechanically in small-scale grain mills similar to those used for maize.

Milling of sorghum and millet into flour is common in all the countries covered by this study. Technology ranges from using small, locally fabricated mills to modern mills run either mechanically or using diesel generators. Nigeria, for example, has a large number of small, diesel-powered mills (mostly hammer millers) that process maize, millet, sorghum and other cereals.

The husks from the grains are typically removed before milling and used as bran for animal feed, especially in the poultry sector. Rolling mills are used in the processing of animal feed or bran. Since milling at village level is mainly for household consumption, packaging is not a prominent activity. There is, however, potential for small-scale packaging of clean grains and flour by millers to sell to larger scale consumers, such as supermarkets and wholesalers.

The most common secondary level processing activities are: flour fortification to make porridge flour, infant flour mixes and baking flour; making of couscous; animal feed production; and brewing of alcoholic and non-alcoholic beverages. These activities are, however, regional and culture-dependent.

Sorghum and millet flour is used to produce a variety of popular, locally baked goods such as cake, flat bread and biscuits. Most of the baking is, however, done by women's groups or micro-enterprises selling processed products using traditional ovens or kilns. Sorghum and millet are increasingly being used for brewing alcoholic and non-alcoholic beverages, but this is usually done on a large scale to get economies of scale[30].

4.3.3 Marketing

Sorghum and millet are generally consumed at household level and only up to an average of 10% is marketed. The main forms of consumption are grain, couscous and flour. Sorghum and millet flour is often mixed with flour from other crops such as maize, teff and wheat to make porridge mixes, infant food and baking flour. There is also a sizeable market for sorghum and millet in the beverage industry and in the production of animal feed[31]. There is little information available on local consumption of millet and sorghum in SSA. This could partly be attributed to the fact that processing is carried

[28] Threshing is similar to the shelling of maize, only it involves removing the grain panicles from the stalk.
[29] Couscous is a popular product in West African countries such as Mali, Senegal and Nigeria.
[30] Common products include malts and lagers.
[31] More information can be found on http://www.afripro.org.uk/papers/paper02obilana.pdf

out primarily for household consumption and so may not be documented. The annual consumption of sorghum and millet in Niger and Mali is estimated at 100-200 kg/capita and 50-57 kg/capita respectively (FARA, IER & ZEF 2015, USAID 2017).

Rural assemblers operate in villages and small rural markets, and are the primary sales outlets. They transport and sell to local buyers such as wholesalers, retailers and consumers, as well as neighbouring urban and peri-urban markets. There is particularly high demand for ready-to-cook flour mixes in urban markets. Unlike maize, where there is demand from large-scale consumers, demand for sorghum and millet products is mainly from private households.

4.3.4 Drivers and challenges

Below we highlight key issues affecting the sorghum and millet sector, in addition to those mentioned in the overview section:

- Demand for sorghum and millet in SSA is mainly driven by the need for food security, particularly in dry and arid regions. This demand continues to grow due to population growth, which has subsequently led to an increase in the area used for production of these crops. Productivity per unit hectare, however, remains stagnant due to minimal use of irrigation, improved seeds and fertiliser.
- Household income plays a crucial role in the consumption patterns of sorghum and millet. In Ugandan households, for example, sorghum consumption drops by up to 60-80% as income levels rise. This is because sorghum is considered a “poor man’s crop” and therefore an inferior food. In contrast, sorghum in Ethiopia is regarded as a “status crop”, hence household consumption increases as income levels increase.
- The price of millet tends to be higher than sorghum due to its higher nutritional value, particularly for making flour mixes for children and infants. Millet is also used for making food and beverages for ceremonial occasions.
- Due to their popularity among lower income households, price changes in sorghum and millet tend to affect consumption significantly. In Ethiopia, for example, a 1% price increase in sorghum lowers consumption by around 0.6% (Gierend and Orr 2015).
- Because millet and sorghum are produced mainly for subsistence use and in small volumes, traders and processors find it financially challenging to purchase the crops in sufficient volumes for processing.
- Sorghum and millet tend not to get as much government attention as other crops and this often translates into less financial support from national research, agricultural and rural development programmes.
- Limited product diversity reduces the competitiveness of sorghum and millet.

4.3.5 Opportunities for MG value addition

Figure 17 describes the main energy-dependent activities and electric machinery used by the sorghum and millet businesses at different stages of the VC. Many activities are quite similar to those of maize and could share the some processing equipment, particularly for cleaning, winnowing, milling and packaging. Local traders and millers could potentially get involved in all three cereals with minimal additional capital costs for equipment. This might work in countries such as Ethiopia, Mali, Mozambique, Nigeria and Senegal, where the three cereals are grown together in some areas – please refer to the maps in Chapter 5.

	Production	Local Processing	Marketing
PUE Activities	• Irrigation • Drying • Cleaning • Threshing • Winnowing • Animal fodder production	• De-hulling • Dry milling • Wet milling • Cleaning and packaging (grain/flour)	• Flour fortification • Animal feed production • Couscous production • Baking • Brewing beverages • Packaging
Machinery	• Irrigation pump (0.2kW) • Electric motor (7.5 kW) • Mechanical dryer (0.2kW) • Cleaning machine (1.5kW) • Mechanical thresher (3kW) • Winnowing machine • Shredder (0.2 kW)	• Huller (3 kW) • Plate mill / Hammer mill (0.75 kW - 7 kW) • Electric motor (up to 7.5 kW) • Packaging machine (2 kW)	• Flour mixer (1.1 kW – 3 kW) • Electric oven (6kW) • Mechanical dryer (0.2 kW) • Brewing machines (10-20 kW) • Packaging machine (2 kW)

Figure 16: Energy-dependent activities along the sorghum and millet value chain in SSA

<u>Opportunities in sorghum and millet production</u>

Similar to maize, the main area where MGs can add value to the production of sorghum and millet is the electrification of post-harvest handling activities. Electric equipment can be used to improve and speed up threshing, cleaning and winnowing. Some cleaning machines can handle up to five tonnes a day. We have not found documented information on small-scale irrigation for these two cereals, but MGs could potentially be used to power water pumping for irrigation.

<u>Opportunities in local processing and marketing of sorghum and millet</u>

Very little primary processing of sorghum and millet takes place beyond milling, and then only in small quantities for household consumption. The by-products of milling are, however, commonly used for animal feed production. The most promising opportunities for MGs in this area include:

- MGs can supply power for de-hulling and milling activities to replace energy inputs from existing manual or diesel-powered milling machines.
- Since demand for high quality and ready-to-cook grains and flour is increasing, especially in urban areas, MGs can potentially provide power to local millers and traders for packaging their own products for sale to these markets.
- In some countries such as Nigeria, sorghum and millet is used for industrial beer making. For these businesses to be viable, the grain needs to be of a certain quality and consistency, and processing must be carried out on a relatively large scale.
- There is strong potential for animal feed production at village level, since there are existing local markets, particularly in the poultry industry. Rolling mills similar to those used in maize processing could also be used to produce animal feed at a small-scale level. Processors in Mali, Nigeria and Mozambique are diversifying into production of poultry feed from sorghum and millet. Demand for poultry feed depends, however, on the growth in demand for poultry and the reliability of supply of sorghum and millet husks.
- MG operators can invest directly in activities that require high energy and economic input, such as making beverages and medium- to large-scale animal feed processing. They can also introduce toll milling services for sorghum and millet and sell the flour to local communities in areas where these activities do not exist.

<u>Other value-addition opportunities</u>

Potential for using post-harvest sorghum and millet waste for energy production is low due to the competing uses for residue stalks and leaves to make livestock fodder. In Niger, for example, farmers leave the residue of the millet crop in the fields for cattle to graze. Sorghum and millet stalks are also important construction materials for fences, houses, and household compounds.

4.3.6 Technology and economic considerations

Technical considerations

As noted above, machinery used for maize processing can also be used for sorghum and millet, so the same technical considerations highlighted in the maize section apply here: seasonal variation of demand, load scheduling requirements, machinery replacement, portability of machinery, use of machinery with multiple crops, high start-up current, and operations and maintenance considerations. Certain mills come with grinding discs of varying sizes that can be interchanged to mill different cereals. It may be worth combining local, small-scale processing activities for sorghum, millet and maize where the crops are grown in the same area.

Economic considerations

Very little information exists on local costs and revenues for small-scale commercialisation of sorghum and millet, particularly processed products. This may be because both crops are produced, processed and consumed primarily for household consumption in rural areas. Any local trading is generally informal and therefore not documented. Prices also fluctuate seasonally and are often determined at point of sale, based on spot checks on quality.

4.4 Rice

Figure 17 shows the main activities in the rural rice VC in SSA, including production, local processing and marketing. The rice VC is quite different from maize, sorghum and millet, involving considerably more mechanical equipment, and this has important implications for MG value addition activities.

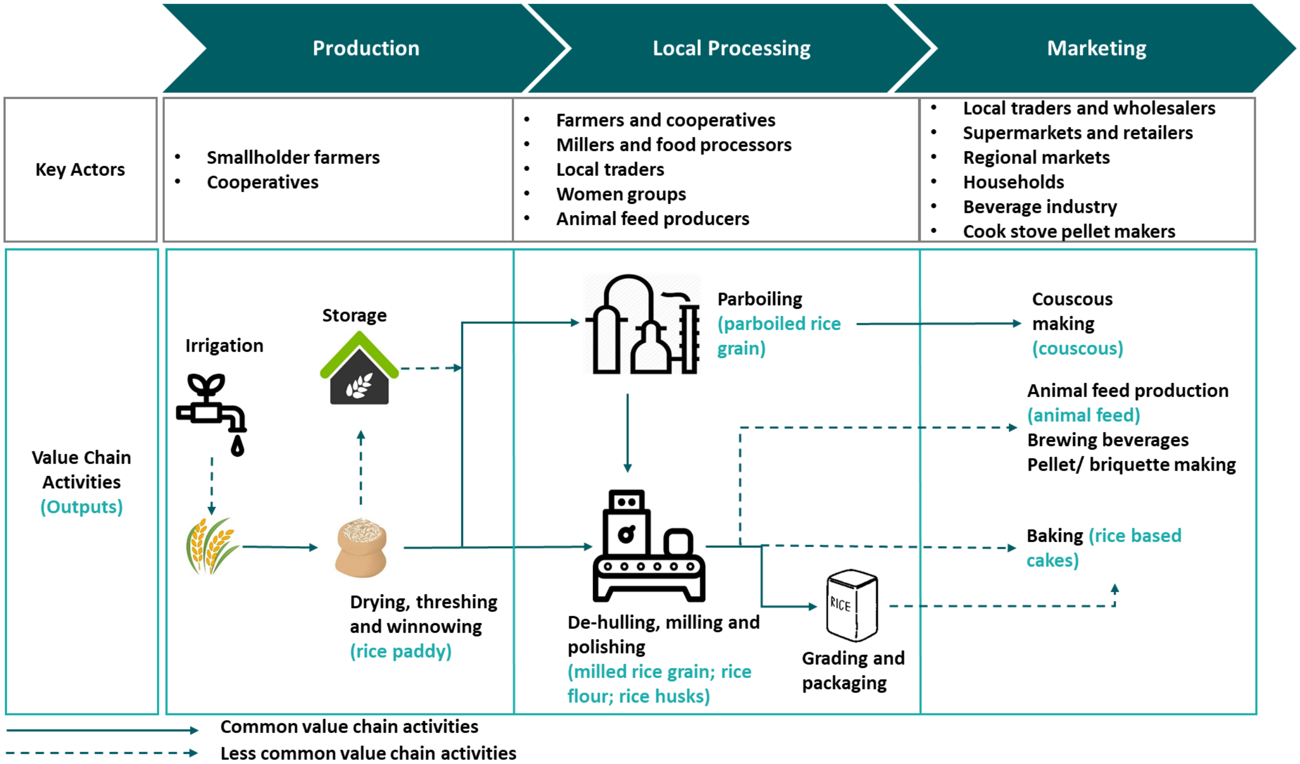


Figure 17: Rice value chain in Sub-Saharan Africa

4.4.1 Production

SSA produces 14.6 million tonnes of rice annually from a cultivated land total of 7.3 million hectares. This is 2.6% of total global production and 4.6% of the global land area dedicated to rice. Smallholder farmers dominate rice production, but larger scale producers, such as organised farmer groups and cooperatives, are also prevalent in Cameroon, Côte d'Ivoire, and Senegal. Cultivation is primarily rain-fed at a small-scale level. Due to the need for large amounts of water, there is scope for increasing productivity by up to 6x through irrigation (by allowing for two harvesting seasons a year, yields can be increased from 1 tonne/ ha to 6 tonnes/ ha).

Africa remains a net importer of rice, accounting for 20-30% of global imports, which translates to over USD 5 billion annually (Diakité, et al. 2012). Asia is the main supplier of white, aromatic rice to the African market[32]. Nigeria, Madagascar, Tanzania, Guinea and Mali are the highest producers of rice by area cultivated and by tonnes of production – see Figure 18. Countries such as Madagascar, Nigeria and Mali are self-sufficient producers, while Senegal and Côte d'Ivoire are deficit producers, i.e. they import more rice than they produce. With the exception of Senegal, any increase in rice production throughout SSA is usually driven by an increase in cultivated land, rather than an increase in productivity (Harvest Choice n.d., Stryke 2013). Rice is grown as a commercial crop in Eastern and Southern Africa, but it is a staple food in Western Africa.

[32] https://www.mordorintelligence.com/industry-reports/africa-rice-market

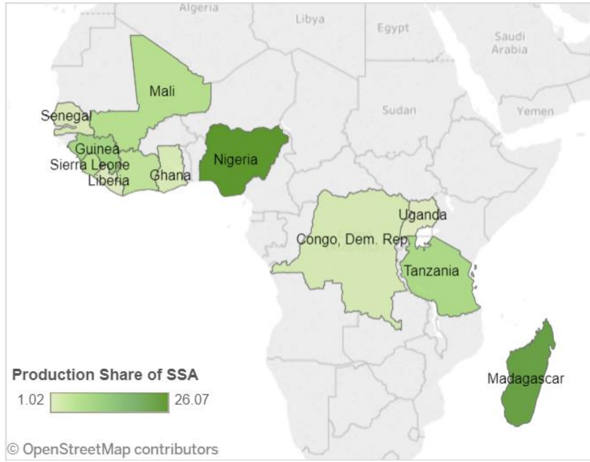


Figure 18: Major rice-producing countries in Sub-Saharan Africa

Source: Harvest Choice

In terms of regional production, Western and Eastern Africa are the major rice producers in SSA, accounting for 96% of rice produced – see Figure 19 below. Yields vary widely from 1.0 tonne/ha in Central Africa, 2.0 tonnes/hectare in Western Africa, 2.7 tonnes/hectare in Southern Africa and 2.9 tonnes/hectare in Eastern Africa.

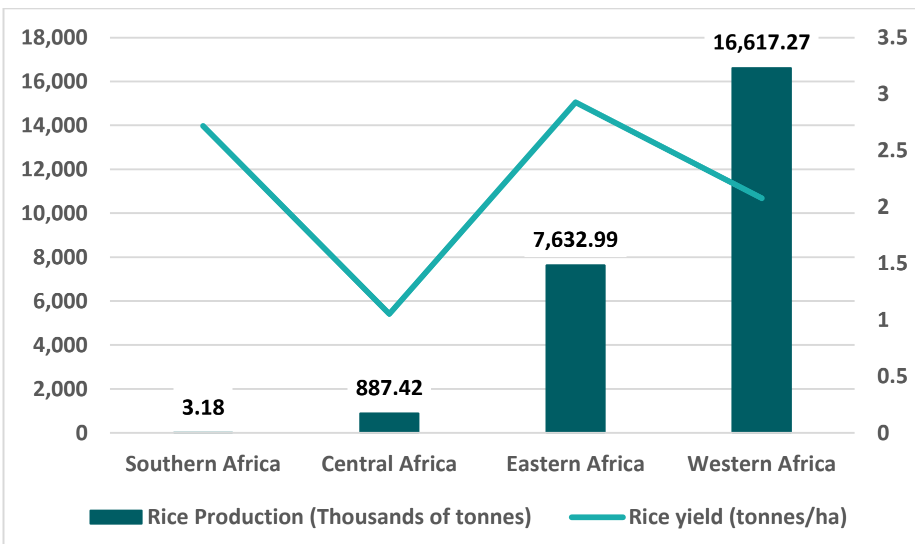


Figure 19: Rice production and yield in SSA regions (2015)

Source: FAOSTAT, 2015

Out of the 15 countries selected for this report, Nigeria, Madagascar, Mali, Côte d'Ivoire and Senegal are the largest producers of rice[33]. They contributed 90% of the 16.8 million tonnes of rice paddy produced by the 15 countries in 2015 – see Figure 20 below.

[33] In Côte d'Ivoire, rice production is mostly large-scale, so is likely to be less relevant for MGs.

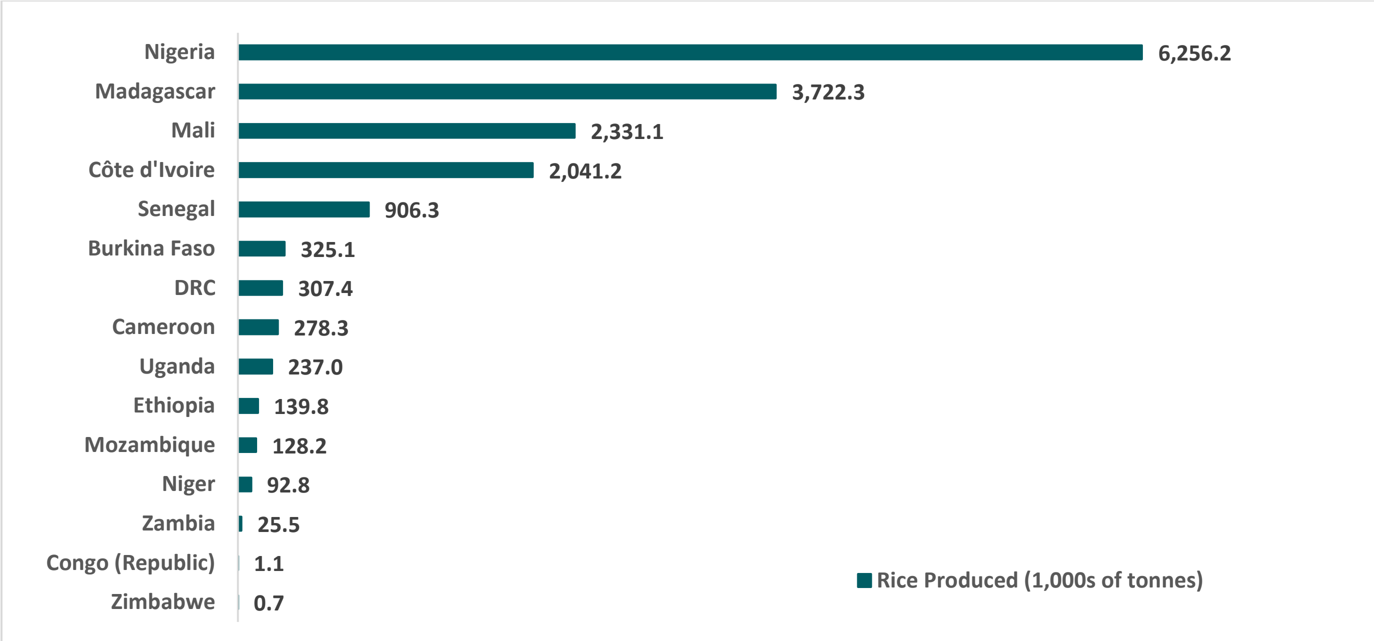


Figure 20: Rice production in focus countries (2015)

Source: FAOSTAT, 2015

As mentioned above, production of rice is dominated by smallholder farmers who cultivate their crops by rain-fed means and using manual inputs. Post-harvest activities, such as drying, threshing and winnowing of harvested rice paddy, are done manually in the fields. Threshing, for example, is done by hitting the panicles against a surface to remove the grain, which results in average grain losses of about 20% - 30% (Rickman, et al. 2013). Countries such as Burkina Faso and Madagascar have adopted hand and pedal threshers with threshing capacities of about 500 kg/day. Though they provide better outputs compared to manual threshing, these machines are still labour- and time-intensive. These processes can be improved by using motor-driven threshers.

Drying is typically done by spreading the paddy on the ground directly under the sun for a few days. This often exposes the grains to contamination by foreign material such as stones and soil, which affects the quality of the paddy being processed. It is also difficult to control the temperature[34] and drying duration. Over-dried paddy causes high levels of grain breakage during milling and consequently low milling yields (Rickman, et al. 2013), while under-drying leads to low extraction rates of milled rice (55-60%), production of powdered rice and frequent breakdowns in milling machines.

4.4.2 Local processing

De-hulling[35], milling, parboiling and packaging are the most common primary processing activities for rice at village level in SSA. Most small-scale millers provide milling services to households for a fee. They usually use single stage, steel huller mills, known as Engelberg mills, which are fabricated locally and run on diesel generators. These machines de-hull and mill the rice in a single stage, producing white rice (55%) and rice bran and husks (45%) (Rickman, et al. 2013). The latter can be utilised as animal feed. The Engelberg mills break down often due to the poor quality of their fabrication and insufficient maintenance. This can affect the quality of the rice, making it difficult to market the product in urban and other regional markets.

Some small- to medium-scale commercial millers use two-stage mills which contain separate chambers for de-hulling and polishing the rice. They are able to process over 250kg of paddy an hour (Rickman, et al. 2013). In the first stage, rubber rolls remove the husks from the paddy to make brown rice. The brown rice is then passed through a polisher that removes

[34] The ideal, ambient temperature required to reduce the moisture levels of rice to 12-14% (the appropriate moisture levels for storage and milling) is estimated to be 42^{0}C. Sun-drying temperatures can go up to 65^{0}C.

[35] Also referred to as de-husking in the case of rice.

the outer brown layer to make white rice and bran. This process leads to better quality rice and less breakage. These mills are normally not available locally, which poses challenges in operation and maintenance, especially since some components such as sieves and rubber rolls need to be replaced every few years to maintain good performance. Utilisation of these machines is therefore feasible only if there are local distributors of spare parts and if maintenance services are available locally.

Most countries in West Africa parboil their paddy rice before milling. This involves partial processing (soaking, steaming and drying) of paddy rice before milling it into white rice[36]. Parboiling softens the husk and hardens the rice grain, making it easier to de-hull and mill. It also sterilises the rice, increasing its shelf life.

Rice is usually packaged through manual loading into 50- 100 kg sisal or nylon bags. This process could be improved by using packaging machines with weighing scales.

4.4.3 Marketing

Consumers typically prefer long-grain, white milled rice, but broken rice is also widely consumed in Burkina Faso, Mali and Senegal. Smallholder farmers in SSA typically keep some rice for their own consumption and sell the excess to local markets, traders and middlemen, processors and mills.

Per capita consumption of rice is shown in Figure 21 below. Madagascar is the second largest producer and largest consumer of rice in the selected countries. While Nigeria is the largest producer of rice, consumption is relatively low compared to other West African countries.

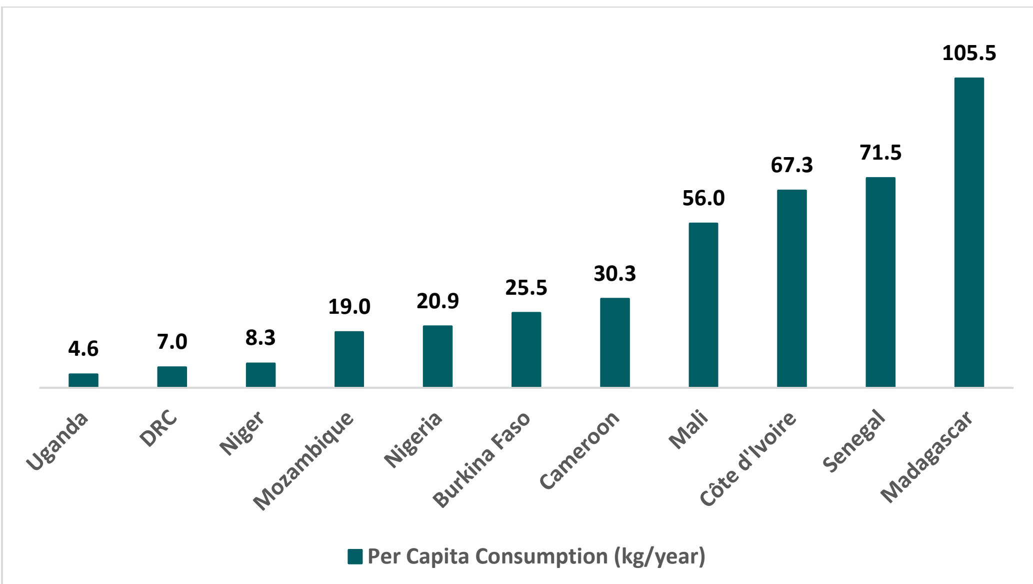


Figure 21: Per capita rice consumption in focus countries (2009)[37]

Source: Global Rice Science Partnership (GRiSP) 2013

In addition to milled rice grain, rice can be processed further to make rice flour. In countries such as Mali rice flour is used to make porridge. Rice bran is often used in the animal feed sector and, in some cases, as raw material for the production of briquettes and pellets for cooking. Countries such as the DRC make alcoholic beverages from rice. Unlike maize, sorghum and millet, secondary processing of rice is not widely practised in SSA.

[36] More information on parboiling of rice can be found on http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling/milling-and-quality/item/parboiling

[37] No information found on consumption in the Republic of Congo, Ethiopia, Zambia and Zimbabwe

4.4.4 Drivers and challenges

The rice VC in SSA is affected by poor processing infrastructure, limited or unreliable access to electricity, weak local business regulations and standards, inconsistent trade policies, and high transaction and financing costs. Please refer to Section 4.1 for more information.

4.4.5 Opportunities for MG value-addition

Figure 22 shows the main energy-dependent activities and electric machinery used by small-scale rice businesses at different stages of the VC. It should be noted that most of the machinery for processing rice is different to that used for other cereals.

	Production	Local Processing	Marketing
PUE Activities	• Irrigation • Drying • Threshing • Winnowing	• Parboiling • De-hulling • Polishing / Milling • Grading and packaging	• Baking • Animal feed production • Brewing beverages • Couscous making • Making briquettes and pallets for cooking
Machinery	• Irrigation pump (0.2kW) • Mechanical dryer (0.2kW) • Shredder (0.2kW) • Electric motor (7.5 kW) • Mechanical thresher (3 kW)	• Rubber Roll mill (0.2 kW – 1 kW) • Hammer mill (0.7 kW - 7.5kW) • Gelantinization/ Parboiling plant • Polisher (0.4 kW - 22kW) • Grader (1.5 kW) • Packaging machine (2kW)	• Flour mixer (1.1 kW – 3 kW) • Electric oven (6kW) • Pellet machine (4kW; up to 200kg/hr) • Brewing machines (10-20 kW)

Figure 22: Energy-dependent activities along the rice value chain in SSA

<u>Opportunities in rice production</u>

Rice production and post-harvest handling is becoming increasingly mechanised in SSA, particularly in West Africa where most of the rice is produced. Today most of the machinery is either operated manually or powered by diesel generators. There are many opportunities for MGs to add value to rice production:

- Replacement of diesel-powered irrigation pumps with electrical ones. Most of the diesel pumps in West Africa have capacities ranging from 150 m^3/hour to 1,500 m^3/hour (Rickman, et al. 2013). One of the challenges with replacing them with electrical pumps is that the irrigation is needed in the paddy fields, which may be located too far away from the village mini-grid.
- Electrification of manual and diesel-powered threshers. Locally fabricated hand, pedal and motorised threshers, have threshing capacities of up to 800 kg/h and are widely used in Burkina Faso, Madagascar, Nigeria and Senegal (Rickman, et al. 2013). Electrification of these machinery could potentially speed up the threshing process and reduce losses from manual threshing. It could also create business opportunities for medium-scale, stationery threshers capable of handling hundreds of kilos an hour.
- Electrification of mechanical dryers for paddy rice. Small-scale, flat-bed and batch dryers are already used for drying rice, but their low drying capacities (around 2-3 tonnes a day) and high capital costs make them less popular among farmers (Rickman, et al. 2013). Hot air mechanical dryers with temperature control and moisture level monitoring devices could improve rice quality by drying the paddy to the right moisture levels and also potentially dry larger quantities of paddy in a shorter period. Furnaces blowing hot air into flat-bed and batch dryers have been recently introduced in West Africa. They are mainly powered by the rice husks from milling. MGs could potentially electrify these drying furnaces so they have energy for drying paddy all year round. Larger commercial millers could consider using column dryers to achieve economies of scale.
- Non electrical opportunities such as central grain storage facilities to allow availability of paddy throughout the year.

Opportunities in local processing and marketing of rice

The most promising opportunities for value addition by MGs are in local processing and marketing of rice. Below are some examples of how MGs can help improve the quality of rice products and create new markets for rice products:

- Replacement of diesel-powered Engelberg and two-stage mills with electrical ones, potentially improving reliability and cutting energy costs.
- Connecting mechanical graders to the milling machines in order to separate whole and broken rice[38] and improve the quality of milled rice.
- Enabling larger scale millers to power multi-stage commercial rice mills which can handle 1-2 tonnes of rice an hour and are equipped with pre-cleaning, de-hulling, polishing, grading and packaging components. The success of such mills would depend on there being a reliable local supply of paddy and demand for milled rice all year round.
- Supplying power to local millers and traders to package and brand their own rice products, which would enable them to move into surrounding markets.
- Secondary activities such as baking, making couscous and brewing of beverages.

Other value-addition opportunities

The high energy content in rice husks makes them suitable for production of briquettes and pellets for use as fuel with cook stoves. Production of briquettes from rice husks is popular in West and East Africa. Rice husks have also been used for production of bio-gas through bio-gasification. The viability of energy production from rice husks depends on the level of competition from animal feed production (which also require rice husks) and if there is a reliable and constant supply of rice husks or other agricultural waste products all year round.

4.4.6 Technical and economic considerations

Technical considerations

The equipment for rice processing needs to be selected carefully. Factors to be considered include: the requirement for mobile machines e.g. irrigation, threshing and drying; the start-up current; the battery maintenance for DC and direct-drive machinery; seasonal variation of electricity demand; and certain factors that are unique to rice which are outlined below:

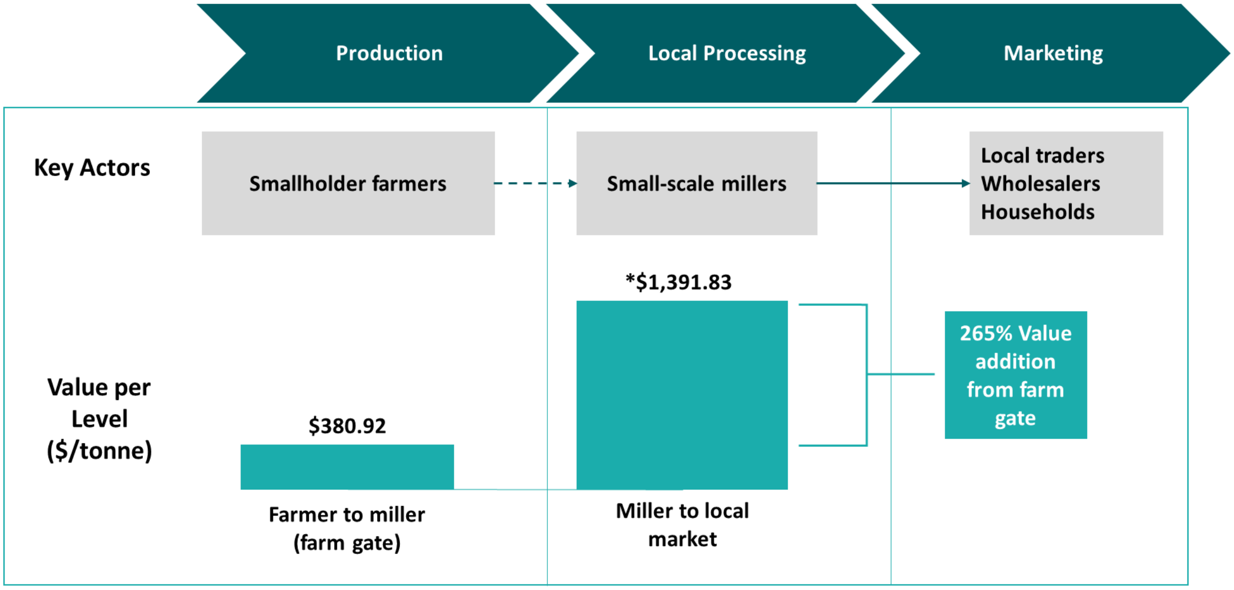
- Short rice straw should ideally be fed into mechanical threshers to increase efficiency and prevent the thresher from clogging.
- A good quality milling machine should yield rice with 40% rice breakage at most. The ideal grain moisture content for good quality milled rice is 12-14%. Higher moisture content may damage the machinery.
- Rubber rollers and sieves for two-stage mills need to be replaced after every 60-80 tonnes processed.

Economic considerations

There are a wide range of values for different milled rice products. The less broken the rice is after it is milled, the higher its price. In Nigeria, for example, milling converts paddy rice into four products: premium milled rice, normal milled rice, broken rice and rice bran and husks[39]. A small-scale miller in Nigeria with a total milling capacity of 0.5 tonne an hour can more than triple the price of rice per tonne by converting one tonne of paddy rice into milled rice products – see Figure 23 below. The story in Zambia is similar, with paddy rice costing about $78 per tonne, while milled rice is about $208 per tonne (Keyser 2007, Table 61).

[38] Graders with double screens have been introduced in Senegal and can be locally fabricated for use with both the Engelberg and two-stage mills (Rickman, et al. 2013)

[39] The percentage extraction rates per tonne of paddy rice are estimated as follows: premium milled rice (30%), normal milled rice (20%), broken rice (15%) and rice bran and husks (35%) (Tan 2016).



Rice paddy
Milled rice products

Aug 2016 Conversion rate:
1 US$ = NGN 315

*Percentage value per product per tonne of paddy milled:
Premium milled rice (42%); Normal milled rice (38%); Broken milled rice (19%); Rice bran (1%)

Note: Processing increases the price per kilo, but also reduces the weight of the product, so the overall monetary value addition is somewhat less than illustrated in the figure.

Figure 23: Value-addition of one tonne of paddy rice into milled rice in Nigeria (2016)

Adapted from (Tan 2016, 4-6)[40]

[40] This diagram is based on the following assumptions: total milling capacity of 0.5 tonnes/hour and an operating duration of 78 days a year (approximately 5 hours a day). The miller operates a single-stage milling machine and a de-stoner. They mainly purchase parboiled paddy rice from farmers, then sells milled products to local markets or to individuals at the mill. They also provide toll milling services, but this is limited to 8% of total daily milling capacity.

4.5 Fisheries

The fisheries and aquaculture sectors play an important role in Africa, with an estimated value of over USD 24 billion in 2011 (de Graaf and Garibaldi 2014). The WorldFish Center (2009) estimates that over 2.5 million people in Africa are involved in fish production, while 7.5 million are involved in trading and processing of fish. Fishing activities are generally defined by the fish habitats and scale of production. The three most common fishing activities in Africa are:

- **Inland capture fisheries:** fishing activities in natural inland fresh water bodies, such as lakes and rivers. Common commercial fish species in this category are the Nile perch, tilapia and the North African catfish.
- **Marine capture fisheries**: fishing activities carried out at sea. Marine fisheries can either be onshore (coastal) or offshore. This report focuses on small-scale coastal fisheries.
- **Aquaculture**: local breeding and culturing of fish. Aquaculture is still a fairly new concept in SSA, having been introduced in the 1950s. The most common fish for aquaculture are the tilapia, catfish, milkfish and trout. Growth in aquaculture in Africa has been slow due to insufficient investment and poor infrastructure, especially a lack of electricity supply.

In this report, we collectively refer to inland and marine capture as "fish capture".

Figure 24 shows a typical fisheries VC in SSA, with activities and potential entry points for MGs described below.

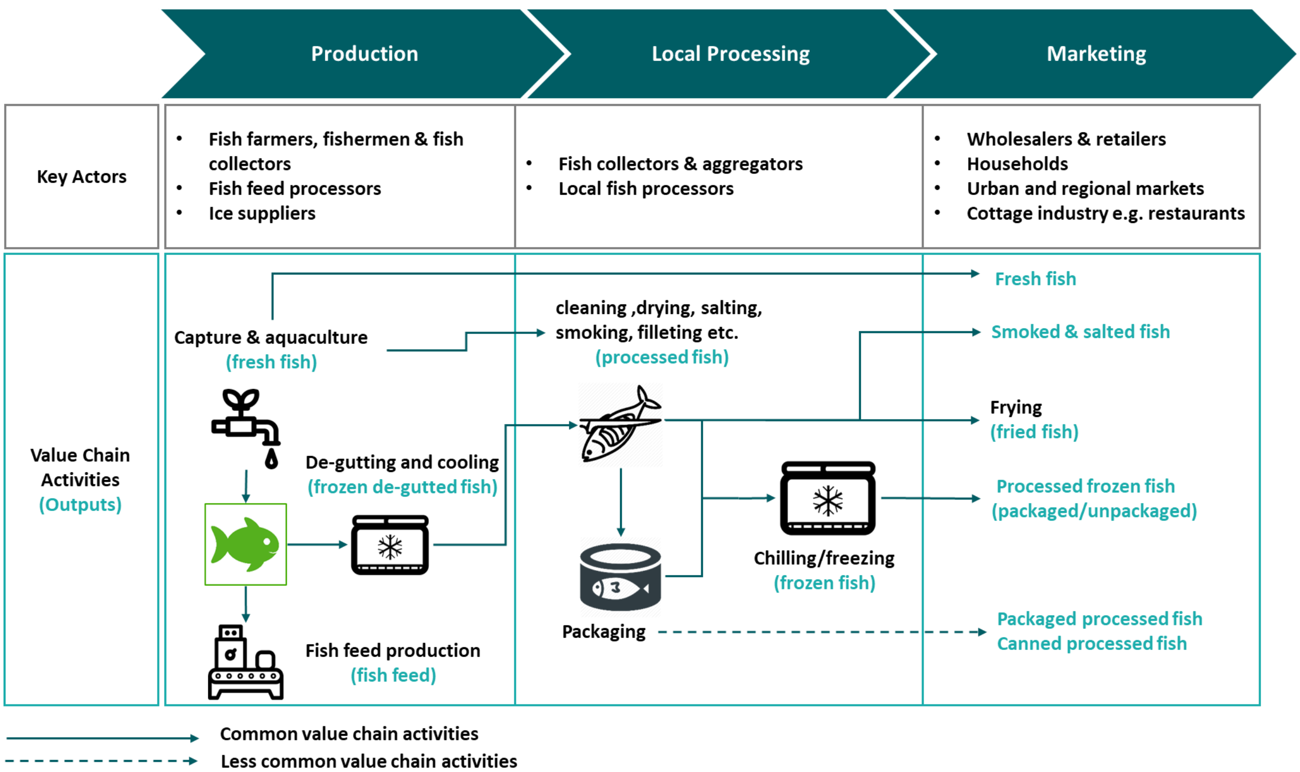


Figure 24: Fisheries value chain in Sub-Saharan Africa

4.5.1 Production

De Graaf and Garibaldi (2014) estimate that small-scale (artisanal) marine fisheries contributed to 0.43% of Africa's GDP in 2012, followed by industrial-scale marine fisheries at 0.36%, inland fisheries at 0.33% and aquaculture at 0.15%.

Fish capture

Africa has 9% of the world's fresh water resources, and supplies about 24% of inland fish production in the world (Gordon, Dugan and Egerton 2006). There are approximately 25 large river basins, the most significant for inland capture being the

Great Rift Valley, Lake Tanganyika, Lake Malawi, Lake Victoria, the Sudd Swamp, the Congo River Basin, the Zambezi Basin and Lake Kariba, the Lake Chad Basin and Niger River (Neiland, et al. 2005, WorldFish Center 2009) [41]. The majority of fresh water resources for inland fishing are found in the far north, south and east of Africa due to higher precipitation levels.

Inland fisheries are important for the economies of countries such as the DRC, Mali, Uganda and Chad, in some cases accounting for over 5% GDP (Neiland, et al. 2005, de Graaf and Garibaldi 2014). Uganda, Tanzania, the DRC, Nigeria and Kenya are the highest inland, freshwater fish producers in SSA, in that order. The five countries produced 62% out of a total 2.2 million tonnes of freshwater fish produced in SSA in 2007 (Gordon, Finegold, et al. 2013).

Artisanal marine fisheries play a significant, economic role in West Africa and Southern Africa. South Africa, Namibia, Senegal, Nigeria, Angola, Ghana and Mauritania are the top marine fisheries producers in SSA. The seven countries accounted for 74% of a total 3.4 million tonnes of fish produced in SSA in 2007 (Gordon, Finegold, et al. 2013).

Out of the 15 countries selected for this report, Nigeria, Senegal, Uganda, Mozambique, the DRC and Cameroon are the highest producers of fish by inland or marine capture. Each of these countries produced over 200,000 tonnes of fish by inland capture in 2016, contributing to 85% out of a total 2.8 million tonnes produced in the 15 countries – see Figure 25 below.

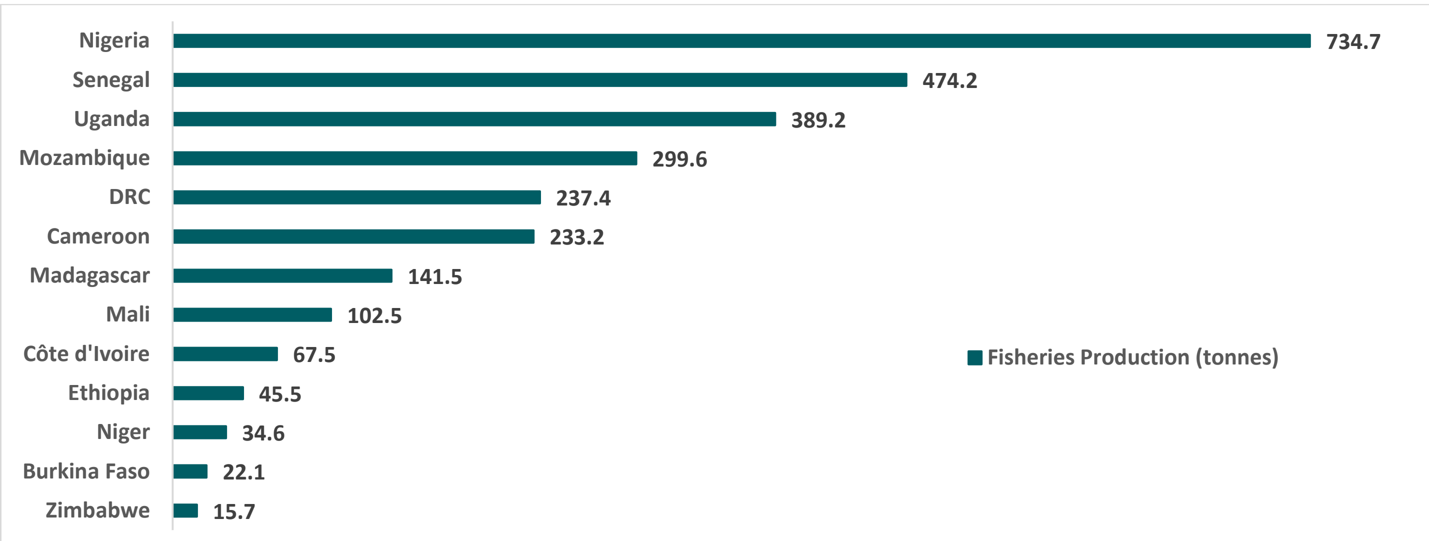


Figure 25: Inland and marine capture production in target countries (2016)[42]

Source: (FAO 2018)

Inland fish capture is dominated by small-scale, artisanal fishers who use low quality tools[43] and target household consumers and other local markets (Gordon, Dugan and Egerton 2006, Neiland, et al. 2005). Most of the production, processing and trading is informal and not properly documented in national records (Kolding, et al. 2016, AU-IBAR 2012, Neiland, et al. 2005). Some high-value fish, such as the Nile Perch in Lake Victoria, have well established and formalised large-scale processing and marketing systems, although the supply still mainly comes from artisanal fishers. Due to seasonal fluctuation in fish availability and other weather-related issues such as droughts and floods, those catching fish often also carry out agricultural activities, such as crop and livestock farming, as a way of diversifying income (Gordon, Dugan and Egerton 2006, Kolding, et al. 2016). This also applies to the marine fisheries and aquaculture sectors.

[41] Gordon et al (2009) and the Indian Ocean Commision (IOC) (2012) provide detailed information on fish by geographic location, species and production in these freshwater bodies.

[42] No information found on inland and marine capture and aquaculture in Zambia and the Republic of Congo.

[43] Examples include undecked canoes with outboard motors, and barrier fishing traps which can only be operated from river banks or lake shores.

Marine fish capture is typically carried out in SSA on a small-scale in coastal areas, rather than the large-scale, deep-water capture prevalent in developed countries. Rural fishing communities in SSA cannot generally afford the sophisticated equipment needed to carry out deep-water capture. As a result, many small-scale fishers fish close to the coast, which can lead to over-exploitation of fish in these areas (Gordon, Finegold, et al. 2013).

In both inland and marine capture, farmers typically fish in the evenings or late nights and sell the fish to fish collectors or traders during the early hours of the morning. Most farmers do not have proper fish preservation facilities, such as freezers or coolers, so they need to sell fish as soon as they catch it before it goes bad. Collectors typically purchase fish from the fishermen and gut it, before selling it fresh to local markets, frozen to processors, or dried or salted to local consumers.

Aquaculture

Western and Eastern Africa account for the bulk of aquaculture production in SSA. In 2014, these regions together were responsible for 98% of the 557,000 tonnes produced and 95% of the monetary value in SSA – see Table 4 below.

Table 4: Aquaculture production in Sub-Saharan Africa (2014)

Region	Production (tonnes)	Value (USD 1,000)
Central Africa	4,352	14,068
Southern Africa	5,921	61,433
Eastern Africa	185,821	522,411
Western Africa	360,857	977,685
Total	**556,951**	**1,575,597**

Source: Adapted from Table 2 in Satia (2017)

Nigeria, Uganda, Kenya, Ghana, Zambia, Madagascar, Zimbabwe and South Africa are the top aquaculture producers in SSA (Gordon, Finegold, et al. 2013, Kolding, et al. 2016, Satia 2017). With the exception of Nigeria and Uganda, each of the other SSA countries contributed less than 5% of total fish captured in 2011, as shown in Figure 26. Aquaculture's contribution to SSA's GDP is negligible, with estimates ranging between 0.001% and 0.7% (Kolding, et al. 2016). It is, however, important at household and community levels, although this is often not documented in national records because these activities largely remain informal (Kolding, et al. 2016, AU-IBAR 2012). De Graaf and Garibaldi (2014) estimate that aquaculture employs 0.9 million people out of 7 million working in the fisheries and aquaculture sectors in Africa.

Country	Metric Tons	Percentage
Egypt	986,820	70.6%
Nigeria	221,128	15.8%
Uganda	85,713	6.1%
Kenya	22,135	1.6%
Ghana	19,092	1.4%
Zambia	10,530	0.8%
Madagascar	8,835	0.6%
Tunisia	8,126	0.6%
Zimbabwe	7,602	0.5%
South Africa	3,573	0.3%
Others	24,539	1.8%
Total	1,398,093	100.0%

Figure 26: Aquaculture production – top countries in Africa (2011)

Source: Gordon, Finegold, et al. (2013)

As Figure 26 shows, aquaculture is not widespread in SSA. This can be partly explained by the relatively high capital and operational costs of aquaculture production which make it less competitive with inland and marine fisheries.

Nigeria, Uganda, Madagascar and Zimbabwe are the largest aquaculture producers out of the 15 countries selected for this report – see Table 5. The four countries accounted for 98% of the 479,000 tonnes of fish produced through aquaculture in 2016.

Table 5: Aquaculture production in focus countries (2016)

Country	Aquaculture Production (tonnes)
Nigeria	306,727
Uganda	118,051
Madagascar	25,995
Zimbabwe	10,085
Côte d'Ivoire	4,701
Mali	4,194
DRC	3,161
Cameroon	2,315
Senegal	2,079
Mozambique	1,180
Burkina Faso	470
Niger	300
Ethiopia	95

Source: FAO (2018)

Aquaculture is practiced in three environments: freshwater (inland), brackish water, and marine water(coastal). Most artisanal farmers practice inland freshwater aquaculture (Satia 2017), usually along with other activities such as crop and animal farming. Farmers in countries such as the Nigeria, Uganda and DRC farm fish along with vegetables, poultry and pigs, as they provide material for the production of fish feed. Aquaculture is also integrated with rice farming in countries such as Madagascar, Burkina Faso, Mali and Nigeria. Marine aquaculture is still new in SSA and is limited to countries such as Madagascar and Mozambique that have coastlines.

Aquaculture and inland fisheries are particularly important to landlocked countries such as Uganda since they are the only forms of local fish production. One of the advantages of aquaculture is its low susceptibility to seasonal availability of fish, which helps to minimise over-fishing during lean seasons and allows for a constant supply of fish throughout the year.

Aquaculture farmers typically purchase fingerlings for breeding and hatching, or catch young fish in freshwater or coastal waters for culturing. Fish is usually cultured in cages, earthen or dam ponds, or concrete or earthen-lined tanks. Cages are the most common and possibly the most profitable of the three fish culturing systems due to their lower capital costs and because the fish are placed in publicly available water (Satia 2017). Ponds are common in some countries such as Côte d'Ivoire and Cameroon. Improved systems using land-based pump and recycling systems are also used in some higher fish-producing countries such as Nigeria and South Africa, but the lack of reliable grid power can make it difficult to sustain production.[44] The lack of reliable power is also a problem for incubation and hatching of fingerlings. Some farmers get

[44] Water has over 30 times less oxygen than air. This concentration reduces with increased temperature, so stagnant, warm water has much lower oxygen levels. Fish using more energy for respiration have less energy to grow, and this can lead to stunted growth and productivity (Kolding, et al. 2016).

round this problem by using diesel generators, but this increases production costs. In Mozambique they use a less common system of production, known as the "tie-tie" system[45], based on seaweed culture.

4.5.2 Local processing

Local processing of fish typically involves primary processing activities such as gutting, drying, smoking and salting, and secondary activities such as filleting, packaging and canning. Due to the highly perishable nature of fish, fishers and farmers need to either sell their produce immediately after capture or preserve it before selling it to other market actors such as collectors and processors. Primary processing is therefore mainly used to preserve the fish before it reaches the target market. Secondary processing is typically carried out by local processors to add value to the fish for distribution to distant domestic and international markets.

The method of processing is largely dictated by the type and size of fish. Smaller sized fish, commonly referred to as pelagic fish, are generally easier to process by drying and salting. Larger fish are processed through smoking, filleting and packaging. In areas where cold storage is available, larger fish are also stored in freezers or tanks filled with water and ice and sold to collectors or processors in frozen or chilled form. Most collectors purchase ice blocks and manually crush them into smaller pieces appropriate for fish preservation. The use of inappropriate tools for crushing ice poses a safety threat to collectors and exposes the fish to contamination from dirt and bacteria, which then affects the quality of the fish. It is possible to use electrified ice-makers and crushers to generate suitable amounts and sizes of ice flakes for fish preservation[46]. Table 6 summarises common local processing methods for different types of fish in Eastern and Southern Africa.

Table 6: Local processing methods for fish in Eastern and Southern Africa

FISH GROUP	COMMON EXAMPLES (BY LOCAL NAMES)	METHODS OF PRODUCTION	COMMON LOCAL PROCESSING ACTIVITIES	COMMON MARKETS WITHIN SUB-SAHARAN AFRICA
Small pelagic	Dagaa/Omena/Mukene, Kapenta, Chisense, Muziri, Ragoogi	Inland capture using nets	**Primary**: Artisanal salting, sun-drying, deep frying and smoking, or commercial milling into fish powder (for human or animal consumption). **Secondary**: Canning and freezing into value packs (Kapenta).	Local and international **Exports**: Mozambique, Tanzania, Zambia **Imports**: Botswana, Burundi, Kenya, Malawi, Mozambique, Namibia, Rwanda, South Africa, South Sudan, the DRC, Zambia, Zimbabwe
Perch Fish	Nile Perch (East Africa), Tangayika Perches (Lake Tanganyika)	Inland capture using gillnets or hooks.	**Primary**: Artisanal gutting, salting, sundrying, smoking and deep-frying, or cold chain preservation before commercial processing. **Secondary:** De-gutting, de-heading, filleting , and packaging to chilled or frozen fresh fish and fillets, head and gutting, and fish-maw products.	Local and international **Exports:** Kenya, Tanzania, Uganda, Zambia **Imports:** Burundi, Egypt, Rwanda, Sudan, the DRC
Tilapia		Inland freshwater capture using gillnets, handlines, baskets and cast nets Inland freshwater aquaculture	**Primary:** Artisanal gutting, salting, sundrying, smoking and deep-frying, or cold chain preservation before commercial processing. **Secondary:** De-gutting, filleting , and packaging to chilled or frozen fresh fish and fillets.	Local and international **Exports:** East African countries **Imports:** Kenya, Rwanda, South Sudan, the DRC, Zambia
Alestes		Inland freshwater capture using gillnets	**Primary:** Artisanal gutting, salting, sundrying, and smoking (for less quality fish). **Secondary:** packaging to chilled or frozen fresh fish.	Local and international **Imports:** South Sudan, the DRC
African Catfish		Inland freshwater capture using longlines and basket traps.	**Primary:** Artisanal gutting and smoking. **Secondary:** steaking, filleting, heading, gutting, skinning, and production of fish sausages (new activity).	Local and international **Exports:** Tanzania, Zambia **Imports:** Angola, Kenya, Sudan, South Africa, the DRC, West and Central Africa
The Rainbow Trout		Inland freshwater capture using hook and line, gillnets and other angling methods. Inland freshwater aquaculture.	**Primary:** Artisanal gutting and smoking. **Secondary:** Filleting, packaging of chilled or frozen fillets/whole fish, or canning.	**Local:** Kenya, South Africa and Zimbabwe (driven mainly be tourism).
Freshwater Shrimp	Caridina nilotica	Inland freshwater capture using nets (usually as a by-catch from capture of small pelagic fish)	**Primary:** artisanal sundrying, or commercial chilling or freezing of fresh shrimp. **Secondary:** Animal feed production	**Local:** Little demand from local households. Demand mainly from the tourist cottage industry and animal feed processors.
Crayfish	The Louisiana crayfish, the Maroon (Cherax tenuimanus), the Yabbie (Cherax destructor), and the Cherax quadricarinatus.	Inland freshwater capture using baited wood or steel traps. Inland freshwater aquaculture (South Africa, Zambia and Zimbabwe)	**Primary:** Specialised storage at moist temperatures of 4-8 ºC. **Secondary:** steaming, fried, and baking.	**Local:** South Africa and Zimbabwe. Demand mainly from the local tourist cottage industry and animal feed processors.

