Crop Suitability and Climate Risks in the *Planalto* region of Angola

Preliminary Analysis

Study undertaken in support of the International Fund for Agricultural Development SADeP project in Angola

Summary report and Recommendations

October 2016

Contents

Executive Summary

The International Fund for Agricultural Development (IFAD) is in the process of preparing the full project proposal for the Smallholder Agribusiness Development Project (SADeP). The latter project is expected to be implemented over a 7 year period (2017-2024) and will be focused on the central highlands *Planalto* region of Angola, including the provinces of Benguela, Bie, Cuanza Sul, Huambo, Huila and Malanje. In support of the project development process, a study was undertaken to determine *inter alia* i) the current and future climate characteristics of the project area; ii) the current and future suitability of various crop species to the project area; and iii) identify risks related to climate change, as well as potential adaptation options and opportunities to increase climate resilience. Crops selected for analysis included staple crops such as cassava, maize, millet and sorghum, as well as cash crops such as banana, sugarcane and coffee.

The following report summarises the preliminary findings of this study, which includes detailed analysis of current climate and crop suitabilities but does not include detailed modelling and analysis of future climate change scenarios. However, the report does include information on observed climate change impacts and general predictions of the impact of climate change on Angola's agriculture sector, which are used to inform predictions of climate change risks to the abovementioned crops in each of the six provinces studied. These preliminary findings can be used to guide the prioritisation of specific crops and identification of potential climate risks during the ongoing design phase of the SADeP project, and will be further complemented by an additional analysis of future climate change scenarios and resultant impacts on the agriculture sector.

1. Angola Background

1.1 Geographic Context

The Republic of Angola is the fifth-largest economy in Africa (USDA, 2015) and the third-largest country in sub–Saharan Africa with an area of 1,246,700 km^2 (FAO, 2014). In 2014 according to the national census Angola had a population of nearly 24,227,524 people with an annual growth rate of 3.3% (WB, 2016). Estimates of urban and rural population vary between sources. Urban population is estimated to be between 26.8% (WB, 2016) and 44.1% (UN, 2015). As a result of rapid urbanization, the urban population is projected to surpass 20,000,000 by 2030 and nearly 35,000,000 by 2050 (FAO, 2013).

1.2 Agriculture in Angola

As a result of Angola's abundance of natural resources (FAO, 2012)and fertile land, the country has the potential to produce a variety of crops and livestock and become one of Africa's foremost agricultural economies (USDA, 2015). Prior to independence (1975), Angola was an independent producer of all major staple foods with the exception of wheat. In addition, the country was an exporter of coffee, sisal, sugar cane, banana and cotton (FAO, 2012; EC, 2014 & USDA, 2015). However, the civil war disrupted agricultural production and displaced millions of people (USDA, 2015) to the extent that by the 1990s, Angola's coffee production was reduced to less than 1% of 1970s levels, while production of cotton, tobacco and sugar cane had ended almost completely.

Currently, agriculture constitutes 11% of Angola's total economy, contributing US$129 billion (USDA, 2015), and is the primary source of employment (42%) (EC, 2014). Post-2002, the recovery of the agricultural sector has been hindered by multiple factors, including *inter alia* the collapse of internal trade and distribution structures, insignificant levels of domestic credit for agriculture and livestock, and poor institutional support (FAO, 2012). In addition, external factors such as low market prices for exportable agricultural commodities and lack of investment have further limited the development of the sector after independence (Tomas, 2011).

Crop production is the main livelihood of rural households in Angola, with the exception of the south, which is dominated by livestock production. Presently, only 8% of an available ~58 million hectares of arable land is under cultivation (USDA, 2015). The majority of this land is managed by smallholder subsistence farmers, who typically cultivate an average area of ~1.4 hectares per family on two or more plots of land. The country's cropping patterns are diverse, however most farmers practice some form of rain-fed agriculture and are dependent on a single rainy season, which occurs from September to December in most regions of the country (FAO, 2014; USDA, 2015). In the north (Cabinda, Uige, Kwanza Norte, Zaire, Malange) and the northeast (Lundas area), the primary cultivated crops are cassava, beans, groundnuts and maize. In the Planalto Central, maize and beans dominate. In the south, a form of mixed agro-pastoralism is practiced, which includes livestock production as well as cultivation of cereal crops such as sorghum and millet, complemented by cowpeas and cassava (EC, 2014). Household income and food is further supplemented, particularly during periods of insufficient production or crop failure, by activities such as wood collection, charcoal production, hunting and fishing (EC, 2014). The diversity of Angola's agro-ecological zones and livelihood types is described in extensive detail in the FEWSNet Livelihood Zone Map of Angola (FEWSNet, 2013), available at:
http://www.fews.net/southern-africa/angola/livelihood-zone-map/october-2013

According to the joint FAO/Government of Angola Country Programming Framework, the government has identified climate change as a particular threat to the agriculture and natural resources sector (FAO, 2013a), noting the need for activities including *inter alia*:

- delivery of an enabling environment through policy and institutional strengthening, including improved stakeholder coordination, for food security, sustainable natural resources management and increasing resilience to shocks and threats from climate change; and
- building resilience of food and agricultural systems to climatic shocks and threats, particularly floods and droughts.

Other major barriers to the development of the agriculture sector include *inter alia*:

- poor agricultural productivity and production;
- poorly commercialized agricultural market;
- degradation of agricultural land; and
- lack of human capacity for enhanced food security, agricultural growth and natural resources management.

2. Climate and Climate Change in Angola

2.1 Baseline Climate of Angola

The country has two distinct seasons – hot, humid and rainy season (October to May) and dry and cool (June to September). Rainfall decreases from north (1800mm) to south (50mm, particularly in desert areas) in the country as the cooling effects of the Benguela current become pronounced. Temperatures in Luanda average 25°C in January and 21°C in the winter month of July. With less rain along the coast, the capital (Luanda) receives an average of ~300mm annually (GoA, 2012). Angola's meteorological records are notoriously unreliable and inconsistent as a result of the disrepair of the country's monitoring network, and as a result there are large geographic and historical gaps in data. For example, rainfall data is based on a monitoring network of 500 station of which only ~20 are considered to be fully functional, which provides an inadequate level of detail to inform accurate and downscaled analysis and forecasts of Angola's climate.

2.2 Observed Climate Change Trends in Angola

According to Angola's Initial National Communication (INC, GoA 2012) surface temperature increases of 0.2 to 1.0 °C were observed from 1970 and 2004 within the coastal areas and northern regions of Angola; and an increase of between 1.0 and 2.0 °C in the central and eastern regions of the country. Air temperature data in Luanda indicated an increase of ~0.2 °C per decade, totalling an increase of 2.1 °C between 1911 and 2016 with greater increases observed during the cool season. Meteorological data extracted from the central plateau of Angola, where data sets are more reliable relative to the majority of the country, do not indicate any clear change in seasonal precipitation trends. (GoA 2012).