[45] Seaweed is tied to about 20 meters of rope stretched between pegs for fish to feed on. This mainly applies to fish cultured in lagoons (Satia 2017).
[46] More information is provided in the 'Opportunities for MG value-addition' section.

Source: (IOC 2012)

Ready-made fish or animal feed is not widely available in rural areas and is relatively expensive. Local fish producers therefore often use domestic organic and agricultural waste (including the by-products of gutting) to make their own fish feed using small-scale milling and pelleting/grinding machines as a more economical alternative (Kolding, et al. 2016). The resulting feed is often of low quality, resulting in low fish productivity[47].

Commercial-scale fish feed production is growing in countries such as Nigeria and Uganda, as a result of the growing aquaculture market and government intervention (Satia 2017). This is likely to lead to higher quality fish feed being produced locally[48] and opportunities for electrical machines powered by MGs.

4.5.3 Marketing

Fish consumption in Africa is around 9.7kg per person per year, which is about half the global average (Kolding, et al. 2016). Fish accounts for over 50% of total animal protein in household diets in countries such as the DRC, Gambia, Ghana, Guinea, Equatorial Guinea, Sierra Leone and Togo (Neiland, et al. 2005).

Figure 27 shows the consumption of fish per capita in our 15 focus countries. Consumption of freshwater fish is much higher than marine fish in all the countries except Côte d'Ivoire, Burkina Faso and Mozambique.

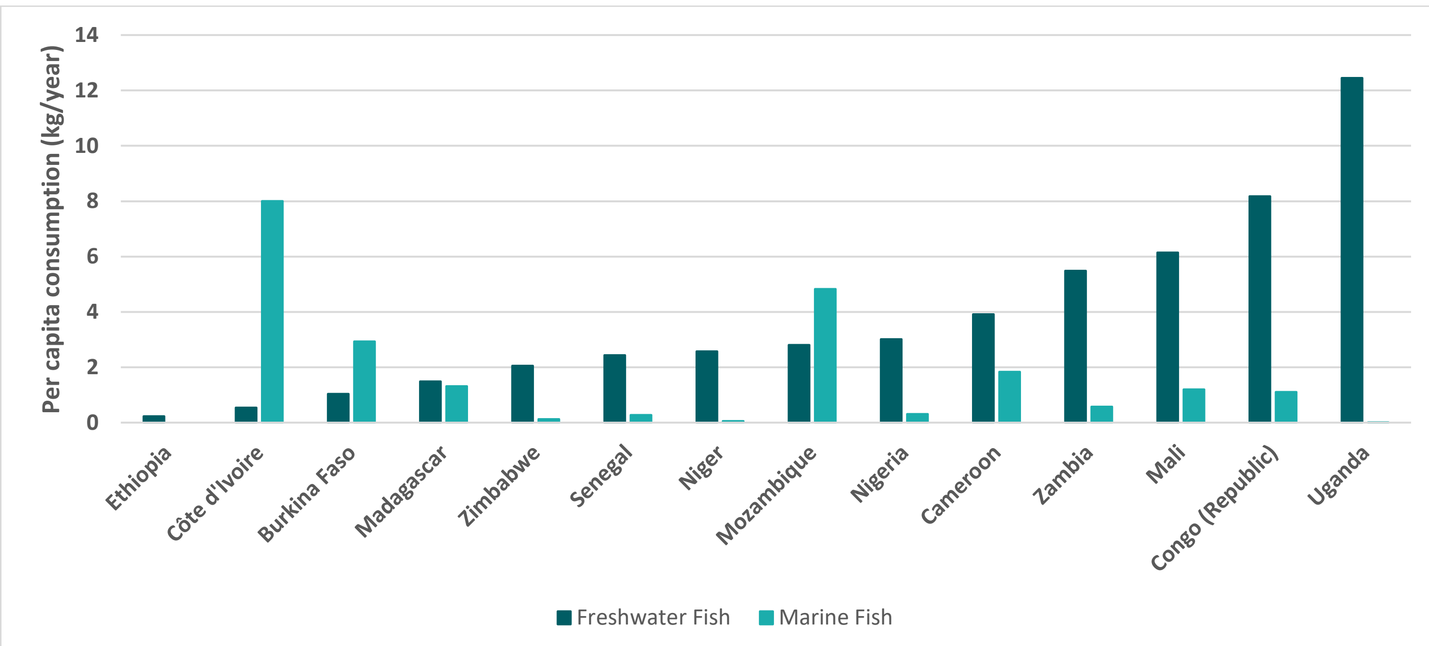


Figure 27: Per capita fish consumption in the 15 target countries (2013)[49]

Source: FAOSTAT (2013)

Fish is a major contributor to the nutritional and dietary needs of most low income households in SSA, since it tends to be the lowest priced animal protein available (Satia 2017). Fish is purchased whole or in small chunks. Some countries such as Burkina Faso create a sauce out of the fish and use it to flavour food.

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[47] Issues arising from artisanal production of fish feed include low digestibility, due to use of the wrong ingredients, and low feed conversion ratios, due to most of the feed sinking to the bottom or dissolving in the water.

[48] Small, pelagic fish and other fish by-products are particularly good sources of protein for carnivorous fish such as the Nile perch (WorldFish Center 2009).

[49] No data found for consumption in the DRC.

Like cereals, fish produced in rural areas is often traded locally within the communities, in nearby markets, or across neighbouring countries and regionally. Unlike cereals, however, trading of fish across countries and regions seems to be more prevalent, owing to better-established formal and informal trading systems (Gordon, Finegold, et al. 2013, Kolding, et al. 2016). Figure 29 shows common marketing channels in SSA.

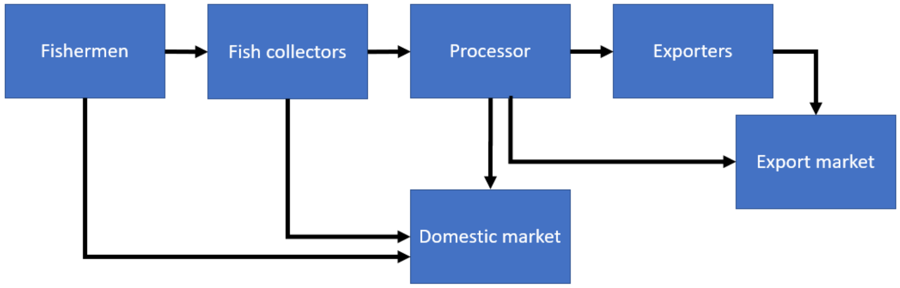

Figure 28: Common fish marketing channels in Sub-Saharan Africa

Source: Hempel (2010)

Most farmers sell fish whole to collectors and local traders straight after capture or harvesting to reduce the costs of preservation. Fresh fish is also preferred by local collectors and traders, because it fetches a high price in the local market. Collectors often sell to local processors, since they tend to buy in bulk. Local traders, on the other hand, gut and sell the fish to local wholesalers, retailers and processors, or use artisanal methods to process and sell it to local consumers. Local traders divide larger fish into smaller chunks to make it affordable to local households. Artisanal, primary processing activities such as drying, salting, smoking, milling into powder and fermenting, help to preserve the fish, which is useful in areas with no access to electricity for cold storage or where traders and consumers cannot afford fridges or freezers for storage (Neiland, et al. 2005, IOC 2012).

Local prices can fluctuate widely and depend on negotiations and spot checks for quality at the points of sale. This especially applies to cooled or chilled and fatty or smoked fish, which have short shelf lives (IOC 2012). Larger fish tend to be sold by weight, whilst small pelagic fish are sold by volume.

Fish that has gone through secondary processing, such as filleting or packaging, is traded through more formal channels and often sold to more distant markets in the city or exported. Larger processors are the primary actors here because they have the financing and equipment to transport these products to distant markets. Inadequate transport infrastructure limits the involvement of local traders in long-distance trade.

There is significant inter- and intra-regional trade in SSA, both formal and informal. Côte d'Ivoire and Senegal are some of the major exporters of fish in SSA. Senegal, for example, exports small pelagic fish in frozen or processed form to countries such as Burkina Faso, Cameroon, Côte d'Ivoire, the DRC and Ghana through formal means (Gordon, Finegold, et al. 2013). Informal cross border trade (ICBT) is prevalent in the West African region and countries close to Lake Victoria. The magnitude of ICBT in terms of volume and value has not been captured in national records due to its informal nature (AU-IBAR 2012, Gordon, Finegold, et al. 2013). ICBT examples include: dried and smoked fish from Mali, Niger and Senegal exported to Nigeria; dried, fresh or frozen fish exported from Mali to Burkina Faso; and fish exported from Zambia to the DRC (Gordon, Finegold, et al. 2013).

4.5.4 Drivers and challenges

The following common drivers and challenges apply to the fisheries and aquaculture sectors:

- Sustainable fishing is a priority for many African governments. As demand for fish increases, so does the risk of over-fishing, especially as most of the fish in Africa is likely to come from over-stretched small-scale inland and marine fisheries for the foreseeable future (WorldFish Center 2009). Gordon et al (2013) and Satia (2017) suggest that aquaculture development could help bridge this gap. However, the considerable start-up and operation costs involved in aquaculture are likely to be challenging for village-scale production.

- Local policies to support cross-border trading of fish and fish products continue to be important. Poor integration of small-scale producers and traders into wider national and regional supply chains has led to low marketability of locally produced fish and fish products in many African countries. Some countries such as Cameroon, Côte d'Ivoire, Nigeria, Uganda, and Zambia have made use of mobile phone technology to disseminate information to local fishers and fish farmers on policy, regulation and market prices (Akande and Diei-Ouadi 2010, Satia 2017). Some large-scale commercial traders and exporters in Uganda have also signed purchase contracts with rural fishing businesses (WorldFish Center 2009).
- Certain fish such as the Nile perch are invasive to other fish species, which could potentially disrupt the local, aquatic eco-system[50]. Care should be taken when considering breeding and rearing these types of fish in natural water bodies.
- Certain aquatic weed in fresh water bodies have detrimental effects on the fish population.
- Unhygienic environments and poor water quality, particularly for offshore ponds in aquaculture production, expose fish to dirt and bacteria, which leads to disease and low productivity. Ponds should be cleaned regularly and the water replaced as often as possible.

4.5.5 Opportunities for MG value addition

Figure 30 shows energy-dependent activities along the fisheries VC, including the typical machinery used and average power requirements. We discuss potential entry points for MGs further below.

	Production	Local Processing	Marketing
PUE Activities	• Animal feed production • Ice supply • Aquaculture operations • Battery charging for general appliances and lanterns • Cooling/freezing	• Drying • Cooling/freezing • Packaging	• Cooling/freezing • Packaging
Machinery	• Feed milling machine (2.2 kW) • Feed pelleting machine (1-4 kW) • Ice making machine (1.5-6 kW) • Water pump (4.2 kW) • Aeration system (14 kW) • Ventilation (0.07 kW per ventilator) • Charger (200 W) • Freezer (23 kW)	• Dryer (1.5 kW) • Freezer (23 kW) • Ice making machine (1.5-6 kW) • Packaging/canning machine	• Refrigeration (fridge/freezer) • Packaging/canning machine

Figure 29: Energy-dependent activities along the fisheries and aquaculture value chains in SSA

Opportunities in fish production

MGs can add value to aquaculture production and post-harvest fish handling activities in different ways:

- Replacing the use of diesel or mechanising manual work. Possible entry points for MGs in aquaculture include powering incubation and monitoring systems in hatcheries, water pumping to ensure a constant supply of fresh water in the ponds or cages, and powering aeration and ventilation systems. MGs could also consider taking on aquaculture as a revenue-generating activity. There is evidence of developers in East Africa taking part in the local tilapia VC by running their own aquaculture business[51].

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[50] More than 200 cichlid fish species in Lake Victoria became on the verge of extinction after the introduction of the Nile perch - Source: Encyclopaedia of Life (http://eol.org/data_objects/15662006)

[51] Jumeme, a mini-grid developer in Tanzania, collects tilapia from fishermen, de-guts them, cleans them and deep-freezes them for transport in cooler boxes to a wholesaler in a nearby market. The company also recently started farming tilapia.

- Powering ice production for the preservation of fish before it reaches local markets. This can improve fish quality and, in some cases, give producers an upper hand in negotiating fish prices with local processors[52]. This can be done in two ways: supplying power to stand-alone freezers with power requirements of less than one kilowatt, or powering larger ice-making machines with much higher power requirements (NREL & Energy 4 Impact 2018). The first option works better in cases where local actors can afford to buy or already have freezers. Where they cannot afford freezers, there is the option of supplying ice for water tanks, though this is only feasible for fish sold in a relatively short period of time. The second option works better in cases with limited supplies of ice for fish preservation or where supply is non-existent[53]. Local demand for ice would, however, need to justify investment in a commercial-scale, ice-making machine, since capital costs tend to be significant.[54]

Opportunities in local processing and marketing of fish

Power from MGs can add value to small-scale primary and secondary processing activities in different ways:

- Mechanisation of drying, smoking and other existing primary processes. A study done in Ghana, Kenya, Mali, Tanzania and Uganda concluded that mechanical drying of fish could help quicken the drying process and improve the quality of fish, thus potentially improving the marketability of dried fish (Akande and Diei-Ouadi 2010). It may be possible to substitute sun-drying with air-heated mechanical dryers for drying fish and fish meal, provided there is enough demand throughout the year. Electrical stoves could be used in place of traditional biomass stoves to smoke fish, provided the additional revenues can cover the upfront costs of the stoves which is most likely to be the case for larger, local fish producers or collectors.
- Providing power to or setting up a mill to produce and pelletise fish feed for local distribution. Much depends on local availability of high quality fish feed ingredients and adoption of appropriate industry standards. MGs could also be used to replace diesel-powered feed mills with electric mills.
- Introducing processing activities locally to reduce transport and transactional costs and losses. The WorldFish Center (2009) says that bringing processing closer to the point of production improves fish quality and helps to reduce transport losses. Where transport infrastructure is inadequate and producers find it challenging to transfer the fish to processors, MGs could play a role in decentralising fish processing. Activities such as cleaning, freezing and packaging of fish could be done close to the areas of fish production. Freezing is especially important for fish sold to distant markets.
- Providing power for cold storage of fish to local retail businesses and households. There may also be opportunities to support businesses that cook, fry and bake fish.

Other opportunities

MG developers can potentially provide a range of non-electric, value-addition services for local fishing businesses including:

- End-user financing for fishing-related equipment, including freezers and refrigerators for fish preservation;
- Provision of market and pricing information, perhaps through the creation of local information and communication technology centres;
- Support linking local producers to external markets; and

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[52] From our work supporting MG developers in East Africa, we note that some fish processing plants offer ice to fishermen and fish farmers for free, often in exchange for dictating fish prices.

[53] See note above on Jumeme in Tanzania. We are also aware of other developers in the Lake Victoria region of Uganda and Kenya running ice-making businesses to meet local demand.

[54] A small three-phase, ice-making machine with typical energy consumption of 1.5kW can produce about 250 kilos of ice a day at -8^{0}C. There also exist bigger and more efficient machines for use at a rural level, which range between 3.5 kW and 6 kW and can produce 625 kg to 1,000 kg of ice per day. Fishermen in countries like Tanzania purchase between two to five kilos of ice block and crush them into smaller blocks to preserve fish. This amount of ice can chill up to eight kilos of fish. Ice-making machines could be connected to a water pump for supplying water and an ice crusher to convert the ice blocks to ice flakes.

- Provision of other types of service such as selling ice to fishermen.

4.5.6 Technical and economic considerations

Technical considerations

As Figure 29 above shows, most fish production and processing machines have significant power requirements, usually above 1 kW and sometimes above 20 kW. This is especially true for ice making and fish freezing, aquaculture and fish feed milling businesses. Please refer to Section 4.1.2 for a summary of the key technical considerations for processing equipment for fisheries and cereals.

Economic considerations

De Graaf and Garibaldi (2014) look at the economic value created from fish capture and harvesting to processing and sale in 23 countries in SSA. They show the percentage value created between catching the fish based on three different scenarios: fish sold fresh, fish processed at a small-scale, artisanal level, and fish processed at a larger, industrial scale.

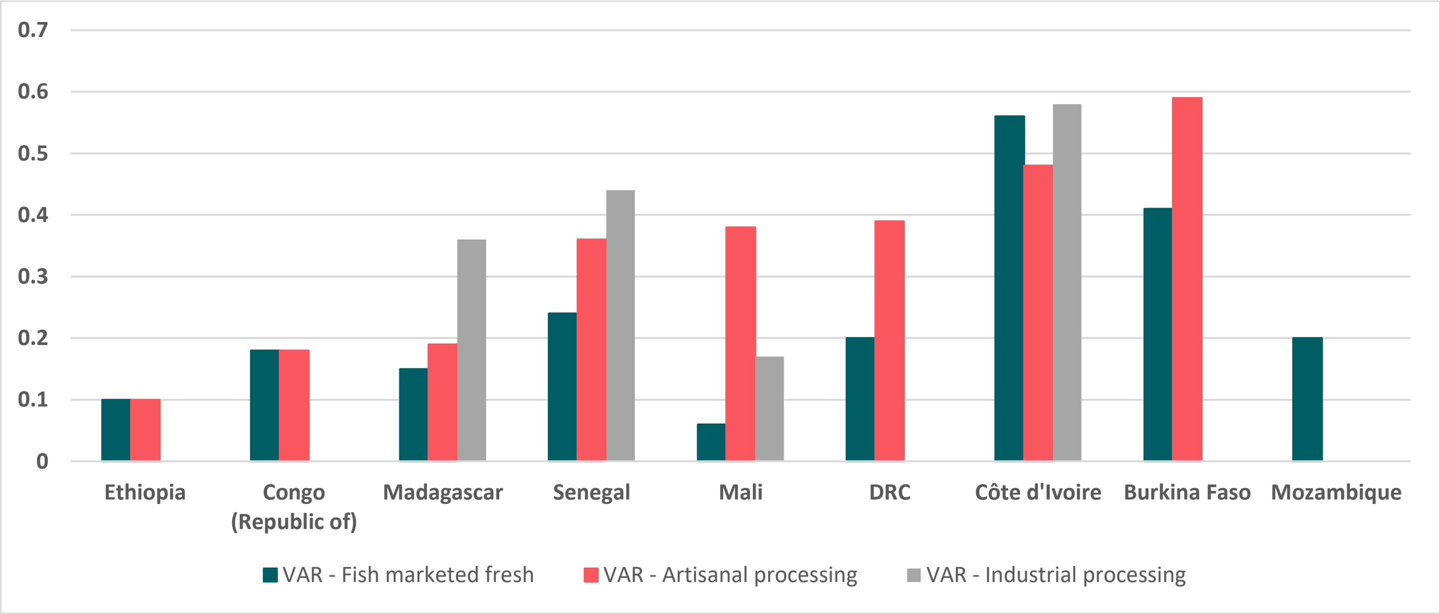

Figure 30: Value-addition ratios for fisheries in target countries

Adapted from Table 17 of de Graaf and Garibaldi (2014)

Figure 30 above shows value addition ratios[55] for these scenarios in nine of the 15 countries covered by this report. In some countries such as Madagascar, Senegal, Mali, the DRC and Burkina Faso, artisanal and industrial fish processing creates significant value. Consumers in these countries are more willing to pay a premium for processed fish products, so there is a strong case for local processing activities such as mechanical drying, small and large scale ice making and fish packaging. In other countries such as Ethiopia, the Republic of Congo, Côte d'Ivoire and Mozambique, the value of fish processing appears to be much lower. Consumers in these countries are less willing to pay a premium for processed fish over fresh fish, so it may make more sense for MGs to support activities that keep fish fresh such as ice-making and cooling or chilling.

It is difficult to measure the value addition of fish processing activities because of the way they are categorised in national records (de Graaf and Garibaldi 2014). For example, the value of fish at the farm gate tends to be recorded under "fish and aquaculture" or something similar, while post harvesting activities is often bundled up in broader categories such as "manufacturing".

[55] VAR is the difference between Gross Production Value and Production Costs, divided by the Gross Production Value.

The market price of fish is driven by the type of fish, the form in which it is sold (fresh versus frozen), the target market (local, regional or export), the distance from the point of production and processing, and seasonality. The level of transparency on fish and fish product prices is higher than that for cereal and cereal products due to the slightly more formalised trading system, but there is still plenty of room for improvement.

Figure 31 below shows how the value per kilo of fish increases by nearly 3x from when it is caught to the sale of fresh fish. It should be noted that the weight of fish reduces each time it goes through a level of processing. The overall weight of tilapia, for example, can reduce by up to 75% as a result of gutting (15%), preservation (10%) and de-heading and filleting (30% - 50%).

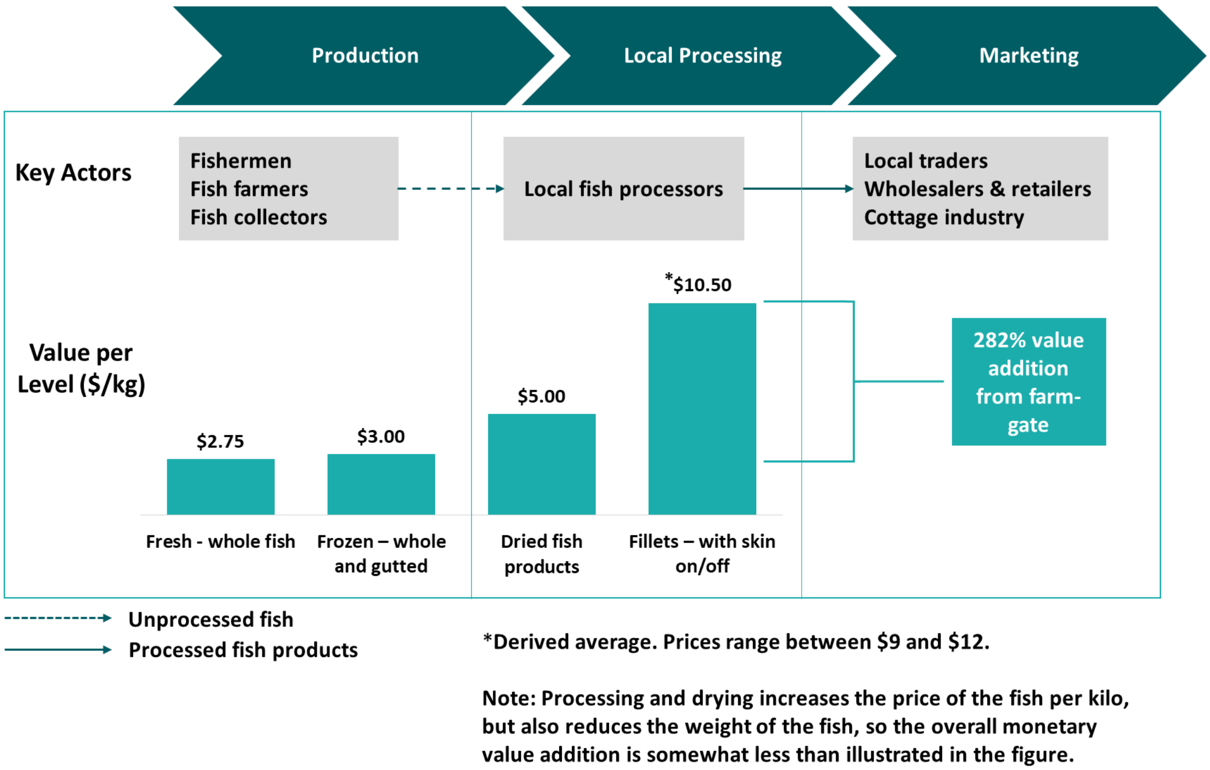

Figure 31: Average value addition of fish products in SSA ($/kg)

Adapted from Satia (2017)

Ice making can be a profitable PU business, particularly in remote fishing communities. Figures 32 and 33 below show two potential ice making business models: a small-scale business using a freezer to make ice (requiring less than a kilowatt of power) and a commercial-scale ice maker (requiring over 10 kilowatts of power). Both cases assume an energy cost of $12/kWh.

The analysis shows that both business models are potentially profitable, with payback periods of less than 3 years. However, to be profitable, the electricity tariff for the commercial ice plant would need to be about three times lower than that for the freezer business. Freezers are likely to be suitable for areas where fish is caught in small quantities and can be used for other services such as selling cold drinks. Ice plants are more suitable for areas with high demand for ice e.g. where fish is caught in large quantities, where fish is sold fresh or frozen to distant markets, and where there is a higher preference for fresh compared to processed fish. The analysis in Figure 33 assumes that the ice plant gets water for free from a public water source such as a lake or river. The cost of water supply will need to be added if the business needs to pay for water supply. Other cost considerations include spare parts for the ice making plant, O&M costs for the auxiliary equipment e.g. the water pump, relevant licenses, and insurance.

VARIABLES	VALUES	UNITS
Size of freezer	90	L
Power rating of freezer	180	W
Amount of power consumed per day	0.36	kWh
Capital cost	365	$
Operational hours[a]	2	hours
Avg. Revenue of cold storage sales (cold drinks, ice cream, ice blocks) per month	110	$/month
Avg. Expenses per month (incl. electricity)	75	$/month
Cost of power	8	$/month
Tariff	0.90	$/kWh
Net Profit	**35**	**$/month**
Profit Margin	32	%
Simple payback for freezer	10[b]	months

[a] Freezer operates for eight hours; compressor cycle period is two hours. This may not represent the ideal operation of a freezer from a business perspective but is indicative of current operational practices. The business/freezer is assumed to operate 24 days per month or roughly 6 days per week.
[b] Simple payback is calculated as total costs divided by monthly profits or in this case ($365/$35)

Figure 32: Ice making business using a freezer

Source: (NREL & Energy 4 Impact 2018, Table 6)

Particulars		Units	Source (As Applicable)/Notes
Cost of the Ice Plant	40,000	$	E4I Data. Incl. auxiliary equipment, licensing and installation, etc.
Capacity of the machine	35	kW	E4I Data
Operational hours	8	hrs/ day	E4I Data. Preference to run directly on solar power, since battery storage is too expensive
Energy consumption	280	kWh/ day	Calculation
Electricity tariff	0.30	$/ kWh	E4I Data
Electricity cost	84	$/ day	Calculation
Capacity of auxilliary equipment	5	kW	E4I Data
Operational hours	8	hrs/ day	E4I Data
Energy consumption	40	kWh/ day	Calculation
Electricity tariff	0.30	$/ kWh	E4I Data
Electricity cost	12	$/ day	Calculation
Total annual electricity cost	35,040	$/ p.a.	Calculation
O&M			
Water Consumption	25	mc/ day	E4I Data
Water Unit Cost		$/ mc	E4I Data. Use public water body.
Water Daily Cost	-	$/ day	Calculation
Personnel Cost	500	$/ month	E4I Data
Other Opex	1,500	$/ p.a.	E4I Data. Legal cost, insurance, etc.
Total annual O&M cost	7,500	$/ p.a.	Calculation
Revenues			
Ice sold	3	T/ day	E4I Data
Ice price	50	$/ T	E4I Data
Ice revenues per day	167	$/ day	Calculation
Total annual ice revenues	60,833	$/ p.a.	Calculation
Net Profit	**18,293**	**$/ p.a.**	**Calculation**
Payback Period	**2.19**	**years**	**Calculation**

Figure 33: Commercial-scale ice making plant

Source: Energy 4 Impact

5 COUNTRY MAPPING OF PUE

5.1 Introduction

This chapter describes the potential for PUE in off-grid areas in the 15 selected Africa countries – see map below.

Figure 34: Focus countries for PUE mapping in SSA

Each country profile contains the following information:

- Basic macroeconomic data, including GDP per capita and broken down by sector;
- Basic electricity data, including maps of the national grid[56], plus stats on electricity consumption, installed capacity, and access to electricity;
- List of the most important PUE businesses, including those described in Chapter 4 i.e. maize, sorghum and millet, rice and fisheries; and
- Maps showing the location of the four PU businesses above alongside the off-grid areas where MGs could potentially add value to these businesses.

In addition to the above, readers should refer to the following tables:

- Table showing all the different types of potential PU business for MGs by country – Table 1
- Table providing detailed information by country on the cereals and fishery businesses covered in Chapter 4 – see Appendix A
- Production and trade maps for cereals and fisheries by country – see Appendix E
- Map of major farming systems in SSA – see Appendix B

[56] Many of the national grid maps used to identify off-grid areas are a few years old, so the information may not be fully accurate.

5.2 Burkina Faso

5.2.1 Overview

Macroeconomic data		
GDP per capita	$611 (2017)	
GDP by sector	Agriculture, Forestry and Fishing	32%
	Industry/Manufacturing	22%
	Services	46%
Population	20 million (29.4% urban)	
Raw materials and exports	Raw materials: manganese, limestone, marble, gold, phosphates, pumice, salt Exports: gold ($3B), raw cotton ($506M), coconuts, brazil nuts, and cashews ($148M)	
Climate	Tropical, warm, dry winters Hot, wet summers Average temperature 25 - 30 °C Average annual rainfall between 600 - 900 mm	

Sources: World Bank, CIA World Fact book, WTO

Electricity Overview	Value
Installed capacity of electricity power sources	306 MW: fossil fuels (87%), hydro (10%), other renewable energy (3%)
Electricity consumption per capita	71 kWh/year
National electrification rate	19%
Urban electricity access	61%
Rural electricity access	<1%

Sources: World Bank, CIA

5.2.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Millet, sorghum, rice
Other VCs to consider	Wheat, shea nuts, groundnuts, sesame seeds, cassava, cashew nuts, cola nuts, cow peas, sugar cane, cotton, tobacco, dates, figs, coconut, oil palm

Sources: Authors

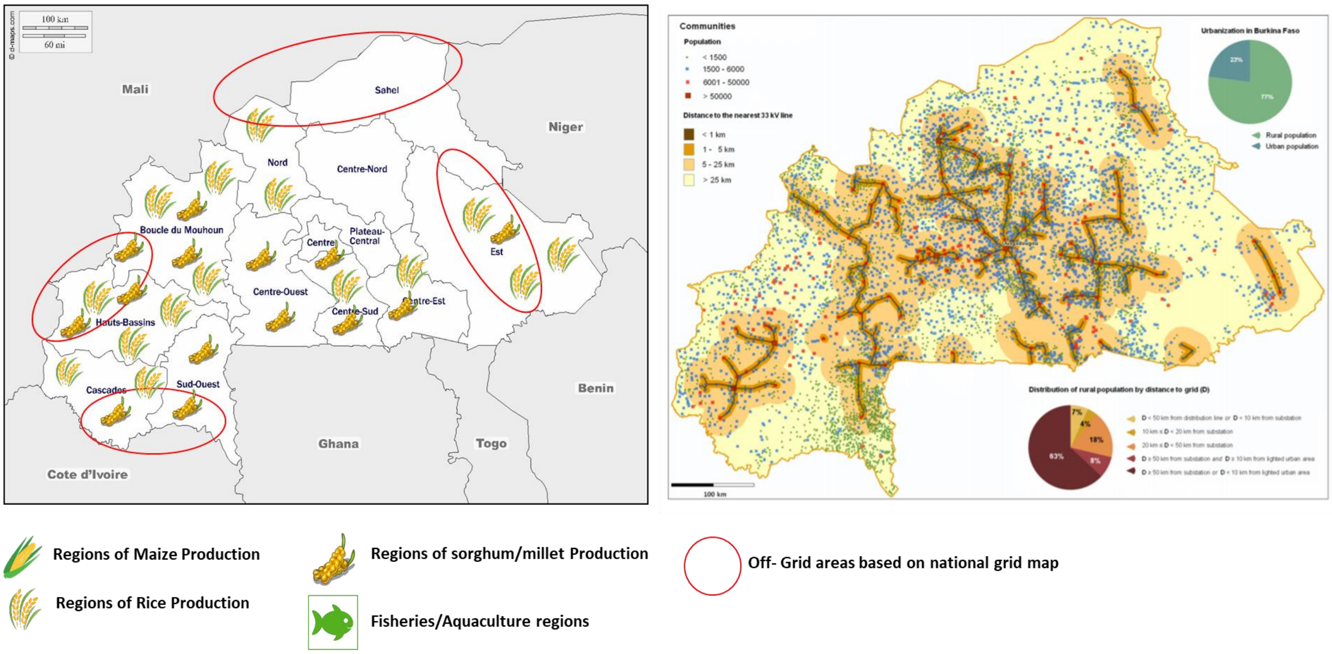

Figure 35: Burkina Faso PU and electrification maps

Sources: Energy 4 Impact, (M, et al. 2017, Figure 25)

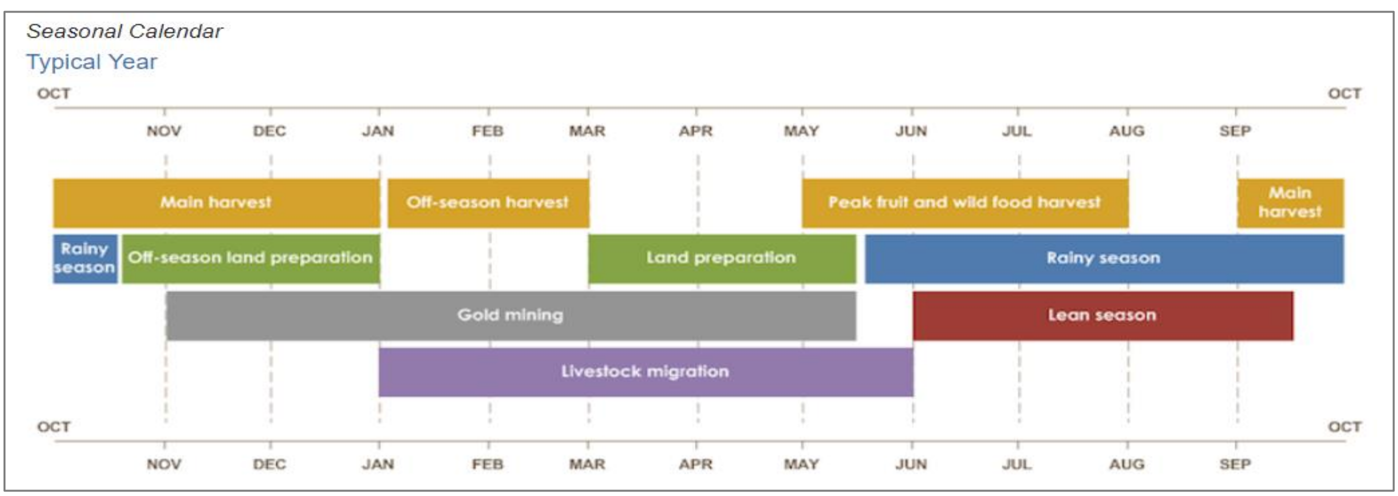

Figure 36: Burkina Faso agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/burkina-faso)

Other notes

Agricultural & Fisheries Market Development Policies

- The government recently started implementing the Bagré Growth Pole Project[57], which focuses on developing VCs of certain promising sectors (such as livestock, fruit and vegetables, shea butter, sesame) through agribusiness, in an attempt to reduce the country's dependence on gold and cotton.

Trade

- Burkina Faso has adopted the WAEMU Common External Tariff (CET), which cuts duty rates on agricultural products from more than 30% to 14.6% on average.
- Exports of sorghum, maize and other staple foods have been banned since 2008 in order to improve food security to avoid acute famine.

[57] More information on the World Bank webpage, http://www.worldbank.org/projects/P119662/burkina-faso-bagre-growth-pole-project?lang=en

5.3 Cameroon

5.3.1 Overview

Macroeconomic data	
GDP per capita	$3,400 (2017)
GDP by sector	Agriculture, Forestry and Fishing 23.1% Industry/Manufacturing 28.9% Services 48.9%
Population	25 million (55.5% urban) (2017)
Raw materials and exports	Raw materials: petroleum, bauxite, iron ore, timber, hydropower Exports: crude petroleum ($1B), cocoa beans ($525M), sawn wood ($433M)
Climate	Tropical savannah climate. Tropical in the south and along coast, semi-arid and hot in north. Average temperature 20 - 30 °C Average annual rainfall of 1,200 mm in semi-arid areas, 4,800 mm in tropical areas.

Sources: CIA World Fact book, UNDP Change Climate Profiles

Electricity Overview	Value
Installed capacity of electricity power sources	2,327.45 MW (2014): hydropower (60%), gas (20%), heavy and light-fuel oil (20%)
Electricity consumption per capita	771 kWh/year
National electrification rate	57%
Urban electricity access	88% (2013)
Rural electricity access	17% (2013)

Sources: RECP, AEEP, Climatescope

5.3.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Rice, fisheries
Other VCs to consider	Banana/plantain, shea nut

Sources: Authors

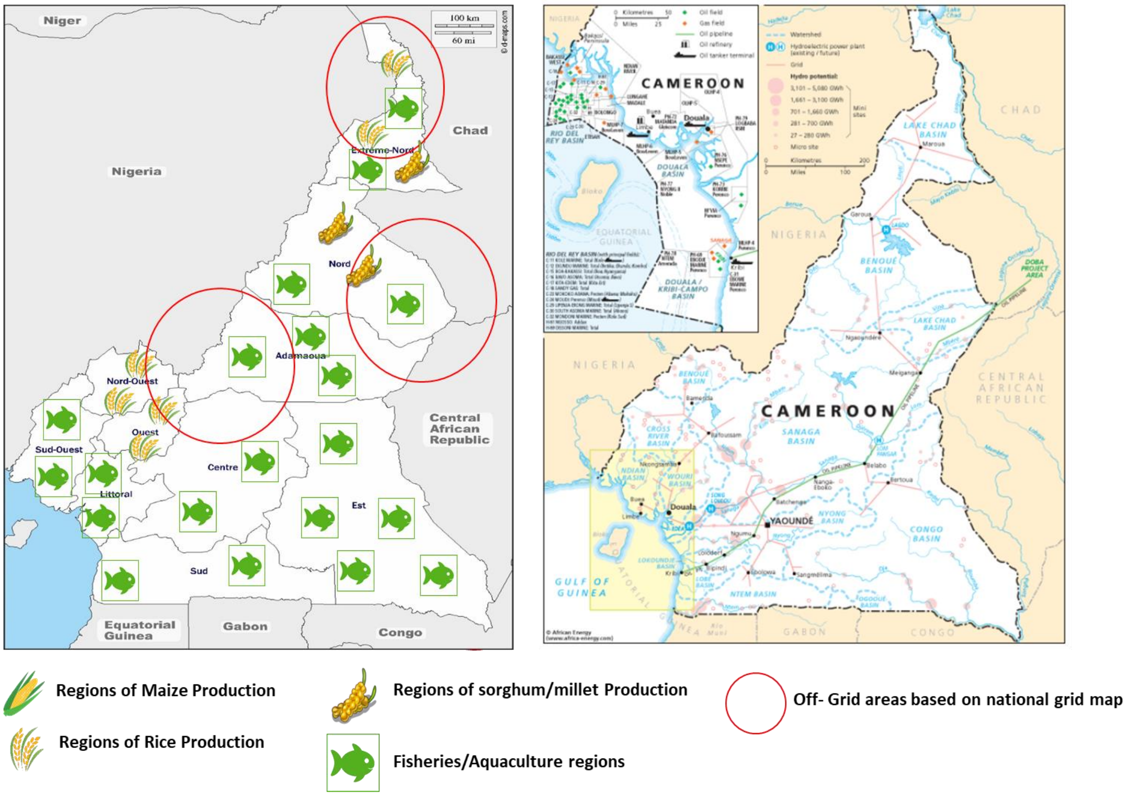

Figure 37: Cameroon PU and electrification maps

Sources: Energy 4 Impact, GENI

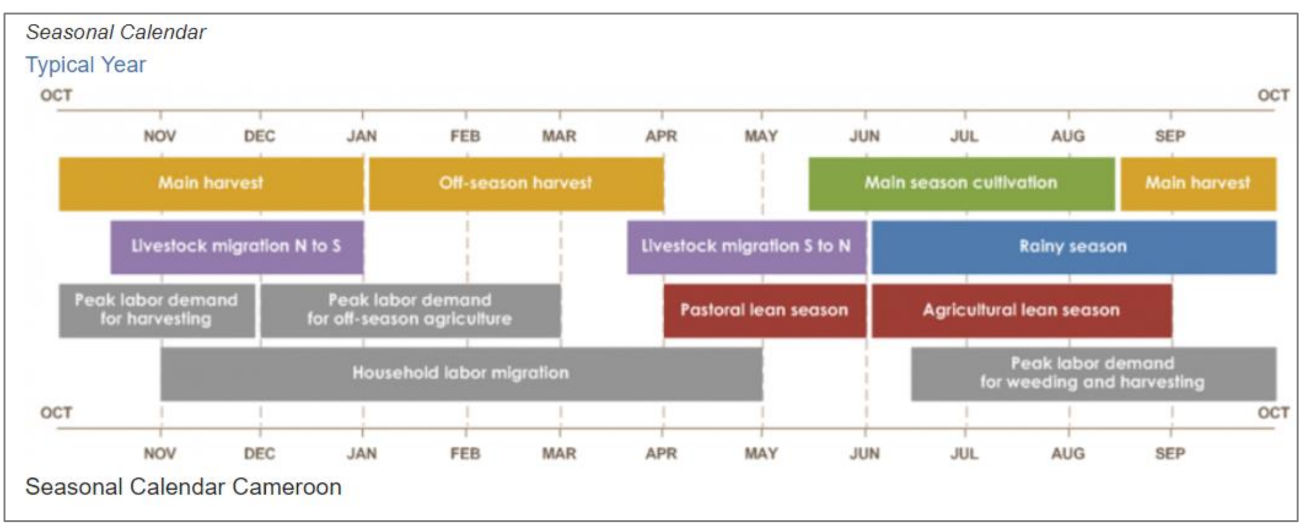

Figure 38: Cameroon agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/cameroon)

Other notes

Agricultural & Fisheries Market Development Policies

- The government is considering developing a policy to incorporate potato or cassava flour (about 5-10%) into bread manufacturing in a bid to reduce the country's dependence on imported wheat flour. This will largely depend on the reliability in supply of cassava or potato flour and the government's support for procurement of appropriate equipment by millers and processors.[58]

[58] FAO (http://www.fao.org/docrep/018/i3222e/i3222e04.pdf)

5.4 Côte d'Ivoire

5.4.1 Overview

Macroeconomic data	
GDP per capita	$1,617 (2017)
GDP by sector	Agriculture, Forestry and Fishing 23.4% Industry/Manufacturing 24% Services 52%
Population	23.7 million (54.9% urban))
Raw materials and exports	Raw materials: Petroleum, natural gas, diamonds, manganese, iron ore, cobalt, bauxite, copper, gold, nickel, tantalum, silica sand, clay, hydropower Exports: crude petroleum ($1.3B), cocoa beans ($545M), natural rubber ($502M)
Climate	Overall tropical savannah climate. Tropical along coast, semi-arid and hot in north. Warm and dry (November to March), hot and dry (March to May), hot and wet (June to October). Average temperature 27.9 °C Average annual rainfall of 2,300 mm

Sources: UK Foreign and Commonwealth Office, CIA World Factbook, WTO, Climate Data.org

Electricity Overview	Value
Installed capacity of electricity power sources	1,886 MW: natural gas/thermal (68%), hydro (32%))
Electricity consumption per capita	276 kWh/year
National electrification rate	64%
Urban electricity access	92% (2014)
Rural electricity access	38% (2013)

Sources: World Bank, RECP

5.4.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, rice, fisheries
Other VCs to consider	Pineapple, mangoes, banana/plantain, cashew nuts, coconut, cocoa beans, cla nuts, oil palm, groundnuts, shea nut, cassava, beans, cotton, rubber plant, cattle meat, yam

Sources: Authors

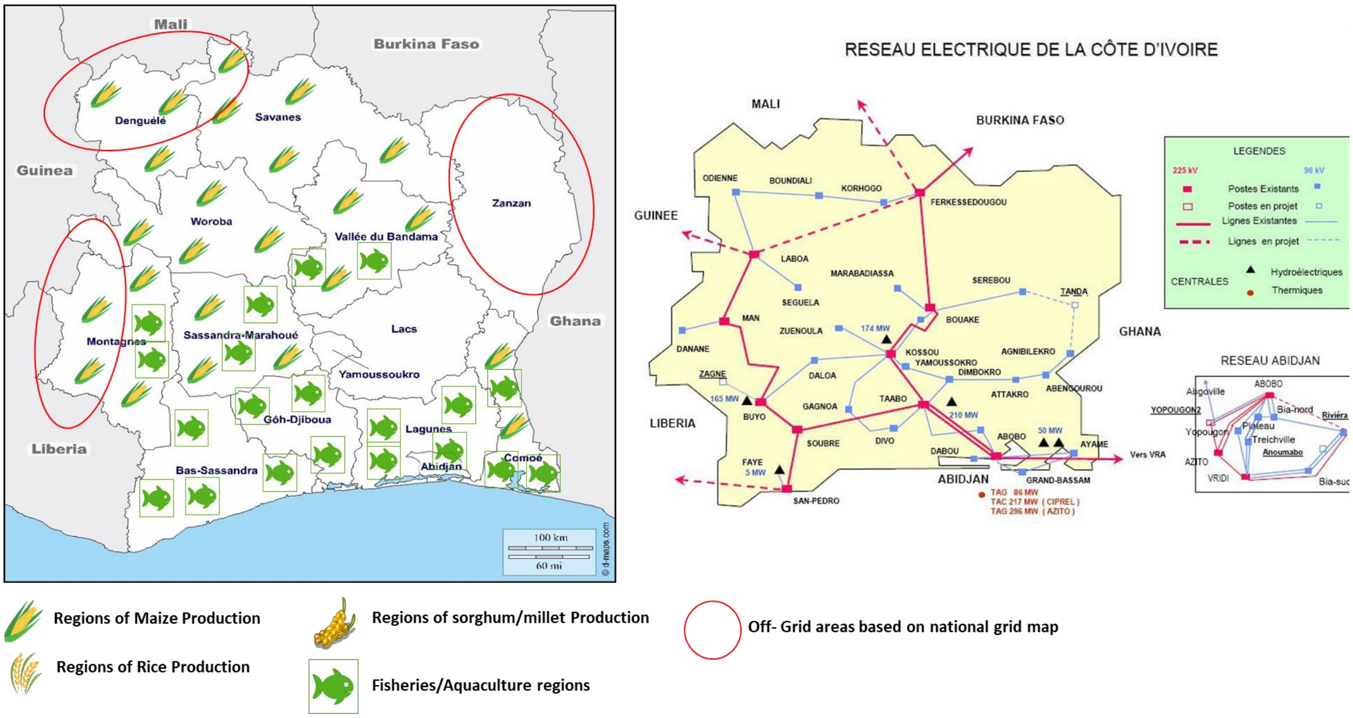

Figure 39: Côte d'Ivoire PU and electrification maps

Sources: Energy 4 Impact, the National Regulatory Authority of the Electricity Sector of Côte d'Ivoire (Anare)

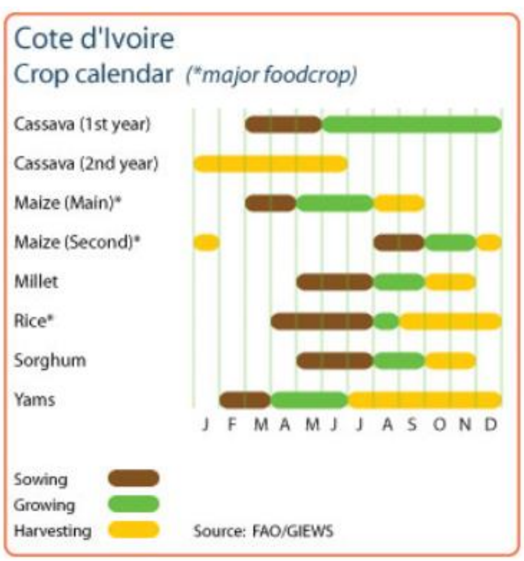

Figure 40: Côte d'Ivoire agricultural seasonal calendar

Source: FAO's GIEWS (http://www.fao.org/giews/background/en/)

5.5 Democratic Republic of Congo

5.5.1 Overview

Macroeconomic data	
GDP per capita	$478 (2017)
GDP by sector	Agriculture, Forestry and Fishing 21.9% Industry/Manufacturing 33.5% Services 44.5%
Population	86.7 million (43% urban))
Raw materials and exports	Raw materials: cobalt, copper, niobium, tantalum, petroleum, industrial and gem diamonds, gold, silver, zinc, manganese, tin, uranium, coal, hydropower, timber Exports: refined copper ($2.4B), cobalt ($760M), diamonds ($378M)
Climate	Overall Tropical savannah climate Average temperature 20 - 30°C Average annual rainfall of 1,400 - 2,000 mm

Sources: UK Foreign and Commonwealth Office, CIA World Factbook, Climate Data.org

Electricity Overview	Value
Installed capacity of electricity power sources	2,677 MW: hydro (94%), thermal (6%)
Electricity consumption per capita	106 kWh/year
National electrification rate	9%
Urban electricity access	19%
Rural electricity access	1%

Sources: World Bank, RECP, USAID Power Africa Factsheet, World Bank

5.5.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, rice, sorghum, fisheries
Other VCs to consider	Banana/plantain, coconut, oil palm, cassava, cocoa bean, coffee beans, rubber plant, beans, pineapples, groundnuts, tea, cola nuts, sugarcane,

Sources: Authors

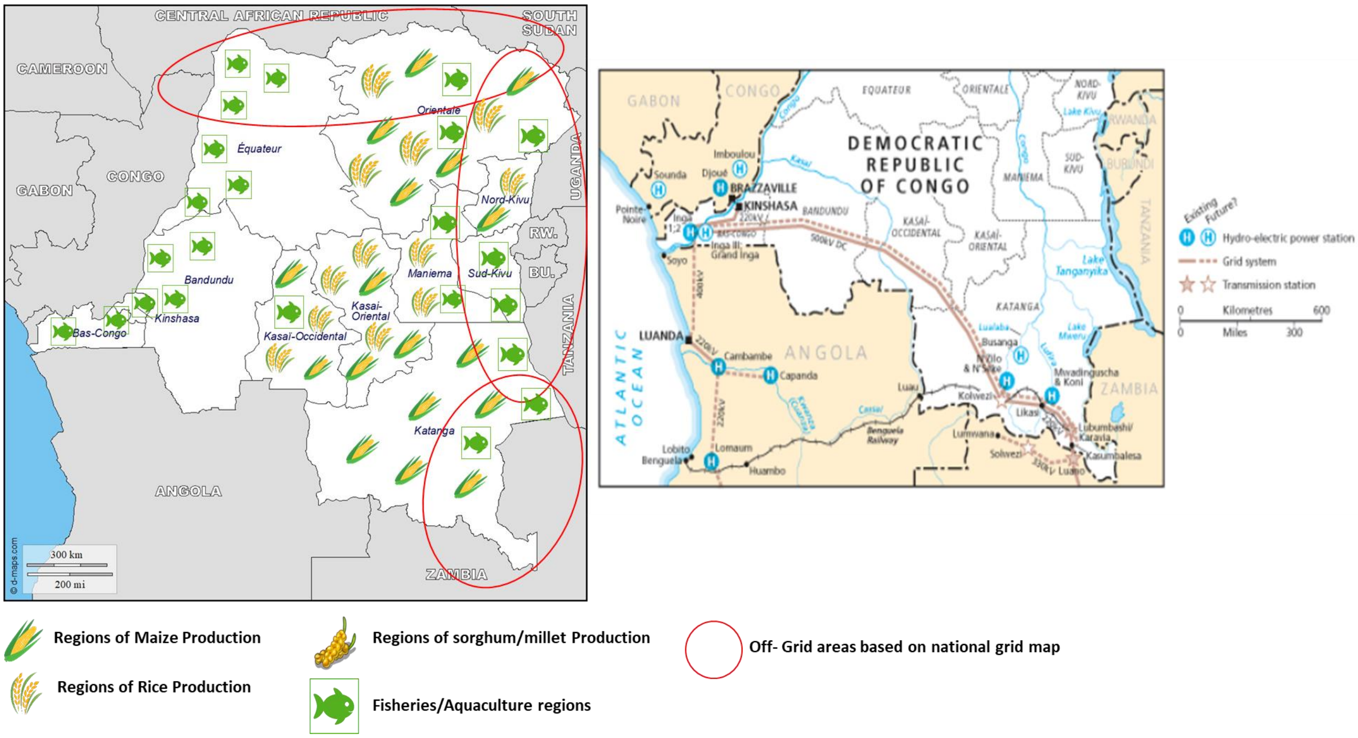

Figure 41: DRC PU and electrification maps

Sources: Energy 4 Impact, GENI

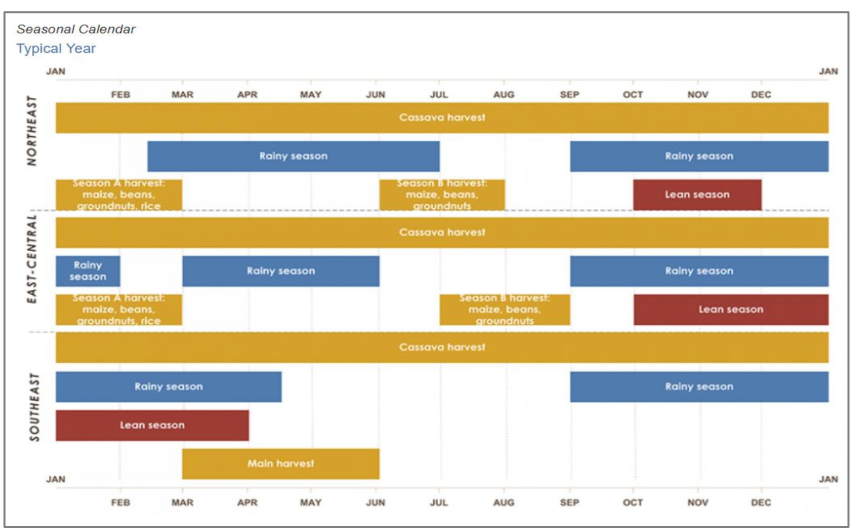

Figure 42: DRC agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/southern-africa/drc)

5.6 Ethiopia

5.6.1 Overview

Macroeconomic data	
GDP per capita	$873 (2017)
GDP by sector	Agriculture, Forestry and Fishing 37.2% Industry/Manufacturing 21.3% Services 41.5%
Population	92.7 million (20% urban))
Raw materials and exports	Raw materials: gold, platinum, copper, potash, natural gas, hydropower Exports: Coffee ($715M), gold ($129M), leather & leather products ($83M), dried leguminous vegetables ($249M), fresh meat ($98M)
Climate	Overall Tropical savannah climate Average temperature 15 20 ^{0}C (highland regions); 25 – 30 ^{0}C (lowland regions) Average annual rainfall of 1,200 - 3,600 mm

Sources: UK FCO Ethiopia Economic Factsheet, CIA World Factbook, WTO's Ethiopia Trade Profile, UNDP Climate Change Country Profile

Electricity Overview	Value
Installed capacity of electricity power sources	4,288 MW: Hydro (90%); Wind (7.7%); Diesel (2%); Geothermal (0.16%)
Electricity consumption per capita	70 kWh/year
National electrification rate	27.2%
Urban electricity access	92%
Rural electricity access	12.2%

Sources: Ethiopia Ministry of Irrigation and Electricity, SE4All Country Data

5.6.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, sorghum
Other VCs to consider	Coffee beans, teff, wheat, sesame seeds, cattle meat, hides and skin, dairy, shea nut

Sources: Authors

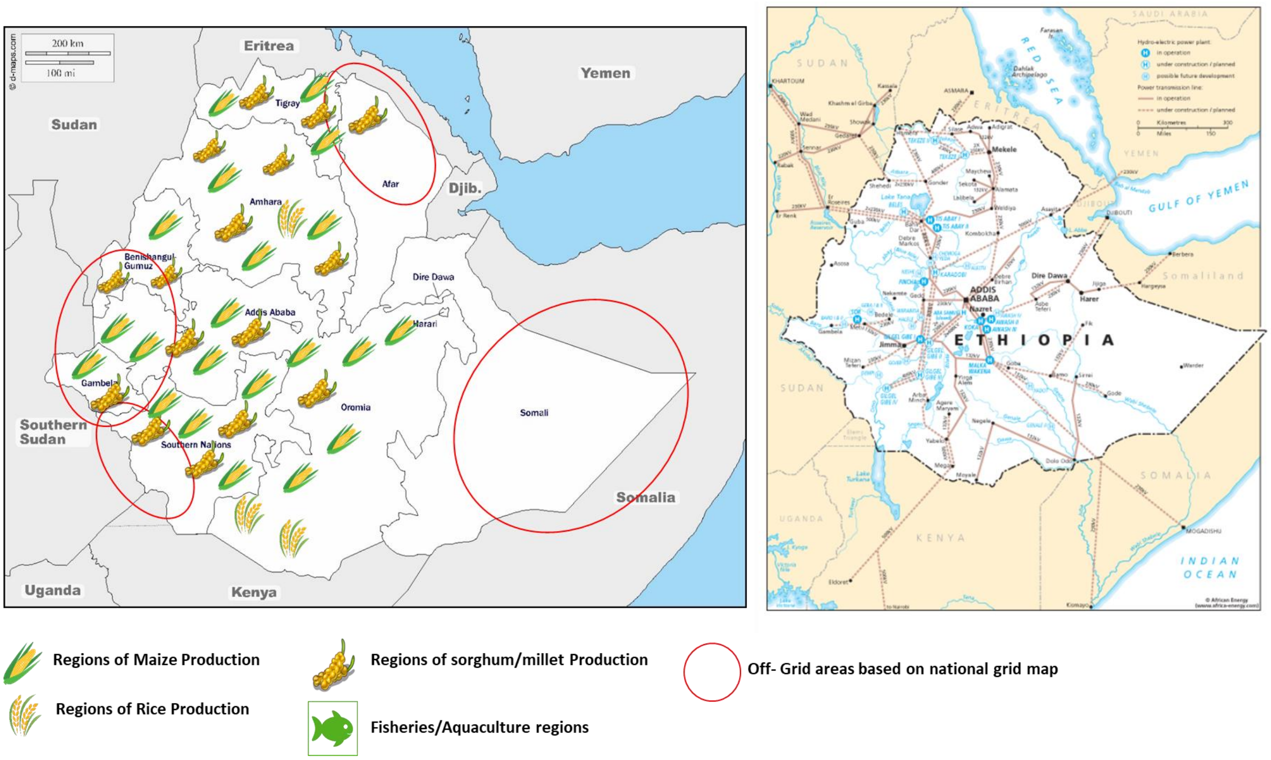

Figure 43: Ethiopia PU and electrification maps

Sources: Energy 4 Impact, GENI

Figure 44: Ethiopia agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/east-africa/ethiopia)

Other notes

Agricultural & Fisheries Market Development Policies

- The Agricultural Ministry is in the process of establishing an Agricultural Economic Zone (AEZ) and identifying appropriate crops for designated land, with a focus on cash crops such as cotton, rubber and palm.

Trade

- The government deals with food price instability on an ad hoc basis. For example, export bans were imposed on maize, sorghum and wheat between 2006 and 2008, and then re-imposed in 2011. Local food prices are therefore subject to fluctuation depending on local policies.
- Marketing of export commodities is mainly handled through the Ethiopia Commodity Exchange platform (ECX). Work is in progress to introduce online trading as a transition from spot/cash trading. The ECX currently handles coffee, sesame and haricot beans.

5.7 Madagascar

5.7.1 Overview

Macroeconomic data	
GDP per capita	$447.6 (2017)
GDP by sector	Agriculture, Forestry and Fishing 24.7% Industry/Manufacturing 19.4% Services 55.9%
Population	25.6 million (35.7% urban)
Raw materials and exports	Raw materials: coffee, vanilla, shellfish, sugar, cotton cloth, clothing, chromite, petroleum products, gems, ilmenite, cobalt, nickel Exports: vanilla ($408M), nickel ($400M), cloves ($150M), clothing ($145M), shellfish ($95M)
Climate	Overall hot and subtropical, temperate inland, arid in south, colder temperatures in the mountains Average temperature: 9-27 °C Average annual rainfall of 1,000 – 1,500 mm

Sources: UK FCO Madagascar Economic Factsheet, CIA World Factbook, WTO's Madagascar Trade Profile, World Weather and Climate Information

Electricity Overview	Value
Installed capacity of electricity power sources	4,288 MW: Hydro (90%); Wind (7.7%); Diesel (2%); Geothermal (0.16%)
Electricity consumption per capita	56 kWh/year
National electrification rate	13%
Urban electricity access	22%
Rural electricity access	8%

Sources: RECP, World Bank, USAID Power Africa Factsheet

5.7.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Sorghum, rice, fisheries
Other VCs to consider	Banana/plantain, groundnuts, Irish potatoes, cassava, cocoa bean, coffee beans, vanilla, beans, sugar cane, cotton, meat (cattle, chicken and goat), hides and skins, small manufacturing (cement and bricks, metalwork, wood products)

Sources: Authors

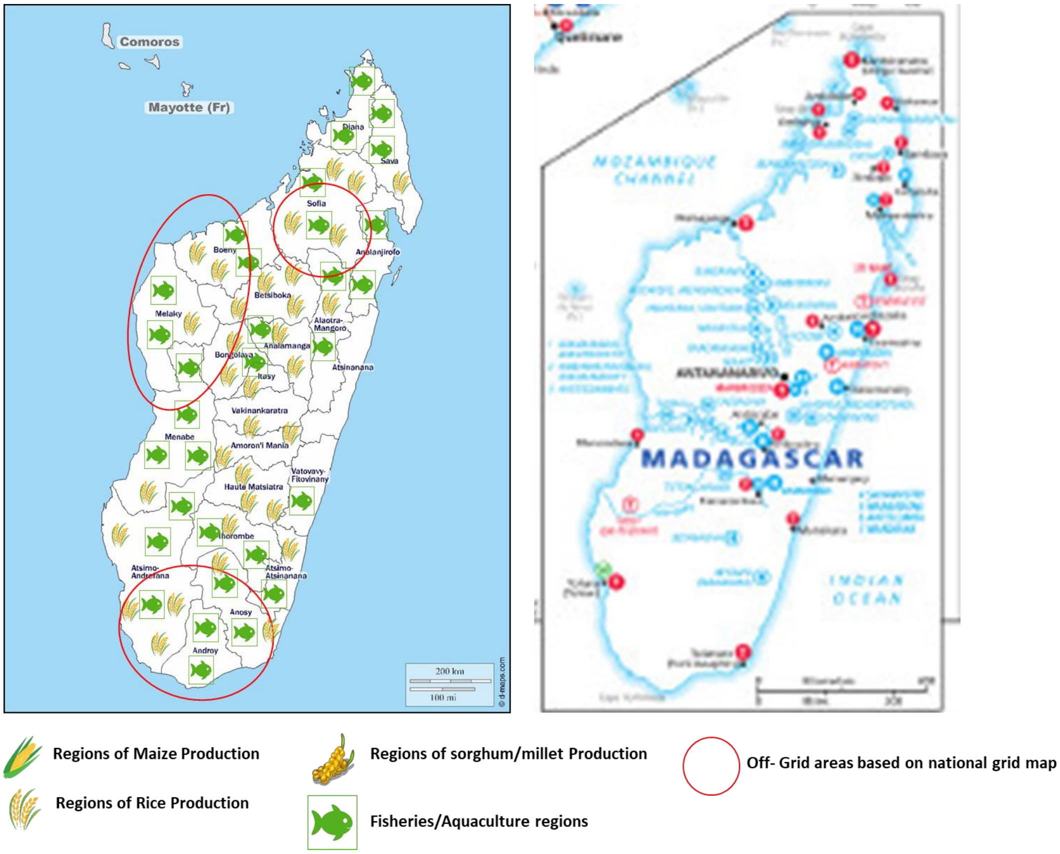

Figure 45: Madagascar PU and electrification maps

Sources: Energy 4 Impact, CbI (https://archive.crossborderinformation.com/Article/Power+sector+infrastructure+in+Mozambique%2C+Madagascar.aspx?date=20141130#)

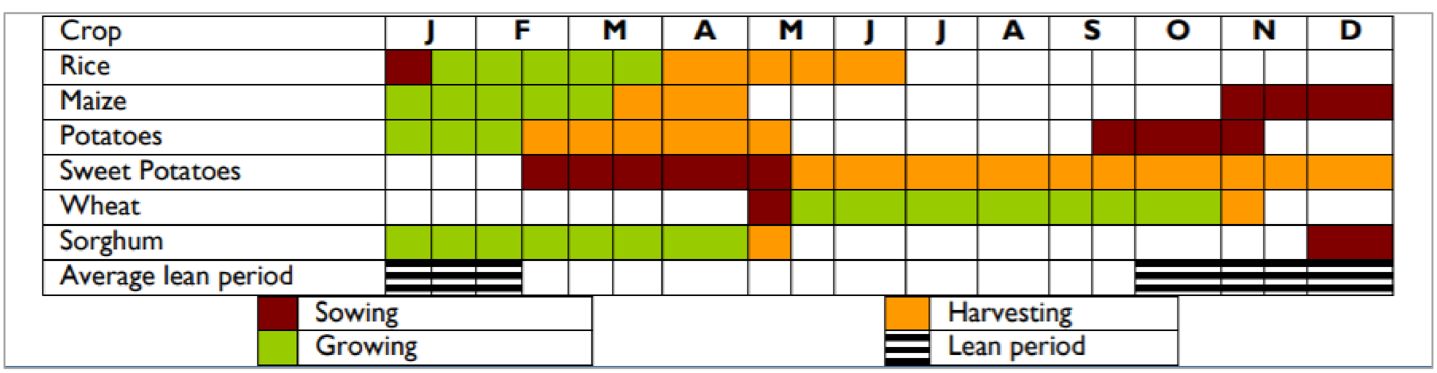

Figure 46: Madagascar agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/sites/default/files/MG_deskreview_2012_11_en_0.pdf)

5.8 Mali

5.8.1 Overview

Macroeconomic data	
GDP per capita	$810.8 (2017)
GDP by sector	Agriculture, Forestry and Fishing 42.1% Industry/Manufacturing 18.1% Services 39.7%
Population	18.9 million (40.7% urban)
Raw materials and exports	Raw materials: gold, uranium, diamonds, calcarous rock deposits, lead and zinc, lithium, bitumen schist, lignite, marble, gypsum, kaolin, phosphate, rock salt, diatomite Exports: Gold ($2B), cotton ($263M), live animals ($124M)
Climate	Overall: subtropical to arid Average temperature: 30 °C Average annual rainfall of 200 - 762 mm

Sources: UK FCO Mali Economic Factsheet, CIA World Factbook, WTO's Mali Trade Profile, climate-zone.com

Electricity Overview	Value
Installed capacity of electricity power sources	310 MW: hydro (60%) diesel (40%)
Electricity consumption per capita	112 kWh/year
National electrification rate	35%
Urban electricity access	55%
Rural electricity access	18%

Sources: World Bank, USAID Power Africa Factsheet

5.8.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Millet, sorghum, rice, fisheries
Other VCs to consider	Groundnuts, shea nut, Irish potatoes, cassava, sugar cane, cotton, meat (cattle and goat)

Sources: Authors

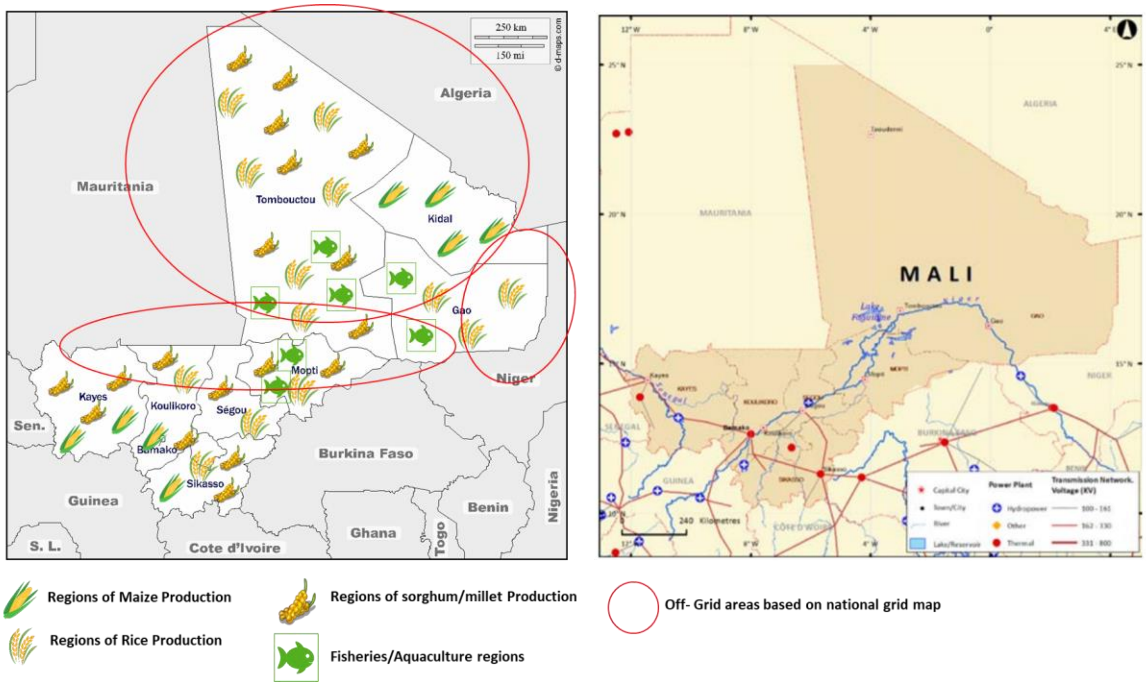

Figure 47: Mali PU and electrification maps

Sources: Energy 4 Impact, UNEP

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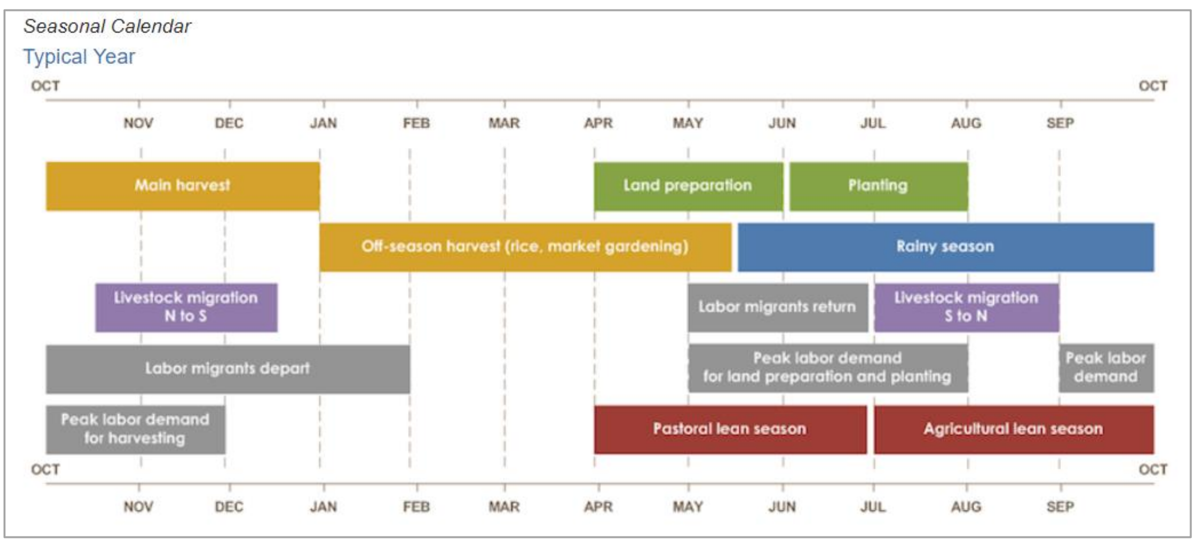

Figure 48: Mali agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/mali)

Other notes

Agricultural & Fisheries Market Development Policies

- The Northern region of Mali is most vulnerable to drought and desertification[59].
- The country has identified rice, maize, millet, sorghum, inland fisheries and livestock products (meat and dairy) as priority areas for strategic investments. This is integrated into the National Programme for Investment in the Agriculture Sector (PNISA – Programme National d'Investissement dans le Secteur Agricole).
- Rice, maize, millet, sorghum and wheat are eligible for subsidised seeds and fertiliser.

Trade

- The government has imposed restrictions on informal exports of millet, sorghum and maize since 2004.
- Import duties and taxes are often revised and at times suspended in a bid to ensure food security during lean agricultural seasons. Rice and maize imports have been the main target in the past. This affects local market and regional export prices due to an increased in-flow of these commodities into the country.

[59] FAO (http://www.fao.org/3/a-i7617e.pdf)

5.9 Mozambique

5.9.1 Overview

Macroeconomic data	
GDP per capita	$429.3 GDP (2017)
GDP by sector	Agriculture, Forestry and Fishing 24.8% Industry/Manufacturing 21.6% Services 53.6%
Population	29.5 million (32.5% urban)
Raw materials and exports	Raw materials: coal, titanium, natural gas, hydropower, tantalum, graphite, gold, gemstones Exports: aluminium and aluminium products ($ 842M), natural mineral products ($455M), electrical energy ($380M), petroleum gases ($280M), tobacco ($234M), sugarcane ($46M)
Climate	Overall: subtropical to arid climate Average temperature: 15-20 °C in inlands and high altitudes, 20-25 °C in lowlands Average annual rainfall of 600 – 1,800 mm in the south, 1,800 – 3,600 mm rest of the country

Sources: UK FCO Mozambique Economic Factsheet, CIA World Factbook, WTO's Mozambique Trade Profile, UNDP Climate Change Profile

Electricity Overview	Value
Installed capacity of electricity power sources	2,687 MW: hydro (78%) thermal (22%)
Electricity consumption per capita	463 kWh/year
National electrification rate	29%
Urban electricity access	57%
Rural electricity access	15%

Sources: World Bank, USAID Power Africa Factsheet

5.9.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, fisheries, millet, sorghum
Other VCs to consider	Cassava, groundnuts

Sources: Authors

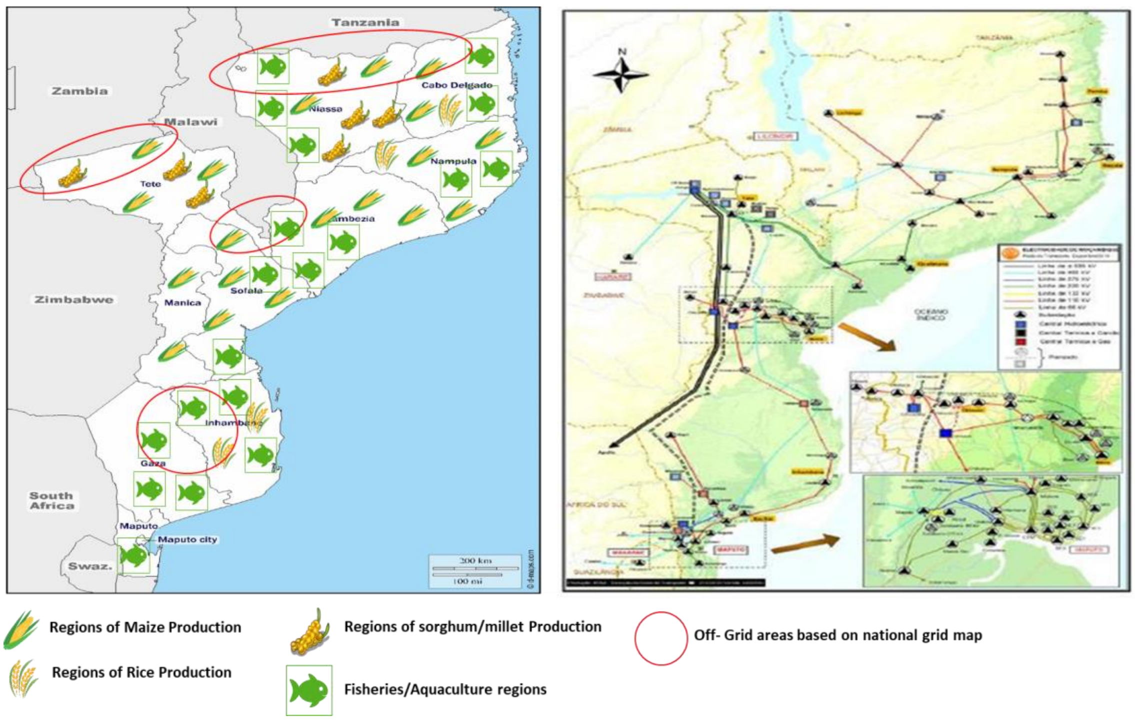

Figure 49: Mozambique PU and electrification maps

Sources: Energy 4 Impact, RECP

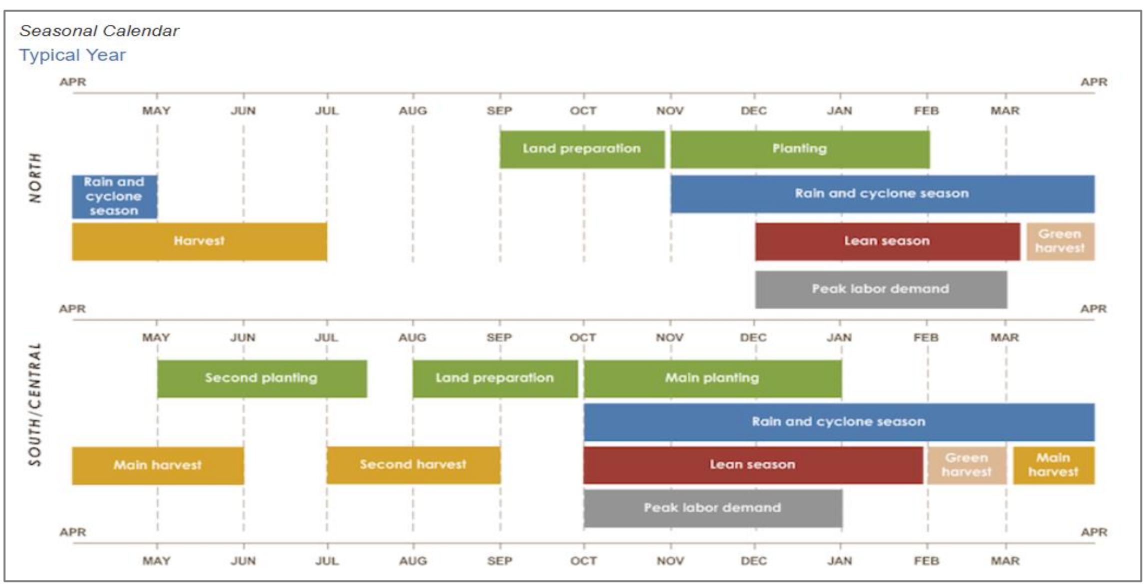

Figure 50: Mozambique agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/southern-africa/mozambique)

Other notes

Agricultural & Fisheries Market Development Policies

- Mozambique is highly vulnerable to drought and floods. The government is developing a National Strategy for Irrigation as a means of mitigating this challenge.

Trade

- There are two distinct maize markets in Mozambique. Maize is mainly grown as a cash crop in the northern region, where cassava is the main food crop. Maize in the southern region mainly comes from imports from South Africa due to poor road infrastructure linking the north and the south. Local maize prices in the north are therefore not linked to prices in the south, which follow market prices in the Southern African region[60].
- Mozambique has liberalised its trade regime now that it is part of the free trade area of the Southern African Development Community (SADC).

[60] Donovan and Tostão 2010 (http://ageconsearch.umn.edu/record/58561/files/AAMP_Maputo_21_Mozambique.pdf)

5.10 Niger

5.10.1 Overview

Macroeconomic data		
GDP per capita	$440 (2017)	
GDP by sector	Agriculture, Forestry and Fishing	41.5%
	Industry/Manufacturing	18.1%
	Services	40.4%
Population	18.8 million (19% urban)	
Raw materials and exports	Raw materials: uranium, coal, iron ore, tin, phosphates, gold, molybdenum, gypsum, salt, petroleum Exports: uranium ($299M), petroleum oils ($151M), rice ($134M), palm oil ($130M)	
Climate	Overall: mostly desert with tropical climate in the extreme south. Average temperature: 31 - 41°C Average annual rainfall of 200mm	

Sources: UK FCO Niger Economic Factsheet, CIA World Factbook, WTO's Niger Trade Profile, World Weather and Climate Information

Electricity Overview	Value
Installed capacity of electricity power sources	140 MW: coal (57%), diesel (43%)
Electricity consumption per capita	51 kWh/year
National electrification rate	16%
Urban electricity access	65%
Rural electricity access	5%

Sources: World Bank, USAID Power Africa Factsheet

5.10.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Millet, sorghum, rice
Other VCs to consider	Groundnuts, shea nut, cassava, beans, cotton, meat (cattle, chicken, goat), small manufacturing (cement and bricks), wheat, sesame seeds

Sources: Authors

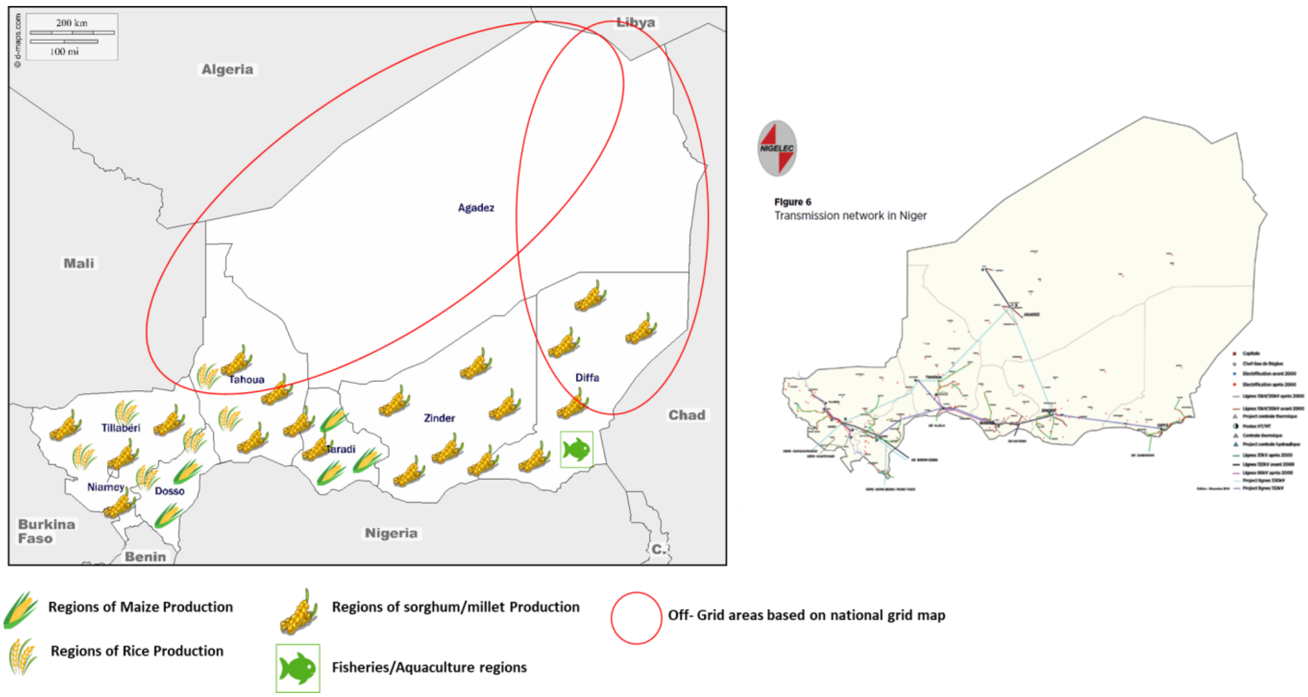

Figure 51: Niger PU and electrification maps

Sources: Energy 4 Impact, IRENA (2013, Figure 6)

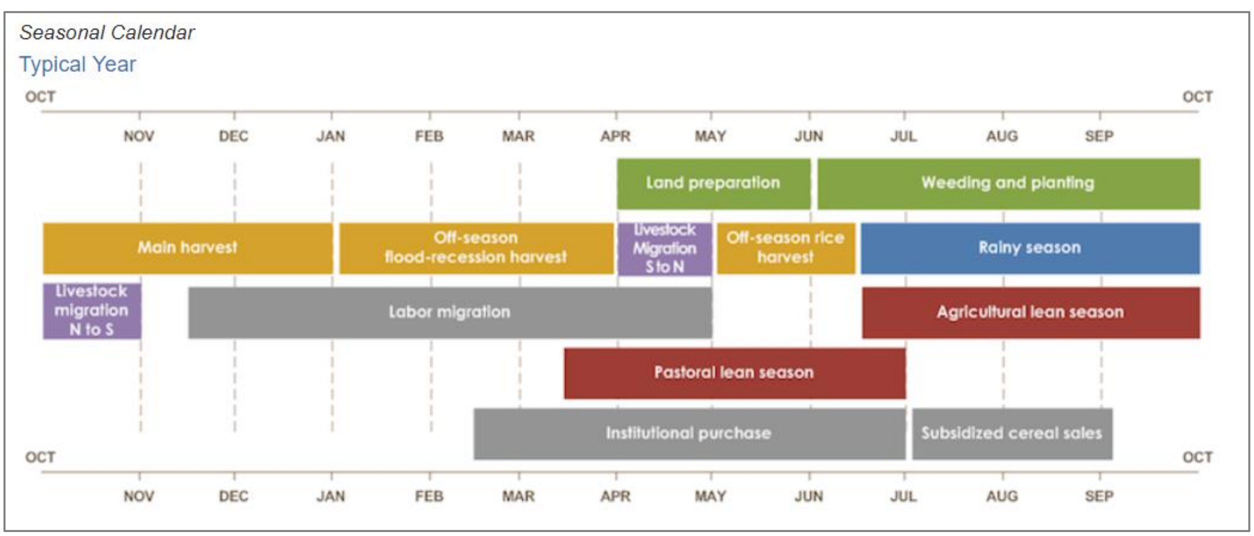

Figure 52: Niger agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/niger)

5.11 Nigeria

5.11.1 Overview

Macroeconomic data	
GDP per capita	$1,994.2 (2017)
GDP by sector	Agriculture, Forestry and Fishing 21.2% Industry/Manufacturing 18.4% Services 60.4%
Population	188.7 million (48.6% urban)
Raw materials and exports	Raw materials: Petroleum, natural gas, tin, iron ore, coal, limestone, niobium, lead, zinc and arable land Exports: petroleum oils ($36B), petroleum gases ($6.17B), cocoa beans ($191M), coal tars ($183M), oil seeds ($136M)
Climate	Overall: tropical humid climate. Average temperature: 20 °C Average annual rainfall of 500 – 1,000mm (central and northern regions), 1,800mm (along the coast), 4,000mm (in the east)

Sources: UK FCO Nigeria Economic Factsheet, CIA World Factbook, WTO's Nigeria Trade Profile, UNDP Climate Change Country Profile

Electricity Overview	Value
Installed capacity of electricity power sources	12,522 MW: thermal (83%), hydro (17%)
Electricity consumption per capita	151 kWh/year
National electrification rate	45%
Urban electricity access	55%
Rural electricity access	36%

Sources: USAID Power Africa Factsheet, PwC (2016)

5.11.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Millet, sorghum, maize, rice, fisheries
Other VCs to consider	Shea nut, sesame seeds, cassava, cocoa beans, yam

Sources: Authors

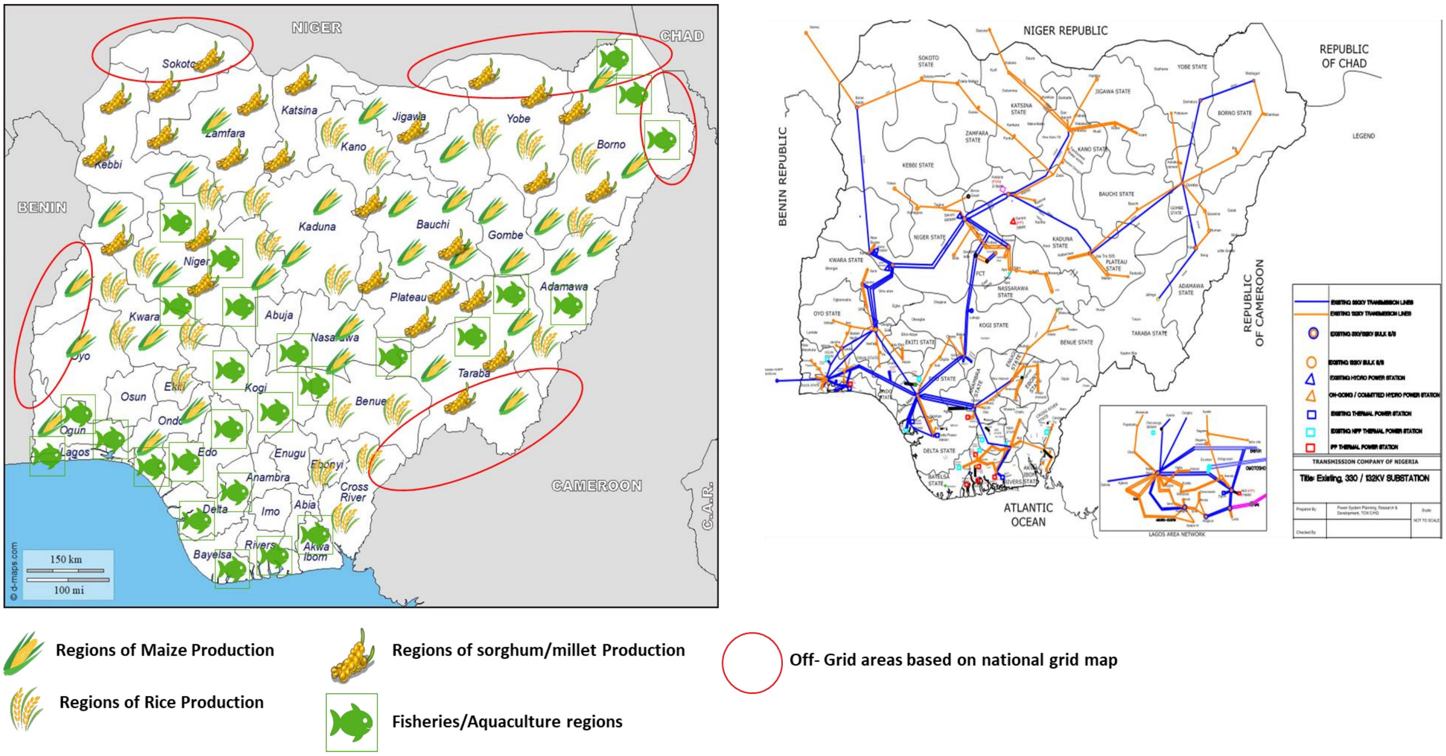

Figure 53: Nigeria PU and electrification maps

Sources: Energy 4 Impact, Nigeria Energy System Operator (NSONG)

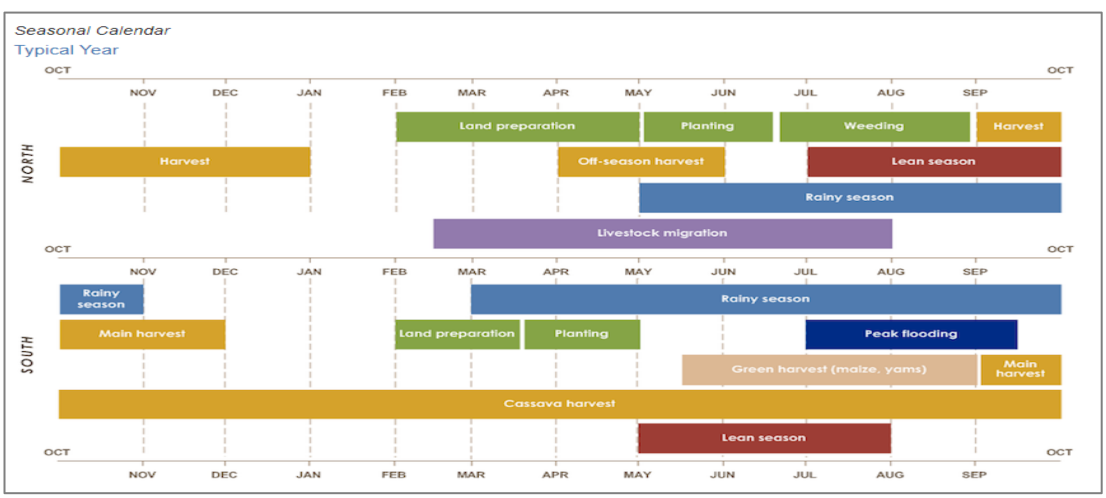

Figure 54: Nigeria agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/nigeria)

Other notes

Electrification

- The government has, in collaboration with the GIZ, developed an interactive map to highlight off-grid areas with potential for mini-grid development and areas where mini-grids already exist.[61]

Agricultural & Fisheries Market Development Policies

- In a bid to shift farming systems from subsistence to commercial systems, the government through the Growth Enhancement Support (GES) scheme provides farmers with a 50 percent subsidy on fertilizer purchased directly from agro-dealers (FAO 2017).
- The government has developed an insurance system under the GES called the Nigerian Agricultural Insurance Corporation (NAIC) which extends insurance to farmers in order to improve agricultural resilience to external forces. Farmers entitled to subsidized inputs will receive financial compensation in the event of crop losses due to flood, drought, fire, pests and diseases.

[61] More information can be found on http://mgf-nigeria.integration.org/

5.12 Republic of Congo

5.12.1 Overview

Macroeconomic data		
GDP per capita	$1,958.2 (2017)	
GDP by sector	Agriculture, Forestry and Fishing	8.7%
	Industry/Manufacturing	50.2%
	Services	41.1%
Population	188.7 million (48.6% urban)	
Raw materials and exports	Raw materials: petroleum, timber, potash, lead, zinc, uranium, copper, phosphates, gold, magnesium, natural gas, hydropower Exports: petroleum ($4B), transport vessels ($1B), vessels not mainly for navigability ($1B)	
Climate	Overall: tropical climate. Average temperature: 20-30 °C Average annual rainfall of 1,050 – 1,850mm	

Sources: UK FCO Congo Economic Factsheet, CIA World Factbook, WTO's Congo Trade Profile, Climate Zone

Electricity Overview	Value
Installed capacity of electricity power sources	545 MW: fossil fuels (62%), hydro (38%)
Electricity consumption per capita	197 kWh/year
National electrification rate	57%
Urban electricity access	74%
Rural electricity access	36%

Sources: World Bank, CIA World Factbook

5.12.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, rice
Other VCs to consider	Banana/plantain, oil palm, groundnuts, yam, cassava, cocoa beans, coffee beans, beans, sugar cane, rubber plant, tobacco, small manufacturing (cement and bricks, wood products)

Sources: Authors

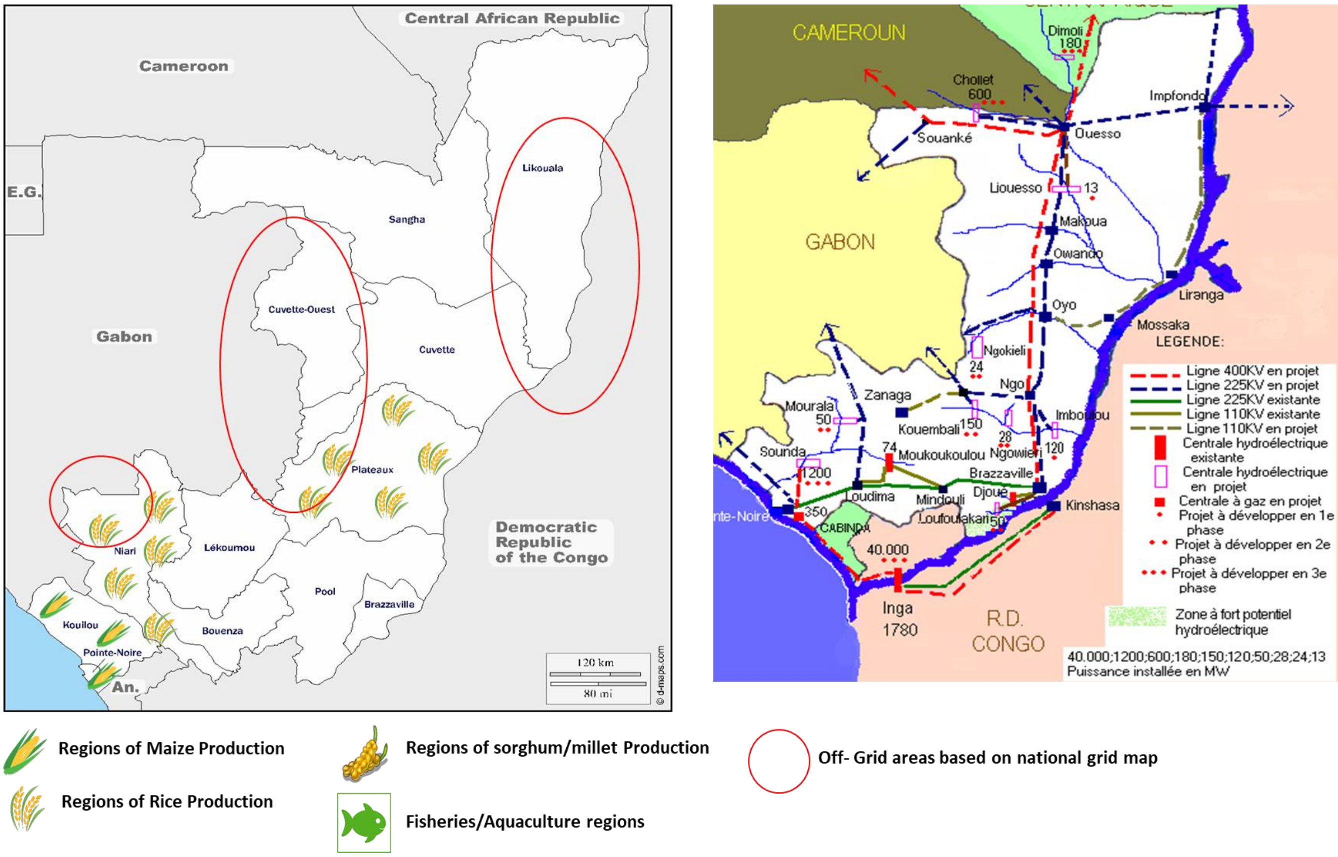

Figure 55: Republic of Congo PU and electrification maps

Sources: Energy 4 Impact, UNDP (n.d., Figure 4)

5.13 Senegal

5.13.1 Overview

Macroeconomic data	
GDP per capita	$1,038.1 (2017)
GDP by sector	Agriculture, Forestry and Fishing 17.5% Industry/Manufacturing 23.3% Services 59.3%
Population	15.9 million (44.1% urban)
Raw materials and exports	Raw materials: Gold, iron ore, limestone, salt, phosphates Exports: petroleum products ($408M), gold ($376M), fish, excluding fillet ($227M), cement ($201M)
Climate	Overall: tropical climate, with sub-tropical semi-arid (Sahel) climate in the northern regions. Average temperature: 25-35 °C Average annual rainfall of 1,200 – 2,400mm

Sources: UK FCO Senegal Economic Factsheet, CIA World Factbook, WTO's Senegal Trade Profile, UNDP Climate Change Country Profile

Electricity Overview	Value
Installed capacity of electricity power sources	864 MW: thermal (87%), hydro (7%), solar (6%)
Electricity consumption per capita	223 kWh/year
National electrification rate	64%
Urban electricity access	90%
Rural electricity access	44%

Sources: World Bank, USAID Power Africa country factsheet

5.13.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, millet, rice, fisheries
Other VCs to consider	Tomatoes, mangoes, groundnuts, shea nut, cotton, sugarcane, beans, meat (cattle, chicken, goat and pork)

Sources: Authors

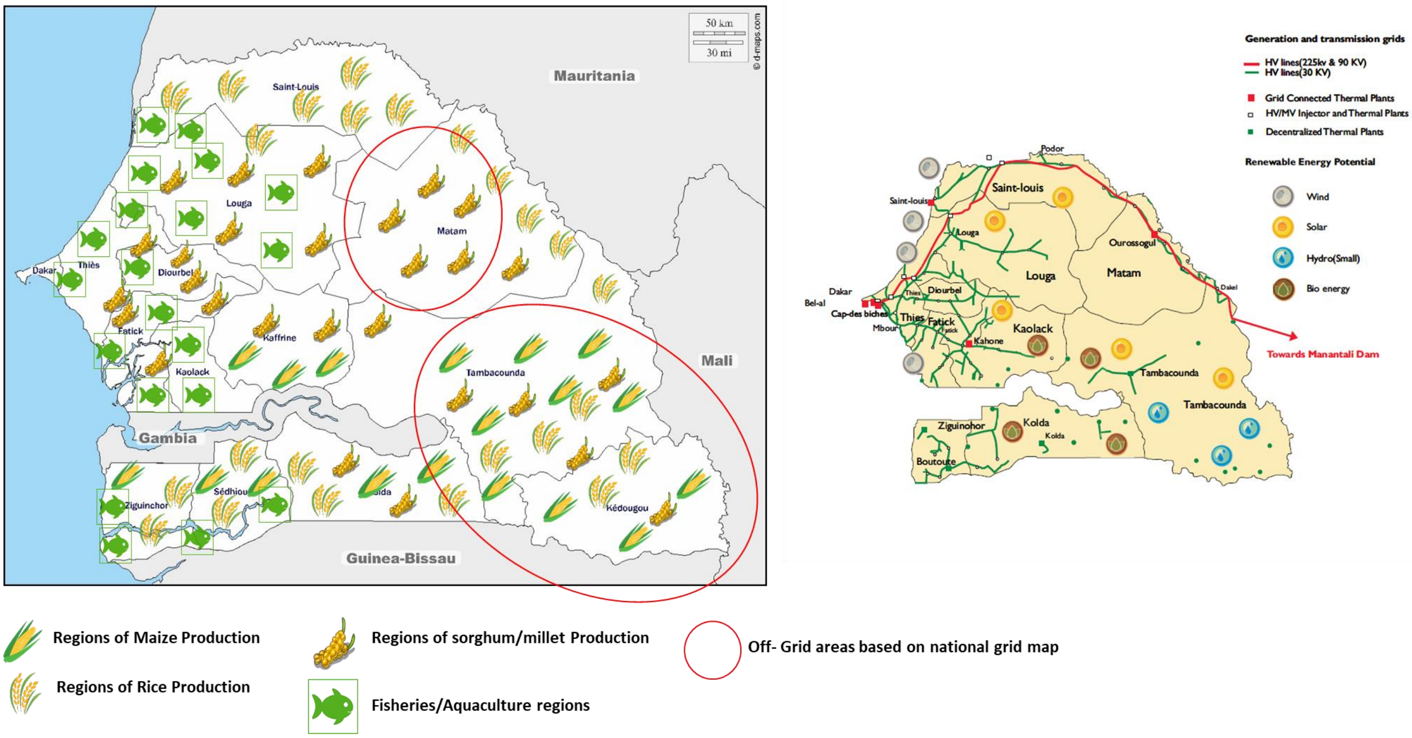

Figure 56: Senegal PU and electrification maps

Sources: Energy 4 Impact, IRENA (2012, 33)

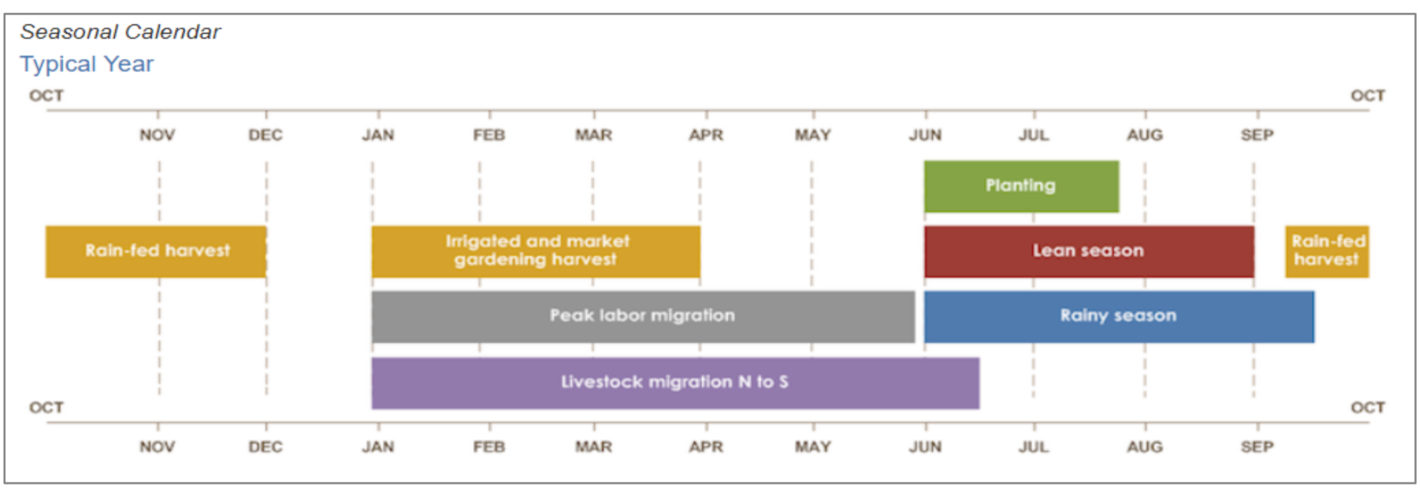

Figure 57: Senegal agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/west-africa/senegal)

Other notes

Agricultural & Fisheries Market Development Policies

- The National Agricultural Insurance Company of Senegal (CNAAS) provides a range of subsidised insurance services to farmers. These include crop and livestock insurance, drought insurance for maize and groundnuts, insurance for artisanal fishing vessels, and rainfall shortage insurance for millet, sorghum, groundnut, cotton, maize and rice[62]. There has been a growing interest in developing the country's horticultural sector for exports, particularly mangos.