The sectors which are considered to be particularly vulnerable to climate change in Angola include natural resources/biodiversity, human health, infrastructure, fisheries, and agriculture and food security. Given the uncertainties in projected trends in precipitation, specific impacts are difficult to predict. However it is anticipated that climate change will increase the severity of existing vulnerabilities (Lotz-Sistika and Urquhart, 2014), notably extreme events such as droughts and floods. The entire SADC region, including Angola, has been severely impacted by the disruptions of the El Nino effect. The country experienced a severe drought during the 2013-2014 agricultural cycle which resulted in widespread food insecurity in the country's southern provinces. The drought affected 1.8 million people in six provinces, particularly Cunene (543,000), Huila (583,000) and Namibe (162,092), where production losses of cereals and legumes were ~100% (UNICEF, 2014). The subsequent agricultural cycle in 2015–2016 was similarly impacted such that the United Nations Office for Coordination of Humanitarian Affairs reports that drought "affected 1.4 million people in seven of Angola's provinces, of which 78% are located in Cunene, Huila and Namibe. Cunene being the greatest affected province, 800 000 people residing in rural communities were affected in 2016 compared to 500 000 affected in the previous year" (OCHA, 2015). The Office of the UN Resident Coordinator reports that the heavy downpours and flash floods that typify the rainy season are expected to exacerbate the food security situation in the 2016–2017 season (UNORC, 2016).

A brief summary of the scale and frequency of climate-related disasters (droughts and floods) in Angola in the period 1976–2014 is presented in Table 2.2.1, below.

Table 2.2.1 Recorded impacts of drought and flood in Angola (1976–2014) (UNICEF, 2014)

Disaster type	Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Drought	Drought	7	58	4443900	0
Flood	Riverine flood	24	468	1088608	10000
Flood	--	9	74	116228	0
Flood	Flash flood	4	134	5755	0

2.3 Projected Climate Change

Considering the limited availability of observational data to inform analytical models, there is a relatively wide range of uncertainty of the likely effect of climate change in Angola. Projections of average annual rainfall over the country from a number of models illustrate a wide range of changes in rainfall patterns for Angola (RoA, 2015). IPCC scenarios (SRES A1B scenario as shown in the IPCC 4th Assessment Report) project an increase of mean annual temperature ranging between 1.2 to 3.2°C by the 2060s, and 1.7 to 5.1°C by the 2090s (IPCC, 2014). However, in general all climate models project that Angola will experience increased temperatures, more extreme weather events, an expansion of arid and semi-arid regions, seasonal shifts in rainfall, localized floods, increased wildfires, sea level rise, increased rainfall in the northern parts of the country, changes in river flows and changes in sea and surface water body temperatures over the coming 100 years (RoA, 2015).

Existing climate-related hazards such as drought and floods are likely to become more frequent and severe, particularly in the southern regions. The National Adaption Programme of Action 2011 (NAPA) emphasises the likelihood of negative impacts on sectors including agriculture and food security, as well as natural resources and biodiversity, fisheries, water resources, human health, infrastructure, and energy (RoA, 2011). The agriculture sector is considered to be particularly vulnerable to the impacts of hazards such as drought and flood, in addition to which it is predicted that changes in the onset and duration of the growing season will further exacerbate food insecurity. Possible shifts in the growing season are likely to include reduced duration of the growing season in Southern and coastal regions, and a shift from two seasons towards one annual growing season in the Northern regions (Lotz-Sistika and Urquhart, 2014).

In addition to the climatic variables which directly influence crop performance (primarily temperature and precipitation), there are a number of other hazards related to climate change that may result in negative impacts on the most climate-vulnerable communities. For example, the widespread disrepair and underdevelopment of Angola's road network is already recognised as a barrier to market access for rural communities, resulting in large transport costs, high rates of spoilage and poor quality in the marketplace. It is likely that these negative impacts on agricultural households are likely to be exacerbated as a result of the increased frequency and severity of floods predicted for Angola. Another existing barrier to the development of the agricultural value chain which may be exacerbated by the effects of climate change is the high rates of food spoilage and limited capacity for post-harvest storage that characterises many subsistence farming households. In certain cases, particularly storage of cereal crops, inadequate drying or storage of grain promotes growth of the *Aspergillus* fungus, which results in contamination of food with the carcinogenic aflatoxin and severely exacerbates existing food insecurity and malnutrition. Baranyi et al. (2015) found that the range of areas characterised by aflatoxin was likely to increase as a result of increased temperatures and humidity, but that this increase would largely occur in temperate climates – it was not clear from the latter study whether sub-tropical and tropical climates would similarly be increasingly vulnerable to aflatoxin outbreaks (Baranyi et al., 2016).

2.4 Identified Adaption and Mitigation Priorities in Agriculture

Angola's INDC emphasises the vulnerability of the agriculture sector to the impacts of climate change and identifies several priorities for adaptation in this sector (RoA, 2015). Adaptation priorities for the agriculture sector included in the INDC include five confirmed adaptation projects, amounting to an investment of ~USD 90.5 million (RoA, 2015), as well as four proposed project concepts, conditional on financial support ~USD 12.5 million (Table 2.4.1, below). In addition to the below-mentioned priority adaptation projects detailed in Angola's NDC, brief descriptions of recent adaptation projects implemented in Angola are summarised in Appendix 2.

Table 2.4.1 Priority climate change adaptation projects in Angola

Project Title	Description	Project Duration	Project Cost (USD)
Land Rehabilitation and Rangelands Management in Small Holders Agro-pastoral Production Systems in Southwestern Angola (Project RETESA) *(implemented by FAO)*	Focused on rehabilitation of degraded lands through Sustainable Land Management (SLM) in agro-pastoral and agricultural development initiatives in south-Western region. (Namibe, Huila and Benguela provinces)	2012–2018	15,397,000
Enhancing climate change resilience in the Benguela current fisheries system (regional project: Angola, Namibia and South Africa) *(implemented by FAO)*	Focused on enhanced resilience and reduced vulnerability of the Benguela Current marine fisheries systems to climate change. (Regional)	2012–2017	16,520,000
Integrating climate change into environment and sustainable land management practices *(implemented by AfDB)*	Focused on promotion of SLM and adaptation techniques in agro-forestry and land management.	2016	24,831,000

Disaster risk reduction/ management to support agro-pastoral communities affected by recurrent droughts and other natural disasters in southern Angola and northern Namibia (Project PIRAN) *(implemented by FAO)*	Improvement of food security and disaster risk reduction/ management for increased resilience of agro-pastoral subsistence farmers. The project aims to strengthen climate resilience of agro-pastoral production (Bie, Huambo, and Malanje provinces)	01/2016–12/2017	1,600,000
Integrating Climate Resilience into Agricultural and Agro-pastoral Production Systems through Soil Fertility Management in Key Productive and Vulnerable Areas Using the Farmers Field School Approach *(implemented by FAO)*	Strengthened climate resilience of agro-pastoral production systems in the vulnerable regions of Angola and mainstreaming of Climate Change Adaption (CCA) into agricultural and environmental policies, programmes and practises through the Farmers Field School approach. (Bie, Huambo, and Malanje provinces)	2014–2018	32,143,000
Promote SLM for increased agricultural yields	Conditional		5,000,000
Diversify crops to less climate sensitive cultures			3,000,000
Study the implication of climate change on disease patterns for humans and livestock			1,500,000
Implement water-harvesting system in drought prone areas			3,000,000

The INDC notes that the agriculture sector will play an important role in Angola's efforts to reduce greenhouse gas (GHG) emissions from the agricultural sector (which accounts for 36% of total GHG emissions - Boko et al., 2007). This will include the production of biofuels from sugarcane, aiming to produce 23,000,000 liters of ethanol and 170 gigawatts (GW) of power from ~34,000 hectares of sugar cane. The budget for this proposed biofuel initiative is between 540 million and 1 billion USD (RoA, 2015).

3. Major Subsistence and Commercial Crops in Angola

As a result of Angola's climatic and geographic variability, the agriculture sector produces a wide range of annual and perennial crops – including subsistence crops for household consumption, cash crops for local sale and marketing, and largescale commercial production of valuable agricultural commodities. For the purposes of this study, the crops considered in detail are limited to a small variety of subsistence and commercial crops, all of which have been prioritised on the basis of total production volume (cassava, banana, various cereals) or potential commercial development (banana, coffee, sugarcane). Furthermore, this study is mainly restricted to crops grown in the *Planalto* region. Table 3.1, below, summarises the main subsistence and cash crops, including main production provinces in the *Planalto* study area. Each of these crops is discussed in further detail in individual chapters

Table 3.1 Important subsistence and commercial cash crops in *Planalto* region of Angola

Crop	Production (tonnes, 2014)	Provinces	Yield (kg/ha, 2014)	Production area (ha)
Cassava	7,638,880	Bie, Benguela, Cuanza Sul, Huambo, Malanje	10,106	755,875
Bananas	3,095,013[1]	Benguela, Cuanza Sul	24,450[1]	126,585
Sweet potato	1,928,953	Cuanza Sul, Huambo, Huila, Malanje	11,434	168,703
Maize	1,686,870	Benguela, Bie, Huambo	1,038	1,625,115

Sugarcane	509,780		39,606	12,871
Sorghum	48,133	Southern regions	242	19,889
Millet	43,056	Southern regions (Huila)	220	19,660
Coffee[2]	63,865	Bie, Benguela, Cuanza Sul, Huambo, Huila, Malanje	200-250	97,490

1. Production for bananas is for the year 2013.
2. Data for coffee is for the year 2015.
(Data derived from FAOSTAT, 2015).

3.1 Cassava

Cassava is widely grown in tropical and sub-tropical African countries, where the average annual consumption of fresh and dried cassava is estimated to be 149.7 kg per capita annually (Latif and Muller, 2015). The greatest consumption is in Angola with 287.3 kg per capita per year (Nhassico et al., 2008). The cassava roots are the most commonly consumed part but the leaves are also consumed, particularly in Central Africa (Hahn, 1998; Latif & Muller, 2015). Cassava is the main crop produced in Angola, valued at US$ 1.1bn per year in 2012 (FAOSTAT, 2015). Cassava production increased from 1,861,000 tonnes per year in 1993 to 7,638,880 tonnes per year in 2014, with a yield of 10.1 tonnes per hectare per year (FAOSTAT, 2015). According to Liu et al. the yield of cassava will not be greatly affected by climate change but could actually increase in certain areas of Africa, particularly in Angola. Jarvis et al. (2012) also report that climate change will result in a net increase in the range of suitable areas for cassava production (although noting that, despite a net increase in suitable area, certain areas are predicted to decline in suitability as a result of temperature increases. The latter study also includes consideration of potential impacts of climate change on common pests and diseases of cassava, including cassava mealybug (*Phenacoccus manihoti*), sweetpotato whitefly (*Bemisia tabaci*) and two viruses commonly spread by insect vectors such as cassava brown streak virus and cassava mosaic virus. In general, the study found that climate change would result in negative impacts on cassava in Angola as a result of increased susceptibility to the abovementioned pathogens, however the predicted decline in overall suitability for Angola was less than 5% and relatively minor compared to the predicted impacts on cassava in East African countries such as Uganda, Kenya and Tanzania.

Cultivation of cassava is practiced throughout the year as the crop is not restricted by seasonality (FEWSNET, 2013). Cassava is the dominant staple food of the northern regions (Malanje) of Angola and covers roughly 75% of cultivated area in these regions (FEWSNET, 2012a). As a result of multiple factors – including, high calorific efficiency with multipurpose low cost/input, reliable and flexible production and can be grown in areas of low-rainfall- cassava is considered an important staple food crop in Angola. In addition, cassava is increasingly promoted as a crop which has the potential to contribute meaningfully to pro-poor economic development. (Theodory et al., 2014).

Currently, multiple barriers exist in the cassava value chain, which undermine the potential contribution of this crop to the food security and household income of cassava farmers. For example, market accessibility for cassava farmers in remote areas is hindered by the short shelf life of the roots (2-3 days after harvesting) furthermore cassava is bulky when wet and costly to transport. It was found that the production of dry shelf-stable cassava by small-scale farmers has the potential to be feasible as transport costs are reduced and shelf life increased (Abayomi, 2015). Cassava roots can be processed into several stable and long-lived products through one of several related methods for drying and/or fermentation. In Angola, the most prominent forms of processed cassava include traditional forms of fermented flours such as *gari* (a process whereby grated cassava undergoes a process of fermentation, pressing, frying and drying) and *fuba de bombó* (a related process where whole cassava stems are soaked and fermented prior to crushing and milling). In addition, there is increasing interest in developing the value chain and commercial use of high-quality cassava flour (HCQF) products through the UNIDO ‘Cassava Adding Value for Africa’ (CAVA) initiative. The latter initiative aims to improve the livelihoods of cassava farmers through stimulation and expansion of the market for HCQF as a cost-effective, climate-resilient substitute for traditional wheat flour (Abayomi, 2015). However, despite the evident commercial potential which remains underexploited in the cassava value chain, various infrastructural and socio-economic barriers have limited the development of value-added cassava products.