Trade

- Temporary bans are often imposed on an ad hoc basis on imports of commodities to encourage local production and trade. Major commodities previously affected include poultry, onions and sugar[63].

[62] Ibid.
[63] Ibid.

5.14 Uganda

5.14.1 Overview

Macroeconomic data	
GDP per capita	$699.4 (2017)
GDP by sector	Agriculture, Forestry and Fishing 25.8% Industry/Manufacturing 22.5% Services 51.7%
Population	37.7 million (16.4% urban)
Raw materials and exports	Raw materials: copper, cobalt, hydropower, limestone, salt, arable land, gold Exports: coffee ($372M), gold ($339M), fish ($79M), sugar cane ($71M), cement ($61M), maize ($57M)
Climate	Overall: tropical climate. Average temperature: 18-25 °C Average annual rainfall of 600 – 2,400mm

Sources: UK FCO Uganda Economic Factsheet, CIA World Factbook, WTO's Uganda Trade Profile, UNDP Climate Change Country Profile

Electricity Overview	Value
Installed capacity of electricity power sources	937.8 MW: hydro (75.5%), thermal (14.5%), biomass (8.2%),, solar PV (1.8%)
Electricity consumption per capita	215 kWh/year
National electrification rate	26.1%
Urban electricity access	54.8%
Rural electricity access	19.9%

Sources: Uganda Bureau of Statistics (UBOS)

5.14.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, fisheries
Other VCs to consider	Sunflower seeds, pineapples, dairy, cattle meat, coffee beans, shea nuts, wood products, vanilla, yam

Sources: Authors

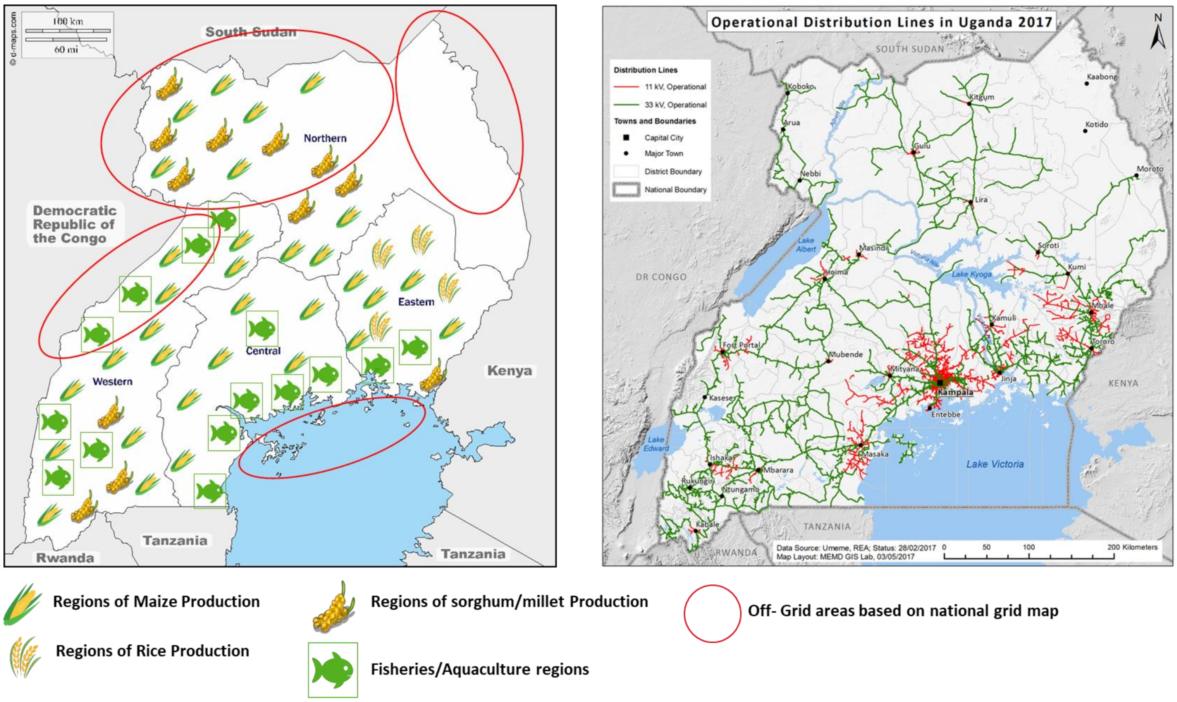

Figure 58: Uganda PU and electrification maps

Sources: Energy 4 Impact, Energy Sector GIS Working Group Uganda (http://www.energy-gis.ug/gis-maps/)

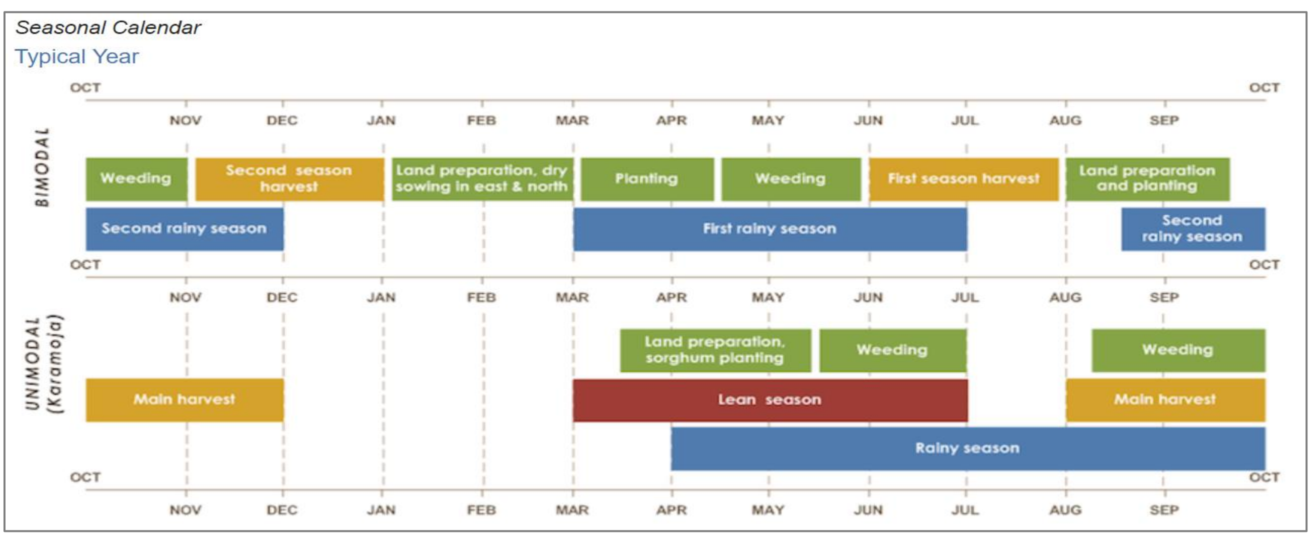

Figure 59: Uganda agricultural seasonal calendar

Source: USAID FEWS NET (http://fews.net/east-africa/uganda)

Other notes

Agricultural & Fisheries Market Development Policies

- The government has been prioritising value-addition in several agricultural sub-sectors in order to increase agricultural productivity and foster agricultural growth. The priority sectors identified are rice, sunflowers, cassava, banana, fish, floricultural and horticultural products. Support for these sectors comes in the form of subsidised distribution of high quality seeds and machinery, training of farmers, improvements in post-production infrastructure and dissemination of market information[64].
- The dairy sector is getting public support for post-production infrastructure in order to increase milk collection and quality.
- Rice is now treated as a priority crop in Uganda, being an urban food commodity and a rural cash crop. Indeed Uganda may become a rice hub for the Eastern African region and it is already exporting to Sudan, Congo and Kenya[65].

Trade

- Uganda's National Export Strategy (NES) prioritises coffee, fish, tea, cotton and textiles, flowers and services for private sector engagement.
- There is a zero percent tariff on goods originating from within the East African Community (EAC), and common external tariffs for other goods depending on the level of processing (raw, intermediate or finished products).
- The trading protocol of COMESA (Common Market for Eastern and Southern Africa) protects local producers of commonly imported goods such as wheat and rice through import tariffs and other incentives.

[64] (FAO 2015)
[65] Ibid.

5.15 Zambia

5.15.1 Overview

Macroeconomic data	
GDP per capita	$ GDP 1,479.5 (2017)
GDP by sector	Agriculture, Forestry and Fishing 6.5% Industry/Manufacturing 36.6% Services 56.9%
Population	17.2 million (41.4% urban)
Raw materials and exports	Raw materials: copper, cobalt, zinc, lead, coal, emeralds, gold, silver, uranium, hydropower Exports: refined copper and copper alloys ($4.4B), unrefined copper ($643M), maize ($201M), sugarcane ($115M), electrical energy ($100M)
Climate	Overall: tropical climate. Average temperature: 15-27 °C Average annual rainfall of 1,800 – 3,600mm

Sources: UK FCO Zambia Economic Factsheet, CIA World Factbook, WTO's Zambia Trade Profile, UNDP Climate Change Country Profile

Electricity Overview	Value
Installed capacity of electricity power sources	2,411 MW: hydro (96%), fossil fuels incl. diesel mini-grids (4%)
Electricity consumption per capita	707 kWh/year
National electrification rate	26%
Urban electricity access	25%
Rural electricity access	3%

Sources: World Bank, USAID Power Africa country factsheet

5.15.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, fisheries
Other VCs to consider	Cassava, cotton, wood products, pineapple, soy beans,

Sources: Authors

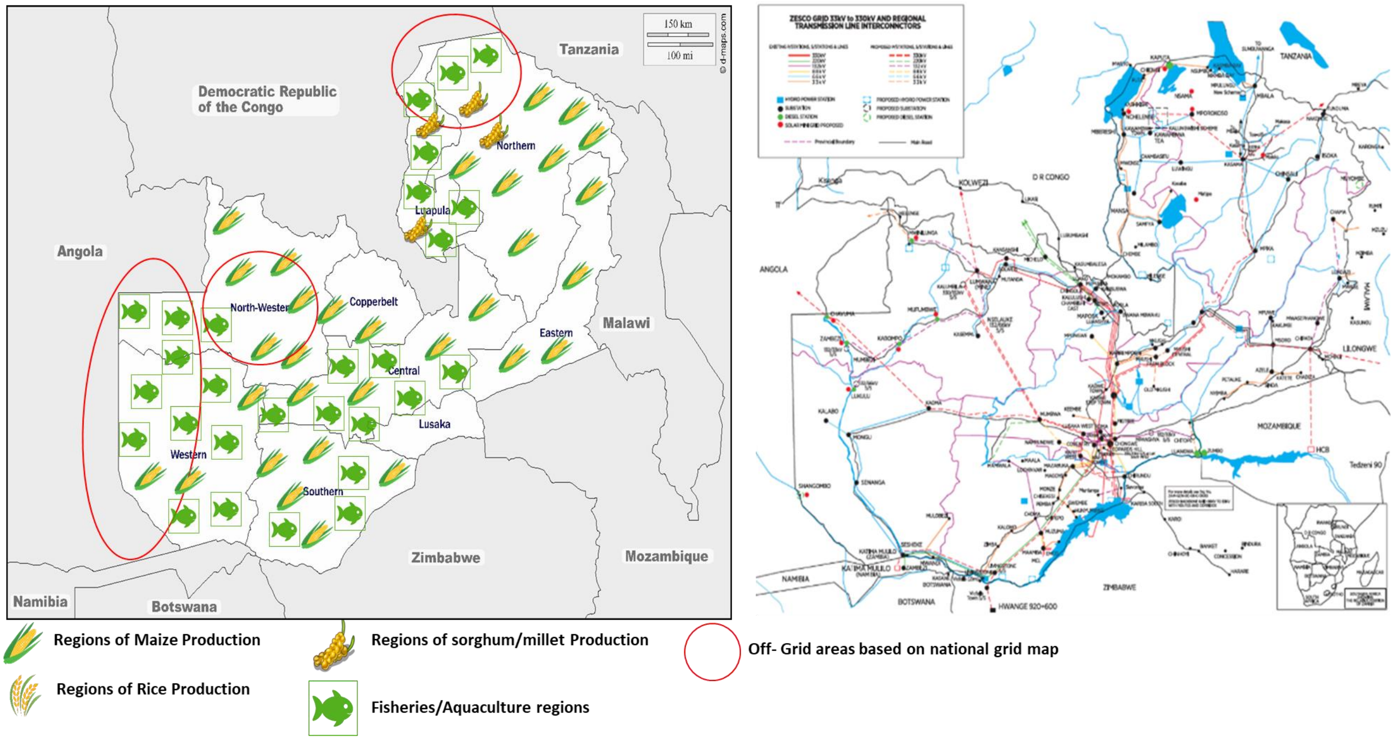

Figure 60: Zambia PU and electrification maps

Sources: Energy 4 Impact, IRENA (2013, Figure 5)

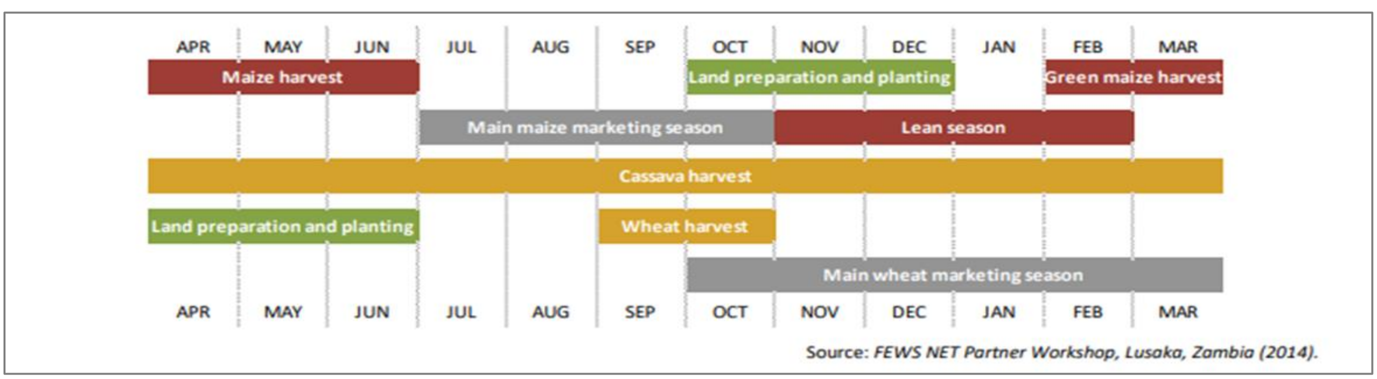

Figure 61: Zambia agricultural seasonal calendar

Source: USAID (2017, Table 2)

Other notes

Trade

- Uncertainty in trade policies, e.g. export bans and government interventions that distort market prices of commodities such as maize, has led to great volatility and disincentives in local food markets in Zambia[66,67].

[66] (USAID 2017)
[67] (ReNAPRI 2017)

5.16 Zimbabwe

5.16.1 Overview

Macroeconomic data	
GDP per capita	$ GDP 1,175.7 (2017)
GDP by sector	Agriculture, Forestry and Fishing 11% Industry/Manufacturing 23% Services 66%
Population	14.9 million (32.3% urban)
Raw materials and exports	Raw materials: coal, chromium ore, asbestos, gold, nickel, copper, iron ore, vanadium, lithium, tin, platinum group metals Exports: unmanufactured tobacco ($887M), gold ($850M), nickel ores and concentrates ($294M), ferro-alloys ($119M), diamonds ($118M), sugarcane ($58M)
Climate	Overall: tropical climate. Average temperature: 12-38 °C Average annual rainfall of 450 – 1,050mm

Sources: UK FCO Zimbabwe Economic Factsheet, CIA World Factbook, WTO's Zimbabwe Trade Profile, World Weather and Climate Information

Electricity Overview	Value
Installed capacity of electricity power sources	1,940 MW: coal (61%), hydro (39%)
Electricity consumption per capita	537 kWh/year
National electrification rate	52%
Urban electricity access	78%
Rural electricity access	40%

Sources: World Bank, RECP

5.16.2 Mapping opportunities for PUE

Opportunities for PUE	
Major VCs assessed	Maize, fisheries
Other VCs to consider	Wheat, soya beans, cotton, tobacco, cattle meat, hides and skins

Sources: Authors

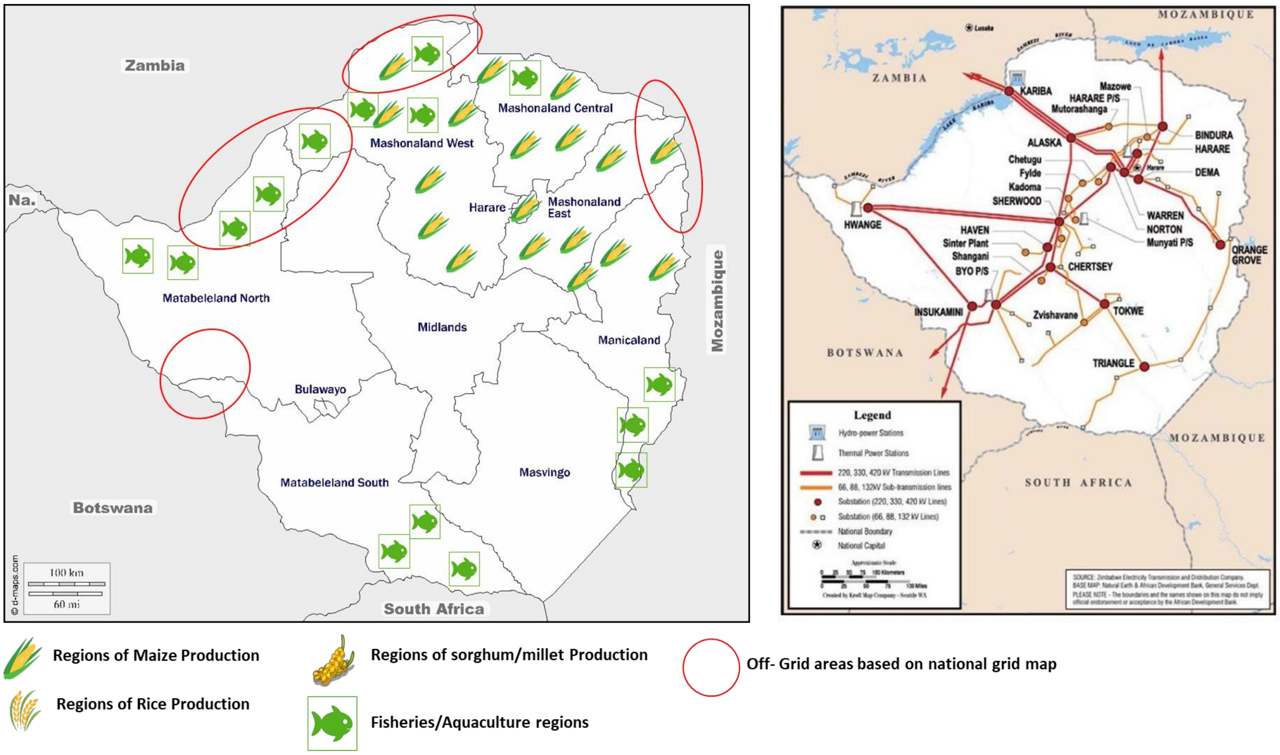

Figure 62: Zimbabwe PU and electrification maps

Sources: Authors, AfDB (2011, Map 8.3)

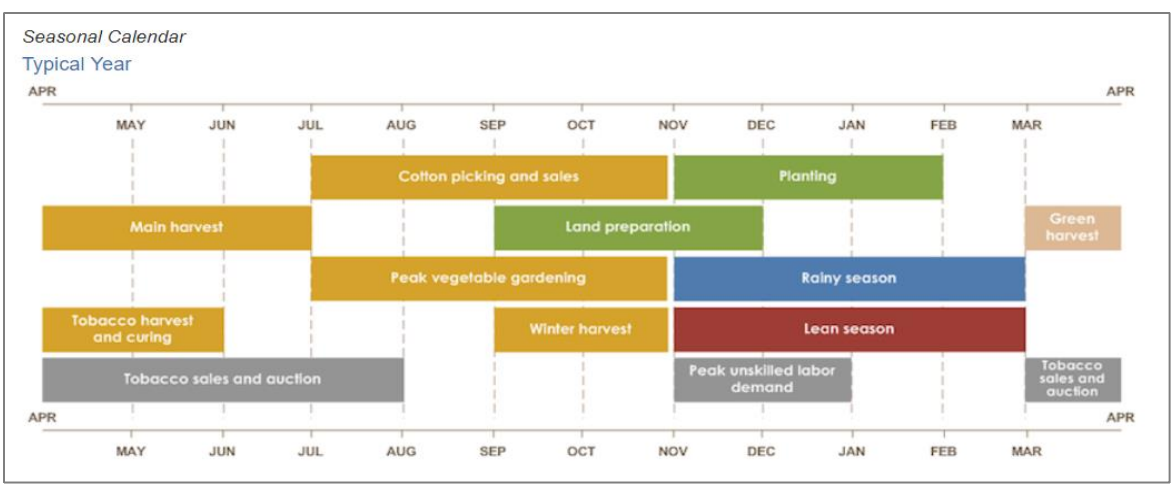

Figure 63: Zimbabwe agricultural seasonal calendar

Source: USAID FEWSNET (http://fews.net/southern-africa/zimbabwe)

Other notes

Agricultural & Fisheries Market Development Policies

- The country is highly susceptible to adverse weather conditions, especially droughts, which mainly affect the southern region, particularly Matabeleland South, Masvingo and Manicaland provinces[68].
- Following the development of the land reform programme, Zimbabwe does not currently have a long-term agricultural policy[69].
- The combination of the government's financial challenges and weather-related shocks has had a detrimental effect on agricultural productivity over the past years, particularly for maize, wheat, cotton and soybean[70].
- Zimbabwe's agricultural sector has traditionally had a dualistic production system, with 80% of agricultural land coming from large-scale commercial farms which mainly grow cash crops, and the remainder coming from small-scale producers cultivating food crops. The recent Fast Track Land Reform Programme (FTLRP) has significantly changed this system by creating small- to medium-sized land holdings from 20% of the large-scale farms, therefore shifting agricultural production and marketing patterns. The downside to this reform has been increased insecurity in land tenure, with many farmers still lacking proper title deeds.

Trade

- The Grain Marketing Board (GMB) is the purchaser of last resort for cereals from local farmers and pays prices higher than the market, particularly for maize and wheat. Delays in these payments have forced farmers to either sell their products at a lower price to private traders, or shift production to more profitable commodities such as tobacco[71].

[68] (USAID 2014)
[69] (FAO 2016)
[70] Ibid.
[71] Ibid.

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APPENDIX A: CEREALS AND FISHERIES – SELECTIVE COUNTRY OVERVIEWS

MAIZE

Maize	Country Overview
Democratic Republic of Congo (DRC)	• Second most important staple food after cassava. • About 1 million tonnes of maize produced in 2012 compared to 15 million tonnes of cassava[72]. • Mainly produced in the Orientale, Katanga, North Kivu, South Kivu and Kasai provinces. • Mainly consumed as flour, either mixed with cassava flour or as a substitute of cassava flour. • Locally produced maize flour is expensive due to challenges in local processing caused by poor electricity connection, poor road networks, inadequate storage facilities, and lack of adequate milling equipment. Decent processing infrastructure can only be found in Katanga Province in the south, and then only small scale artisanal milling in rural villages[73]. • Local producers and traders prefer to export their maize to Uganda and Rwanda and then import maize flour, usually through informal channels and on demand. The local market prefers imported maize flour to imported maize grain since it is easier to prepare in meals. • Storage is a major challenge in the maize sector in DRC. Availability of maize is therefore heavily dependent on seasonal production
Ethiopia	• Second most important cereal after teff. • Production is dominated by smallholder farmers with land holdings of 0.5 ha to 2 ha on average. • Produced primarily for subsistent consumption at farm level. Only 18% of the maize produced by smallholders is marketed. The rest of the marketed maize comes from commercial farms and the state (USAID 2010). • Maize in Ethiopia is mainly marketed in grain form and only processed at household level either using traditional methods or using small scale mills. • Only 6% of the marketed maize is processed into flour. This is because wheat is more commonly processed for the food industry. • Formal trading of maize grain takes place in the Ethiopia Commodity Exchange (ECX) platform using the warehouse receipt system. Only industry accepted grades are traded.
Mozambique	• Important for food at household level. 71% of smallholder farmers in the rural areas grow maize to supply the household food and poultry industry, which makes production highly fragmented[74]. Average cultivated land is 0.9 hectares per household[75]. Production is usually rain fed. • Mainly produced and consumed locally in the northern regions. The southern regions largely rely on maize imports from South Africa due to inadequate transport linkages which make it challenging for the northern producers to supply to the south. As such, maize processing in the north is dominated by small scale and medium scale millers to serve the local market, while the southern region is dominated by larger scale processors serving the local market with imported maize[76]. Maize prices in the southern region tend to be linked to South African maize prices. • Surplus maize produced in the northern region is supplied to neighbouring countries, especially Malawi.
Nigeria	• Nigeria is the second largest maize producer in Africa, after South Africa. About 10.79 million tonnes produced in 2014[77]. Mainly produced by smallholder farmers at an average 0.65ha per farmer. • Farmers in the southern part of the country typically tend to intercrop maize with other food such as yam, cassava, guinea corn, rice, cowpea, groundnut, and soybeans while those on the northern part farm the maize on its own[78]. • Maize processing for the feed industry is quite prominent in the country, owing to the growing local poultry market[79]

72 http://mineconomie.gouv.cd/IMG/pdf/cahier_sectoriel_agriculture.compressed.pdf
73 http://fews.net/sites/default/files/documents/reports/DRC_MarketFundamentals_20160111_508Compliant.pdf
74 https://pdf.usaid.gov/pdf_docs/PA00JZ7F.pdf
75 http://ageconsearch.umn.edu/record/58561/files/AAMP_Maputo_21_Mozambique.pdf
76 https://www.researchgate.net/publication/285594414_Postharvest_losses_in_Africa_-_Analytical_review_and_synthesis_the_case_of_Mozambique
77 http://sahelcp.com/wp-content/uploads/2017/06/Sahel-Newsletter-Volume-14.pdf
78 http://sahelcp.com/wp-content/uploads/2017/06/Sahel-Newsletter-Volume-14.pdf
79 https://www.giz.de/fachexpertise/downloads/giz2013-en-reducing-food-losses-improve-food-security.pdf

Senegal	• Third most important cereal after millet and sorghum[80]. • Mainly produced by smallholder farmers on an average of 4.3 ha per farmer. • Main producing regions are in the south of the country. Major local markets are Tambacounda, Kaolack, Touba and Bakel where maize is in deficit.
Uganda	• Produced by smallholder farmers primarily for income generation rather than food security, since it does not form a major part of household diet in Uganda[81]. • Approximately 1 million hectares are cultivated annually, with a local annual market of 350,000 - 400,000 metric tonnes[82]. • Local market mainly consists of institutions such as prisons, schools and hospitals, as well as households in the Karamoja region[83]. • Exports maize in the East African region to Kenya, Burundi, Sudan, Tanzania, and Rwanda, through both formal and informal channels. • Three main products of maize processing: "No.1" grade maize flour where maize is hulled before milling and preferred by urban households; "No.2" grade maize flour, a wholemeal type flour preferred by rural households; and maize bran supplying the animal feed industry.
Zambia	• Annual production of 0.9 million tonnes[84]. Second largest staple food exporter in the Southern Africa region after South Africa. • Over 80% of smallholder farmers grow maize to supply the local and regional market[85]. • Maize meal in rural areas is produced using hammer mills. Households find it cheaper than buying commercially produced maize meal. • Highly dependent on seasonality since maize production is mainly rain-fed. • Approximately 50% of all maize produced is consumed at household level and never enters the market. Maize is mainly used for food consumption, either as dry, fresh or as flour. It is also used for animal feed production and brewing, but on a local small scale level[86]. • Uncertainty in government policies is a major challenge for the local grains market in Zambia, which discourages private businesses from investing in grain trade and processing. For example, a recent export ban from the government has led to uncertainties in grain trade to surrounding countries such as Zimbabwe, Malawi and Mozambique[87] • Very low prices at harvest, often below costs of production, reduce incentives for smallholders to invest in productivity-enhancing inputs from commercial sources (WB competitiveness report – 2011).
Zimbabwe	• Mainly grown in marginal drier areas which are also suitable for draught tolerant crops such as sorghum and millet[88]. It accounts for 80-90 percent of domestic staple production. • Most maize meal consumed by rural and urban households comes from local traders through informal channels since it is milled locally in rural areas using hammer mills[89]. Majority of Zimbabwe households prefer locally produced maize products to imported products. Most of the maize meal consumed in the country comes from informal traders who get it from rural millers. • Market dominated by farmers associations who facilitate linkages between maize producers and traders. • Load shedding and power cuts from the Zimbabwe Electricity Supply Authority (ZESA) has seriously affected large scale and medium scale maize millers who rely on the national grid to run their machinery. Small scale millers, mostly located in small trade centres and rural areas do not feel the effect as much since they operate off-grid using diesel generators[90].

[80] http://www.senegalbusinessservices.com/cereal-chains/corn
[81] https://www.fews.net/sites/default/files/documents/reports/FEWS_NET_Uganda_Staple_Food_Market_Fundamentals_January_2017.pdf
[82] http://pdf.usaid.gov/pdf_docs/Pnadw642.pdf
[83] https://www.fews.net/sites/default/files/documents/reports/FEWS_NET_Uganda_Staple_Food_Market_Fundamentals_January_2017.pdf
[84] http://www.jaicaf.or.jp/publications/Zambia.pdf
[85] https://reliefweb.int/report/zambia/zambia-staple-maize-market-fundamentals-october-2017
[86] http://www.jaicaf.or.jp/publications/Zambia.pdf
[87] http://www.renapri.org/wp-content/uploads/2017/11/2016_Market-Intermediaries_Policy_Brief-2016.pdf
[88] http://fews.net/sites/default/files/documents/reports/Zimbabwe_Food_Security_Brief_2014_0.pdf
[89] http://www.fao.org/fileadmin/templates/est/AAACP/eastafrica/UnvPretoria_GrainChainZimbabwe_2010_1_.pdf
[90] http://www.fao.org/fileadmin/templates/est/AAACP/eastafrica/UnvPretoria_GrainChainZimbabwe_2010_1_.pdf

	• Easier to find maize flour in southern part of the country all year round[91]. Processing consists of dry milling of maize to flour and animal feed and wet milling for the brewing industry[92].

MILLET AND SORGHUM

Millet and Sorghum	Country Overview
Burkina Faso	• Sorghum and millet account for 66% of national cereal supplies. Official sorghum and millet exports are minimal. • Sorghum production 1.7 million MT (2015/2016). Low yields, estimated at less than 1,000 kg/ha. • Millet production 0.98 million MT (2015/2016). Grown under rain fed conditions on about 1.1 million ha. Low yields, estimated at less than 700 kg/ha. • Minimal processing of sorghum into retail food products. Millet based products are mostly *degue*, couscous, flour and porridge mixes. • Typical VC includes small farmers with family, collectors based in crop collection areas will either make the rounds of local farmers to purchase their crops or the farmers will bring their crops to the collector or semi-wholesaler in the marketplace. Wholesalers (distributors, exporters, and importers) are based in large urban areas, where they store or package the crops for resale at a later date.
Ethiopia	• Most sorghum is produced by smallholders and a small share of commercial farmers (2%). • Sorghum is mostly produced for household consumption with only 13% of it being marketed and sold. • Average annual per capita consumption of sorghum was 25.34kg[93]. • Sorghum is consumed in various forms, including *enjera* (spongy flatbread), porridge, *dabo, (*loafed bread) and traditional beer and alcohol such as *tella* and *arekie.* • Sorghum is normally marketed in grain form and is processed at household level using traditional means or using the services of small grain mills. • Other activities carried out at village level include threshing and dehulling.
Mali	• Sorghum and millet are grown in the cotton-cereal production basins of Mali and belong to traditional cotton-cereal farming systems. • Sorghum and millet contribute 5% to the gross domestic product and account for about 15% of consumption shares (in monetary terms). • Sorghum is produced by a large network of smallholder farms. Farms are organized primarily at the village level, where land is allocated in a traditional land tenure system (communal plots) and village associations often act as farm cooperatives, assisting farmers in securing input loans and purchasing inputs. • Annual production of sorghum and millet is about 1.2 million MT and 1.7 million MT respectively. • Sorghum processing goes mostly into traditional beer (*dolo*) and some of the millet crop is also used for beer. • Millet-based products are mostly *degue,* couscous, flour and porridge mixes. • Village level activities include cleaning, threshing, dehulling and milling. The VC includes farmers, collectors, wholesalers and processors or retailers which serve final consumers.
Mozambique	• Sorghum is a major cereal in Mozambique with a cultivated area of 2.7 million hectares. Cultivation of sorghum is done on small holder farms on rain-fed systems. Almost all sorghum produced by the average household is consumed in the household. Only 5% is estimated to be sold. About 60% of

[91] http://fews.net/sites/default/files/documents/reports/Zimbabwe_Food_Security_Brief_2014_0.pdf
[92] http://www.fao.org/fileadmin/templates/est/AAACP/eastafrica/UnvPretoria_GrainChainZimbabwe_2010_1_.pdf
[93] https://d3n8a8pro7vhmx.cloudfront.net/eatradehub/pages/859/attachments/original/1433145982/ETHIOPIA_Staple_Foods_Value_Chain_Analysis_April_2010.pdf?1433145982

	sorghum is consumed as boiled meal in farmer households whereas about 23% of the total produce is used for brewing alcoholic beverage e.g beer particularly in the northern and central regions. About 10% is used for other non-alcoholic beverages. It is consumed in the form of *nshima* (hard porridge). Sorghum is also eaten as fresh grain in the field. • Other village level activities, include dehulling, threshing, winnowing and milling. Further up the VC, value addition activities include packaging of sorghum flour as well as using it as a composite for wheat flour, teff flour and maize meal. Residues are also used in production of animal feed.
Niger	• Sorghum and millet are the main staple foods in Niger – annual per capita consumption is estimated between 100–200 kg. • Millet and sorghum together contribute to over 90% of cereal production in Niger. Yield is about 0.35 MT/ha, about one third that of maize and slightly lower than that of pearl millet.. Production is dominated by smallholder farmers operating under rain fed conditions. • After harvest, the grains are pounded with a mallet and mortar, or ground with a flour mill, and the kernels or flour are generally cooked, cooled and formed to make the food of a type of pudding called "*patte*" or "*toou*" for human consumption. The husks are used as chicken feeds and the stalks are used as building materials for houses (roof and wall) or as forage for animals. • Value addition for millet and sorghums: converting sorghum and millet grain to flour; creating couscous and a series of other millet products such as *degue,* tchakri yogurt, arraw, and infant food.
Nigeria	• Nigeria is the largest sorghum producer in West Africa, accounting for about 71% of the total regional sorghum output. • Millet and sorghum farmers typically follow low-input, low-output production systems, characterized by limited access to agricultural credit, inefficient use of fertilizers, and no access to high-yielding millet and sorghum varieties or improved seed. Farm yields are typically 1-1.5 MT/ha. • Annual millet and sorghum consumption is 32-40 kg per capita. The crops are consumed in three ways: traditional, industrial and for animal feed. Traditional uses include cooked grains, thick porridge from non-fermented flour called "tou", slightly fermented porridge, cake and flat bread, couscous, donut, and a local beer called "dolo". The crop residues or all stems, leaves and panicles stalk are used by farmers as fodder for feeding their livestock. • The supply chain for sorghum and millet is not well developed because they are mainly grown for self-consumption.
Senegal	• Millet accounts for more than 60% of cereal production in Senegal. About 1.0 million hectares or one-third of Senegal's arable land is devoted to millet. Most of the producers are family farms, with 70% of cultivating 1-5 ha each. • Millet is consumed as a porridge, made into couscous, "Sankal", bread, cookies. • Village activities include: threshing, dehulling, drying (for couscous) and milling. Value addition activities include production of millet flour and couscous.

RICE

Rice	Country Overview
Burkina Faso	• 33 kg per capital annual rice consumption. 35% is locally produced, the rest is imported. There are about 100,000 smallholder rice producers in Burkina Faso. • There are no commercial or large millers in the country. At least 50% of production undergoes manual processing and parboiling. Processing includes transforming paddy rice to milled rice (white rice). • Customer preferences for broken rice, but brown rice imports are increasing.
Cameroon	• 23 kg per capita annual rice consumption.

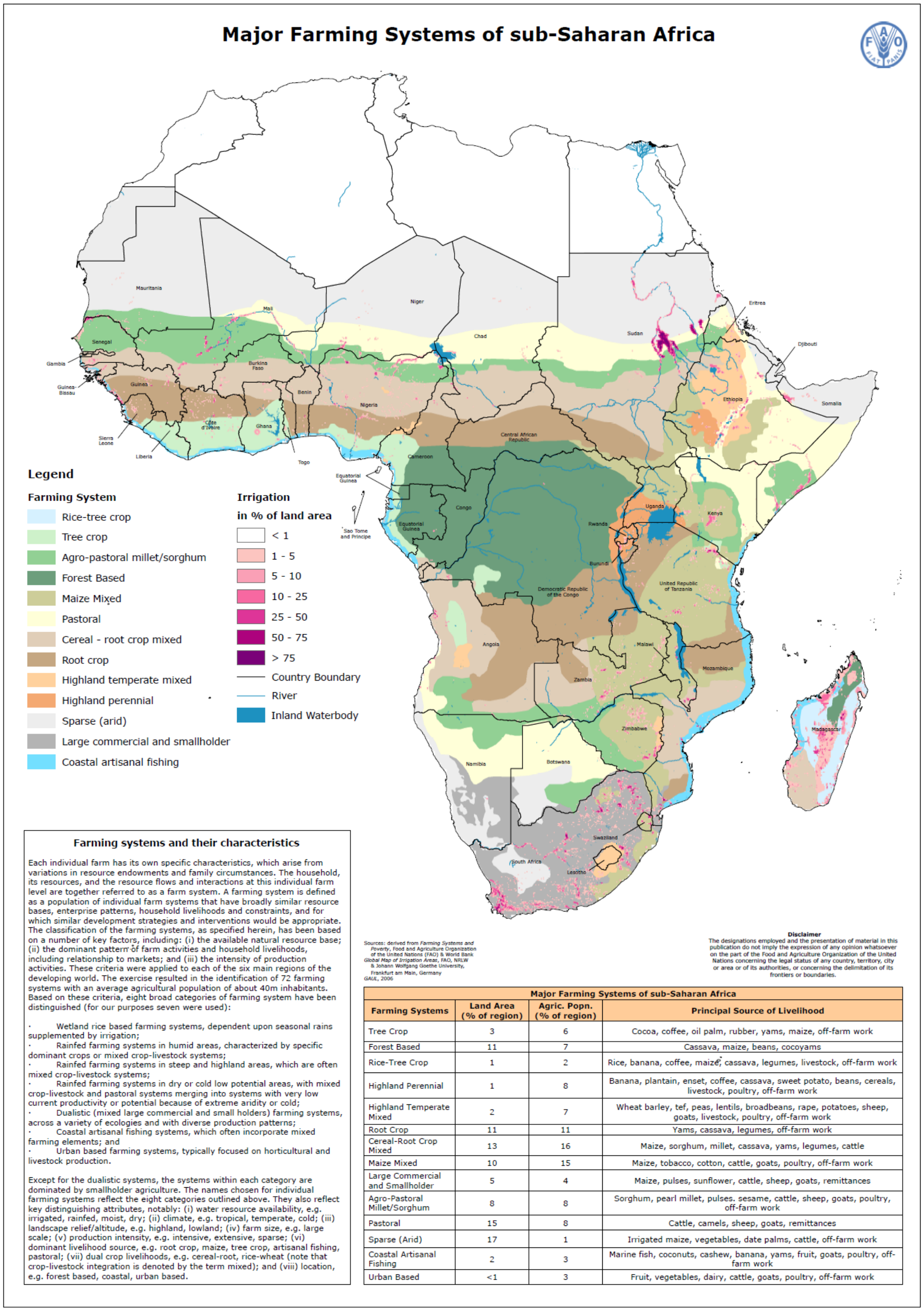
	• Most of rice produced in Cameroon is sold to neighbouring countries in its raw form, mainly due to lack of processing equipment. • Possible PUE opportunities: small scale and medium scale milling in rural areas in the far north and west regions, production of rice flour; processing or rice-based products.
Côte d'Ivoire	• 73 kg per capital annual rice consumption. • More than 2 million rice producers. • There are small village hulling plants (6,600 small-scale and semi-industrial units). • Processing of paddy rice to milled rice (white rice). A substantial amount of paddy is diverted to Guinea for hulling and parboiling. • Women are heavily involved in post-harvest operations (threshing, winnowing) and hold a virtual monopoly for local rice sales in the markets in most production zones. • Rice by-products include briquettes from husks.
Democratic Republic of Congo (DRC)	• About half of the rice harvest is used for beer production, the other half is used for consumption by local people. • The main challenges include: deficient infrastructure (energy and transport); poor governance and business regulations; lack of skilled workers; and high cost of financing; access to electricity (fewer than 9% of households); road infrastructure and access to markets.
Mali	• 80 kg per capital annual rice consumption. Households generally boil the cereal for couscous or porridge to form the base of the meal. Rice is the most widely consumed cereal in Mali but also one of the most expensive ones • Most rice is milled using small, sometimes portable mills. In Mali, for-hire mini rice mills operate with polishers and graders capable of presenting a clean, polished product and sorting it into homogeneous lots by kernel size. Other local activities include: husking (3,500 hullers), and parboiling (30,000 steaming stations). Regional exports to Burkina Faso and Guinea. • Most consumers (80-85%) eat broken rice, 10% eat broken grains, 3% long grain rice, and there is a small portion of aromatic imported rice.
Madagascar	• 118 kg per capita annual rice consumption. Rice is grown by 2 million smallholder farmers, which account for 85% of rice farmers. • There are 30,000 operators many of whom are involved in collection, husking and wholesale and retail.
Nigeria	• Nigeria currently is the world's second largest rice importer. 90% of domestic rice is produced by smallholders. • Activities at the village level include: drying, winnowing, husking and milling.
Senegal	• 68.5 kg per capita annual rice consumption. There is a market preference for broken rice. • Senegal River Valley has irrigated production systems and well developed supply chains, but the South does not. • Most producers sell rice as paddy without further processing. Processing is done manually with small mechanical mills at the village level. Markets are accessed through weekly markets or wholesale to urban markets. • Poor processing results in rice not conforming to customer preferences. There are four rice types: broken, intermediary, whole and ungraded rice. The urban markets have a strong preference for broken rice. Improved drying, sorting and processing of rice is needed.

FISHERIES

Fish	Country Overview
Madagascar	• Madagascar has more than 5,600 km of coastline and inland water bodies. • Fisheries sector contributes 7% to the GDP.[94] However, the average local fish consumption is still relatively low with 6.9 kg per person per year.[95]
Mozambique	• With a coast line area of 2,700 km^2, the fisheries sector contributes 4% to the GDP.[96] • The fisheries sector faces a lot of challenges such as illegal fishing, poor fishing handling (especially in artisanal fish markets) and poor storage facilities like cold rooms.
Nigeria	• In 2015, the total fisheries production was 1,027,000 tonnes and the fisheries sector contributed 0.5% to the GDP with an annual fish consumption of 12.5 kg per person.[97] Small scale artisanal fishing in rural communities contributes 80% of the total fish production in Nigeria.
Senegal	• The fisheries sector contributed 1.5% to the GDP in 2015, generating around $353 million in revenues and $20 million in export with a high annual consumption of 23.9 kg per person.[98] • The fisheries sector in Senegal accounts for 53,100 direct jobs and 540,000 indirect jobs largely in artisanal fishing, many of which are in rural or semi-rural areas.
Uganda	• Uganda is the second largest aquaculture producer after Nigeria in SSA. • Aquaculture has created more than 12,000 jobs in Uganda.[99] Most of these jobs are related to capturing, processing or selling fish.
Zambia	• Zambia is a landlocked country with only 9,220 km^2 area of water bodies. It has an annual fish production of about 106,798 tonnes which represents 1% of GDP. • The annual fish consumption per capita is around 7 kg[100]. In an attempt to reduce fish imports, Zambia secured $50 Million from the AfDB to develop the aquaculture sector.[101]

[94] FAO (http://www.fao.org/fishery/facp/MDG/en#CountrySector-SectorSocioEcoContribution)
[95] FAO (http://www.fao.org/3/a-br796e.pdf)
[96] FAO (http://www.fao.org/fishery/docs/DOCUMENT/fcp/en/FI_CP_MZ.pdf)
[97] FAO (http://www.fao.org/fishery/facp/NGA/en)
[98] FAO (http://www.fao.org/fishery/facp/SEN/en)
[99] FAO (http://www.fao.org/fishery/countrysector/naso_uganda/en)
[100] FAO (https://www.sadc.int/files/9514/8724/5615/SADC_Fisheries_Fact_Sheet_Vol.1_No._2__Focus_on_Zambia.pdf)
[101] Ibid.

APPENDIX B: MAP OF MAJOR FARMING SYSTEMS IN SSA (SOURCE: FAO)



Farming systems and their characteristics

Each individual farm has its own specific characteristics, which arise from variations in resource endowments and family circumstances. The household, its resources, and the resource flows and interactions at this individual farm level are together referred to as a farm system. A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. The classification of the farming systems, as specified herein, has been based on a number of key factors, including: (i) the available natural resource base; (ii) the dominant pattern of farm activities and household livelihoods, including relationship to markets; and (iii) the intensity of production activities. These criteria were applied to each of the six main regions of the developing world. The exercise resulted in the identification of 72 farming systems with an average agricultural population of about 40m inhabitants. Based on these criteria, eight broad categories of farming system have been distinguished (for our purposes seven were used):

- Wetland rice based farming systems, dependent upon seasonal rains supplemented by irrigation;
- Rainfed farming systems in humid areas, characterized by specific dominant crops or mixed crop-livestock systems;
- Rainfed farming systems in steep and highland areas, which are often mixed crop-livestock systems;
- Rainfed farming systems in dry or cold low potential areas, with mixed crop-livestock and pastoral systems merging into systems with very low current productivity or potential because of extreme aridity or cold;
- Dualistic (mixed large commercial and small holders) farming systems, across a variety of ecologies and with diverse production patterns;
- Coastal artisanal fishing systems, which often incorporate mixed farming elements; and
- Urban based farming systems, typically focused on horticultural and livestock production.

Except for the dualistic systems, the systems within each category are dominated by smallholder agriculture. The names chosen for individual farming systems reflect the eight categories outlined above. They also reflect key distinguishing attributes, notably: (i) water resource availability, e.g. irrigated, rainfed, moist, dry; (ii) climate, e.g. tropical, temperate, cold; (iii) landscape relief/altitude, e.g. highland, lowland; (iv) farm size, e.g. large scale; (v) production intensity, e.g. intensive, extensive, sparse; (vi) dominant livelihood source, e.g. root crop, maize, tree crop, artisanal fishing, pastoral; (vii) dual crop livelihoods, e.g. cereal-root, rice-wheat (note that crop-livestock integration is denoted by the term mixed); and (viii) location, e.g. forest based, coastal, urban based.

Major Farming Systems of sub-Saharan Africa

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Source of Livelihood
Tree Crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work
Forest Based	11	7	Cassava, maize, beans, cocoyams
Rice-Tree Crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Highland Perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work
Highland Temperate Mixed	2	7	Wheat barley, tef, peas, lentils, broadbeans, rape, potatoes, sheep, goats, livestock, poultry, off-farm work
Root Crop	11	11	Yams, cassava, legumes, off-farm work
Cereal-Root Crop Mixed	13	16	Maize, sorghum, millet, cassava, yams, legumes, cattle
Maize Mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
Large Commercial and Smallholder	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances
Agro-Pastoral Millet/Sorghum	8	8	Sorghum, pearl millet, pulses. sesame, cattle, sheep, goats, poultry, off-farm work
Pastoral	15	8	Cattle, camels, sheep, goats, remittances
Sparse (Arid)	17	1	Irrigated maize, vegetables, date palms, cattle, off-farm work
Coastal Artisanal Fishing	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work
Urban Based	<1	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work

Source: FAO (http://www.ipcinfo.org/fileadmin/user_upload/faowater/docs/ruralmaps/farmingsystems_colour.pdf

APPENDIX C: TECHNICAL CONSIDERATIONS FOR ELECTRICAL MACHINERY FOR SMALL-SCALE OFF-GRID CEREAL PROCESSING

PU Activity	Example of Machinery (Manufacturer)	Description	Notes
Threshing	Maize Sheller/Thresher 100W (Project Support Services PNG, Papua New Guinea)	Small-scale DC type machine. Production capacity of 250 kg/hr. Operated by a 100 W motor. Requires a lead-acid battery with a capacity of 120 Ah and above. Requires a charge controller of 20-40 A. Standby of 1-2 hours therefore suitable for toll milling.	The thresher is designed to typically work with a milling machine and should therefore be compatible with a DC operated milling machine. Requires replacement of battery and DC brushes every 2-5 years.
Milling	Grain Mill 750 W (Project Support Services PNG, Papua New Guinea)	Small-scale DC type machine. Production capacity of 25-50kg/hr depending on type of grain. Operated by a 750 W motor. Requires a lead-acid battery of 120 Ah and above. Requires a charge controller of 20-40 A. Standby of 1-2 hours therefore suitable for toll milling.	This machine is capable of milling maize, millet and/or sorghum. Can be used with the thresher mentioned above. Battery and DC brushes need replacement every 2-5 years.
Milling	Grain Milling Solar Milling Machine (Seine Tech, Spain)	A medium-scale AC type machine. Daily electricity consumption of 4.4 kWh. Contains a 3-phase synchronous motor (230/400 V, 50 Hz) Production capacity of 25 – 150 kg/hr depending on type of grain and hardness of the grain. Direct drive of the system using batteries is possible (optional).	Designed to target smallholder farmers, rural communities, co-operatives and projects in off-grid rural areas Production capacity varies between 30 – 150 kg/hr for maize, wheat and barley, and between 25 – 40 kg/hr for millet, tef and sorghum.
Milling	Grain Mill BOSS Pro Farina (Phaesun GmbH, Germany)	Medium to large scale AC type machine. Comes with an adjustable grinder to mill different types of grains. Contains a 3-phase synchronous motor (3 x 230/400 V, 50 Hz, 750 W) Production capacity of 45 – 160 kg/hr depending on type of grain and hardness of the grain.	The company has experience in developing milling machines tailor-made for use in rural areas in Africa. Local distributing partners are equipped with the capacity for service, maintenance and system optimisation of the machinery as well as spare parts.