3.2 Bananas

After cassava, bananas are the second highest produced crop in Angola valued at US$ 842 m per year (FAOSTAT, 2015). Angola accounts for 2% of total world banana production (FAO, 2013). Banana production increased from 285,000 tonnes per year in 1993 to 3,095,013 tonnes per year in 2013 with a yield of 24.5 tonnes per hectare per year (FAO, 2015). Banana production primarily takes place in the Benguela and Cuanza Sul provinces of Angola (FEWSNET, 2013). Predictions of impacts brought about by climate change on bananas show that increasing minimum temperatures by 2020 would expand the suitable range of black leaf streak disease (*Mycospharella fijiensis*) of bananas in Angola, severely affecting yield (Ramirez et al., 2011). Conversely, despite the increased vulnerability to leaf streak, analyses undertaken by the CGIARs's Research Program on Climate Change, Agriculture and Food Security indicate that increased temperatures will result in small (~10-20%) increase in areas suitable for banana production in Angola (CGIAR, 2016).

3.3 Sweet Potatoes

Production of sweet potatoes increased from 185,000 tonnes per year in 1993 to 1,928,954 tonnes per year in 2014 with a yield 11.4 tonnes per hectare per year (FAOSTAT, 2015). The majority of sweet potato production in Angola takes place in the Northern provinces of Malanje, Cuanza Sul, and the northern region of Huambo where surpluses produced are transported to Luanda and to a lesser extent Malanje for retail in market. Sweet potatoes in the eastern regions of the country are mostly produced on a subsistence scale with minor surpluses. The CGIAR's World Sweet-potato Atlas (CGIAR, 2007) notes that sweet potato is cultivated almost entirely on a subsistence basis by smallholders and as a result there is a near-complete absence of data to assess the current spatial extent and average yield of this crop. Furthermore, little is known of specific cultivation practices or diseases and other constraints of sweet-potato production. The sweet-potato weevil is known to be a widespread pest in southern Africa, particularly in dry areas and seasons, however no detailed information on the incidence of this pest in Angola is available (CGIAR, 2007).

3.4 Maize

During the 2013/2014 season national maize flour production was 53,100 tonnes (Nguema et al., 2015). Before the civil war, maize exported from Angola accounted for 2% of total agricultural exports, currently Angola does not export any of its maize produce (FAO, 2013a). Maize is mainly grown by small-scale producers who intercrop with beans, peanuts, sweet potatoes and/or cassava (JADAFA, 2013). Between 1993 and 2014, maize production increased from 275,000 tonnes per year to 1,686,869 tonnes per year with a yield of 1 tonne per hectare per year (FAOSTAT, 2015).

Despite the low volume of maize produced, area planted to maize has increased. Yields rose from 0.57 mega tonnes per hectare per year to 0.75 mega tonnes per hectare per year between 2001/2002 and 2012/2013 (USDA, 2012). The reason for these trends include, increased public sector investments and increased use of improved seed varieties (JADAFA, 2013). Angola, a deficit maize producer, imported on average 54,787 mega tonnes per year between 2001 and 2011. Primary suppliers to Angola include Brazil, South Africa, Portugal and in some years the U.S. (JADAFA, 2013).

Maize is a staple food crop in the northern regions of Angola with production concentrated in Huambo, Benguela and Bie provinces (FEWSNET, 2016). Within these three provinces, maize contributes up to 40% of total crop production (JADAFA, 2013). Maize is grown during the months of November to February (FEWSNET, 2015). Despite the importance of the crop as a staple in Southern Africa, maize is generally considered to be a poorly climate-resilient crop with limited tolerance for drought or irregular rainfall. Apart from this sensitivity to climate variability, the threat of increased temperature and an increase in severe drought events (arising from climate change) is a major concern to cereal production in sub-Saharan Africa. Increases in diseases, pests, and parasitic plants also presents a continuous challenge to the productivity of cereal grains in sub-Saharan Africa (AfDB, 2015).

In sub-Saharan Africa it is expected that current warming trends could reduce the production of major cereal crops by 20% by the mid-century (Schlenker and Lobell, 2010), of which maize is likely to be particularly negatively affected. A study conducted on projected changes in maize as a result of climate change in Angola predict a reduction of up to 30% in the yield of maize throughout southern Africa by the 2030s (Lie et al., 2008). As a result, there is increasing interest in the promotion of drought-tolerant maize varieties, as well as comparatively drought-resilient cereals such as millet and sorghum (3.6, 3.7, below).

3.5 Sugar Cane

Production and the quality of sugar in Angola decreased between 1975 and 2000 as a result of multiple factors such as: limited or under-maintained irrigation infrastructure, lack of agricultural equipment and fertilizers, and poor drainage in the cane fields. This resulted in the sucrose content in sugarcane produced decreasing from 9.5% pre-1975 to an average of 3.5% by 1987. This made it necessary to produce three times the amount of sugarcane to produce the equivalent pre-1975 amount of sugar (USAID, 2009). By 2002 rehabilitation of the sugar industry became a priority for government to reduce national dependence on oil, decrease food imports and ultimately reduce poverty (JADAFA, 2013). Per capita consumption of sugar is estimated to be ~12 kg per year (Faus, 2012). Growing consumer demand and a newly emerging bio-fuels industry has estimated annual domestic demand for sugar to be 400,000 MT (Booysens, 2012). Production of sugar cane rose from 250,000 tonnes per year in 1983 to 509,780 tonnes per year in 2014, with a yield of 39.6 tonnes per hectare per year in 2014 (FAOSTAT, 2015).

3.6 Sorghum

Sorghum production increased from 10,000 tonnes per year in 2000 to 48,133 tonnes per year in 2014, with a yield of 242.1 kilograms per hectare per year in 2014 (FAOSTAT, 2015). Due to favourable climatic characteristics, sorghum and millet are the main cereal crops produced in the southern regions of Angola, which when combined cover ~80% of the planted area (FEWSNET, 2012).

There is an increasing demand for sorghum and millet in sub-Saharan Africa. However, the productivity of these two cereal grains has remained too low to satisfy the increase in demand as a result of factors such as (AfDB, 2015):

- limited investment in plant breeding, development and selection of locally appropriate varieties;
- Limited use of high-quality inputs.

Additional challenges to the development of sorghum and millet value chains in sub-Saharan Africa include (AfDB, 2015):

- overcoming the low productivity and profitability of dryland agriculture and manage the high risks, caused by low-irregular rainfall, poor soils, and high temperatures;
- responding to and addressing issues related to climate change and land degradation;
- limited adoption of modern agronomic techniques, market orientation and private enterprise development;
- lack of investment in infrastructure such as roads, storage, and market facilities;
- limited access to resources and inputs for smallholders to invest in business development; and
- Weak national institutions for agronomy, crop improvement and extension services.

3.7 Millet

The bulk of the countries millet is produced in the Southern provinces such as Huila (FEWSNET, 2012b). In Angola, millet is grown between the months of January and March and harvested from April to May (FEWSNET, 2015). Millet is a drought-resistant crop and can be grown in areas of low rainfall (EC, 2013). The production of Millet decreased from 101,982 tonnes per year in 1996 to 43,056 tonnes per year in 2014, with a yield of 219.7 kilograms per hectare per year in 2014 (FAOSTAT, 2015). Millet is primarily cultivated on a local-level for household consumption (Pröpper, 2009). Predictions show that climate change could favour millet production, increasing crop yield in Angola and sub-Saharan Africa (Liu et al., 2008).