		Direct drive of the system using batteries is possible (optional).s	Production capacity varies between 40 – 260 kg/hr for maize, wheat and barley, and 45 kg/hr for millet, tef and sorghum.
Baking	Haridas Instruments & Equipment Co (Mumbai, India)	Wattage 6 kW 415 V, Three-phase AC, 50 Hz Input current: 8.6 Amps / Phase Production capacity of 0-100kg	The oven is designed to save 50%-75% of power as compared to tray type models.
Packaging	Henan Institute Of Grain Machinery Manufacturing Co., Ltd (Henan Province, China)	Wattage 3.5kW Voltage 220V/380V 30-60 bags per minute Food, grain, corn, rice, wheat flour	Automatic filling, weighing, sealing
Brewing		Wattage 10kW (could be lower depending on size) Capacity 50 Litres/day 3 Phase, 220V/380V	Fermenting Equipment, milling, brewing, filtration, filling

Source: Authors, GIZ 2016
(https://energypedia.info/images/9/98/GIZ_(2016)_Catalogue_PV_Appliances_for_Micro_Enterprises.pdf)

APPENDIX D: CROP CLASSIFICATION SYSTEM (SOURCE: FAO)

Group	Class	Sub-class	Order	Title	Crop type[1]
1				**Cereals**	**1**
	11			Wheat	1
	12			Maize	1
	13			Rice	1
	14			Sorghum	1
	15			Barley	1
	16			Rye	1
	17			Oats	1
	18			Millets	1
	19			Other cereals, n.e.c.	1
		191		*Mixed cereals*	*1*
		192		*Other*	*1*
2				**Vegetables and melons**	**1**
	21			Leafy or stem vegetables	1
		211		*Artichokes*	*1*
		212		*Asparagus*	*1*
		213		*Cabbages*	*1*
		214		*Cauliflowers & broccoli*	*1*
		215		*Lettuce*	*1*
		216		*Spinach*	*1*
		217		*Chicory*	*1*
		219		*Other leafy or stem vegetables, n.e.c.*	*1*
	22			Fruit-bearing vegetables	1
		221		*Cucumbers*	*1*
		222		*Eggplants (aubergines)*	*1*
		223		*Tomatoes*	*1*
		224		*Watermelons*	*1*
		225		*Cantaloupes and other melons*	*1*
		226		*Pumpkin, squash and gourds*	*1*
		229		*Other fruit-bearing vegetables, n.e.c.*	*1*
	23			Root, bulb, or tuberous vegetables	1
		231		*Carrots*	*1*
		232		*Turnips*	*1*
		233		*Garlic*	*1*
		234		*Onions (incl. shallots)*	*1*
		235		*Leeks & other alliaceous vegetables*	
		239		*Other root, bulb, or tuberous vegetables, n.e.c.*	*1*
	24			Mushrooms and truffles	1
	29			Vegetables, n.e.c.	1
3				**Fruit and nuts**	**2**
	31			Tropical and subtropical fruits	2
		311		*Avocados*	*2*
		312		*Bananas & plantains*	*2*
		313		*Dates*	*2*
		314		*Figs*	*2*
		315		*Mangoes*	*2*
		316		*Papayas*	*2*
		317		*Pineapples*	*2*
		319		*Other tropical and subtropical fruits, n.e.c.*	*2*
	32			Citrus fruits	2
		321		*Grapefruit & pomelo*	*2*
		322		*Lemons and Limes*	*2*
		323		*Oranges*	*2*
		324		*Tangerines, mandarins, clementines*	*2*
		329		*Other citrus fruit, n.e.c.*	*2*

1. 1 = temporary; 2 = permanent.

Group	Class	Sub-class	Order	Title	Crop type[1]
	33			Grapes	2
	34			Berries	2
		341		*Currants*	*2*
		342		*Gooseberries*	*2*
		343		*Kiwi fruit*	*2*
		344		*Raspberries*	*2*
		345		*Strawberries*	*2*
		346		*Blueberries*	
		349		*Other berries*	*2*
	35			Pome fruits and stone fruits	2
		351		*Apples*	*2*
		352		*Apricots*	*2*
		353		*Cherries & sour cherries*	*2*
		354		*Peaches & nectarines*	*2*
		355		*Pears & quinces*	*2*
		356		*Plums and sloes*	*2*
		359		*Other pome fruits and stone fruits, n.e.c.*	*2*
	36			Nuts	2
		361		*Almonds*	*2*
		362		*Cashew nuts*	*2*
		363		*Chestnuts*	*2*
		364		*Hazelnuts*	*2*
		365		*Pistachios*	*2*
		366		*Walnuts*	*2*
		369		*Other nuts n.e.c.*	*2*
	39			Other fruits, n.e.c.	2
4				**Oilseed crops**	
	41			Soya beans	1
	42			Groundnuts	1
	43			Other temporary oilseed crops	1
		431		*Castor bean*	*1*
		432		*Linseed*	*1*
		433		*Mustard*	*1*
		434		*Niger seed*	*1*
		435		*Rapeseed*	*1*
		436		*Safflower*	*1*
		437		*Sesame*	*1*
		438		*Sunflower*	*1*
		439		*Other temporary oilseed crops, n.e.c.*	*1*
	44			Permanent oilseed crops	2
		441		*Coconuts*	*2*
		442		*Olives*	*2*
		443		*Oil palms*	*2*
		449		*Other oleaginous fruits, n.e.c.*	*2*
5				**Root/tuber crops with high starch or inulin content**	**1**
	51			Potatoes	1
	52			Sweet potatoes	1
	53			Cassava	1
	54			Yams	1
	59			Other roots & tubers, n.e.c.	1
6				**Beverage and spice crops**	
	61			Beverage crops	2
		611		*Coffee*	*2*
		612		*Tea*	*2*
		613		*Maté*	*2*
		614		*Cocoa*	*2*
		619		*Other beverage crops, n.e.c.*	*2*

1. 1 = temporary; 2 = permanent.

Group	Class	Sub-class	Order	Title	Crop type[1]
	62			Spice crops	
		621		*Temporary spice crops*	*1*
			6211	Chilies & peppers (capsicum spp.)	1
			6212	Anise, badian, and fennel	1
			6219	Other temporary spice crops, n.e.c.	1
		622		*Permanent spice crops*	*2*
			6221	Pepper (piper spp.)	2
			6222	Nutmeg, mace, cardamoms	2
			6223	Cinnamon (canella)	2
			6224	Cloves	2
			6225	Ginger	2
			6226	Vanilla	2
			6229	Other permanent spice crops, n.e.c.	2
7				**Leguminous crops**	1
	71			Beans	1
	72			Broad beans	1
	73			Chick peas	1
	74			Cow peas	1
	75			Lentils	1
	76			Lupins	1
	77			Peas	1
	78			Pigeon peas	1
	79			Leguminous crops, n.e.c.	1
8				**Sugar crops**	**1**
	81			Sugar beet	1
	82			Sugar cane	1
	83			Sweet sorghum	1
	89			Other sugar crops n.e.c.	1
9				**Other crops**	
	91			Grasses and other fodder crops	
		911		*Temporary grass crops*	*1*
		912		*Permanent grass crops*	*2*
	92			Fibre crops	
		921		*Temporary fibre crops*	*1*
			9211	Cotton	1
			9212	Jute, kenaf, and other similar crops	1
			9213	Flax, hemp, and other similar products	1
			9219	Other temporary fibre crops	1
		922		*Permanent fibre crops*	*2*
	93			Medicinal, aromatic, pesticidal, or similar crops	
		931		*Temporary medicinal, etc. crops*	*1*
		932		*Permanent medicinal, etc. crops*	*2*
	94			Rubber	2
	95			Flower crops	
		951		*Temporary flower crops*	*1*
		952		*Permanent flower crops*	*2*
	96			Tobacco	1
	99			Other crops	
		991		*Other crops – temporary*	*1*
		992		*Other crops – permanent*	*2*

1. 1 = temporary; 2 = permanent.

Source: FAO (http://www.fao.org/fileadmin/templates/ess/documents/world_census_of_agriculture/appendix3_r7.pdf)

APPENDIX E: CEREALS AND FISHERIES PRODUCTION AND TRADE MAPS – SELECTIVE COUNTRY MAPS

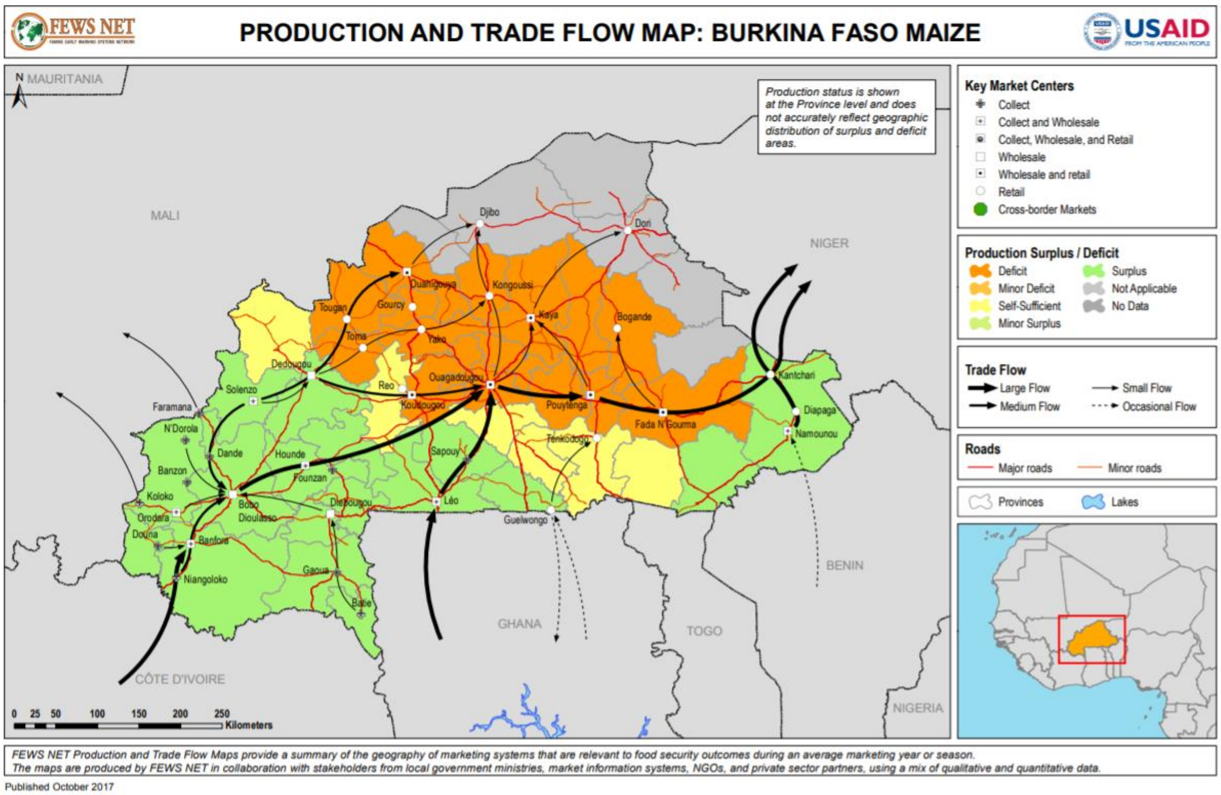
Main sources for maps

USDA's IPAD: https://ipad.fas.usda.gov/ogamaps/cropproductionmaps.aspx

USAID's FEWS NET programme: http://fews.net/

MAIZE

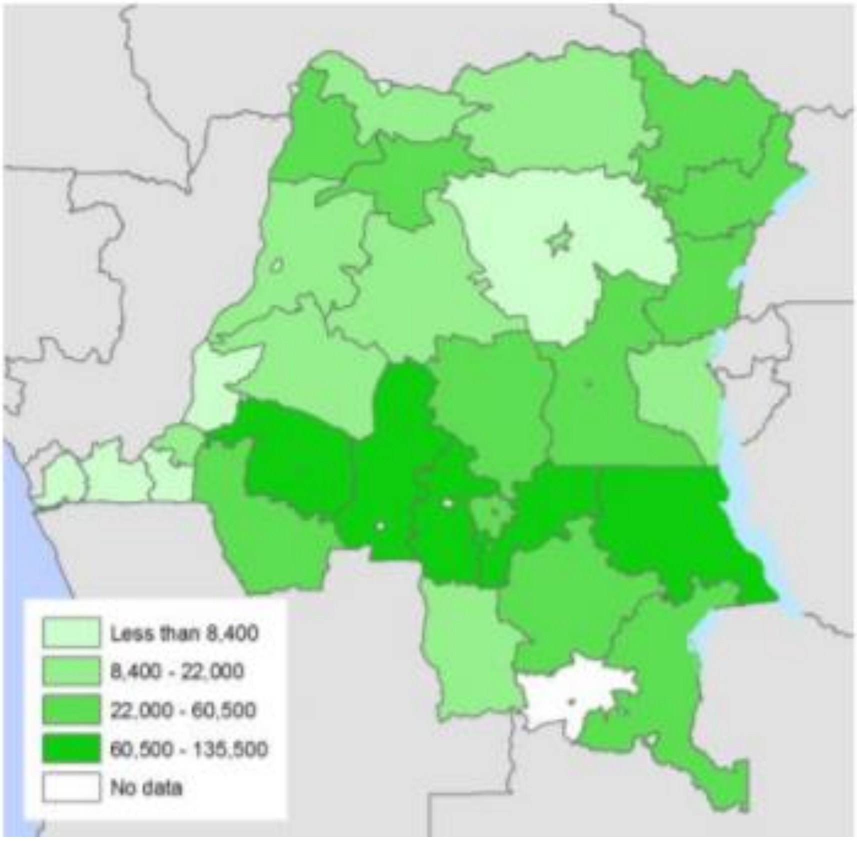
Burkina Faso



Source: USAID's FEWS NET, 2017

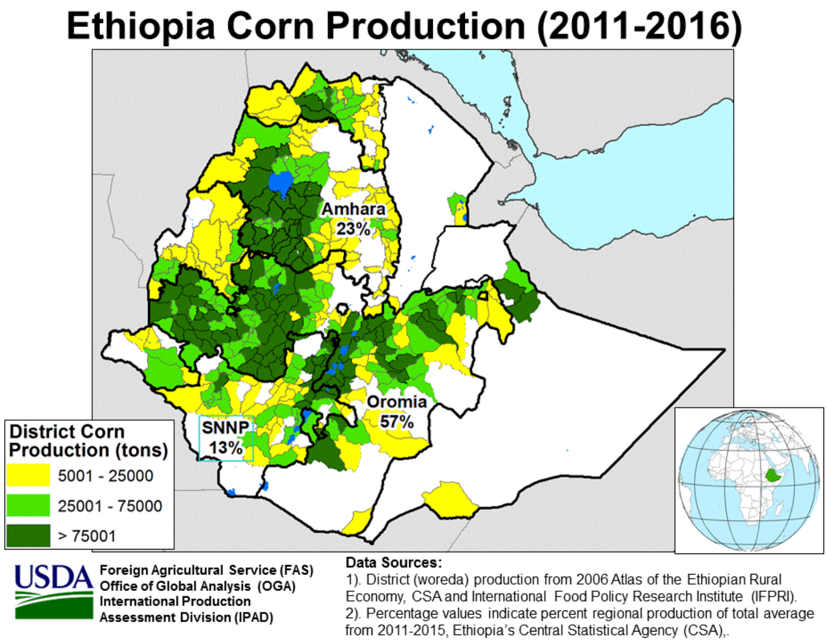
Democratic Republic of Congo

Figure 6 Average maize production (MT), 2005-2011

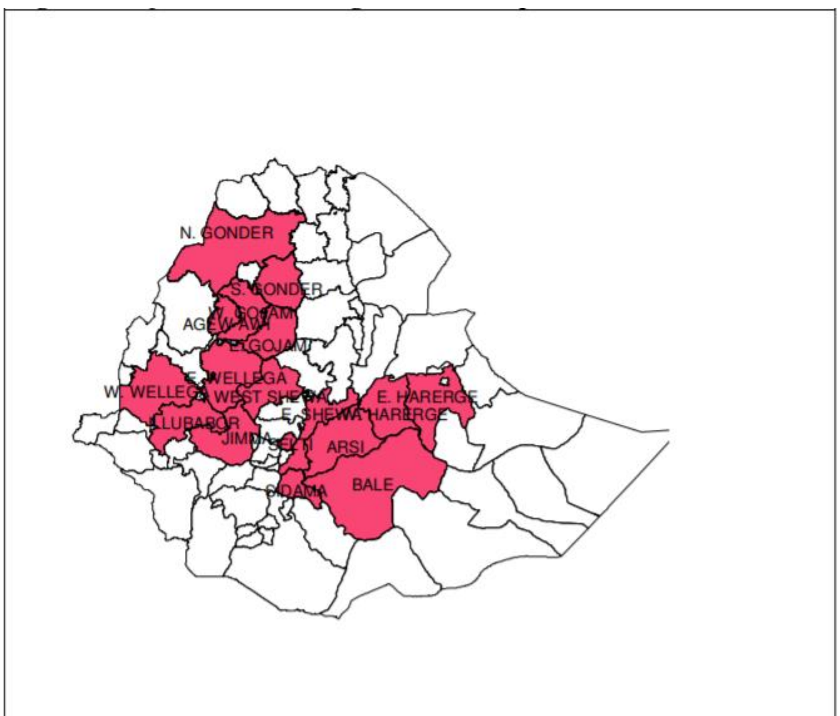


Source: DRC Staple Food Market Fundamentals (2015)

Ethiopia



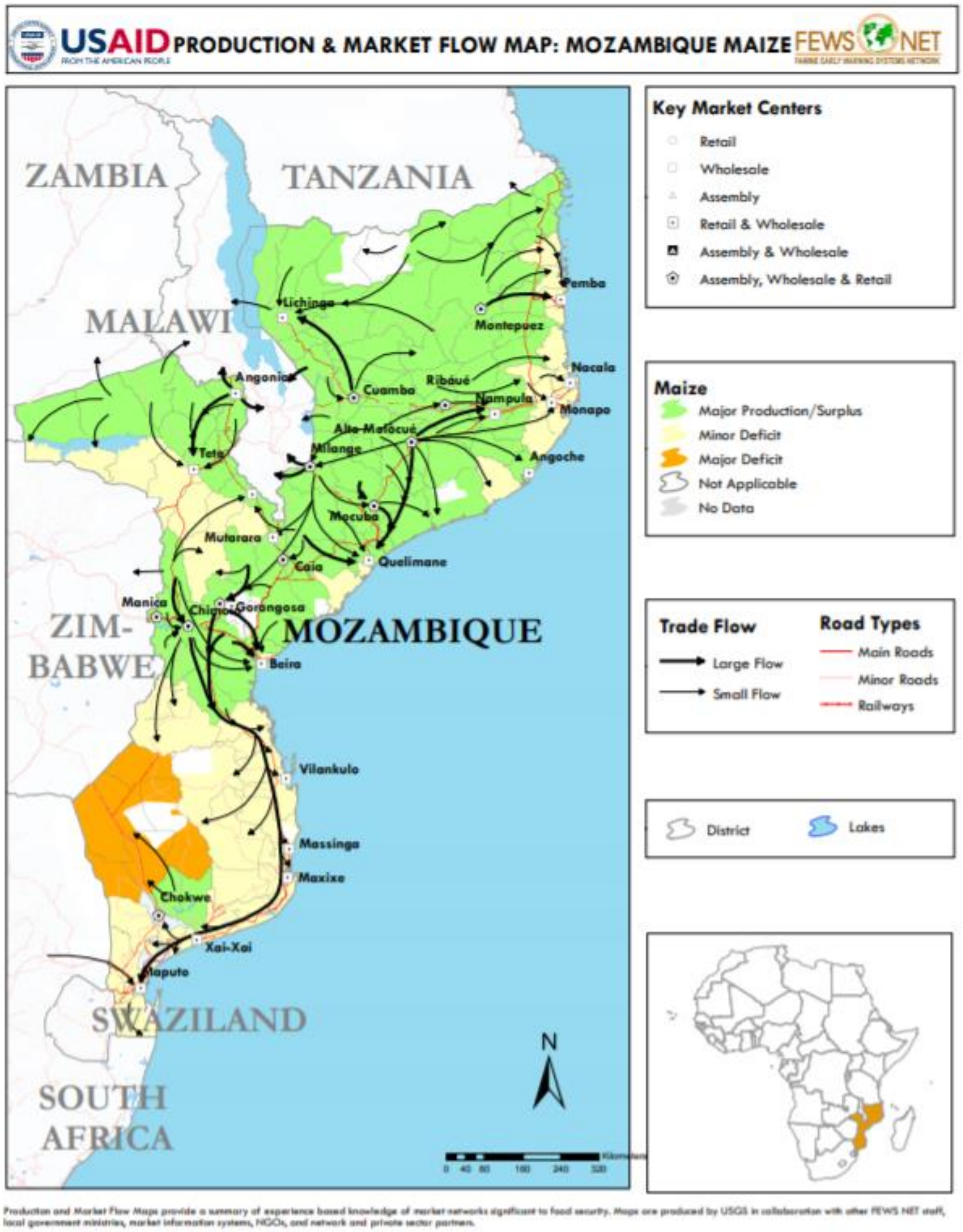
Source: USDA's IPAD



These zones produce about 80% of national maize production

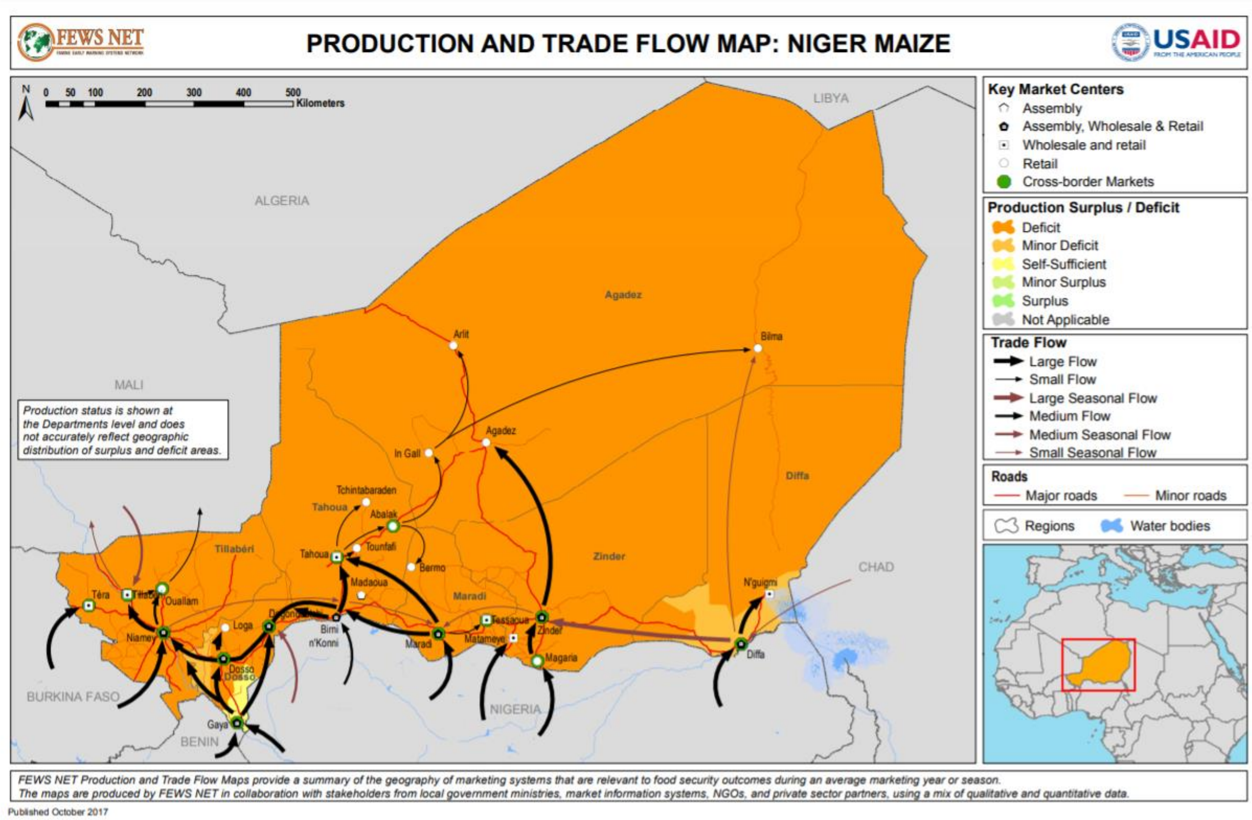
Source: USAID, Staple Foods Value Chain Analysis: Country Report – Ethiopia (2010)

Mozambique



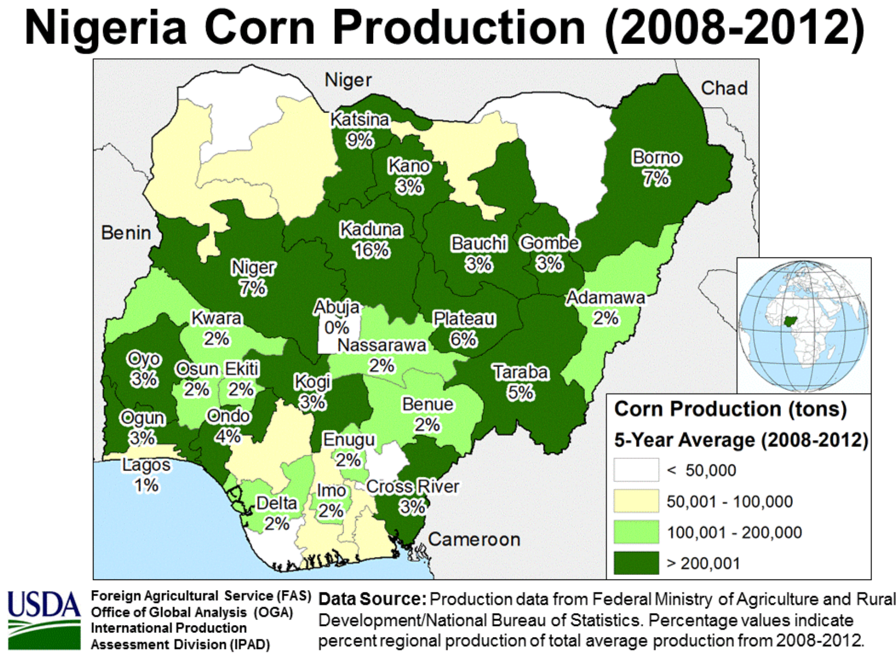
Source: USAID's FEWS NET, 2009

<u>Niger</u>

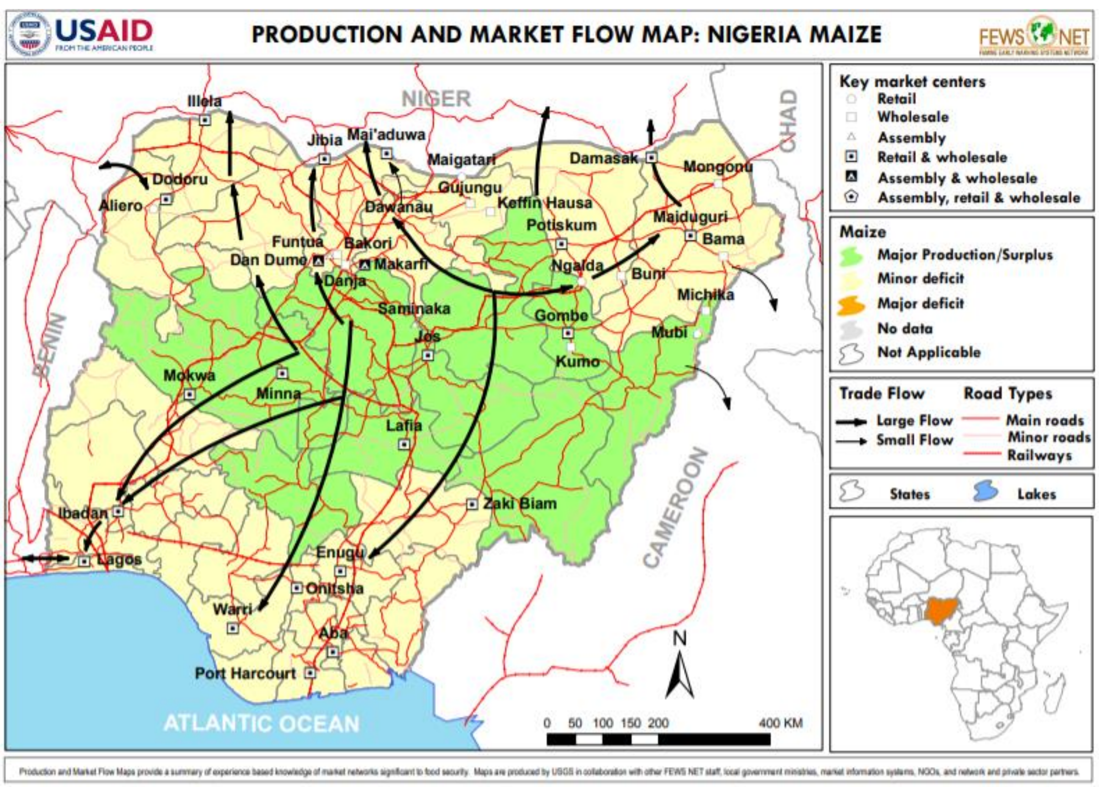


Source: USAID's FEWS NET, 2017

Nigeria

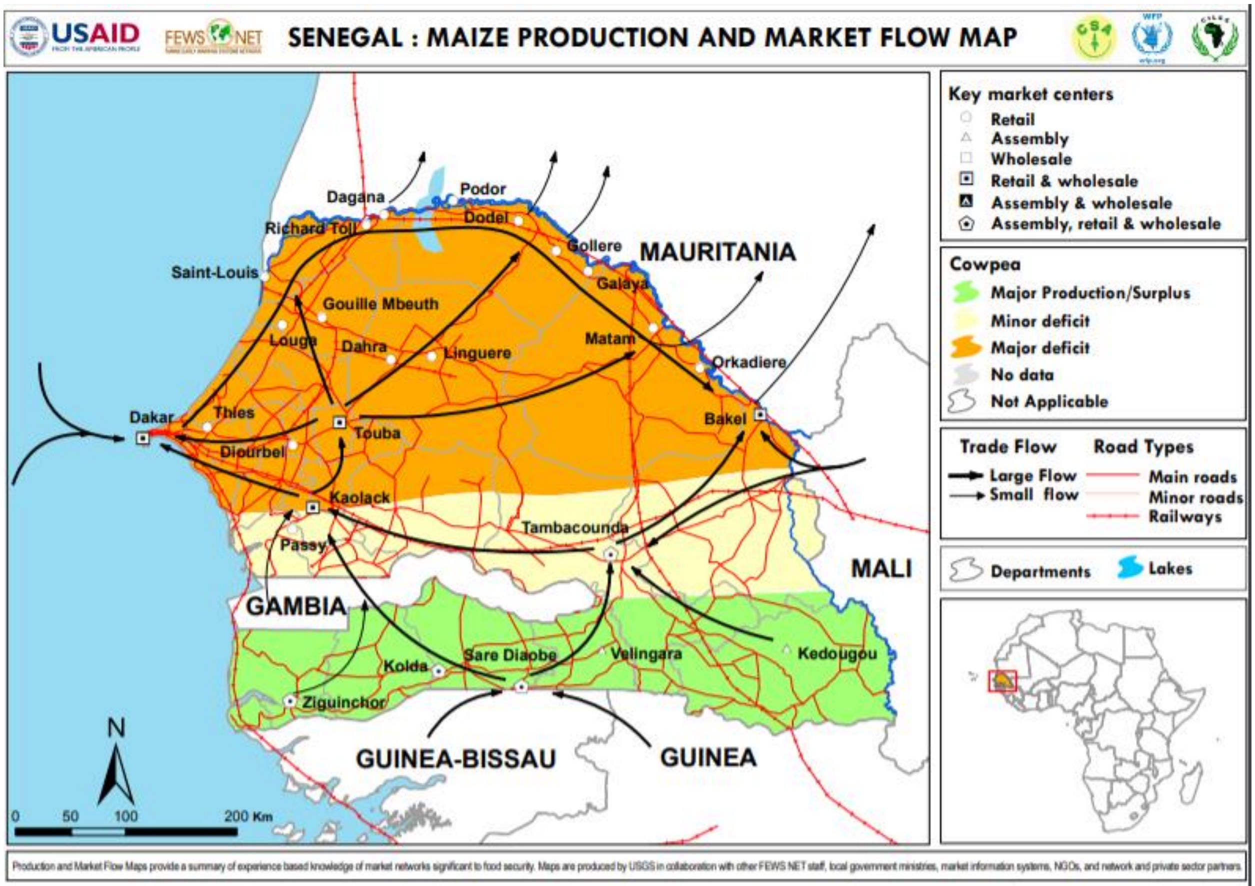


Source: USDA's IPAD



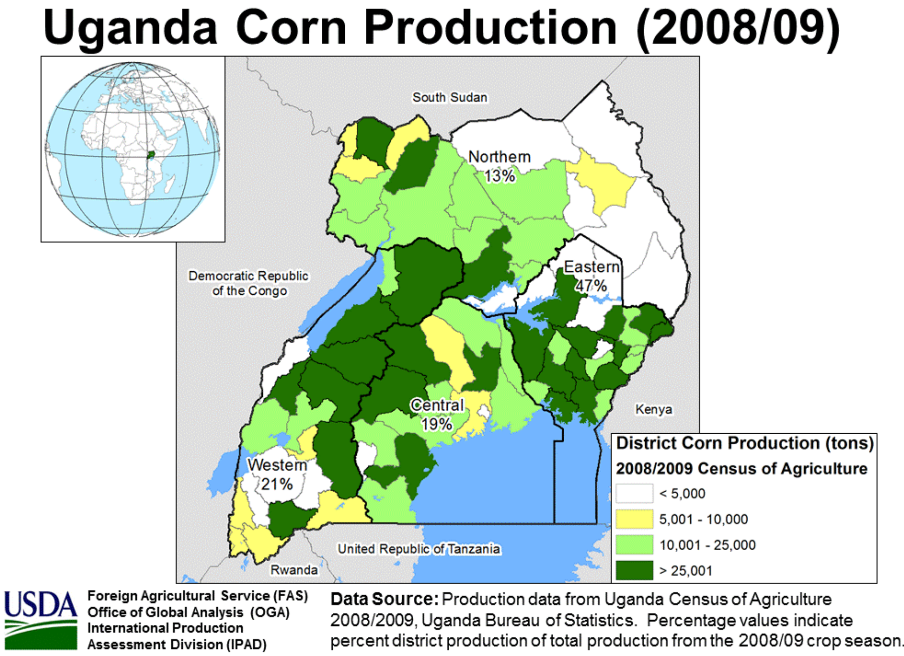
Source: USAID's FEWS NET, 2008

<u>Senegal</u>

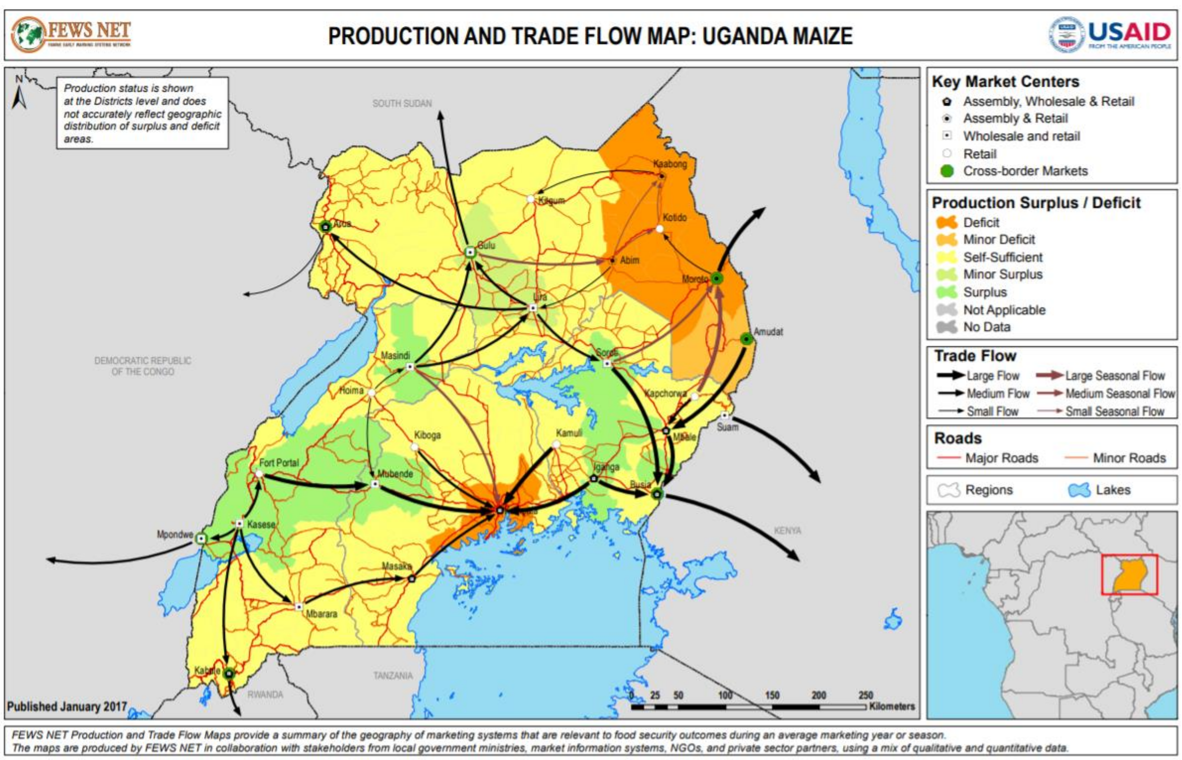


Source: USAID's FEWS NET, 2010

Uganda

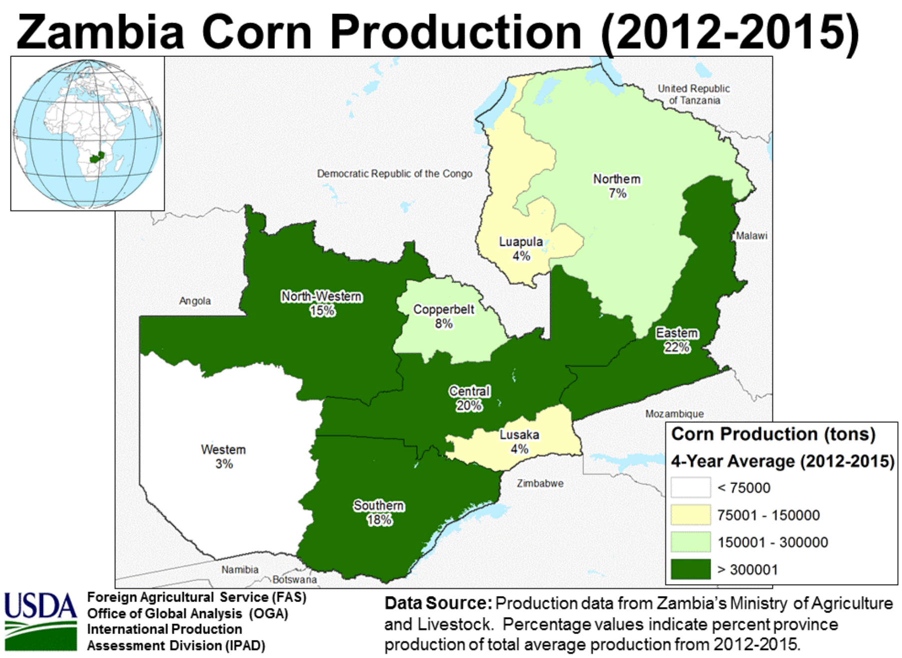


Source: USDA's IPAD

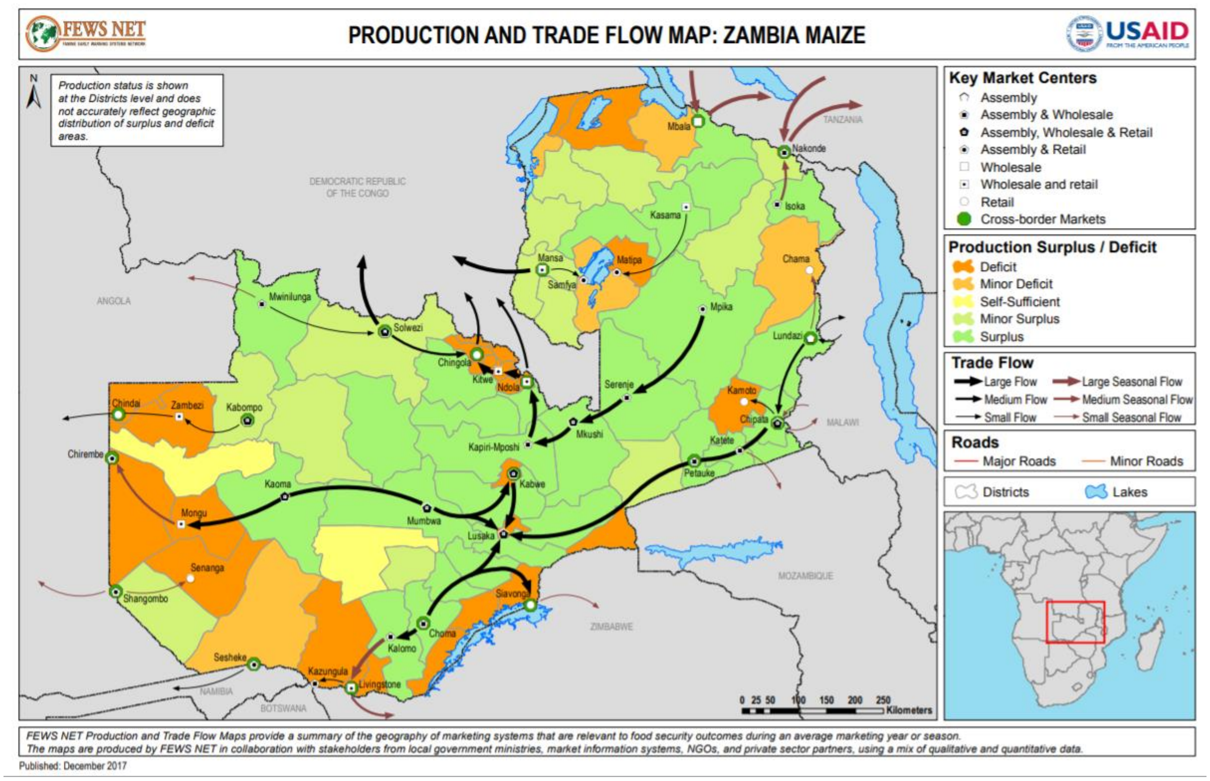


Source: USAID's FEWS NET, 2017

Zambia

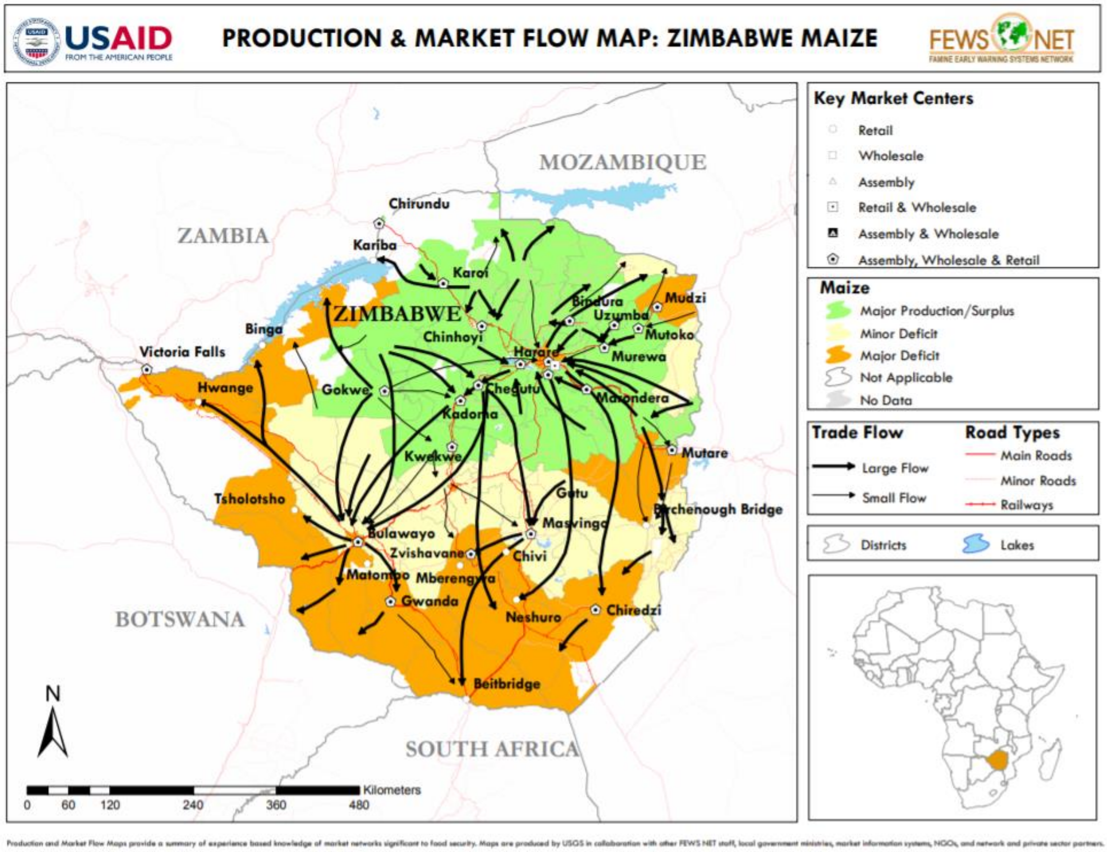


Source: USDA's IPAD



Source: USAID's FEWS NET, 2017

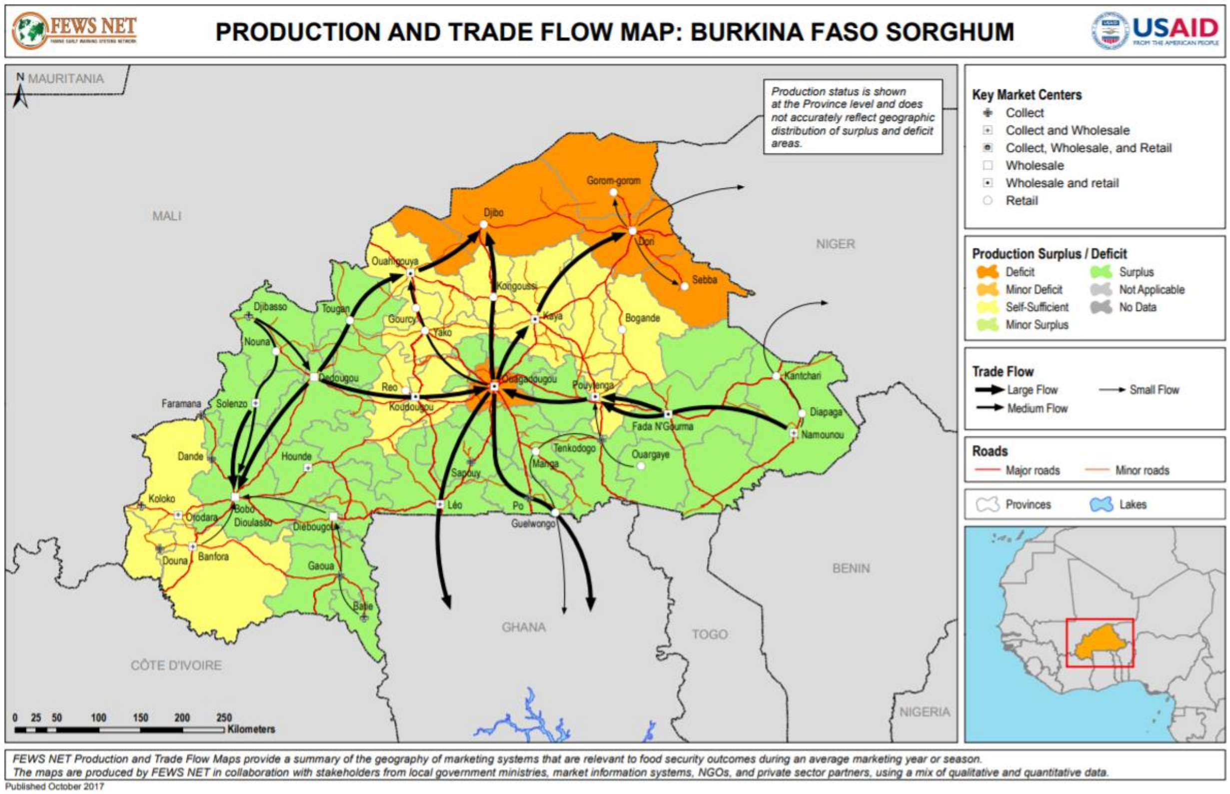
Zimbabwe



Source: USAID's FEWS NET, 2009

SORGHUM

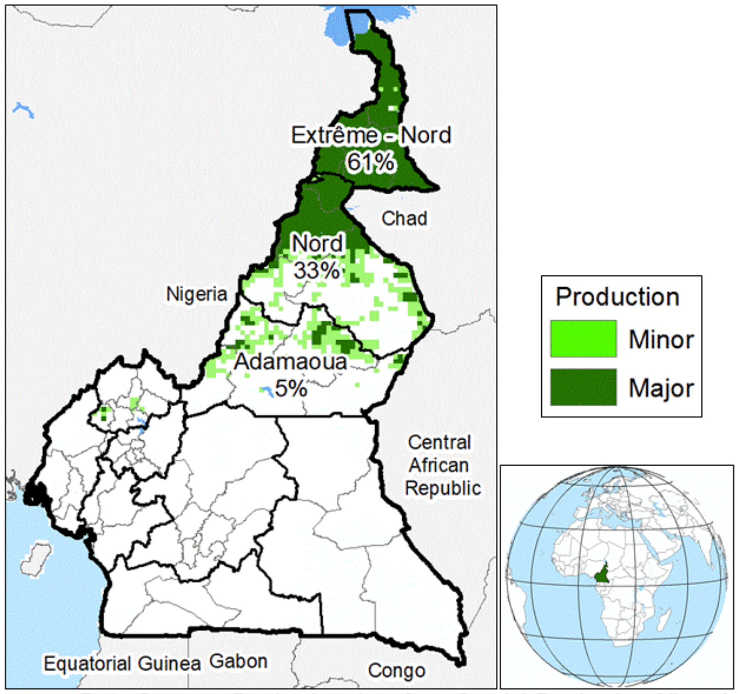
Burkina Faso



Source: USAID's FEWS NET, 2017

Cameroon

Cameroon Sorghum Production



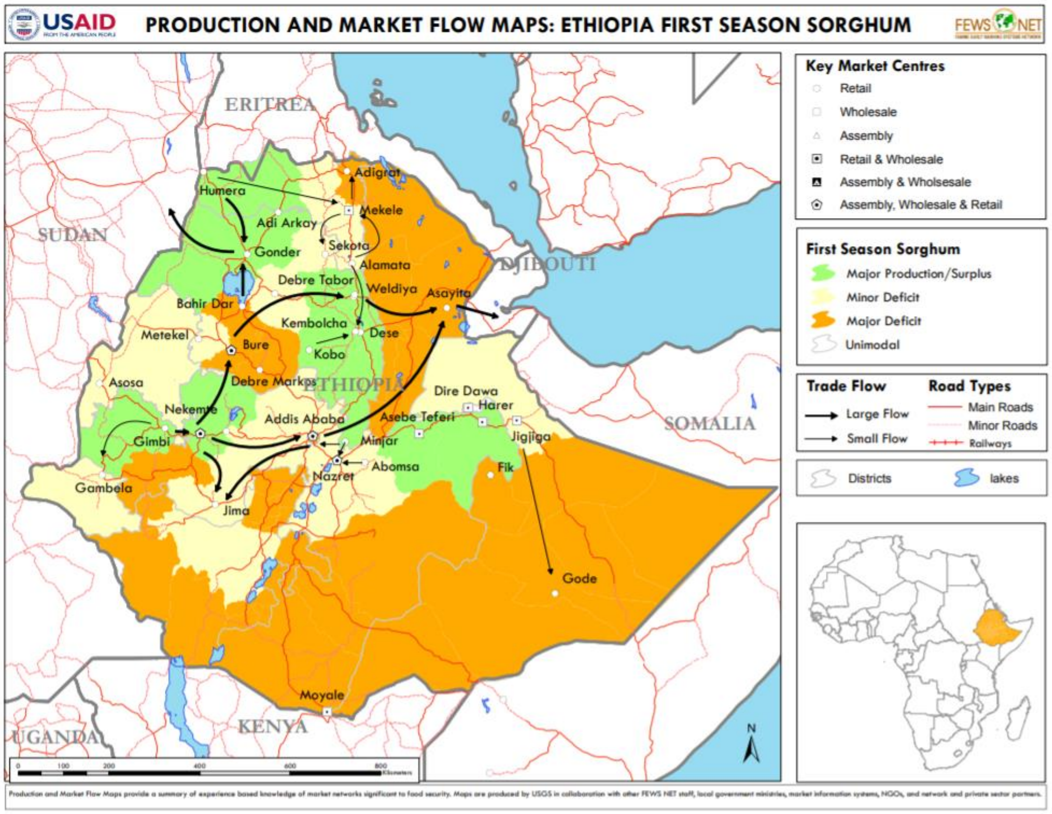
USDA

Foreign Agricultural Service (FAS)
Office of Global Analysis (OGA)
International Production Assessment Division (IPAD)

Data Source: Production data from Spatial Production Allocation Model (SPAM) 2005 v3.1, IFPRI, http://mapspam.info/. Percentage values indicate percent production of total production.