As described in 3.6 (above), there are several underlying institutional and technical barriers which have limited the development of cereals such as millet and sorghum in Angola.

3.8 Coffee

Coffee is the main agricultural export of Angola accounting for 43% of total agricultural exports (BIIA, 2016). Arabica (*Coffea arabica*) coffee is mainly cultivated in the highlands of Huambo, Bie, Huila and Benguela (BIIA, 2016). Robusta coffee (*C. robusta*) is produced in Cuanza Sul and Malanje (Bellachew, 2015). Coffee cultivation has high capital costs, due to the large amount of labour required throughout the cycle of coffee production and the plant rehabilitation to produce good yields (UNDP, 2015).
The size of coffee farms in Angola range between >250 ha (large-scale farms) found mainly in Kwanza Sul, Kwanza North and Uige provinces and <10 ha (small-scale subsistence farming) (INCA communication). The total number of farms where coffee is currently cultivated in Angola is 25,371, of which 472 are large-scale commercial plantations, covering a total area of 347,990 ha (ICO, 2015). Coffee is cultivated and produced in all six provinces of the study area (Table 3.8.1, below), with the highest area of land cultivated in Cuanza Sul, where area of coffee cultivation has increased from 11, 880 hectares to 97,490 hectares between 2002 and 2015 (ICO, 2015). Cuanza Sul is also the highest producer of coffee within the considered provinces with production increasing from 1,440 tonnes in 2002 to 18,210 tonnes in 2015. Total annual production of coffee in Angola in 2015 averages 63,865 tonnes of which nearly 40% is produced in the six provinces of the study area (ICO, 2015). Coffee production in Angola ranges between 200-250 kilogrammes per hectare and is harvested between June and July (UNDP, 2015).

Table 3.8.1 Coffee production area and annual harvest per province in 2015 (ICO, 2015).

Province	Benguela	Bie	Cuanza Sul	Huambo	Huila	Malanje
Hectares	1,300	7,680	97,490	6,500	1,300	1,201
Yield (tonnes)	85	1,410	18,210	1,280	1,225	1,500

Future climate predictions for 2050 show that the suitability for growing coffee may increase in certain parts of Angola (Sacha et al., 2015). However, coffee production in Angola faces a number of barriers including (UNDP, 2015):

- Limited availability of planting material to meet demand for good-quality seedlings and seeds);
- Lack of technically trained personal to assist potential producers;
- Lack or absence of processors at field level;
- Low demand for high-quality coffee in the area; and
- Lack of infrastructure for pulping and grading quality coffee.

There are several opportunities to focusing on the recovery of coffee production in Angola (Bellachew, 2015):

- Angola has the potential to be a leading global market competitor through coffee increased production;
- Angola has previous experience in coffee production;
- Angola has fertile land and suitable climatic conditions for the production of Robusta and Arabic coffee;
- Angola has the means to allocate the required capital to rehabilitate abandoned coffee farms;
- Restoration of coffee industry through policies;
- Support from functional structures such as the National Coffee Institute (INCA), coffee research stations and farmers associations, which provide assistance to farmers at small-scale levels.

4. Climate and weather in Angola’s ‘Planalto’ provinces

The provinces prioritised for inclusion in this preliminary climate risk analysis include the coastal provinces of Benguela and Cuanza Sul and the inland provinces of Malanje, Bie, Huambo and Huila, encompassing an area ranging in altitude from 0 to ~1,600m above sea level. The majority of the contiguous area between these provinces is covered by the *Planalto* midland plateau region, which extends from the escarpment ~30-50km inland from the semi-arid coastal zone towards the interior highlands of the country. Figure 4.1.1a (below) depicts the provinces assessed.

Figure 4.1.a Map of provinces selected for analysis of climate risks

4.1 Summarised temperature and precipitation across study area

The coastal zone and interior *planalto* varies widely in climate, soil type and topography and consequently supports a wide variety of subsistence and cash crops. The three following figures depict the average variation in monthly precipitation, monthly minimum temperature and monthly mean temperature, respectively, across the six provinces assessed. Firstly, Figure 4.1.b, below, depicts the average of all provinces in the Planalto region by month. Figure 4.1.c, further below, indicates the individual provincial averages of temperature and precipitation across all 12 months. Finally, Figure 4.1.d depicts the spatial variability in Temperature and Precipitation across the full extent of the study area.

Despite the annual and spatial differences in climate within the study area, Figures 4.1.b-d broadly depict the onset of a bi-modal rainy season which begins in ~October and peaks in December, before a second ‘late’ rain at the end of the season in March-April. The winter months of May to August/September are dry and characterised by a mean temperature of ~17^{O}C, ~4-5^{O}C lower than the mean temperatures in summer. The climate of each individual province is described further in Sections 4.2–4.7.

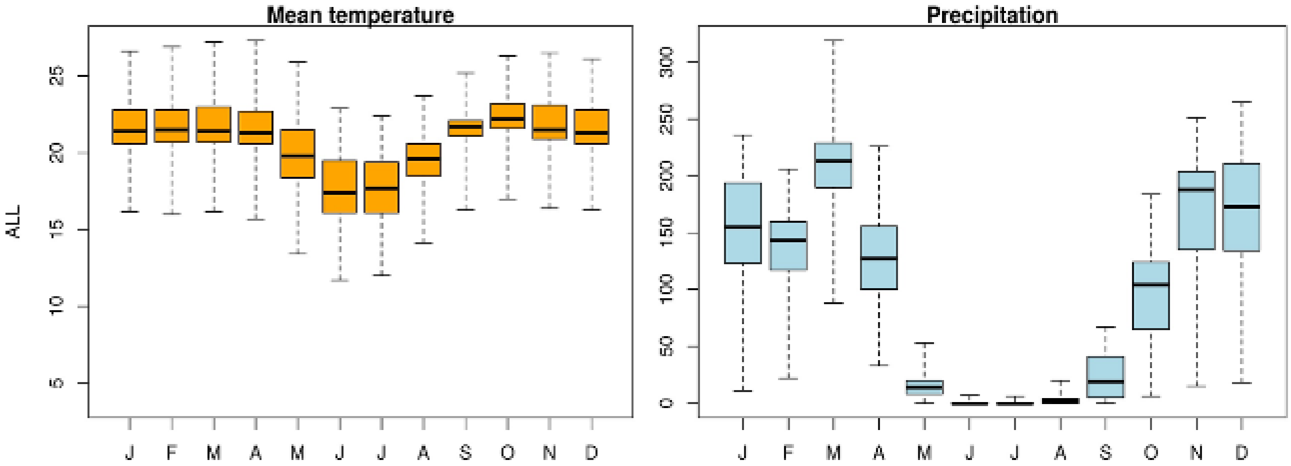

Figure 4.1.b Mean monthly temperature and precipitation across the central *planalto* region of Angola