Source: USDA's IPAD

Ethiopia

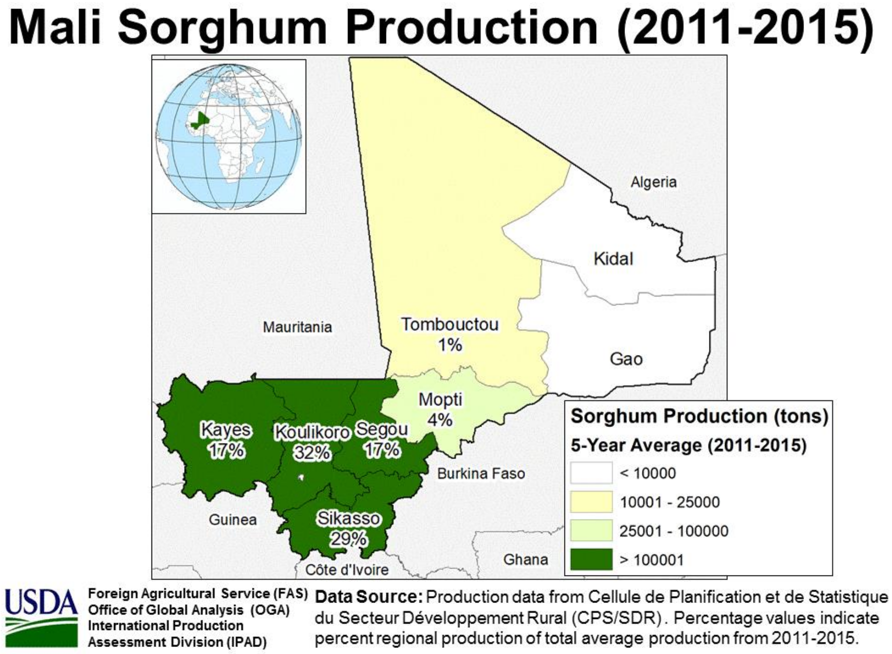


Source: USAID's FEWS NET, 2009

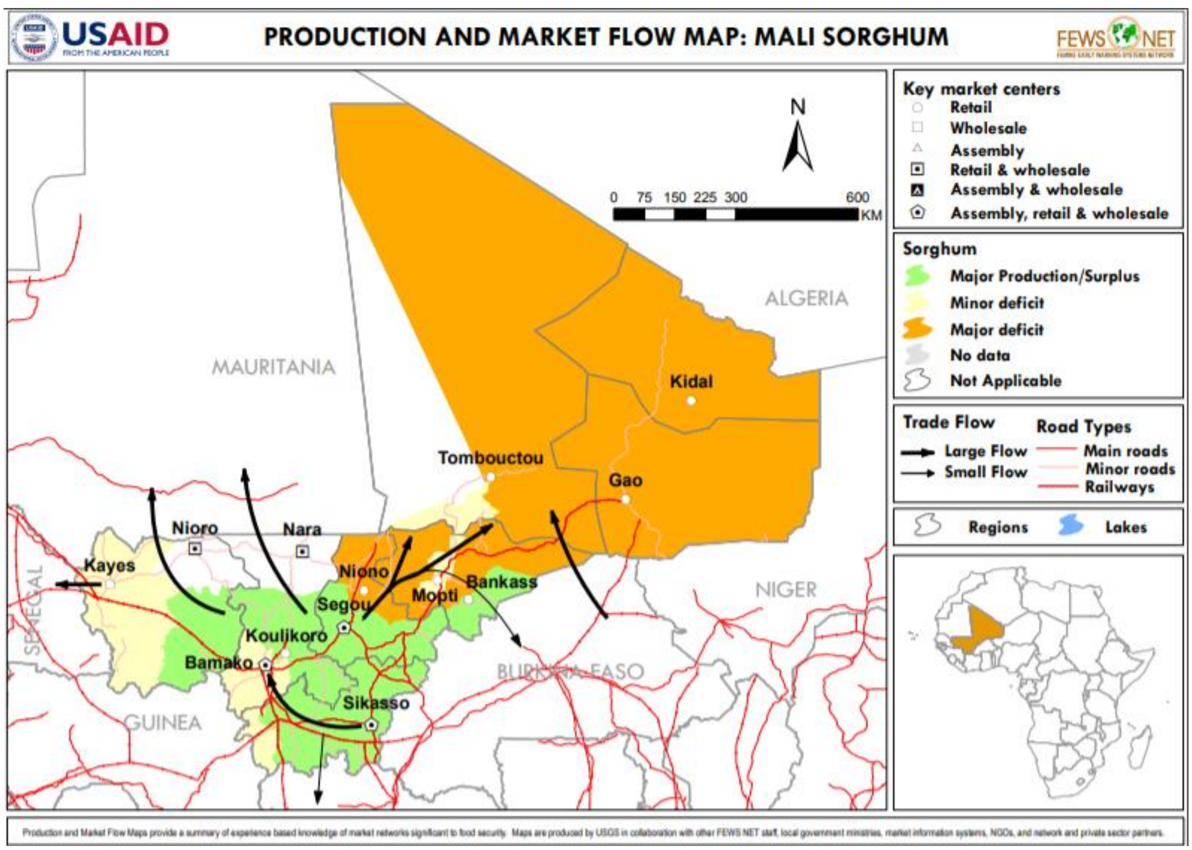
Source: USAID, Staple Foods Value Chain Analysis: Country Report – Ethiopia (2010)

These zones produce most of the sorghum in Ethiopia.

Mali

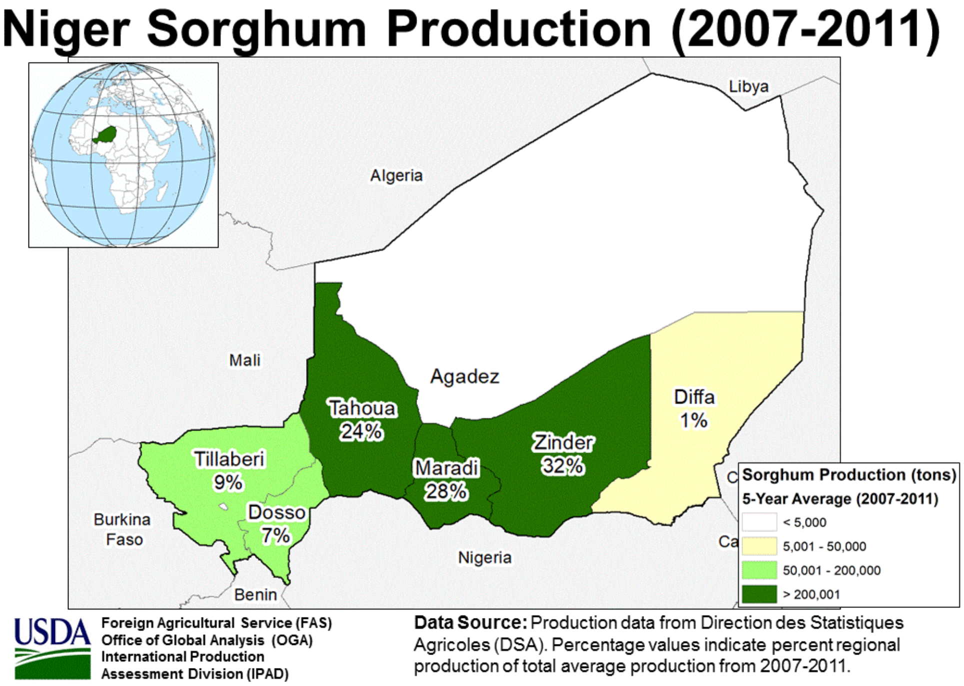


Source: USDA's IPAD

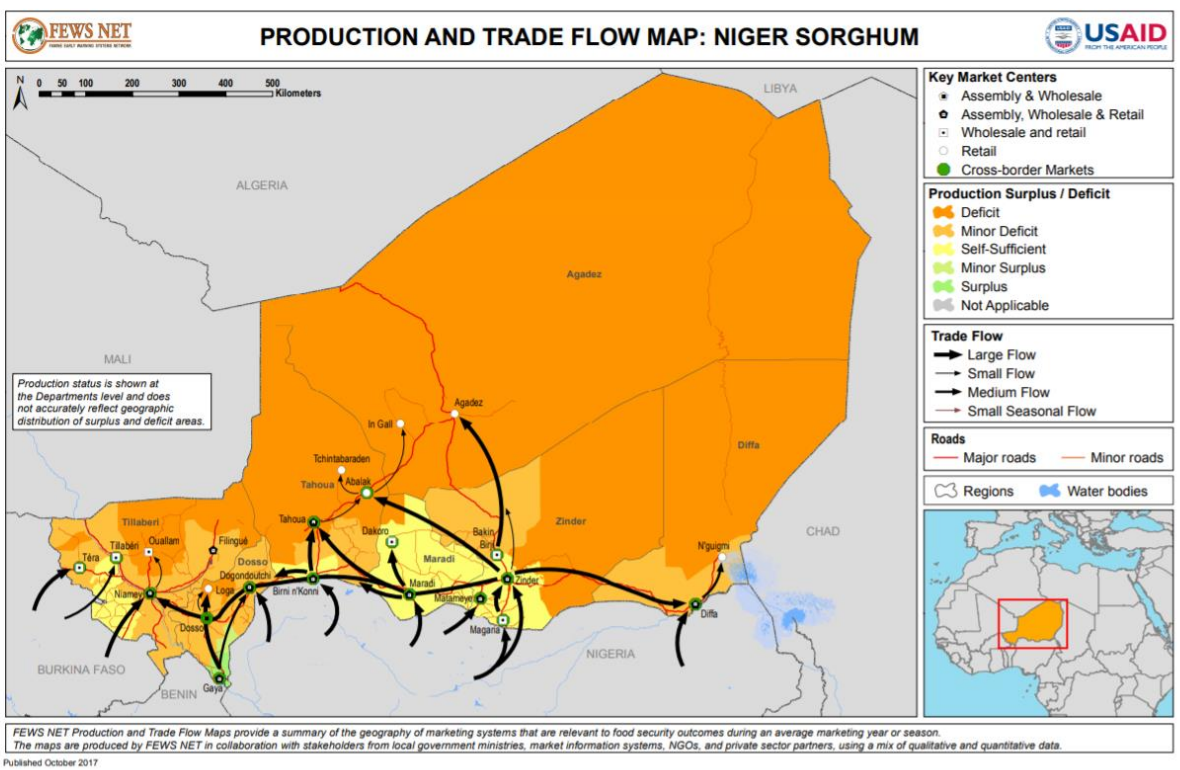


Source: USAID's FEWS NET, 2008

Niger

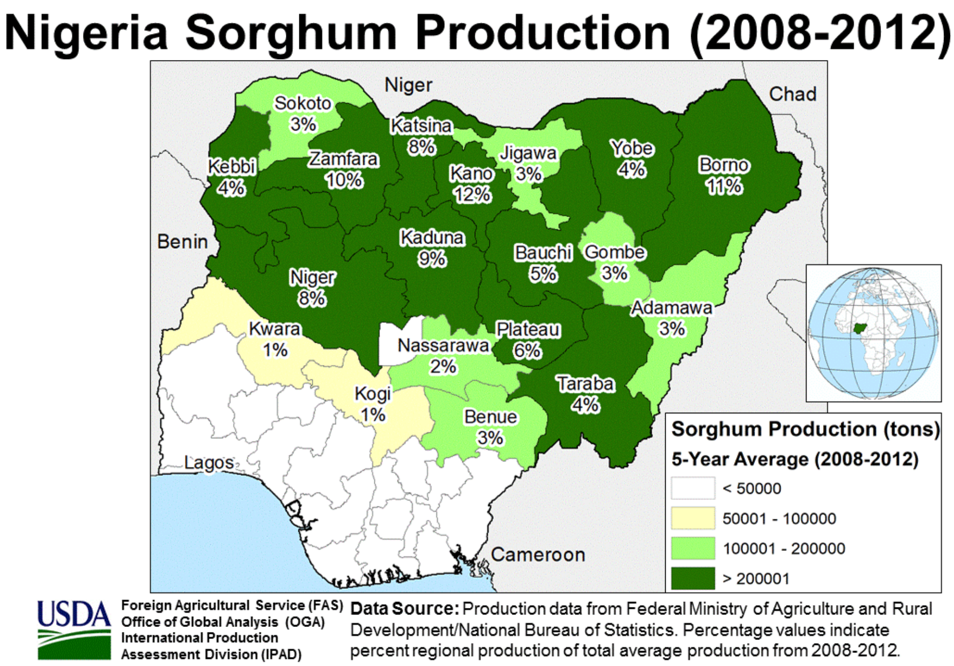


Source: USDA's IPAD

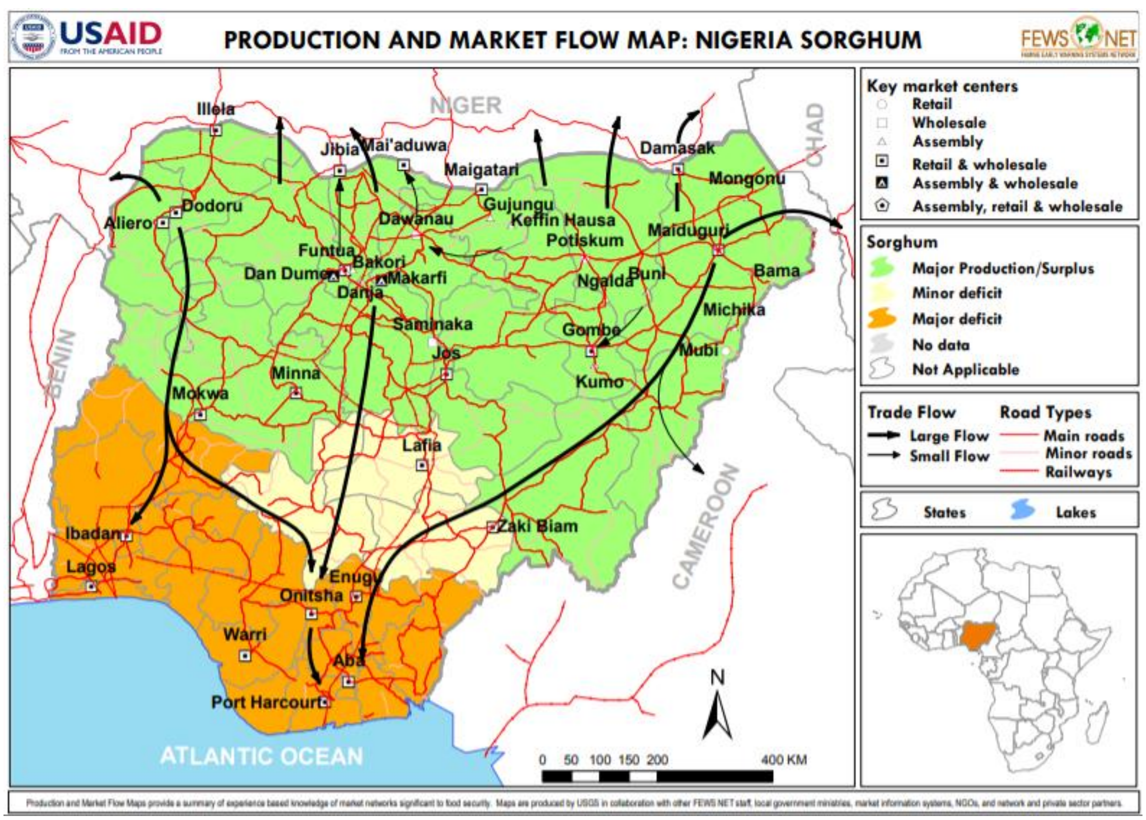


Source: USAID's FEWS NET, 2017

Nigeria

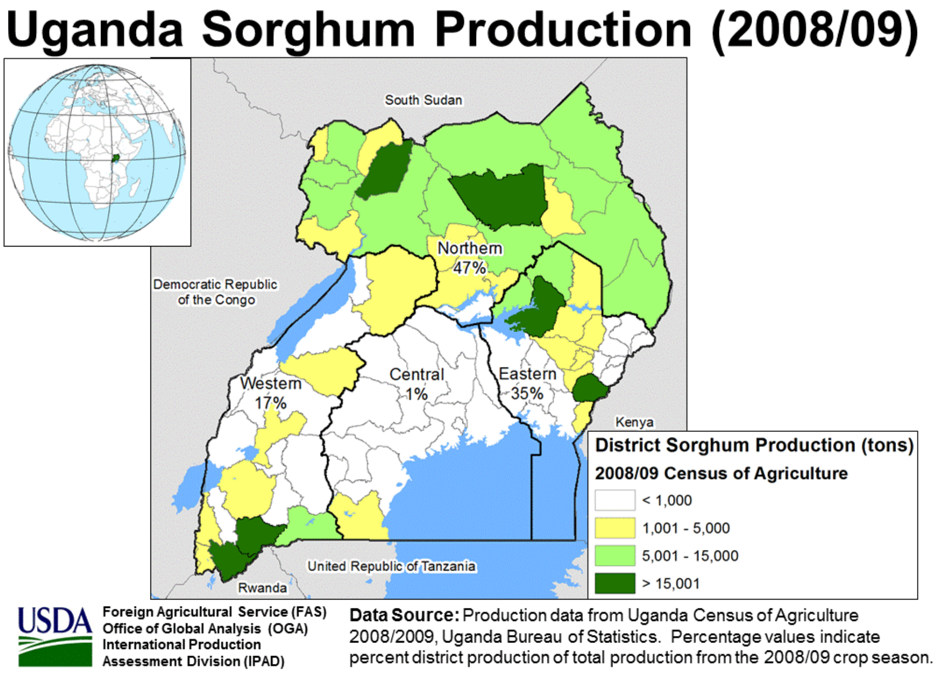


Source: USDA's IPAD

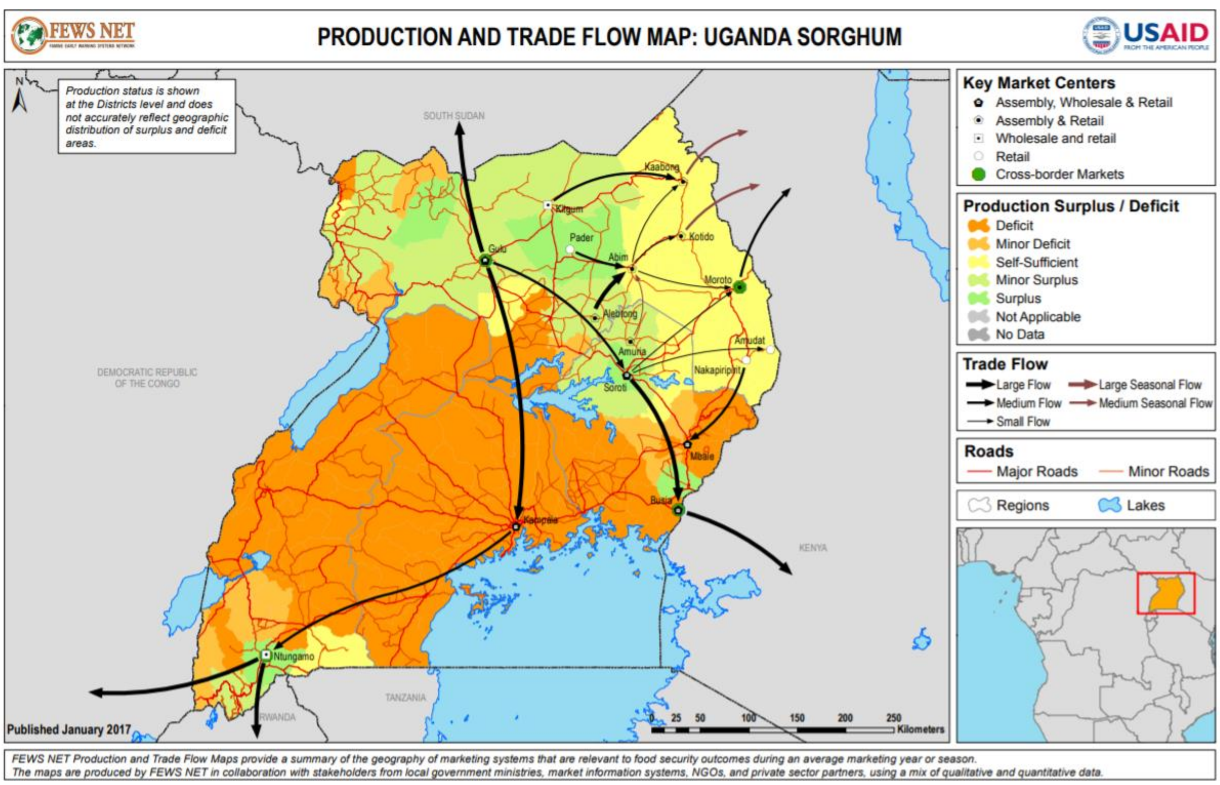


Source: USAID's FEWS NET, 2008

Uganda



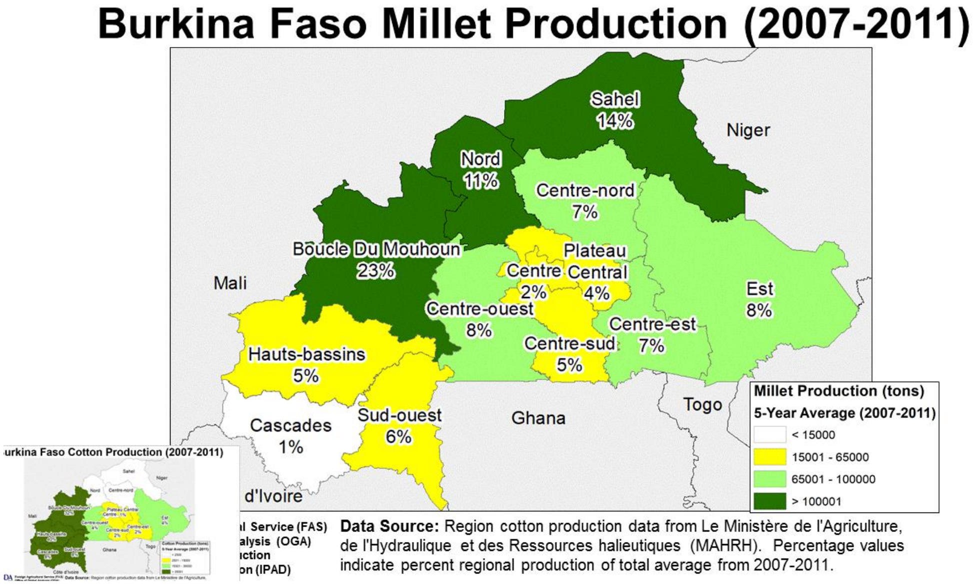
Source: USDA's IPAD



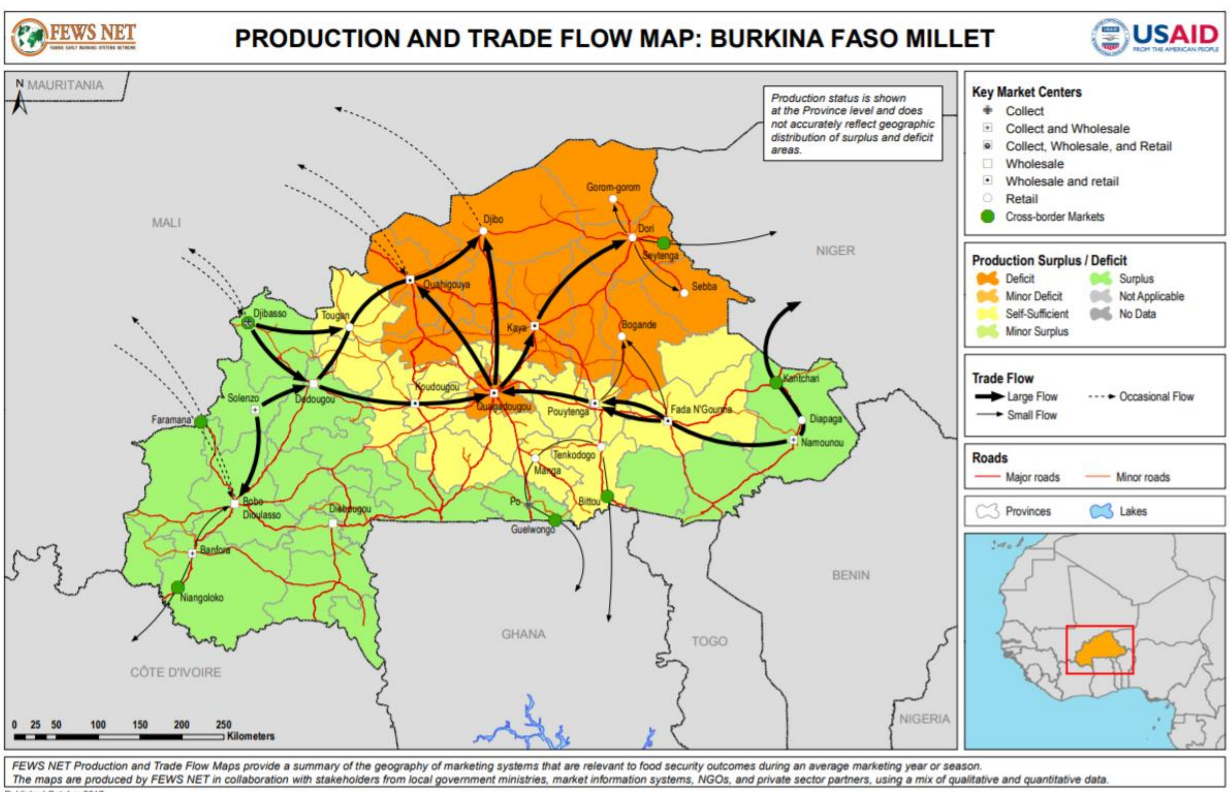
Source: USAID's FEWS NET, 2017

MILLET

Burkina Faso

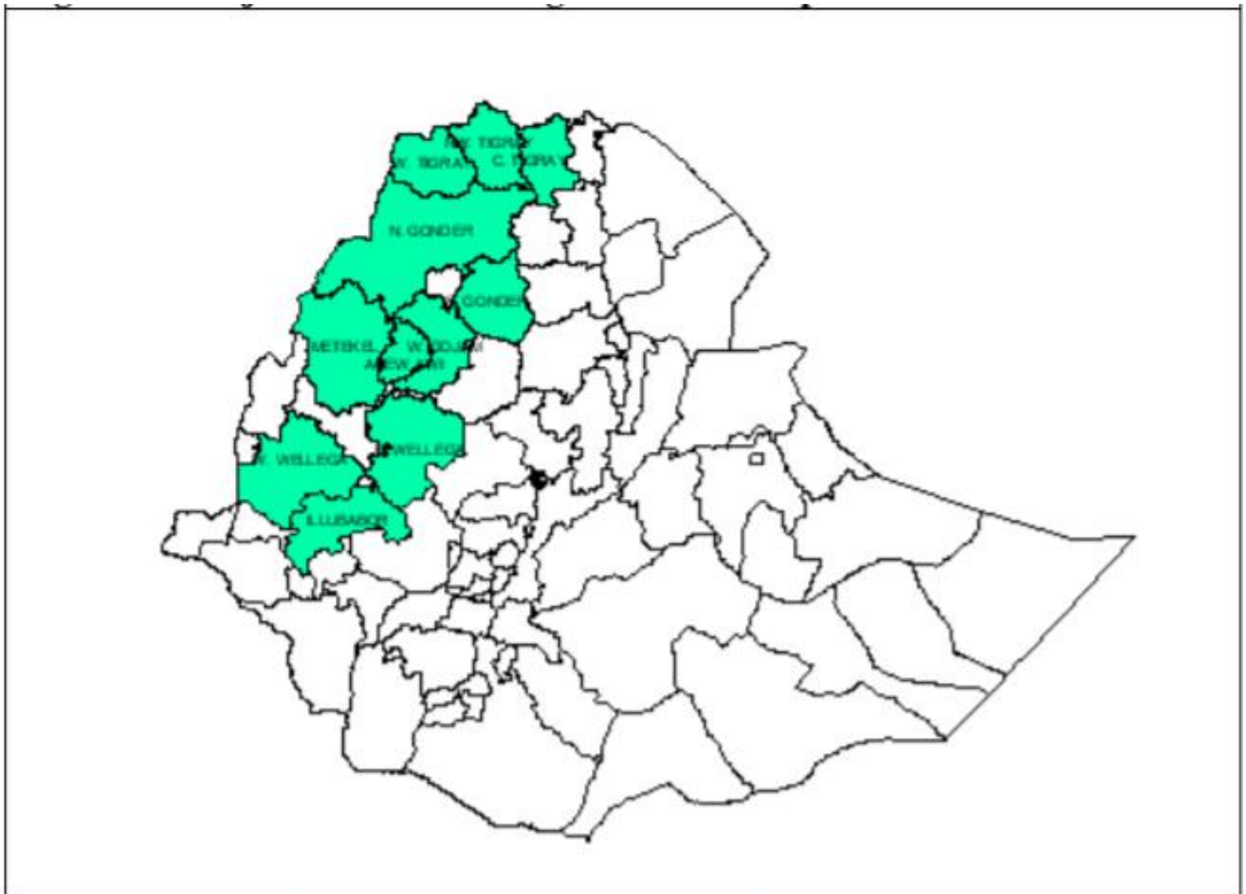


Source: USDA's IPAD



Source: USAID's FEWS NET, 2017

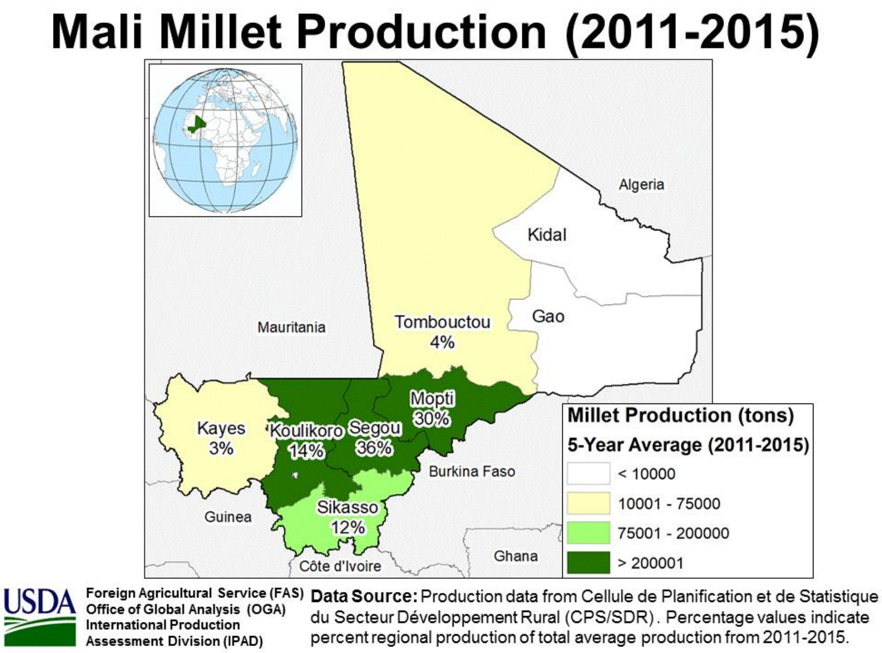
Ethiopia



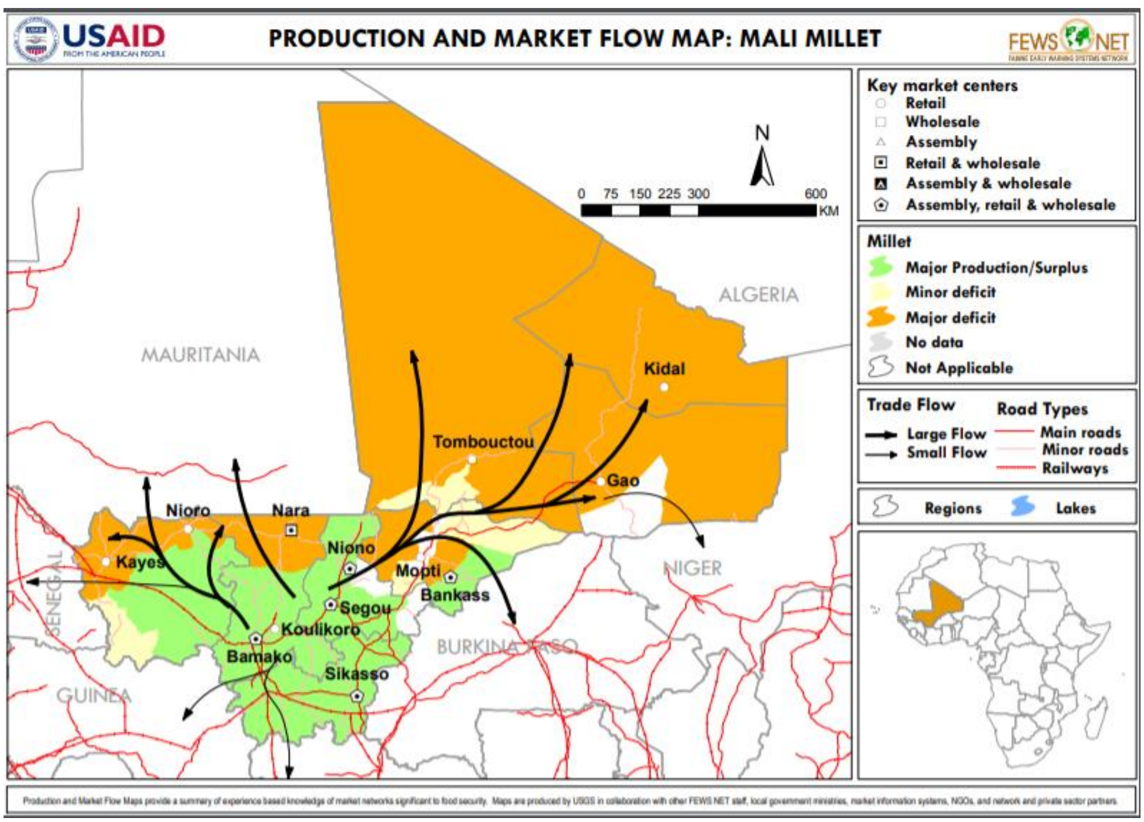
These zones produce about 90% of the national millet production

Source: USAID, Staple Foods Value Chain Analysis: Country Report – Ethiopia (2010)

Mali

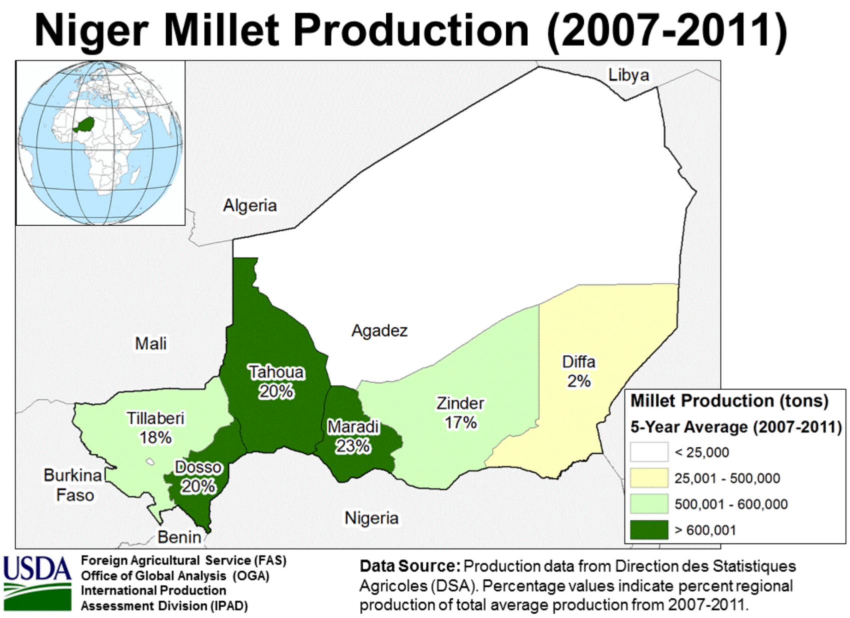


Source: USDA's IPAD

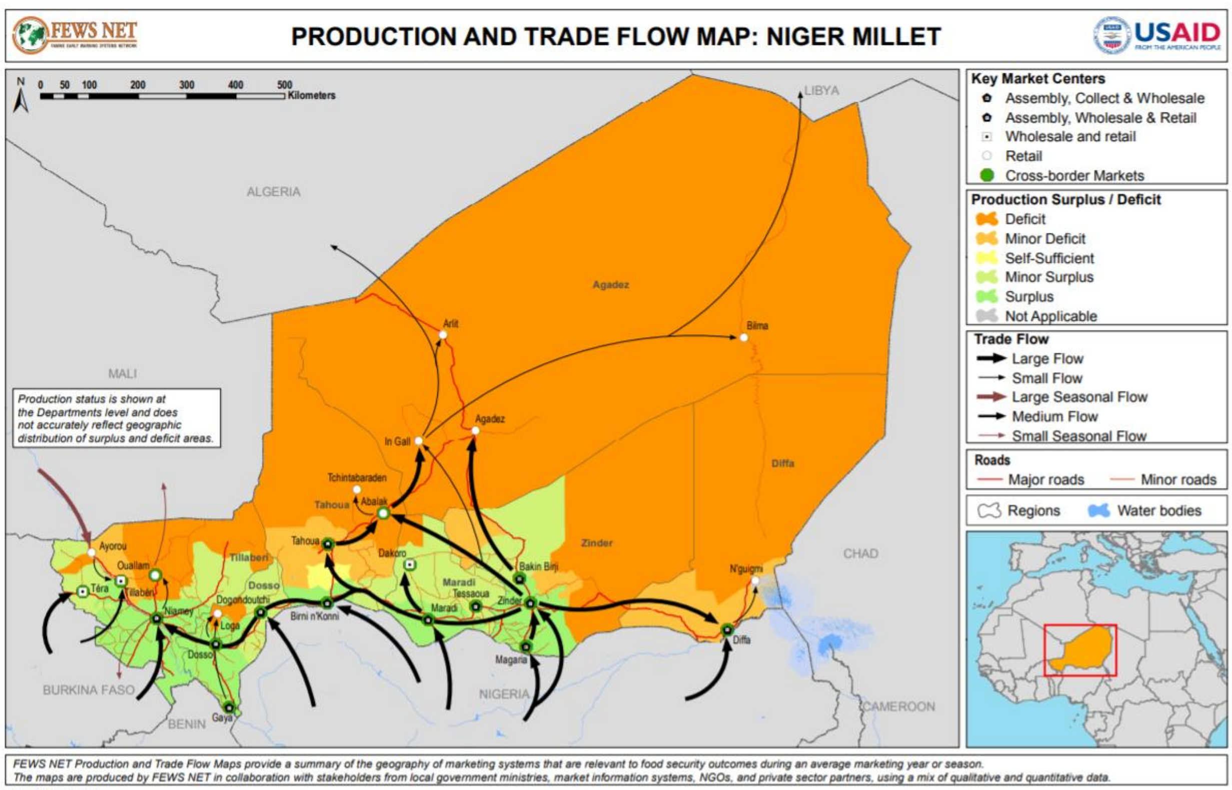


Source: USAID's FEWS NET, 2008

<u>Niger</u>

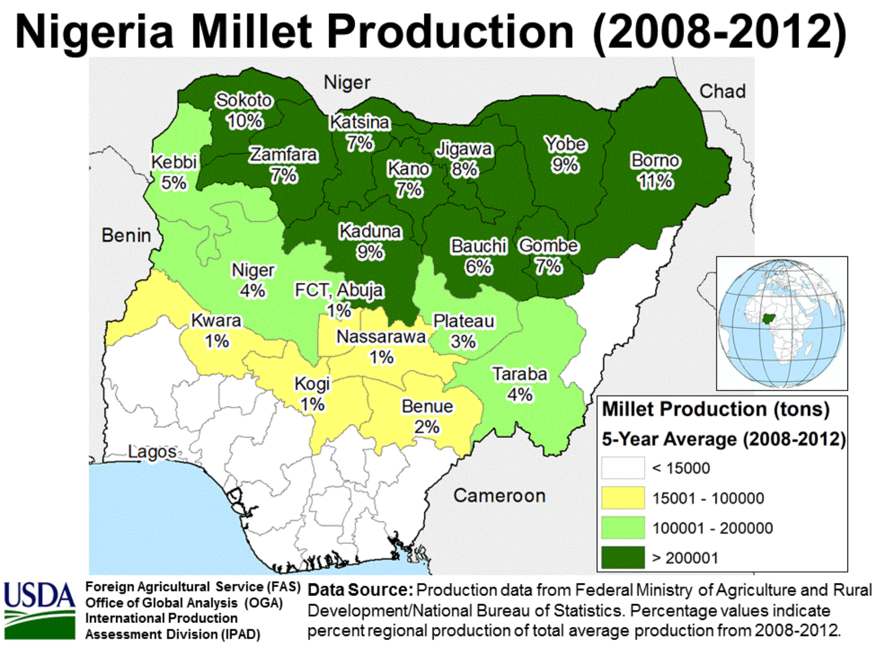


Source: USDA's IPAD

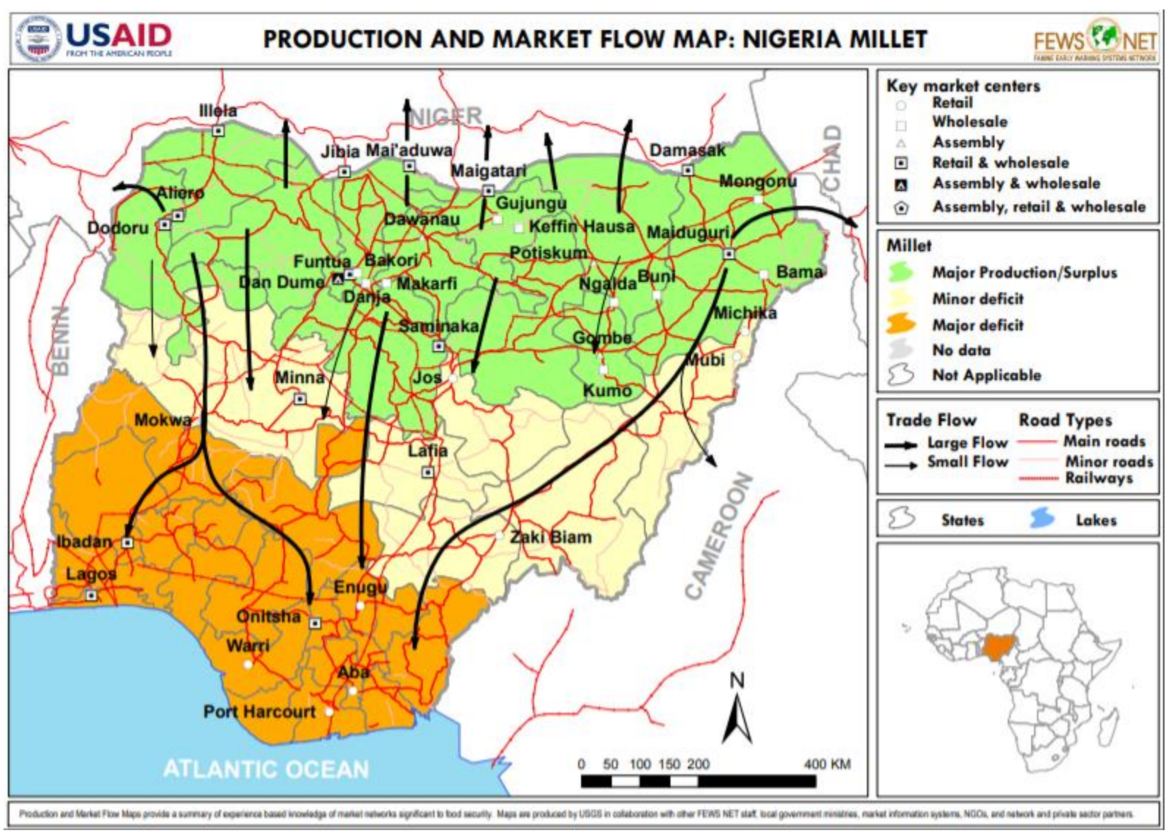


Source: USAID's FEWS NET, 2017

Nigeria

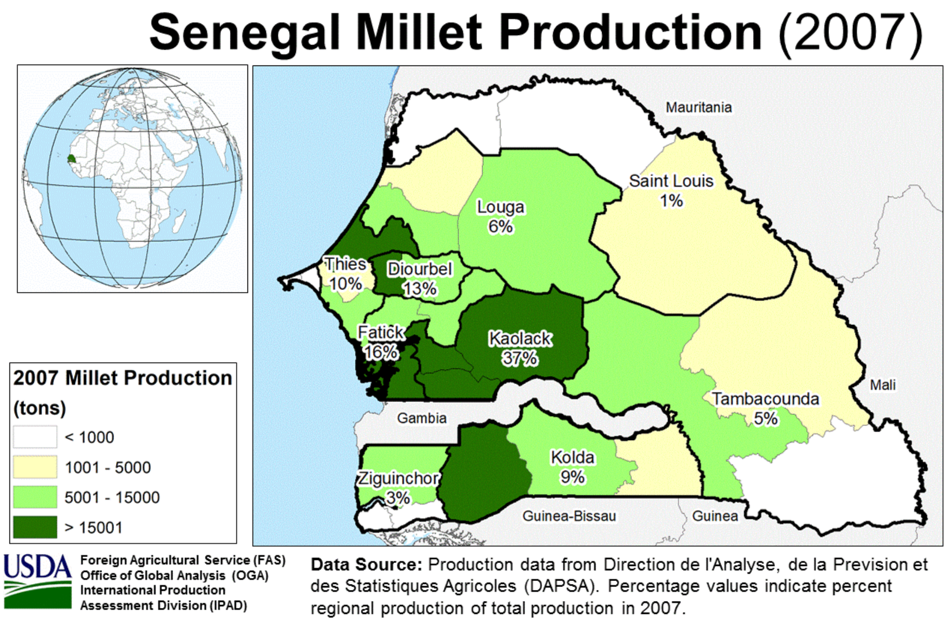


Source: USDA's IPAD

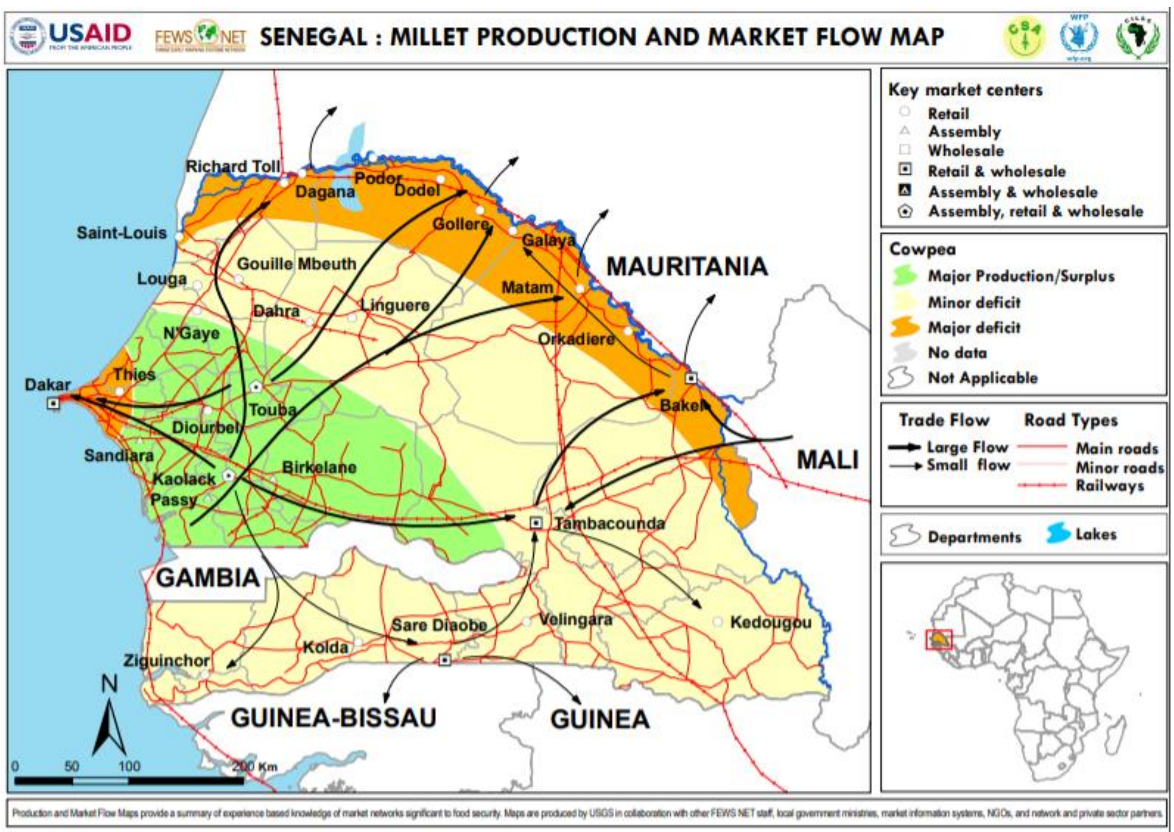


Source: USAID's FEWS NET, 2008

Senegal

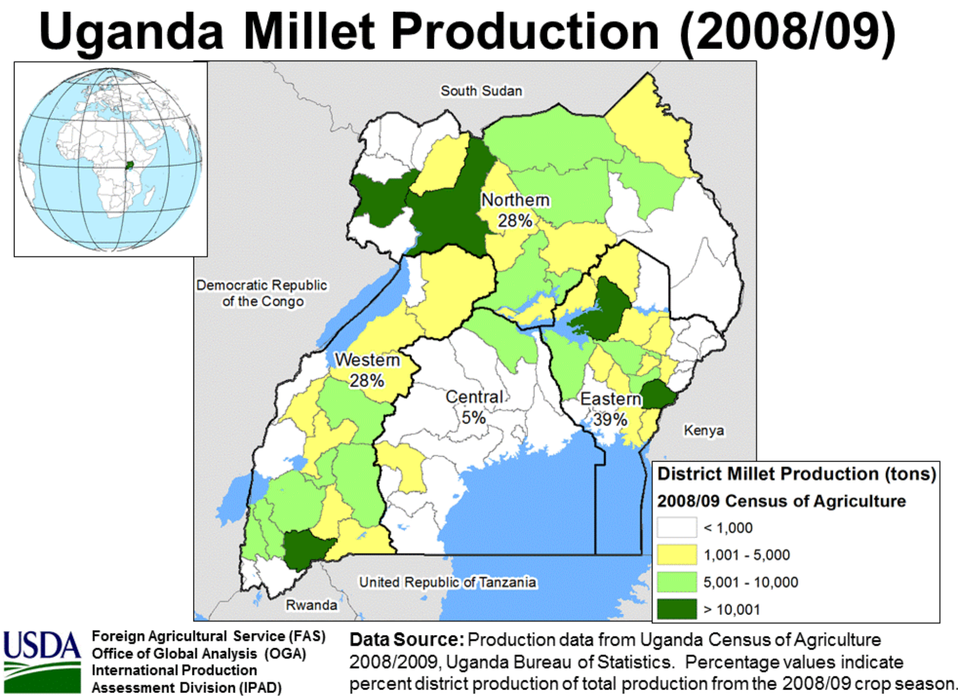


Source: USDA’s IPAD

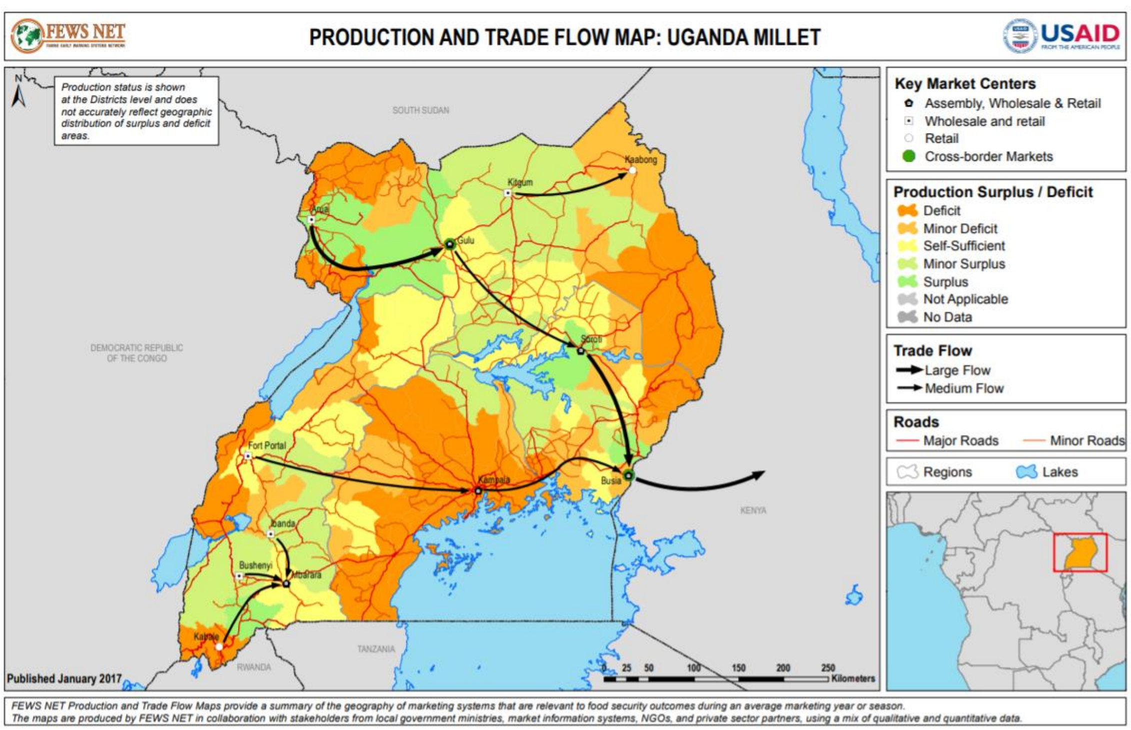


Source: USAID’s FEWS NET, 2010

Uganda



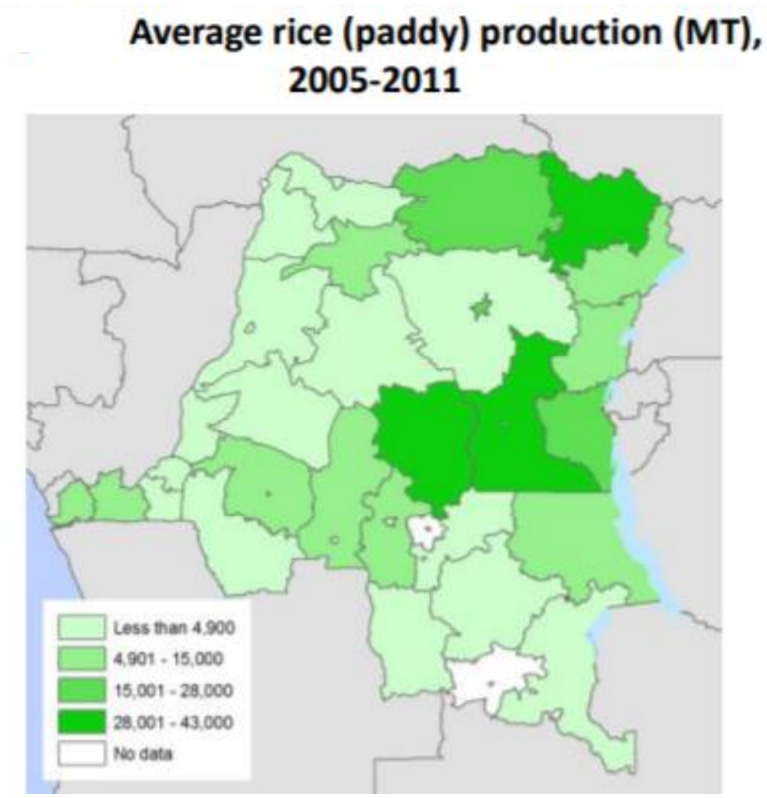
Source: USDA's IPAD



Source: USAID's FEWS NET, 2017

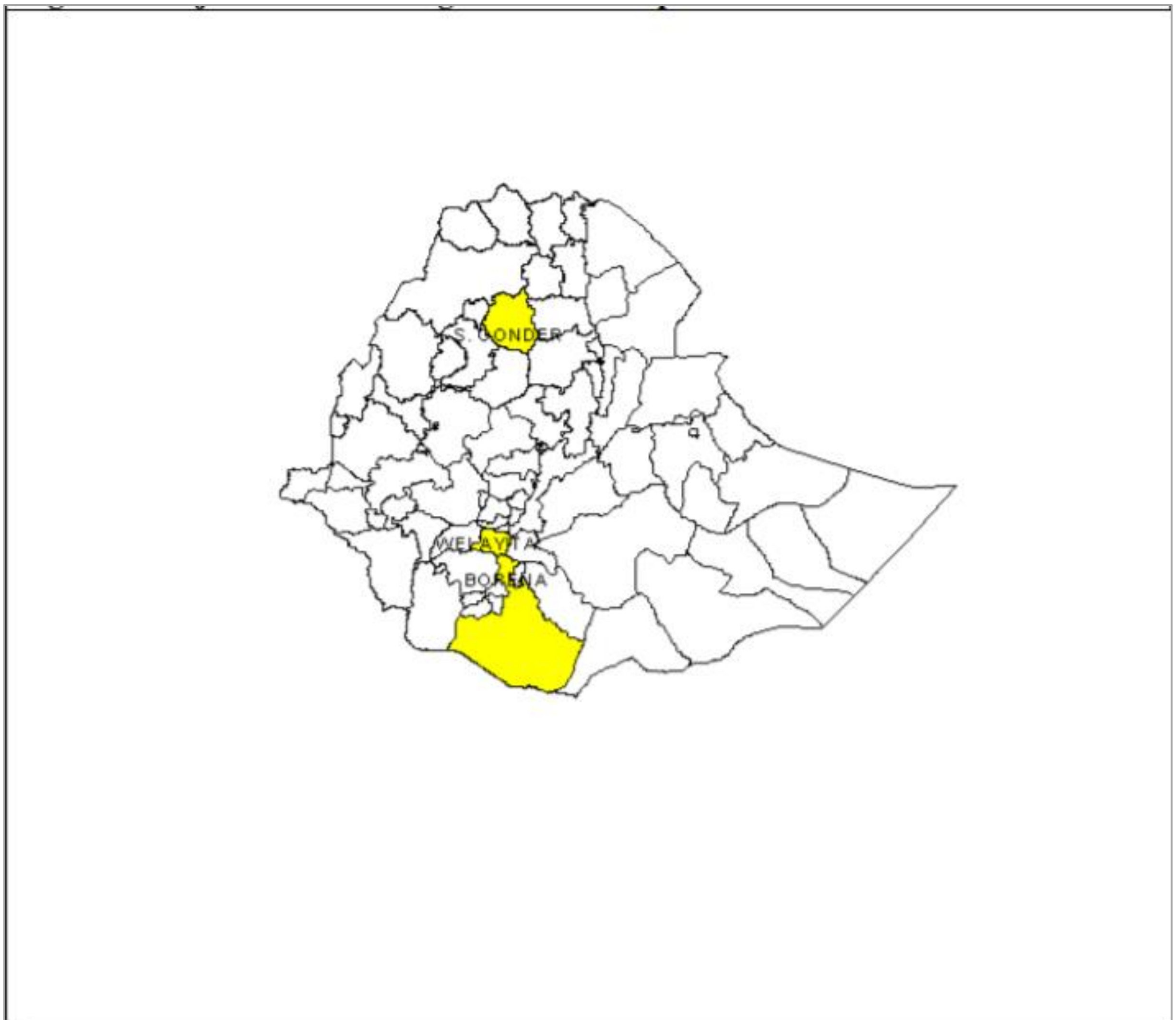
RICE

Democratic Republic of Congo



Source: USAID, DRC Staple Food Market Fundamentals (2015)