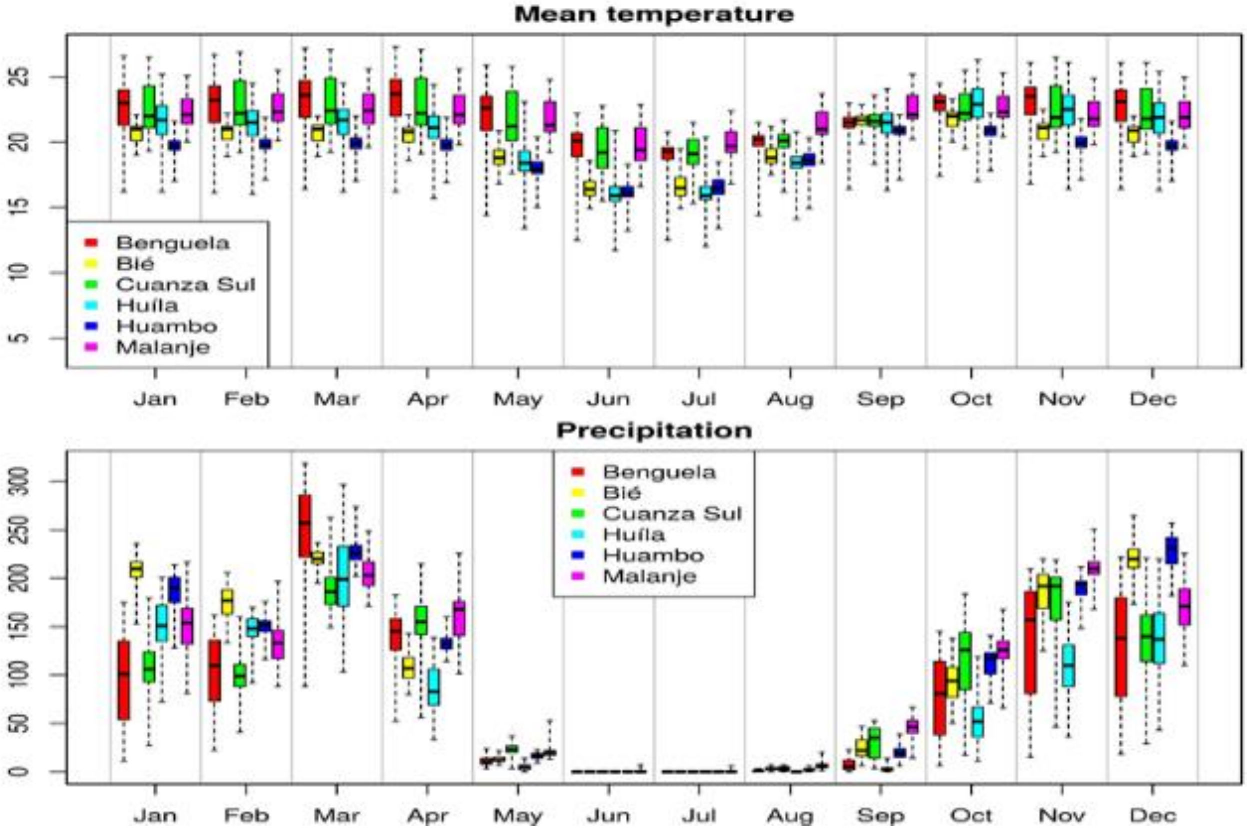

Figure 4.1.c Mean monthly temperature and precipitation for each of six individual provinces in the *planalto* region of Angola

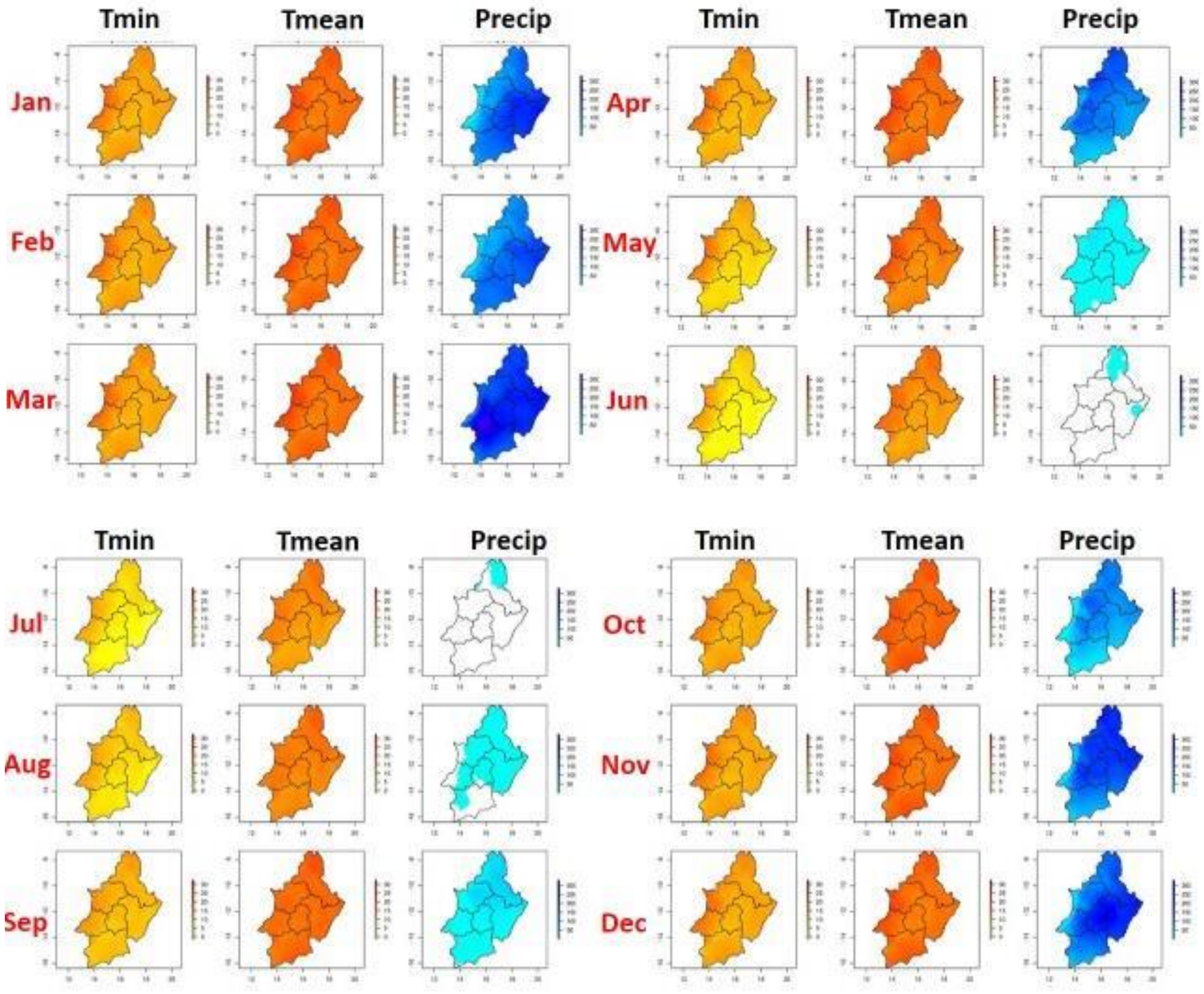

Figure 4.1.d Seasonal variation in minimum temperature, mean temperature and mean precipitation across the *planalto* study region in Angola.