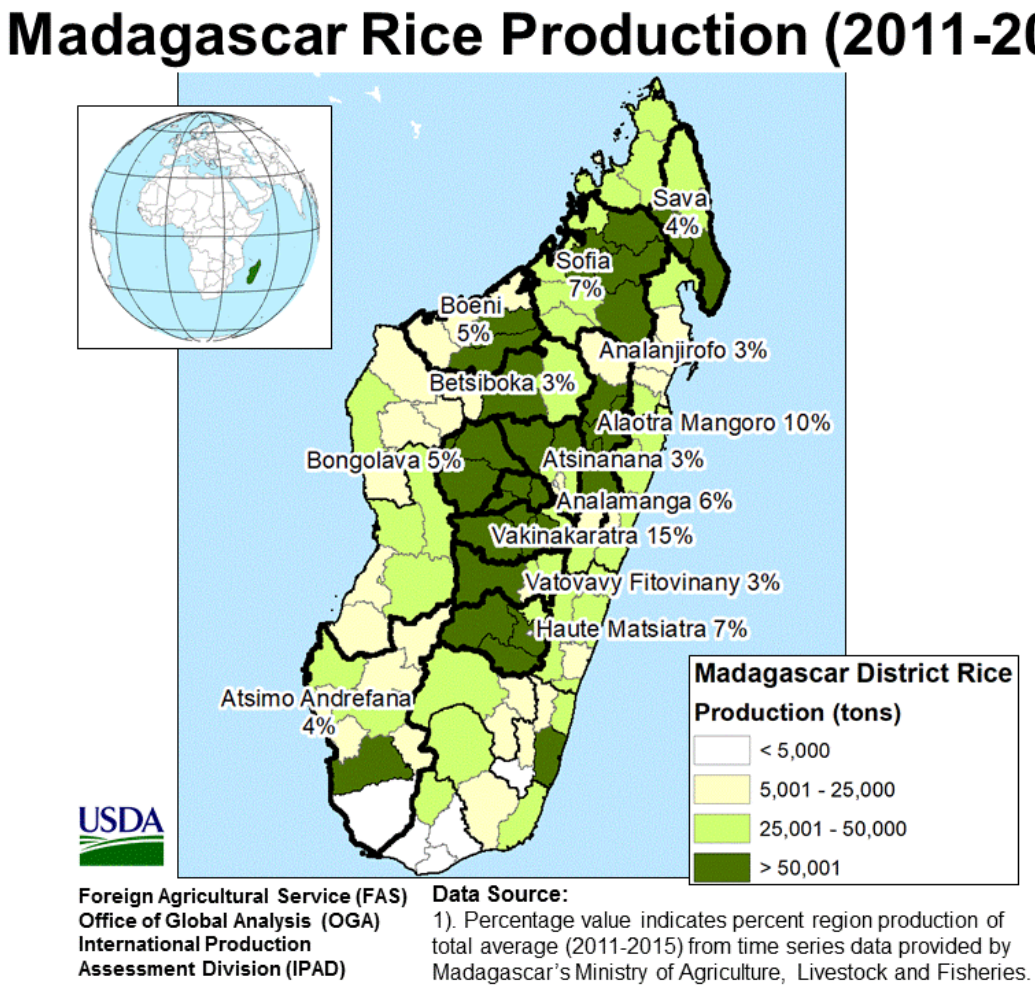
Ethiopia



The selected zones produce more than 85% of the national rice production

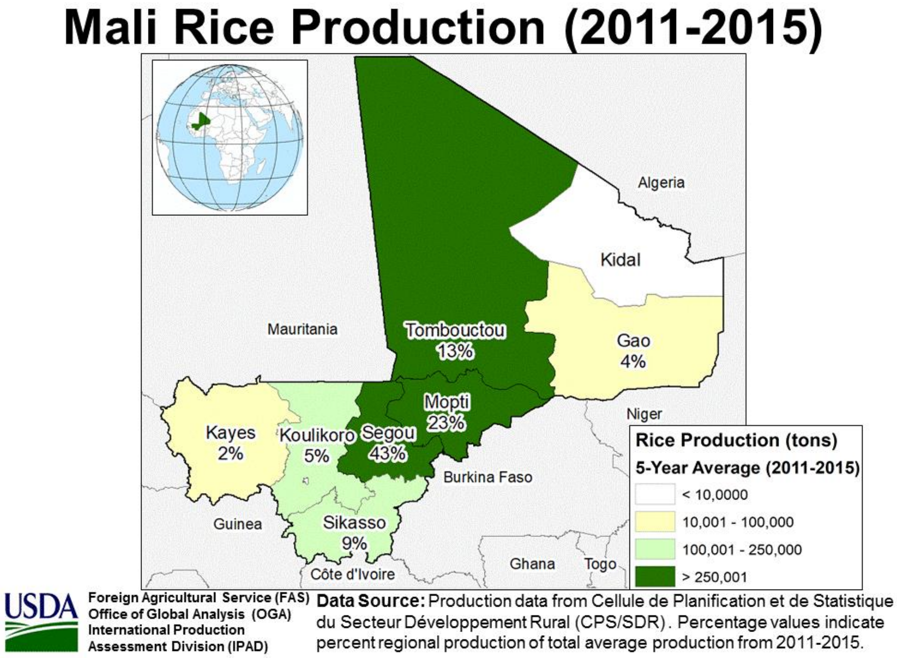
Source: USAID, Staple Foods Value Chain Analysis: Country Report – Ethiopia (2010)

Madagascar

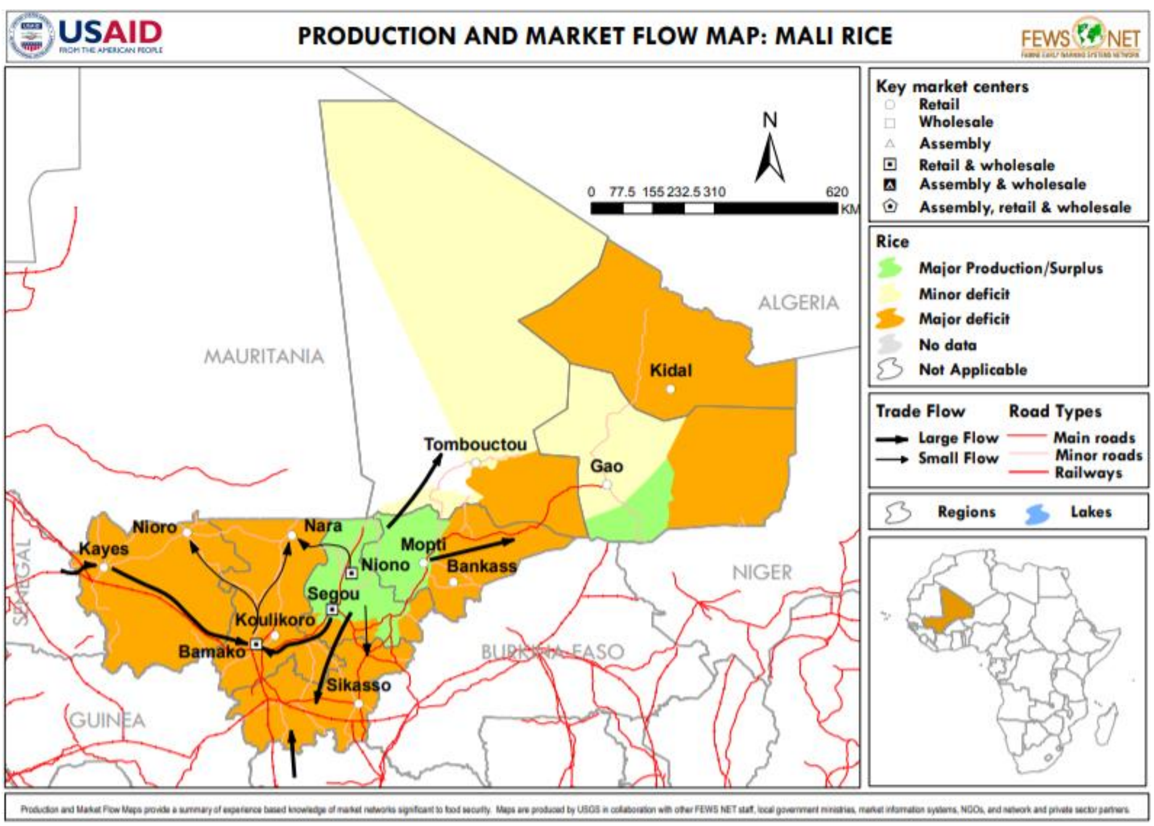


Source: USDA's IPAD

Mali

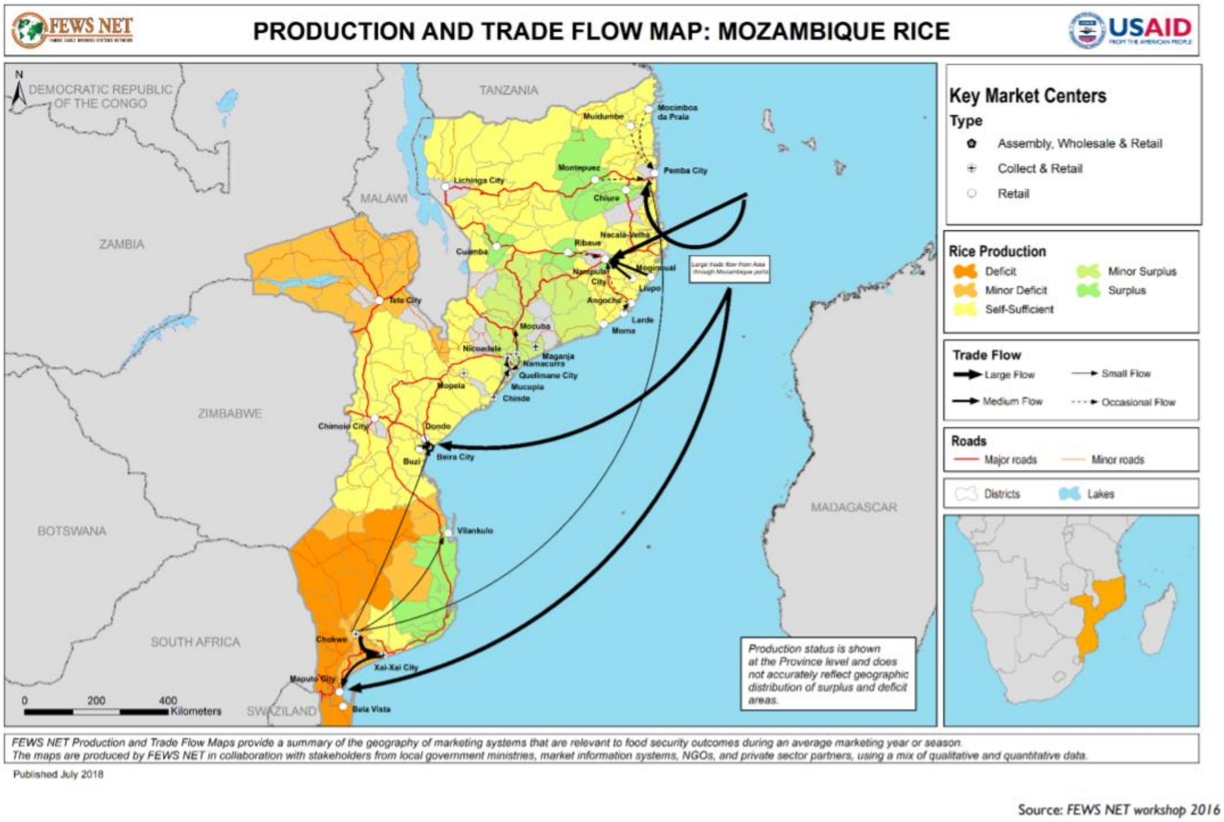


Source: USDA's IPAD



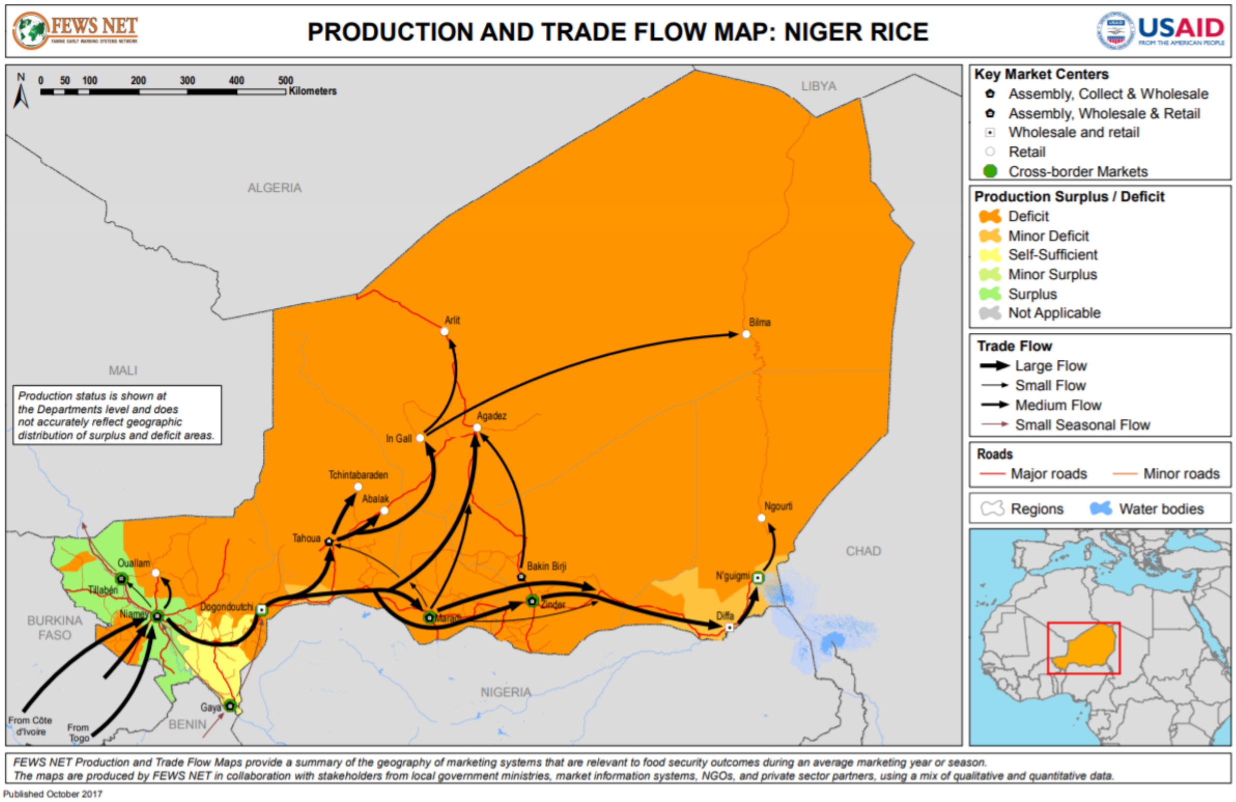
Source: USAID's FEWS NET, 2008

Mozambique



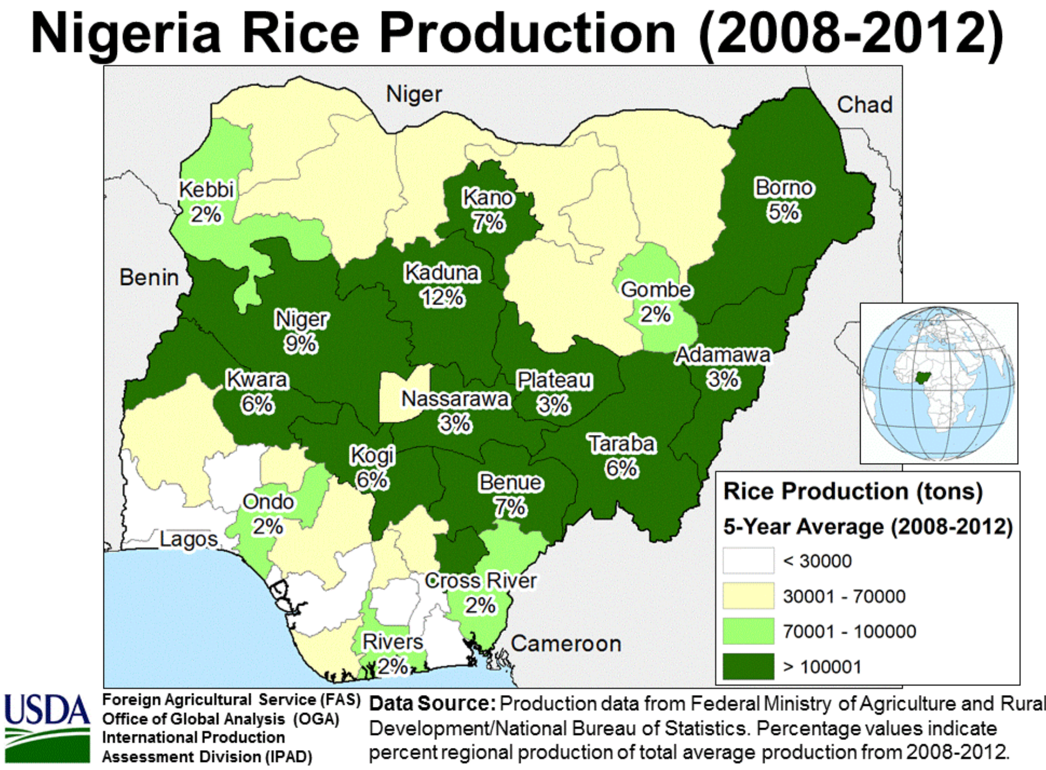
Source: USAID's FEWS NET, 2016

Niger



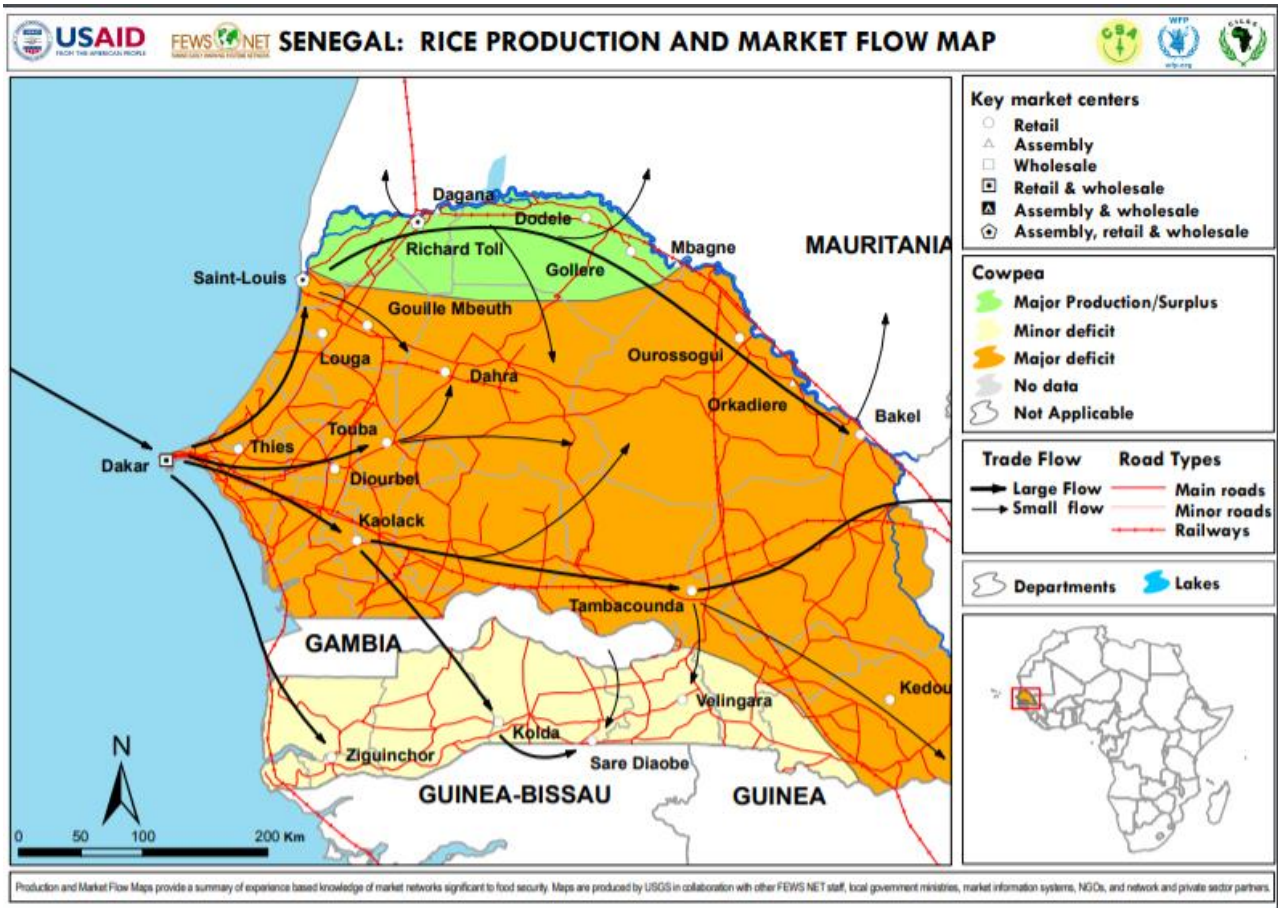
Source: USAID's FEWS NET, 2017

Nigeria



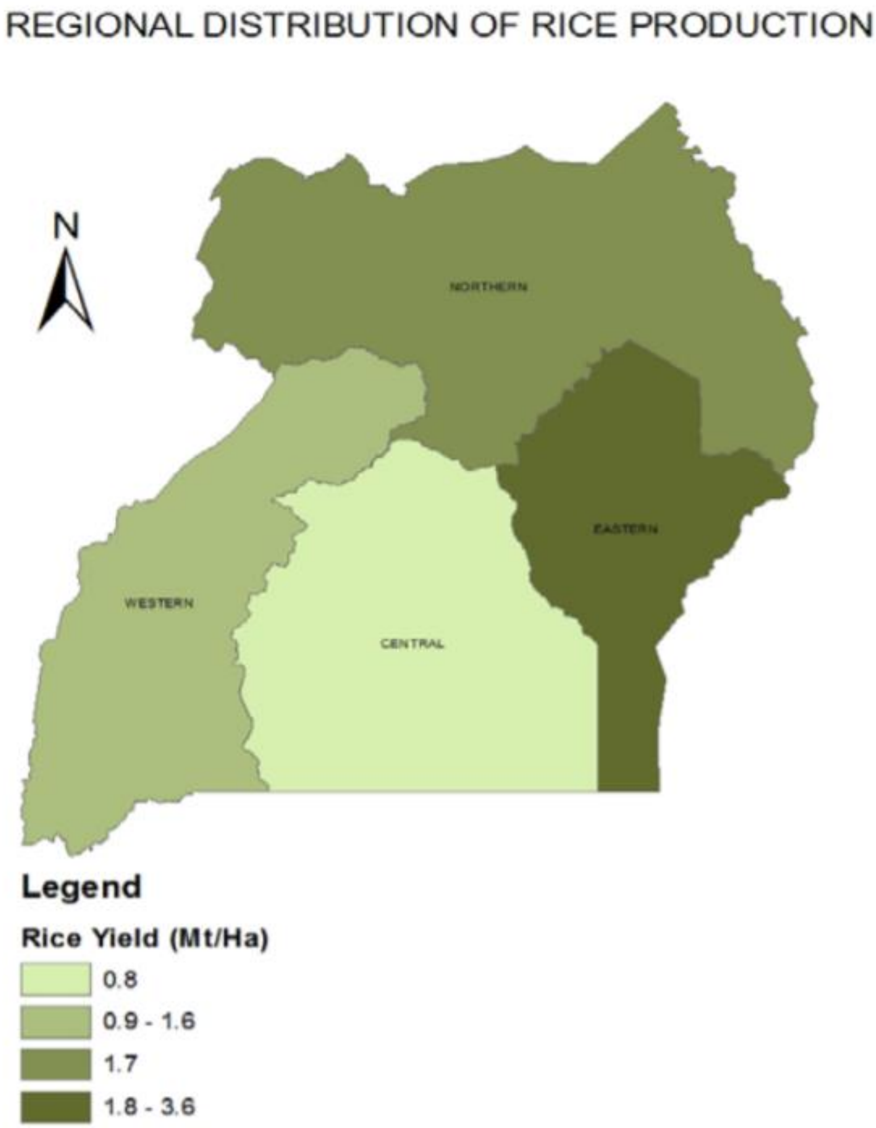
Source: USDA's IPAD

Senegal



Source: USAID's FEWS NET, 2010

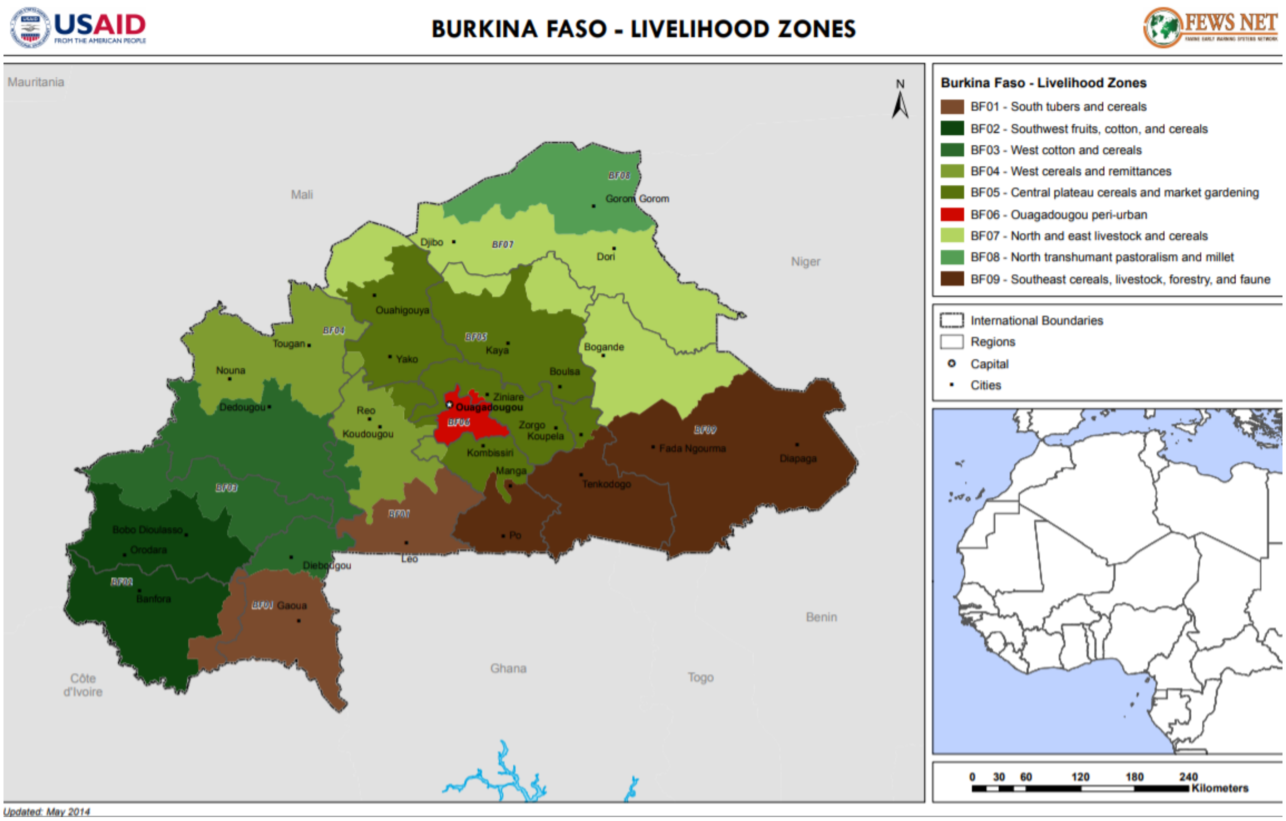
Uganda



Source: EPRC (2016)

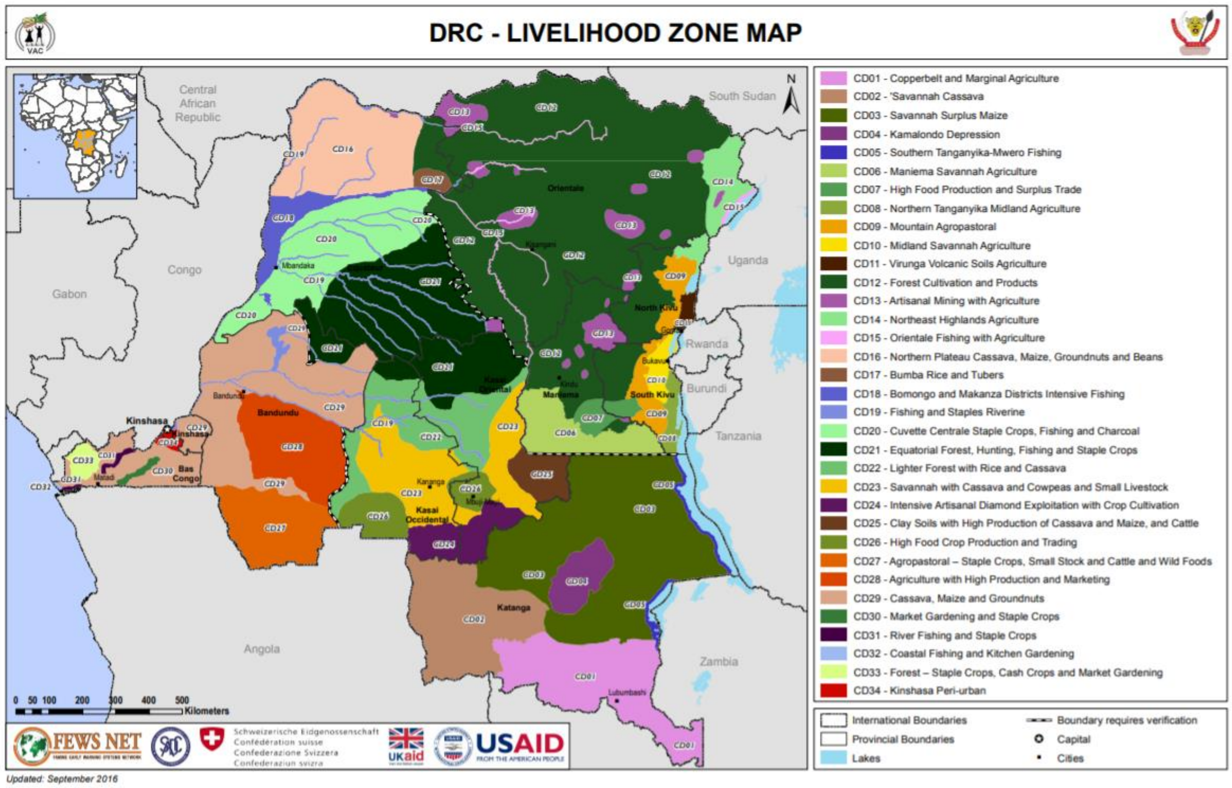
FISHERIES AND LIVELIHOOD ZONES

Burkina Faso



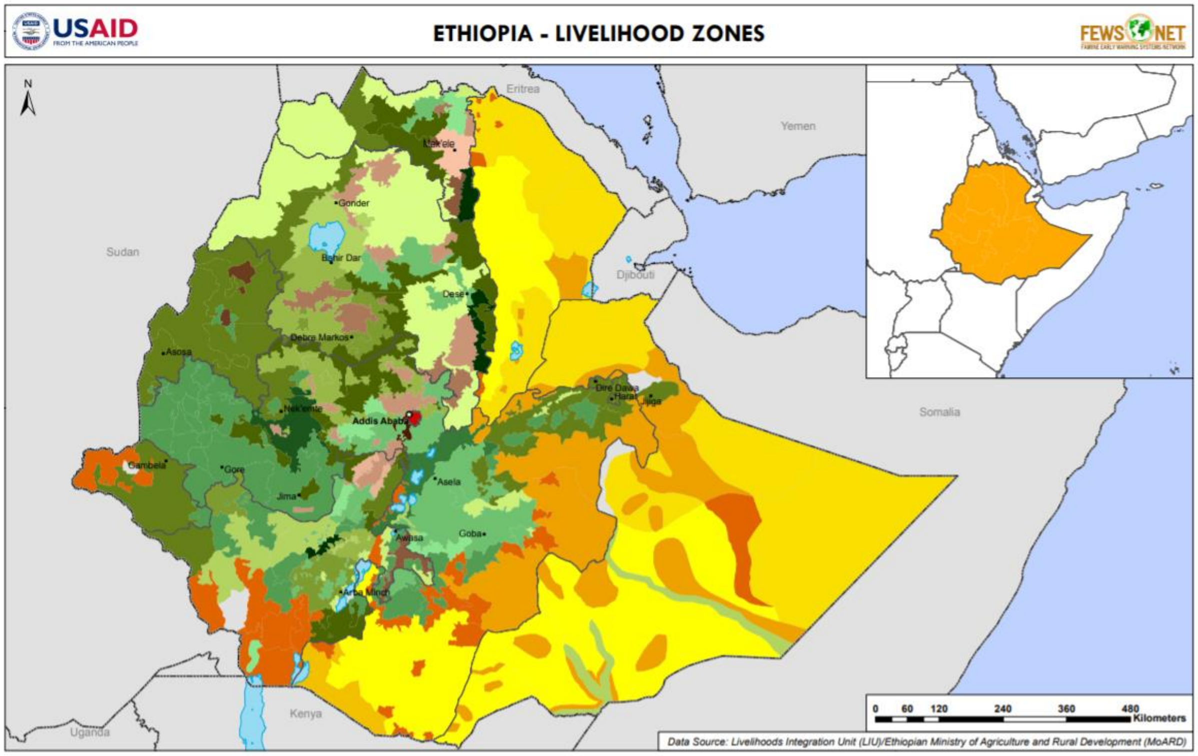
Source: USAID's FEWS NET, 2010

Democratic Republic of Congo

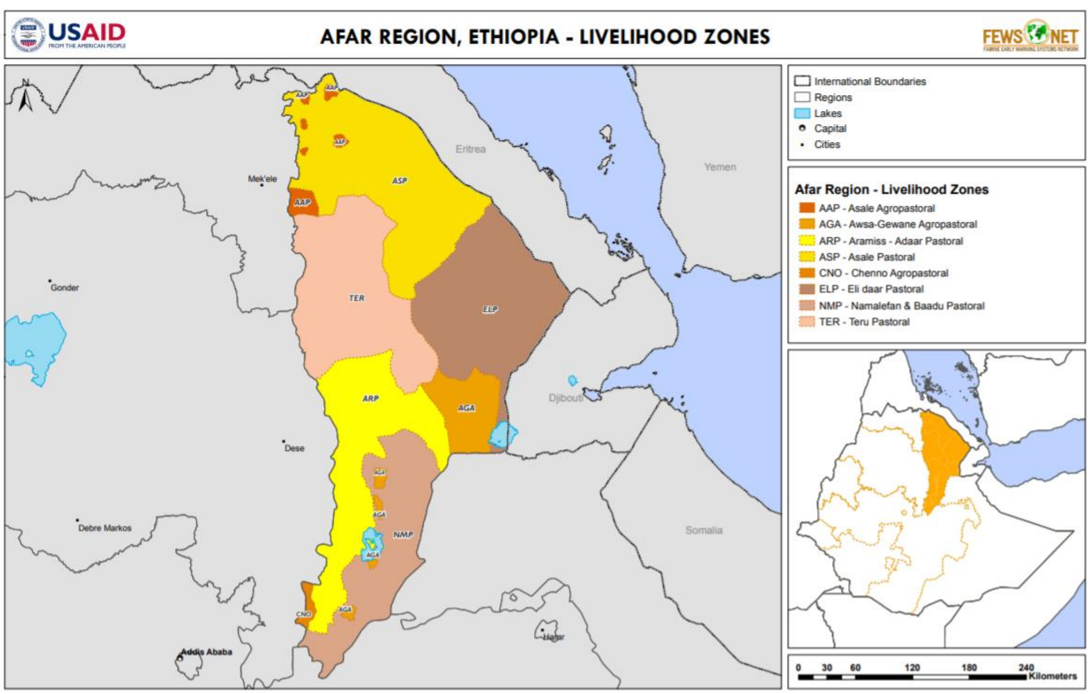


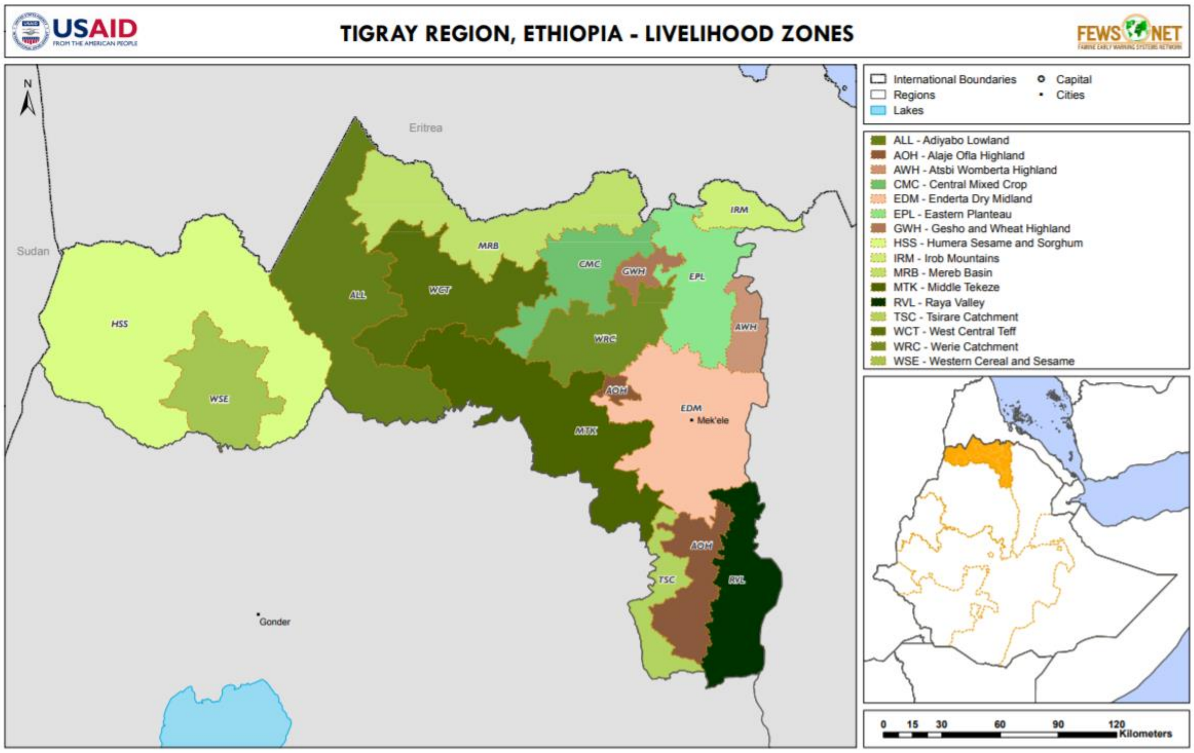
Source: USAID's FEWS NET, 2016

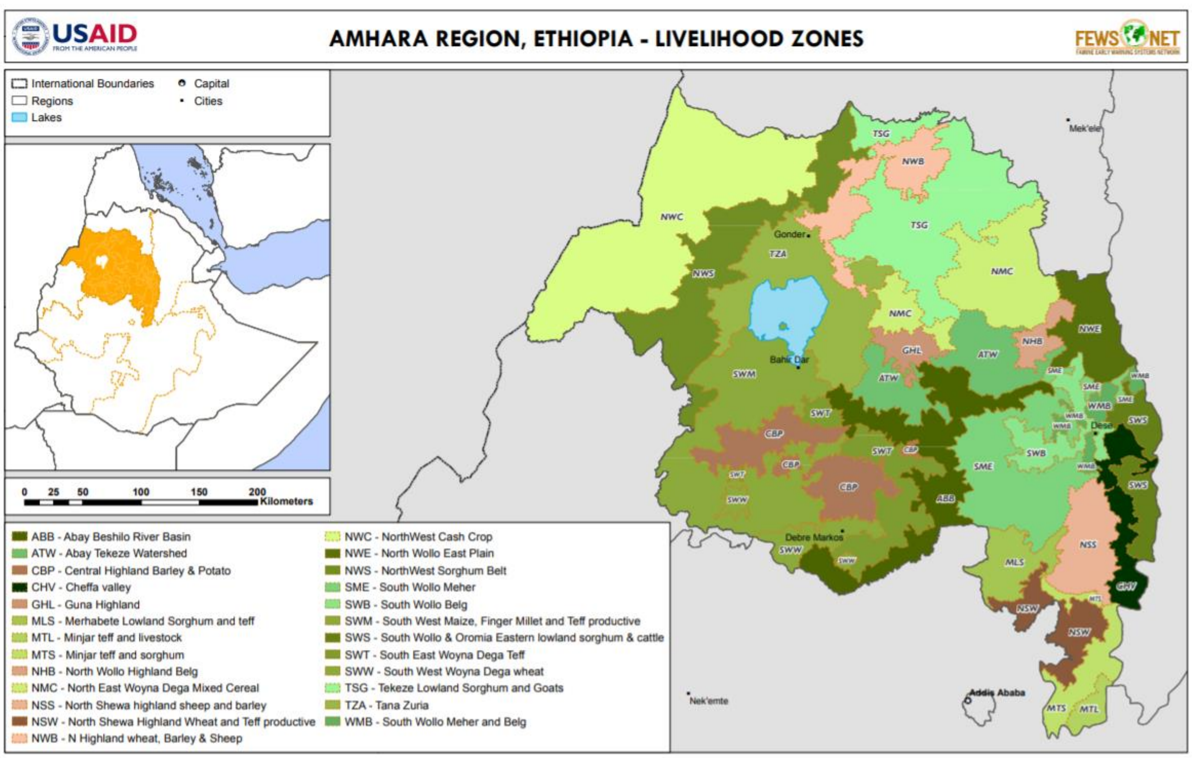
Ethiopia

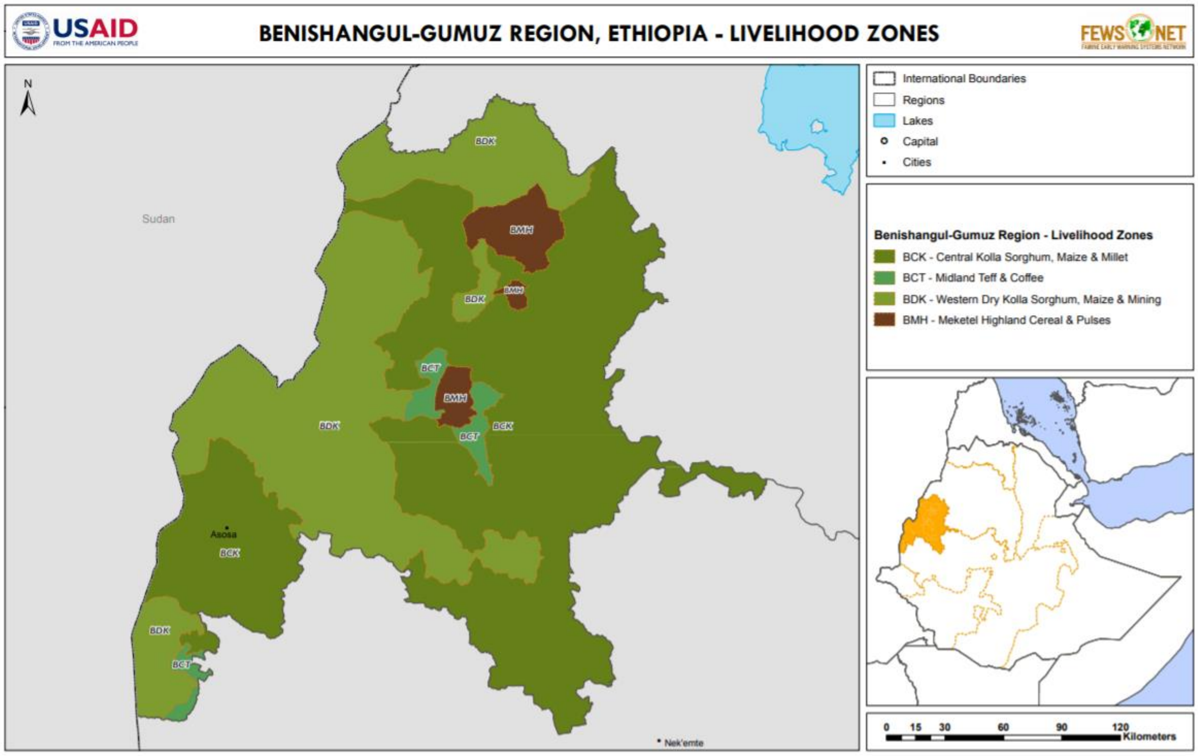


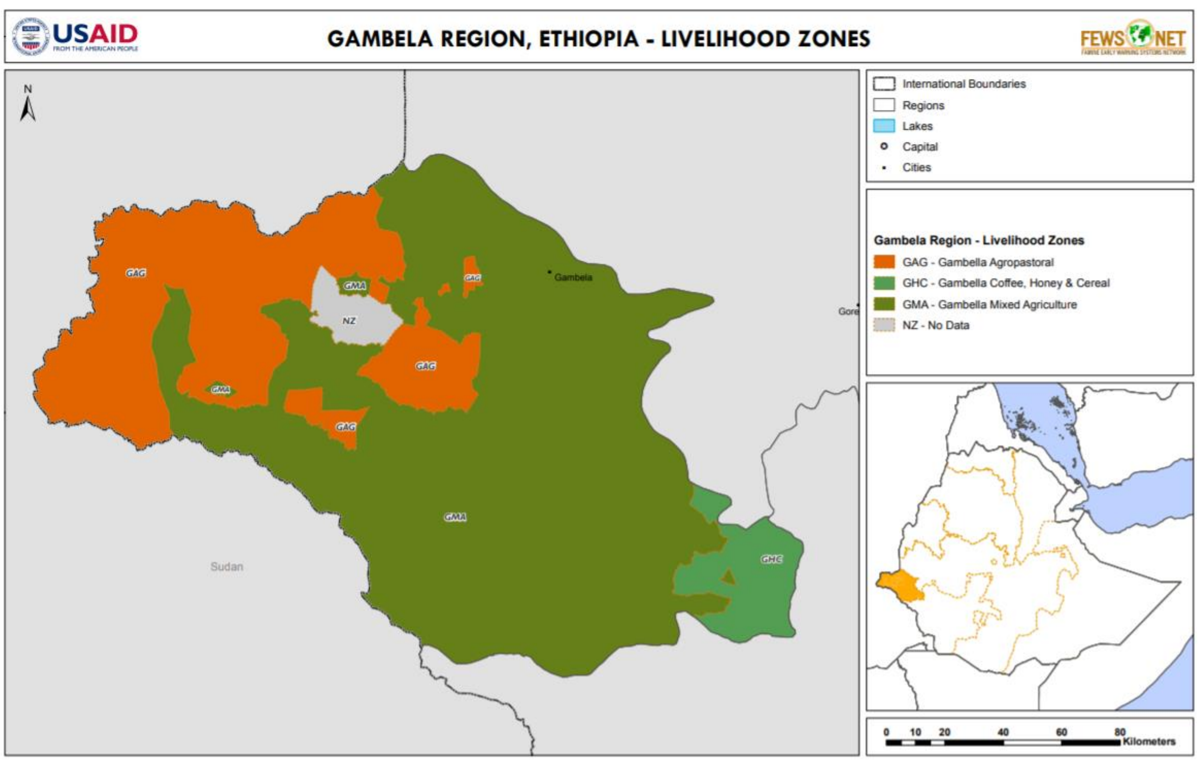
Source (for all regions in Ethiopia): USAID's FEWS NET, 2009

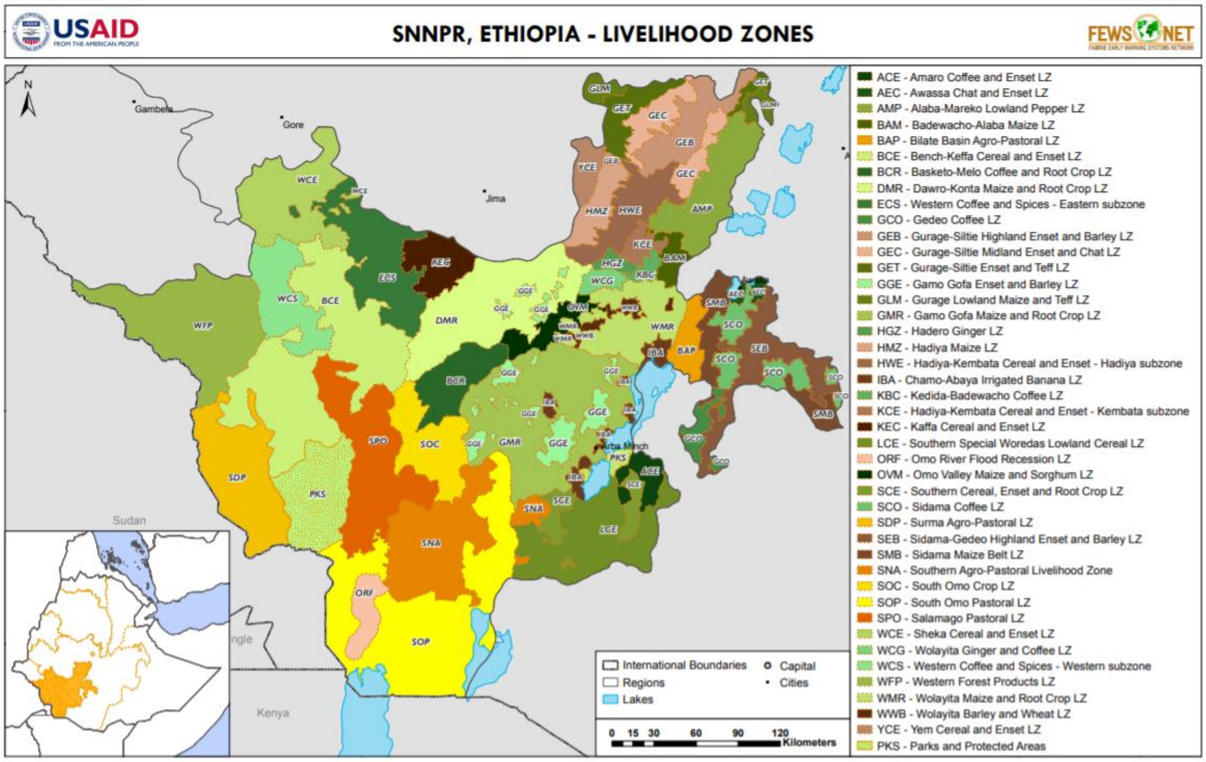


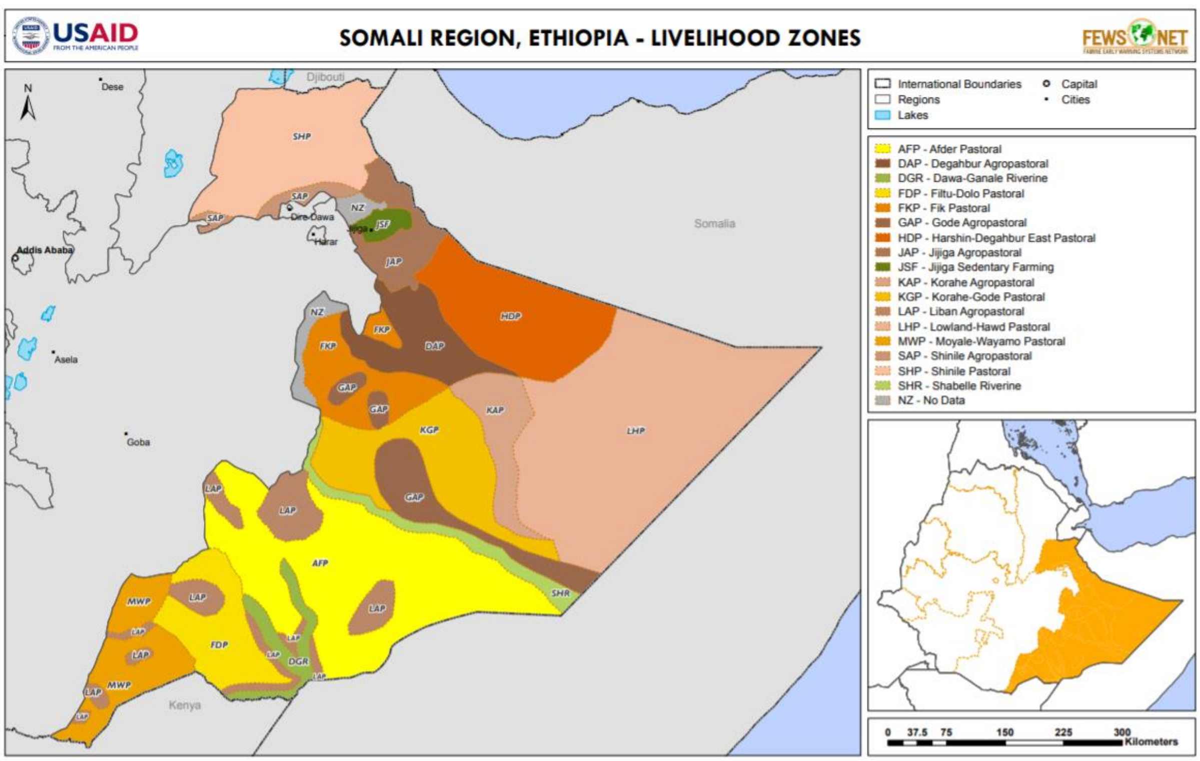

USAID
FROM THE AMERICAN PEOPLE
TIGRAY REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
International Boundaries
Regions
Lakes
Capital
Cities
ALL - Adiyabo Lowland
AOH - Alaje Ofla Highland
AWH - Atsbi Womberta Highland
CMC - Central Mixed Crop
EDM - Enderta Dry Midland
EPL - Eastern Planteau
GWH - Gesho and Wheat Highland
HSS - Humera Sesame and Sorghum
IRM - Irob Mountains
MRB - Mereb Basin
MTK - Middle Tekeze
RVL - Raya Valley
TSC - Tsirare Catchment
WCT - West Central Teff
WRC - Werie Catchment
WSE - Western Cereal and Sesame
Eritrea
Sudan
HSS
WSE
ALL
WCT
MRB
CMC
GWH
EPL
IRM
AWH
WRC
AOH
EDM
Mek'ele
MTK
AOH
TSC
RVL
Gonder
0 15 30 60 90 120
Kilometers

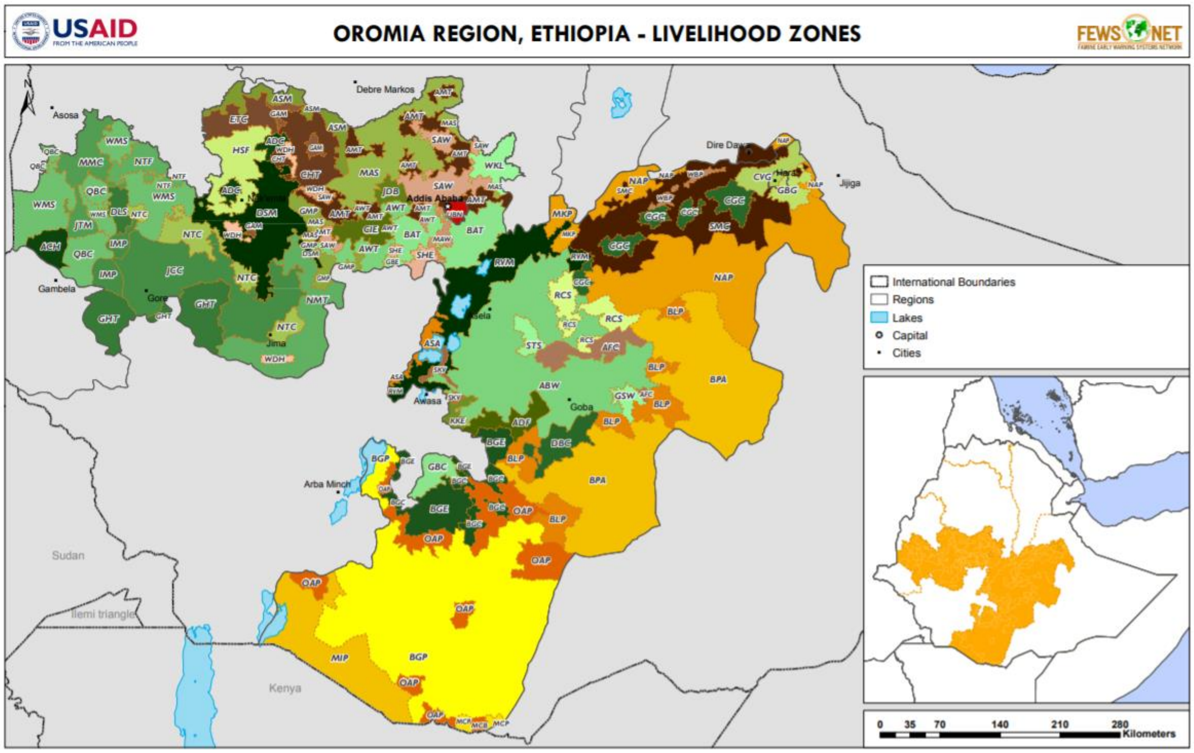

USAID
FROM THE AMERICAN PEOPLE
AMHARA REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
International Boundaries
Regions
Lakes
Capital
Cities
0 25 50 100 150 200
Kilometers
ABB - Abay Beshilo River Basin
ATW - Abay Tekeze Watershed
CBP - Central Highland Barley & Potato
CHV - Cheffa valley
GHL - Guna Highland
MLS - Merhabete Lowland Sorghum and teff
MTL - Minjar teff and livestock
MTS - Minjar teff and sorghum
NHB - North Wollo Highland Belg
NMC - North East Woyna Dega Mixed Cereal
NSS - North Shewa highland sheep and barley
NSW - North Shewa Highland Wheat and Teff productive
NWB - N Highland wheat, Barley & Sheep
NWC - NorthWest Cash Crop
NWE - North Wollo East Plain
NWS - NorthWest Sorghum Belt
SME - South Wollo Meher
SWB - South Wollo Belg
SWM - South West Maize, Finger Millet and Teff productive
SWS - South Wollo & Oromia Eastern lowland sorghum & cattle
SWT - South East Woyna Dega Teff
SWW - South West Woyna Dega wheat
TSG - Tekeze Lowland Sorghum and Goats
TZA - Tana Zuria
WMB - South Wollo Meher and Belg
Mek'ele
TSG
NWB
NWC
Gonder
TZA
TSG
NMC
NWS
NMC
NWE
NHB
GHL
ATW
ATW
SWM
Bahir Dar
SME
WMB
SWT
SWS
CBP
Dese
SWB
SME
CBP
CBP
SWW
ABB
Debre Markos
NSS
MLS
NSW
CHV
NSW
Nek'emte
Addis Ababa
MTS
MTL

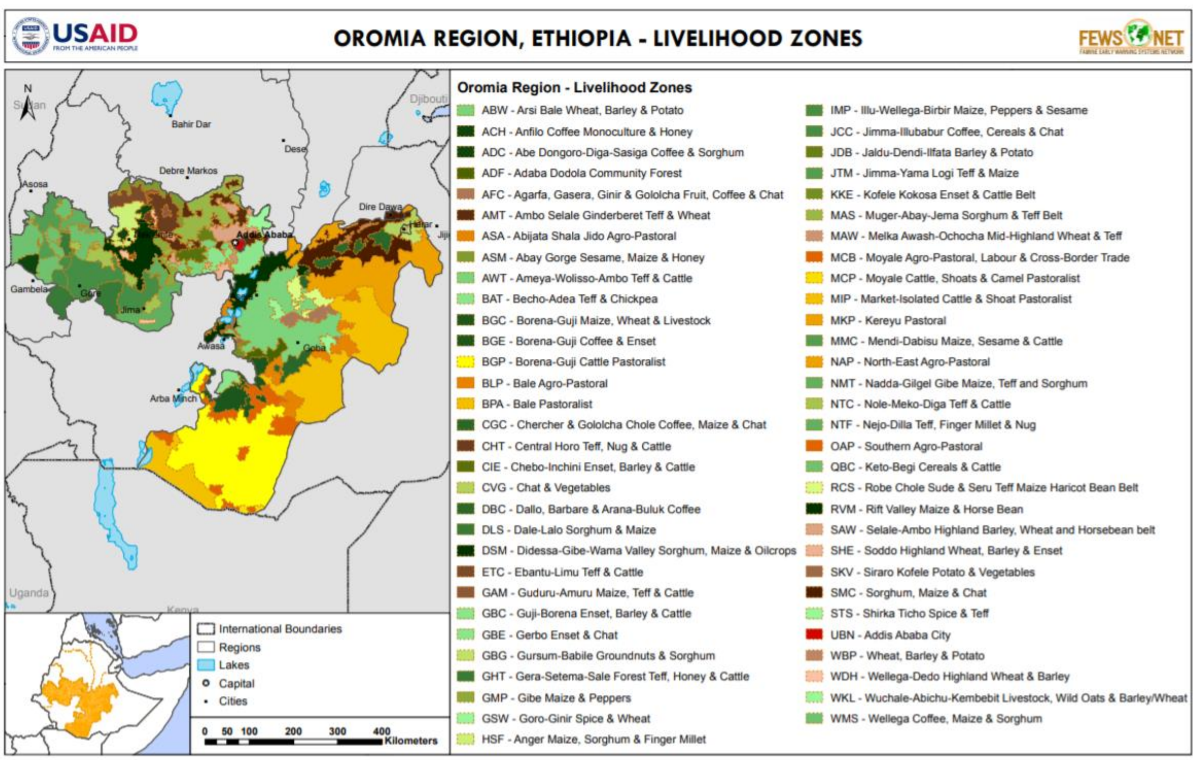

USAID
FROM THE AMERICAN PEOPLE
BENISHANGUL-GUMUZ REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
N
Sudan
BDK
BMH
BCT
BCK
Asosa
Nek'emte
International Boundaries
Regions
Lakes
Capital
Cities
Benishangul-Gumuz Region - Livelihood Zones
BCK - Central Kolla Sorghum, Maize & Millet
BCT - Midland Teff & Coffee
BDK - Western Dry Kolla Sorghum, Maize & Mining
BMH - Meketel Highland Cereal & Pulses
0 15 30 60 90 120
Kilometers


USAID
FROM THE AMERICAN PEOPLE
GAMBELA REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
N
Sudan
GAG
GMA
NZ
GHC
Gambela
Gore
International Boundaries
Regions
Lakes
Capital
Cities
Gambela Region - Livelihood Zones
GAG - Gambella Agropastoral
GHC - Gambella Coffee, Honey & Cereal
GMA - Gambella Mixed Agriculture
NZ - No Data
0 10 20 40 60 80
Kilometers

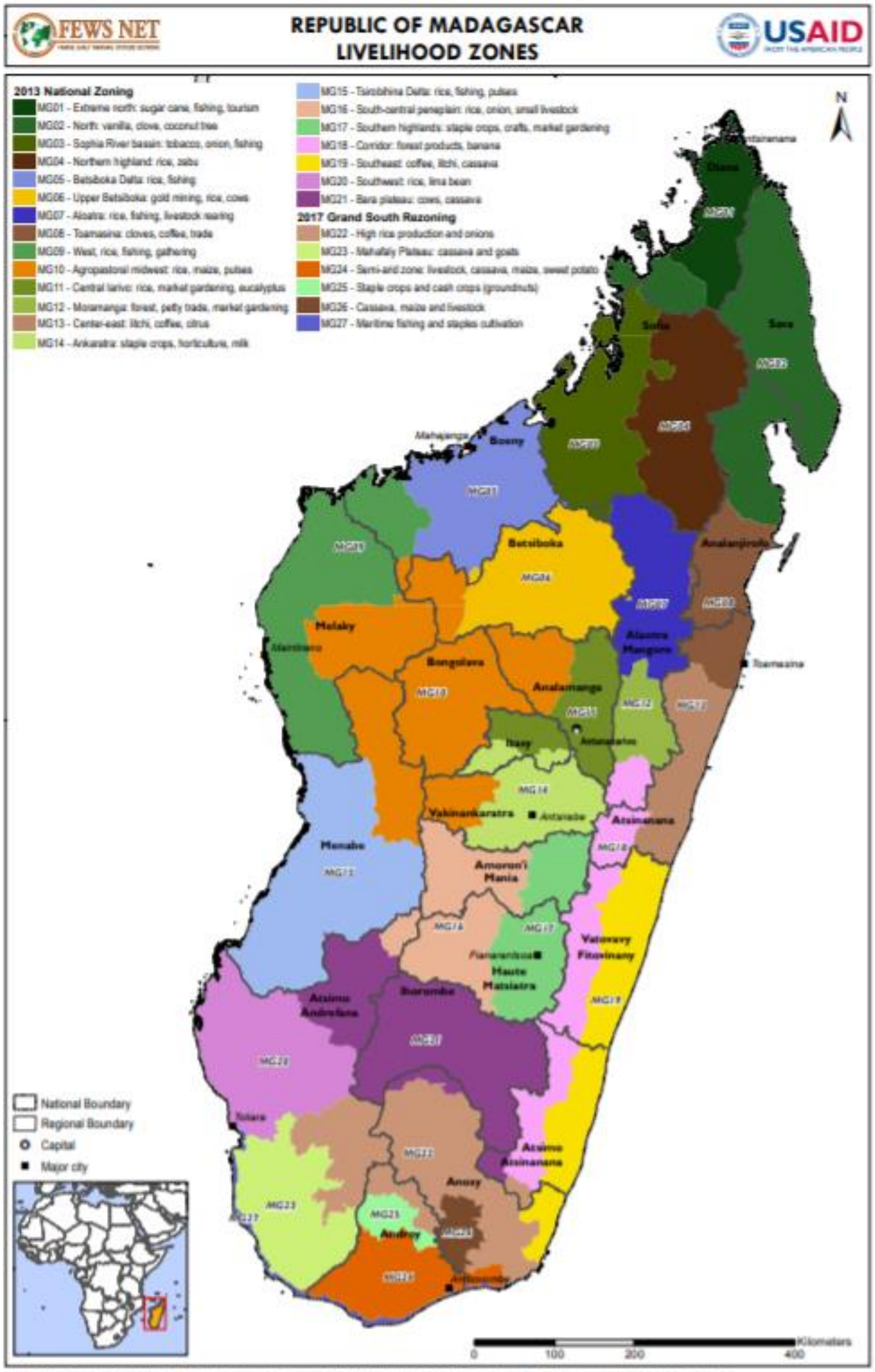

USAID
FROM THE AMERICAN PEOPLE
SNNPR, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
ACE - Amaro Coffee and Enset LZ
AEC - Awassa Chat and Enset LZ
AMP - Alaba-Mareko Lowland Pepper LZ
BAM - Badewacho-Alaba Maize LZ
BAP - Bilate Basin Agro-Pastoral LZ
BCE - Bench-Keffa Cereal and Enset LZ
BCR - Basketo-Melo Coffee and Root Crop LZ
DMR - Dawro-Konta Maize and Root Crop LZ
ECS - Western Coffee and Spices - Eastern subzone
GCO - Gedeo Coffee LZ
GEB - Gurage-Siltie Highland Enset and Barley LZ
GEC - Gurage-Siltie Midland Enset and Chat LZ
GET - Gurage-Siltie Enset and Teff LZ
GGE - Gamo Gofa Enset and Barley LZ
GLM - Gurage Lowland Maize and Teff LZ
GMR - Gamo Gofa Maize and Root Crop LZ
HGZ - Hadero Ginger LZ
HMZ - Hadiya Maize LZ
HWE - Hadiya-Kembata Cereal and Enset - Hadiya subzone
IBA - Chamo-Abaya Irrigated Banana LZ
KBC - Kedida-Badewacho Coffee LZ
KCE - Hadiya-Kembata Cereal and Enset - Kembata subzone
KEC - Kaffa Cereal and Enset LZ
LCE - Southern Special Woredas Lowland Cereal LZ
ORF - Omo River Flood Recession LZ
OVM - Omo Valley Maize and Sorghum LZ
SCE - Southern Cereal, Enset and Root Crop LZ
SCO - Sidama Coffee LZ
SDP - Surma Agro-Pastoral LZ
SEB - Sidama-Gedeo Highland Enset and Barley LZ
SMB - Sidama Maize Belt LZ
SNA - Southern Agro-Pastoral Livelihood Zone
SOC - South Omo Crop LZ
SOP - South Omo Pastoral LZ
SPO - Salamago Pastoral LZ
WCE - Sheka Cereal and Enset LZ
WCG - Wolayita Ginger and Coffee LZ
WCS - Western Coffee and Spices - Western subzone
WFP - Western Forest Products LZ
WMR - Wolayita Maize and Root Crop LZ
WWB - Wolayita Barley and Wheat LZ
YCE - Yem Cereal and Enset LZ
PKS - Parks and Protected Areas
International Boundaries
Regions
Lakes
Capital
Cities
0 15 30 60 90 120 Kilometers
Gambela
Gore
Jima
Arba Minch
Sudan
Kenya


USAID
FROM THE AMERICAN PEOPLE
SOMALI REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
International Boundaries
Regions
Lakes
Capital
Cities
AFP - Afder Pastoral
DAP - Degahbur Agropastoral
DGR - Dawa-Ganale Riverine
FDP - Filtu-Dolo Pastoral
FKP - Fik Pastoral
GAP - Gode Agropastoral
HDP - Harshin-Degahbur East Pastoral
JAP - Jijiga Agropastoral
JSF - Jijiga Sedentary Farming
KAP - Korahe Agropastoral
KGP - Korahe-Gode Pastoral
LAP - Liban Agropastoral
LHP - Lowland-Hawd Pastoral
MWP - Moyale-Wayamo Pastoral
SAP - Shinile Agropastoral
SHP - Shinile Pastoral
SHR - Shabelle Riverine
NZ - No Data
0 37.5 75 150 225 300 Kilometers
Djibouti
Dese
Dire Dawa
Harar
Addis Ababa
Asela
Goba
Somalia
Kenya


USAID
FROM THE AMERICAN PEOPLE
OROMIA REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
International Boundaries
Regions
Lakes
Capital
Cities
0 35 70 140 210 280 Kilometers
Debre Markos
Asosa
Gambela
Gore
Jima
Addis Ababa
Dire Dawa
Harar
Jijiga
Asela
Awasa
Goba
Arba Minch
Sudan
Ilemi triangle
Kenya


USAID
FROM THE AMERICAN PEOPLE
OROMIA REGION, ETHIOPIA - LIVELIHOOD ZONES
FEWS NET
Oromia Region - Livelihood Zones
ABW - Arsi Bale Wheat, Barley & Potato
ACH - Anfilo Coffee Monoculture & Honey
ADC - Abe Dongoro-Diga-Sasiga Coffee & Sorghum
ADF - Adaba Dodola Community Forest
AFC - Agarfa, Gasera, Ginir & Gololcha Fruit, Coffee & Chat
AMT - Ambo Selale Ginderberet Teff & Wheat
ASA - Abijata Shala Jido Agro-Pastoral
ASM - Abay Gorge Sesame, Maize & Honey
AWT - Ameya-Wolisso-Ambo Teff & Cattle
BAT - Becho-Adea Teff & Chickpea
BGC - Borena-Guji Maize, Wheat & Livestock
BGE - Borena-Guji Coffee & Enset
BGP - Borena-Guji Cattle Pastoralist
BLP - Bale Agro-Pastoral
BPA - Bale Pastoralist
CGC - Chercher & Gololcha Chole Coffee, Maize & Chat
CHT - Central Horo Teff, Nug & Cattle
CIE - Chebo-Inchini Enset, Barley & Cattle
CVG - Chat & Vegetables
DBC - Dallo, Barbare & Arana-Buluk Coffee
DLS - Dale-Lalo Sorghum & Maize
DSM - Didessa-Gibe-Wama Valley Sorghum, Maize & Oilcrops
ETC - Ebantu-Limu Teff & Cattle
GAM - Guduru-Amuru Maize, Teff & Cattle
GBC - Guji-Borena Enset, Barley & Cattle
GBE - Gerbo Enset & Chat
GBG - Gursum-Babile Groundnuts & Sorghum
GHT - Gera-Setema-Sale Forest Teff, Honey & Cattle
GMP - Gibe Maize & Peppers
GSW - Goro-Ginir Spice & Wheat
HSF - Anger Maize, Sorghum & Finger Millet
IMP - Illu-Wellega-Birbir Maize, Peppers & Sesame
JCC - Jimma-Illubabur Coffee, Cereals & Chat
JDB - Jaldu-Dendi-Ilfata Barley & Potato
JTM - Jimma-Yama Logi Teff & Maize
KKE - Kofele Kokosa Enset & Cattle Belt
MAS - Muger-Abay-Jema Sorghum & Teff Belt
MAW - Melka Awash-Ochocha Mid-Highland Wheat & Teff
MCB - Moyale Agro-Pastoral, Labour & Cross-Border Trade
MCP - Moyale Cattle, Shoats & Camel Pastoralist
MIP - Market-Isolated Cattle & Shoat Pastoralist
MKP - Kereyu Pastoral
MMC - Mendi-Dabisu Maize, Sesame & Cattle
NAP - North-East Agro-Pastoral
NMT - Nadda-Gilgel Gibe Maize, Teff and Sorghum
NTC - Nole-Meko-Diga Teff & Cattle
NTF - Nejo-Dilla Teff, Finger Millet & Nug
OAP - Southern Agro-Pastoral
QBC - Keto-Begi Cereals & Cattle
RCS - Robe Chole Sude & Seru Teff Maize Haricot Bean Belt
RVM - Rift Valley Maize & Horse Bean
SAW - Selale-Ambo Highland Barley, Wheat and Horsebean belt
SHE - Soddo Highland Wheat, Barley & Enset
SKV - Siraro Kofele Potato & Vegetables
SMC - Sorghum, Maize & Chat
STS - Shirka Ticho Spice & Teff
UBN - Addis Ababa City
WBP - Wheat, Barley & Potato
WDH - Wellega-Dedo Highland Wheat & Barley
WKL - Wuchale-Abichu-Kembebit Livestock, Wild Oats & Barley/Wheat
WMS - Wellega Coffee, Maize & Sorghum
International Boundaries
Regions
Lakes
Capital
Cities
0 50 100 200 300 400 Kilometers
Sudan
Djibouti
Bahir Dar
Dese
Debre Markos
Asosa
Gambela
Gore
Jima
Addis Ababa
Dire Dawa
Harar
Awasa
Goba
Arba Minch
Uganda
Kenya

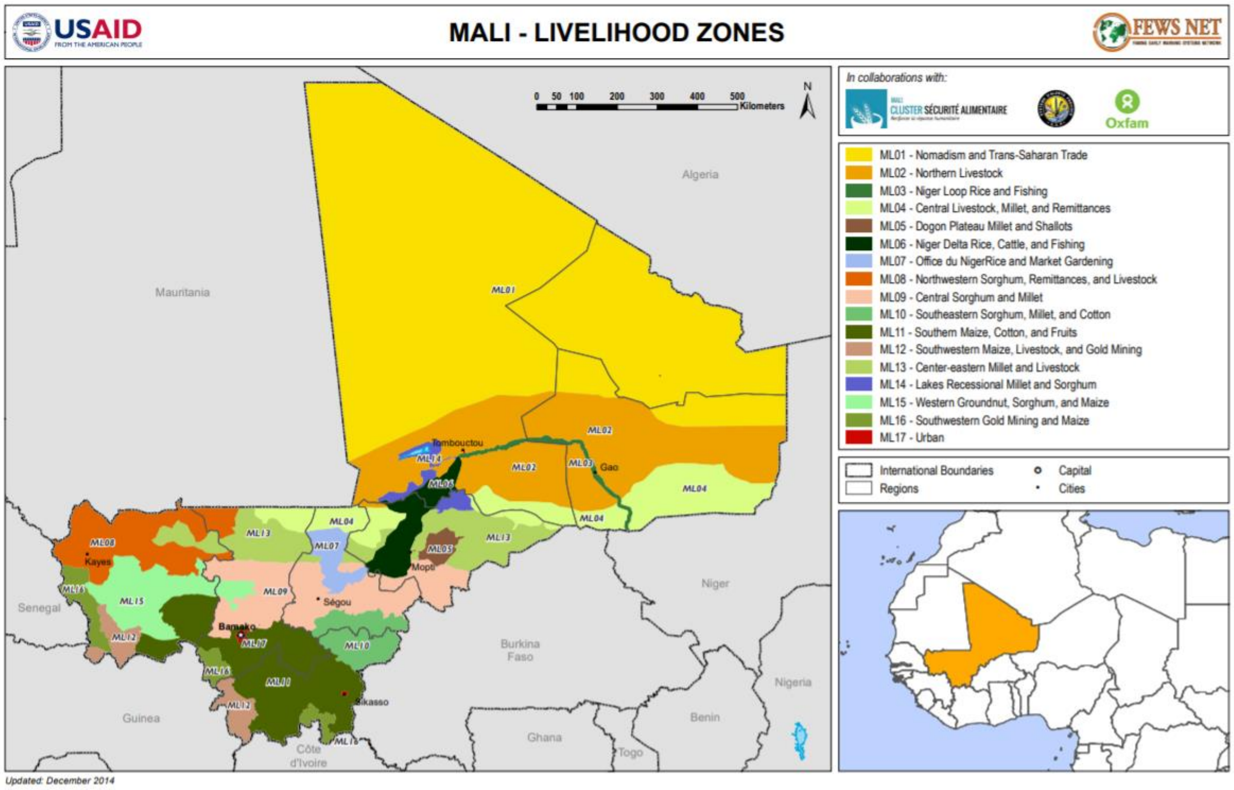
Madagascar



Note: This map is a consolidation of a rezoning exercise in 2017 in the Grand South Region of Southern Madagascar, and the national zoning exercise in 2013. Map updated in November 2017

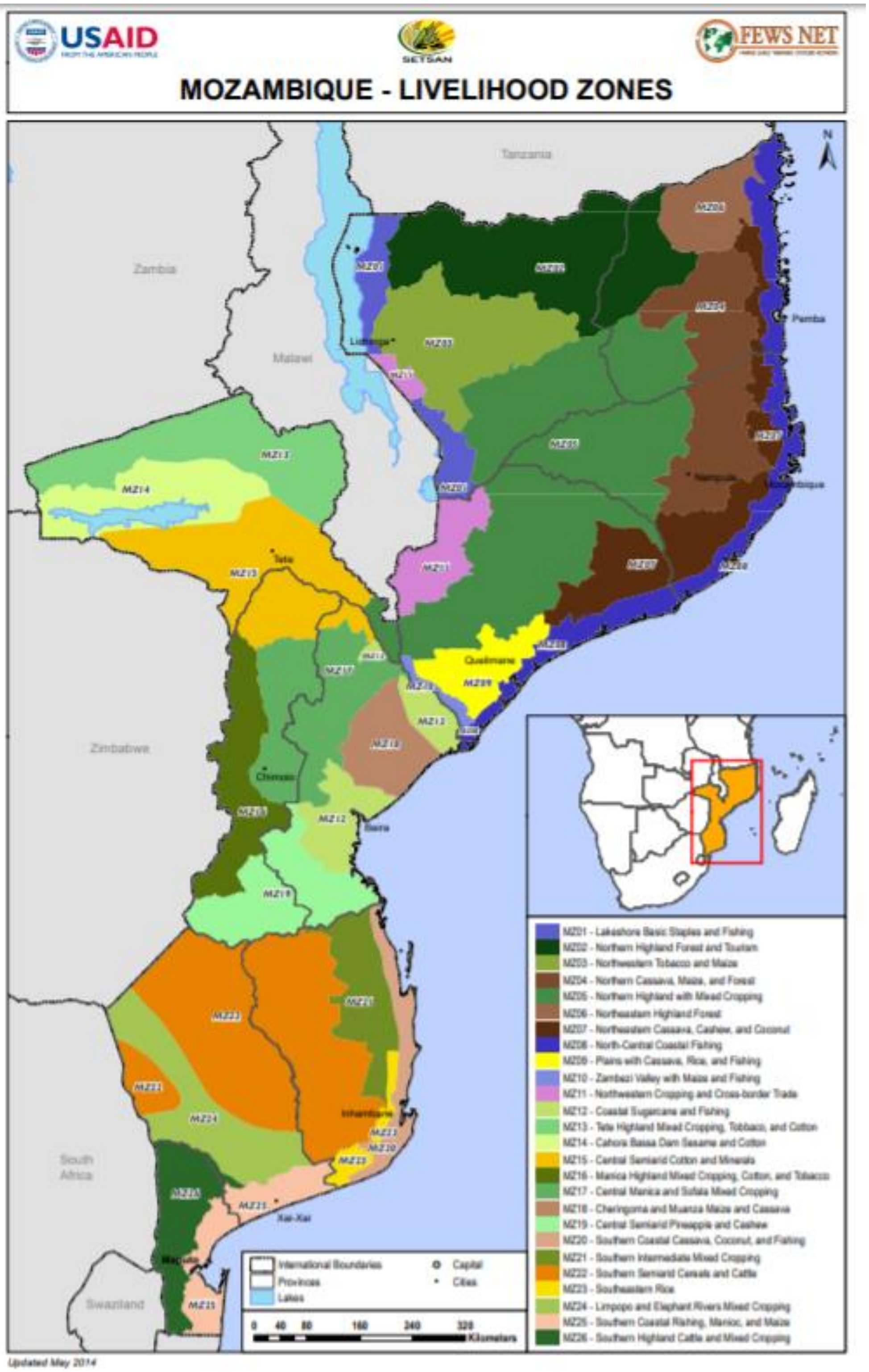
Source: USAID’s FEWS NET, 2017

Mali



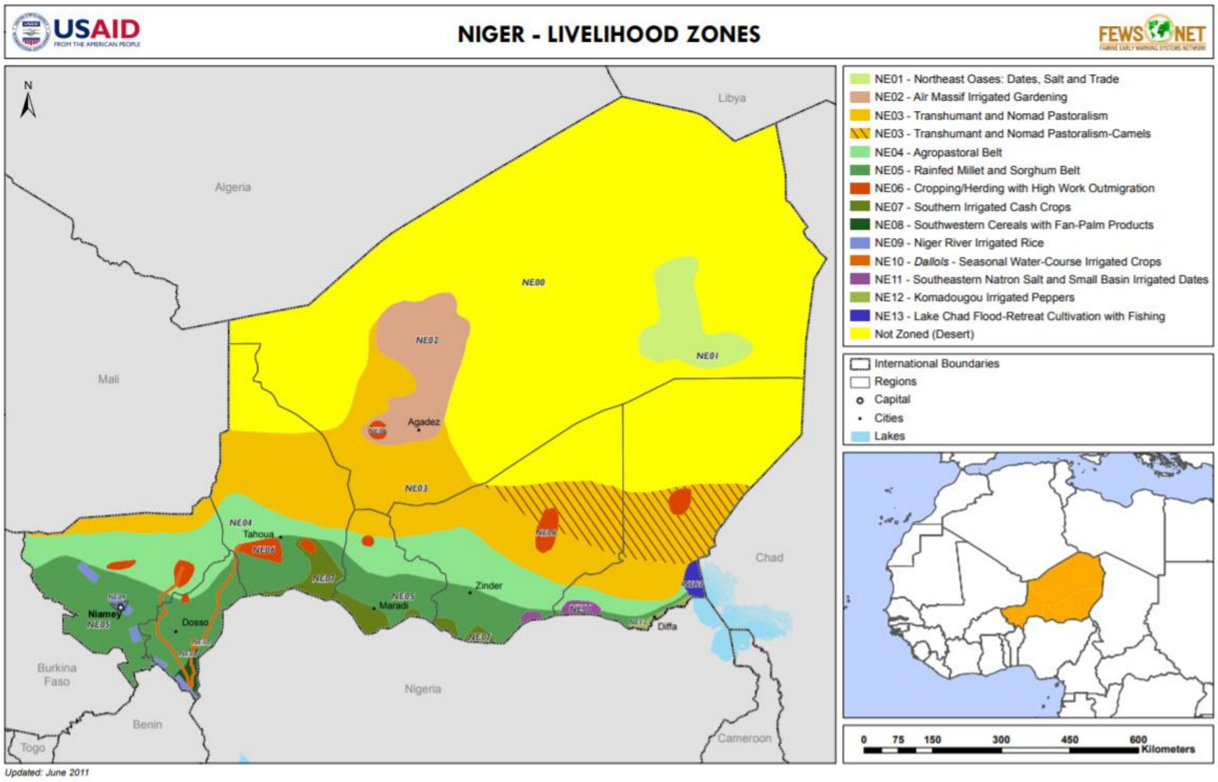
Source: USAID's FEWS NET, 2014

Mozambique



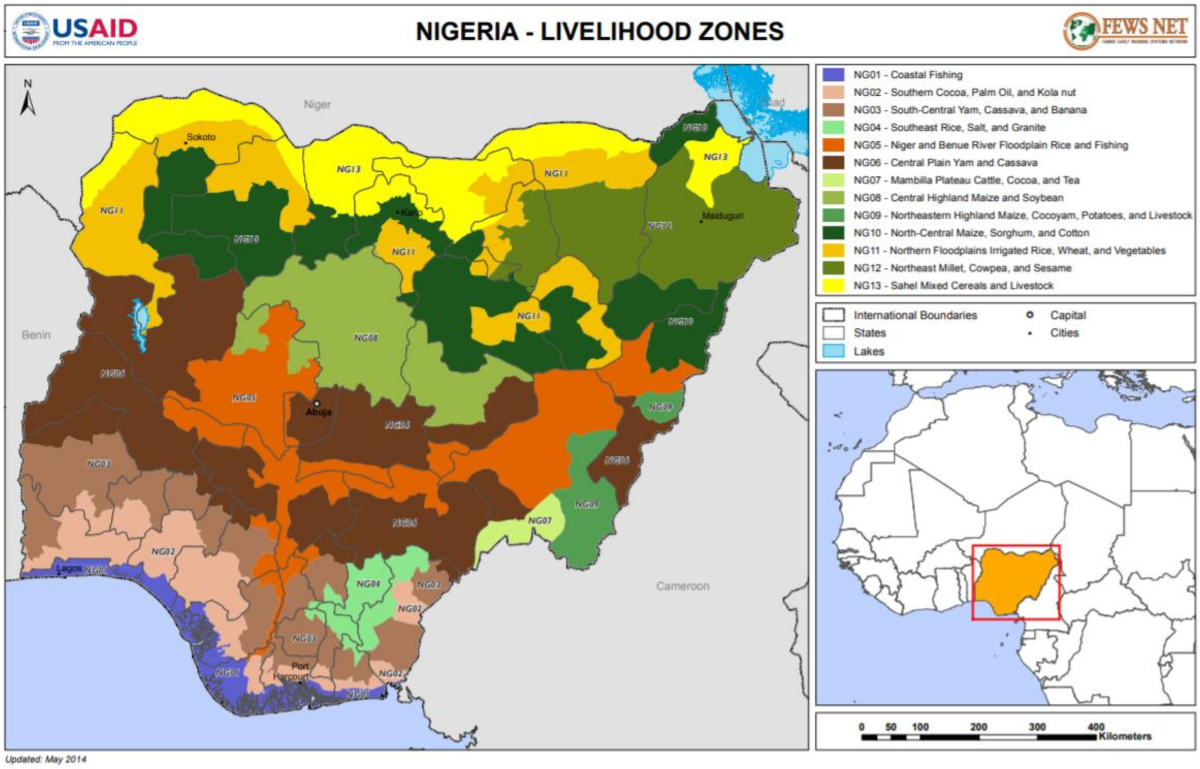
Source: USAID's FEWS NET, 2014

<u>Niger</u>



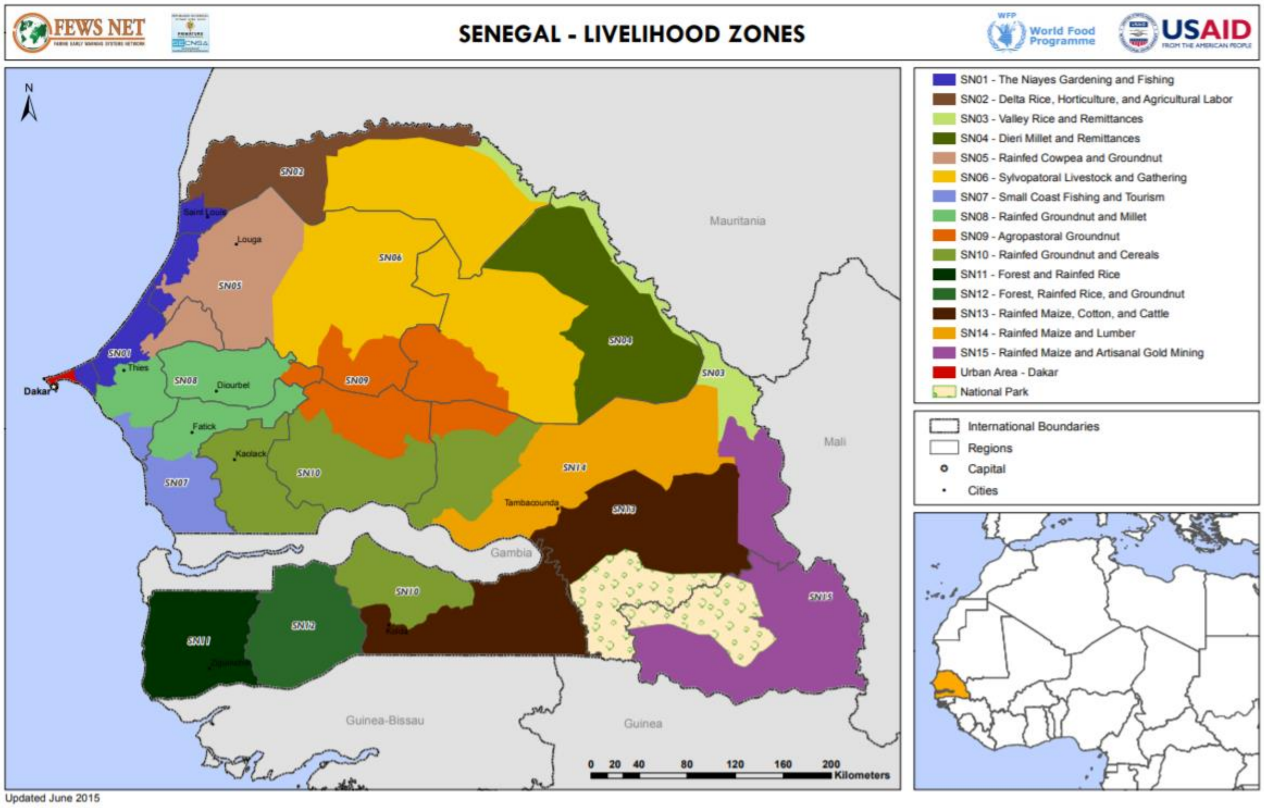
Source: USAID’s FEWS NET, 2011

Nigeria



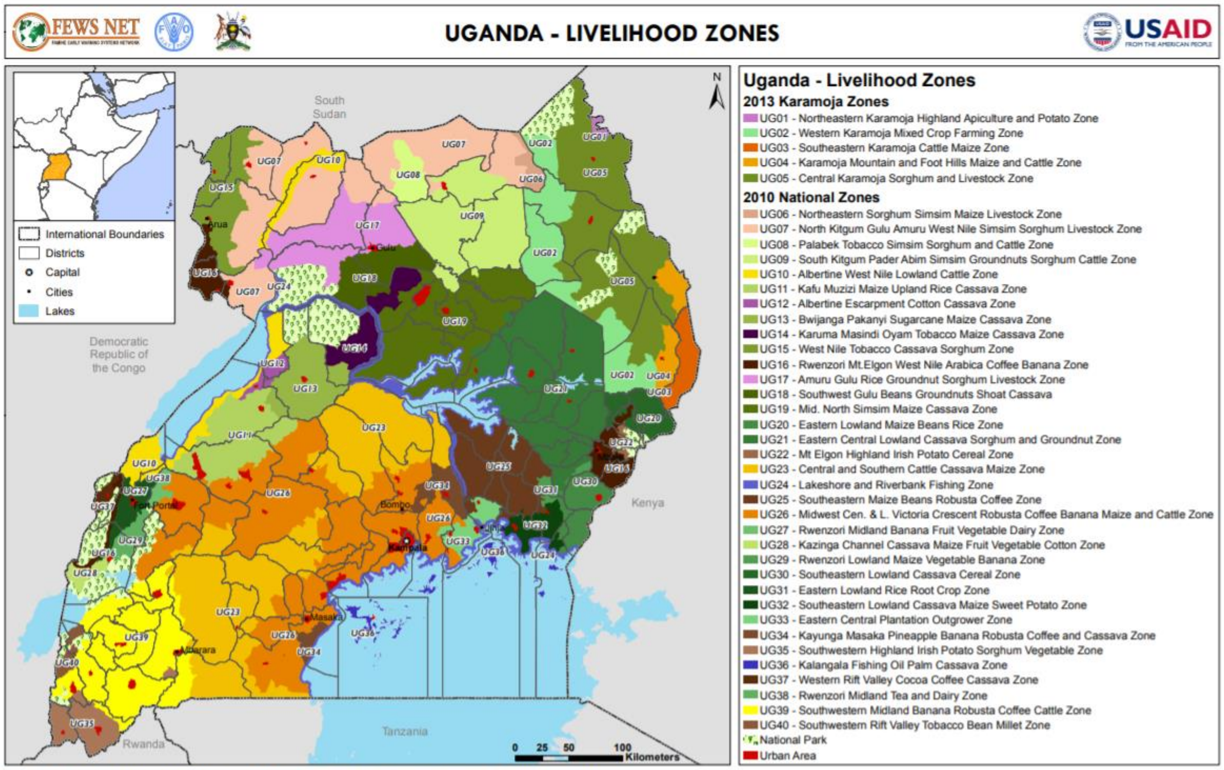
Source: USAID's FEWS NET, 2014

Senegal



Source: USAID's FEWS NET, 2015

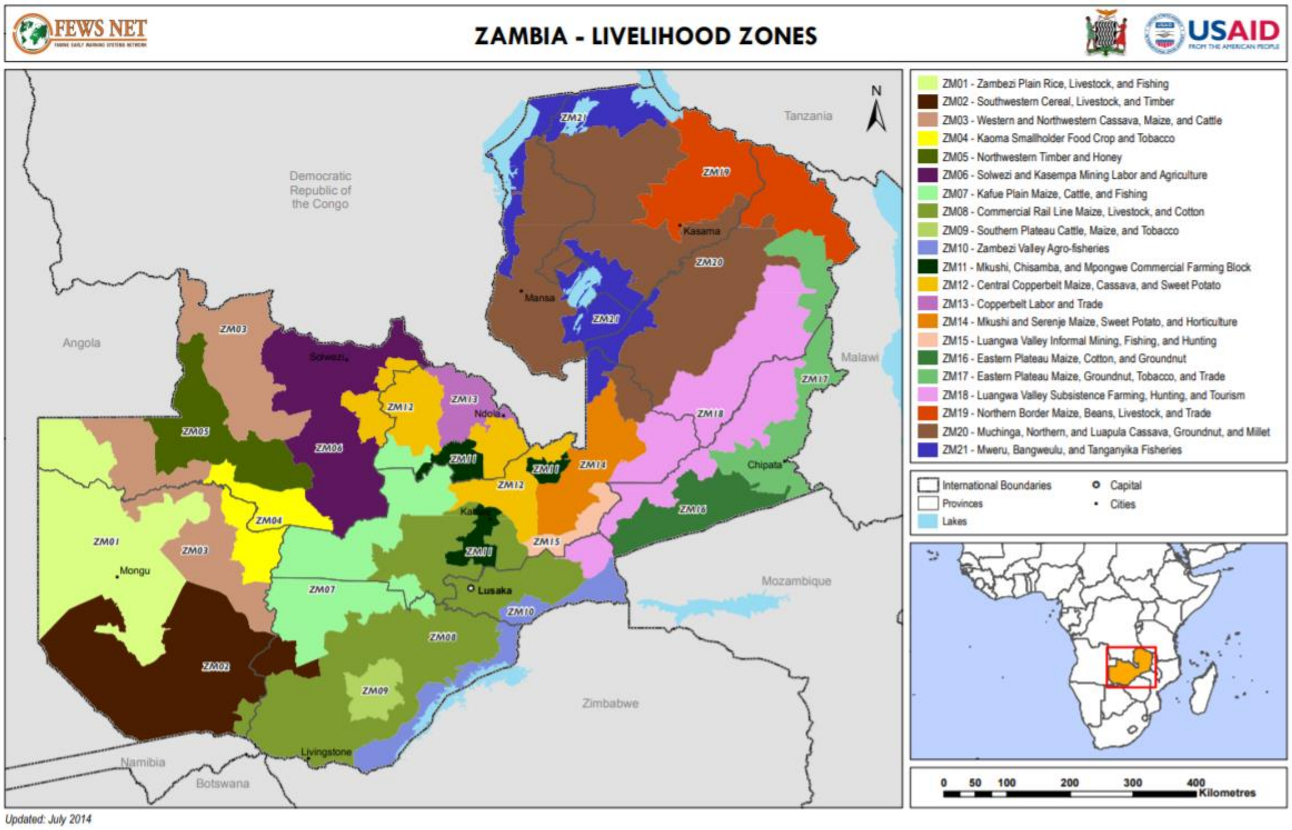
Uganda



Note: This map is a consolidation of the 2010 national livelihood zoning, and the updated zoning completed in 2013 in the Karamoja region.

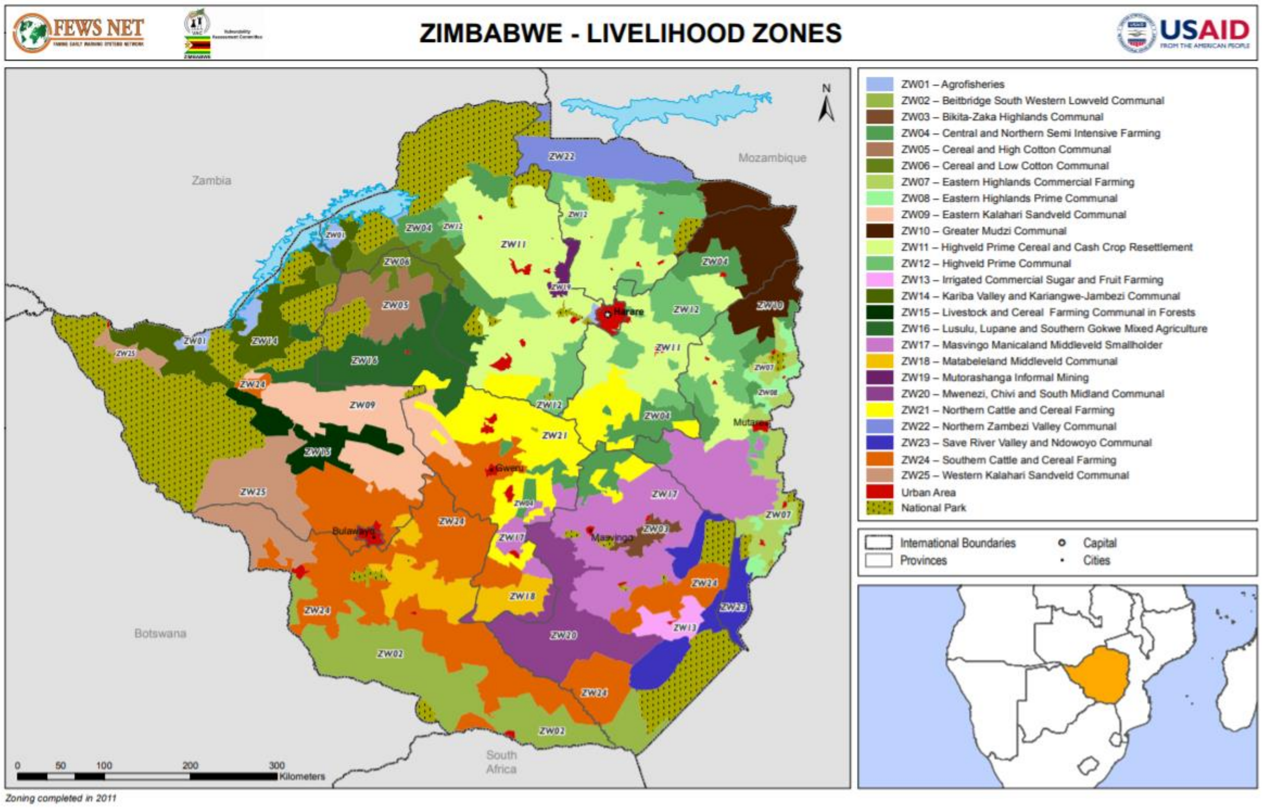
Source: USAID's FEWS NET, 2013

<u>Zambia</u>



Source: USAID's FEWS NET, 2014

<u>Zimbabwe</u>



Source: USAID's FEWS NET, 2011