4.2 Mean annual temperature and precipitation in Bie province

Bie's climate is relatively stable and homogenous with small deviation in monthly average temperature compared to the geographically heterogeneous provinces such as Benguela and Cuanza Sul. The province is characterised by an extended dry season during the winter months from May to August, after which the planting season for rainfed agriculture begins with the onset of rains in September and October.

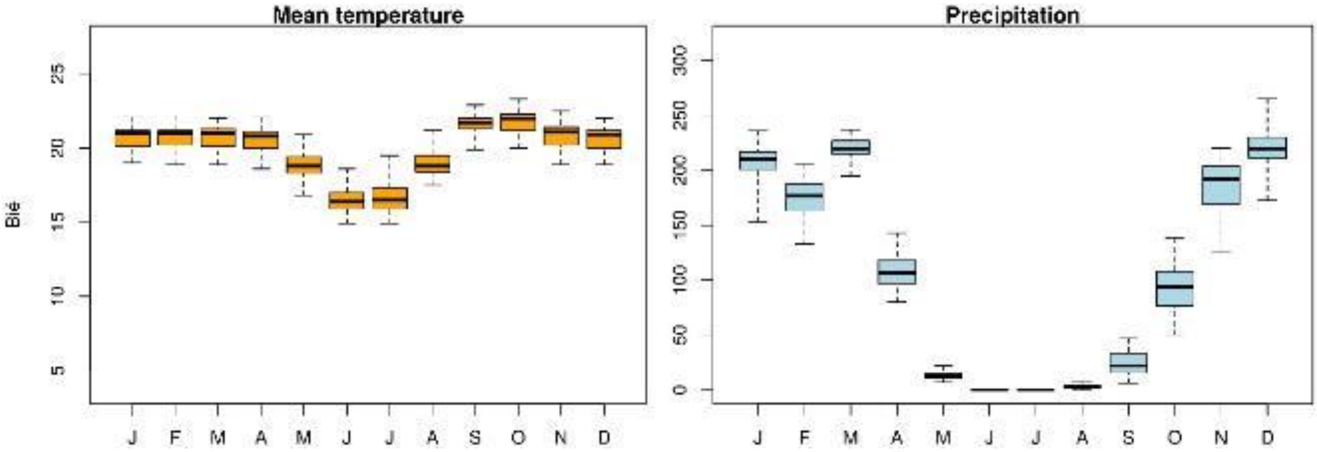

Figure 4.2a. Mean monthly temperature and precipitation in Bie province.

4.3 Mean annual temperature and precipitation in Benguela province

Benguela province, similar to Cuanza Sul (below) is one of the hottest and most climatically variable of the six provinces assessed. The wide variability in mean temperature and precipitation within individual months (Figure 4.3.a, below) is consistent with the heterogeneity of the landscape from the semi-arid coastal plains eastwards to the interior plateau. The coastal lowlands of Benguela are particularly prone to drought and water shortages as a result of the high temperatures, extended winter dry season and erratic rainfall. The interior uplands of Benguela to the east of the coastal escarpment are comparatively cooler with higher rainfall, and are markedly different from the coastal plans in terms of suitability for different crops.

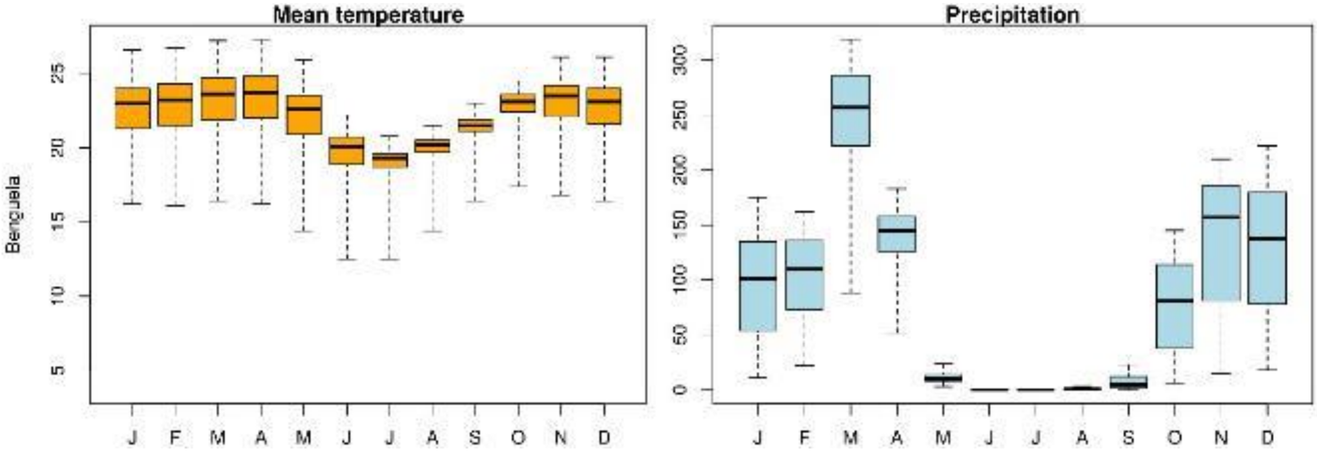

Figure 4.3.a Mean monthly temperature and precipitation in Benguela province.

4.4 Mean annual temperature and precipitation in Cuanza Sul province

The climate of Cuanza Sul province is comparable to Benguela province, and is similarly defined by the heterogeneous topography of the region extending from the coastal plains inland towards and beyond the coastal escarpment towards the *planalto* highlands. The primary difference between the climates of the two provinces is that the rainy season in Cuanza Sul begins slightly early (in September) in the northern latitudes of the province, allowing for comparatively earlier planting and longer growing seasons for rainfed crops.

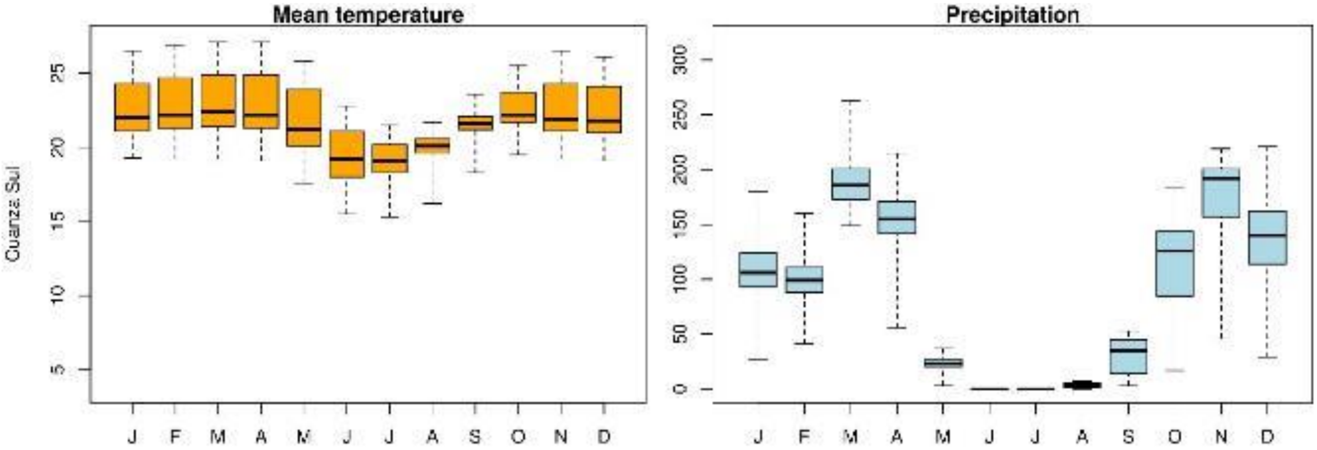

Figure 4.4.a Mean monthly temperature and precipitation in Cuanza Sul province

4.5 Mean annual temperature and precipitation in Huambo province

The climate of Huambo is relatively consistent across the geographic extent of the province compared to the more heterogeneous provinces such as Benguela and Cuanza Sul. The onset of the rainy season in this central province and neighbouring Huila province begins in October and extends until April, declining sharply during the dry season from May to August.

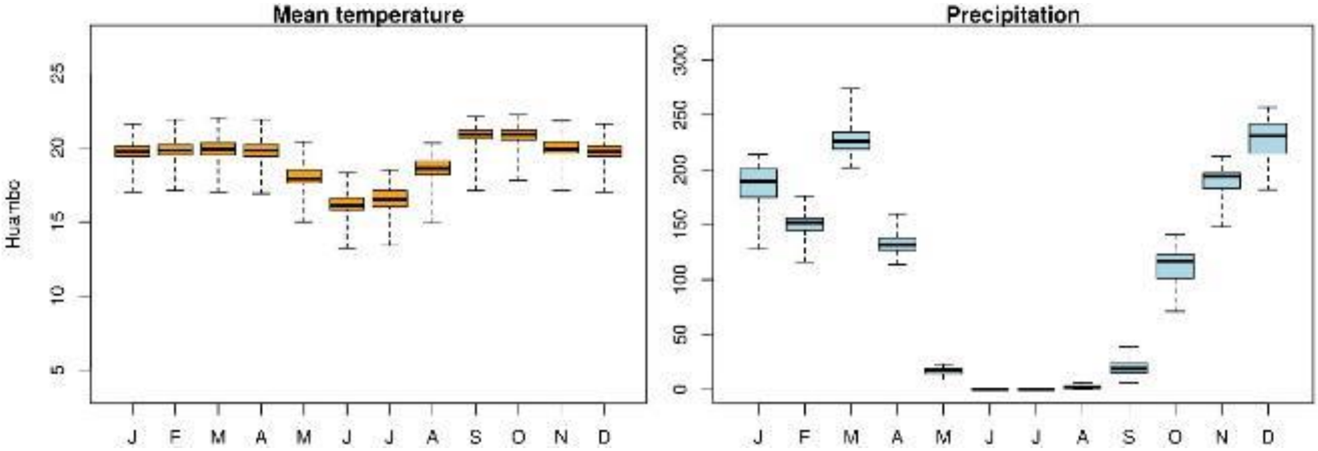

Figure 4.5.a Mean monthly temperature and precipitation in Huambo province

4.6 Mean annual temperature and precipitation in Huila province

Huila is the most southerly of the provinces in the study area and is also the most arid. In the months at the onset of the rainy season, Huila is the only province which receives an average precipitation of less than 50 mm in the month of October. Similar to Huambo province and the interior of Bie, the winter months of June-July in Huila province are cooler (winter average of ~15-16 ^{o}C) than the coastal plains and particularly arid in the period from May–September.

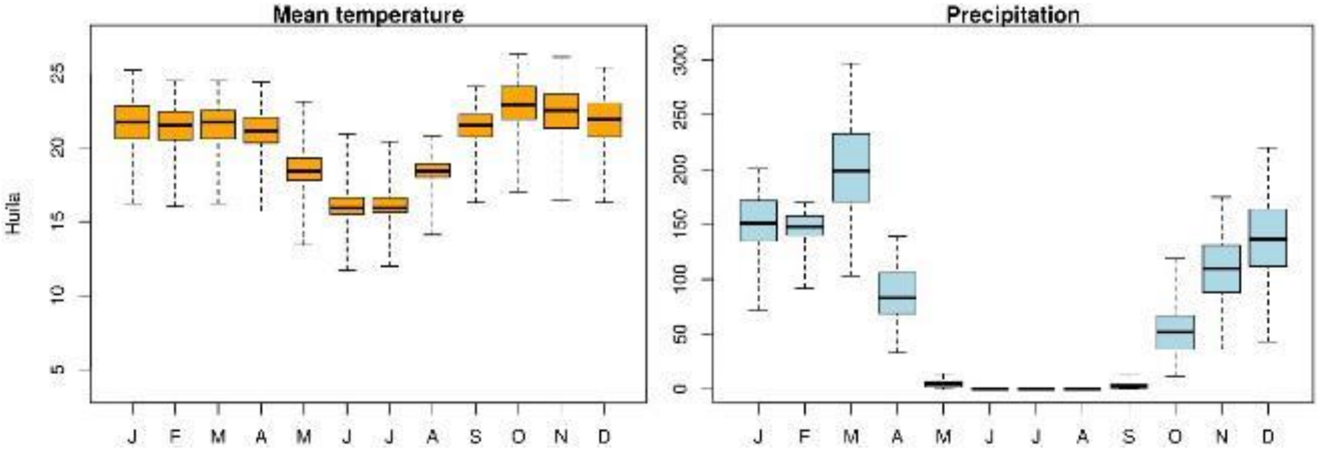

Figure 4.6.a Mean monthly temperature and precipitation in Huila province

4.7 Mean annual temperature and precipitation in Malanje province

Malanje, the northernmost of the six provinces assessed, has the highest mean annual precipitation and the wettest winter months relative to other provinces. Typical of a humid sub-tropical climate, the average temperature in Malanje is above 20°C all year around, even in winter months, and averages ~23°C for the rainy period from September to April.

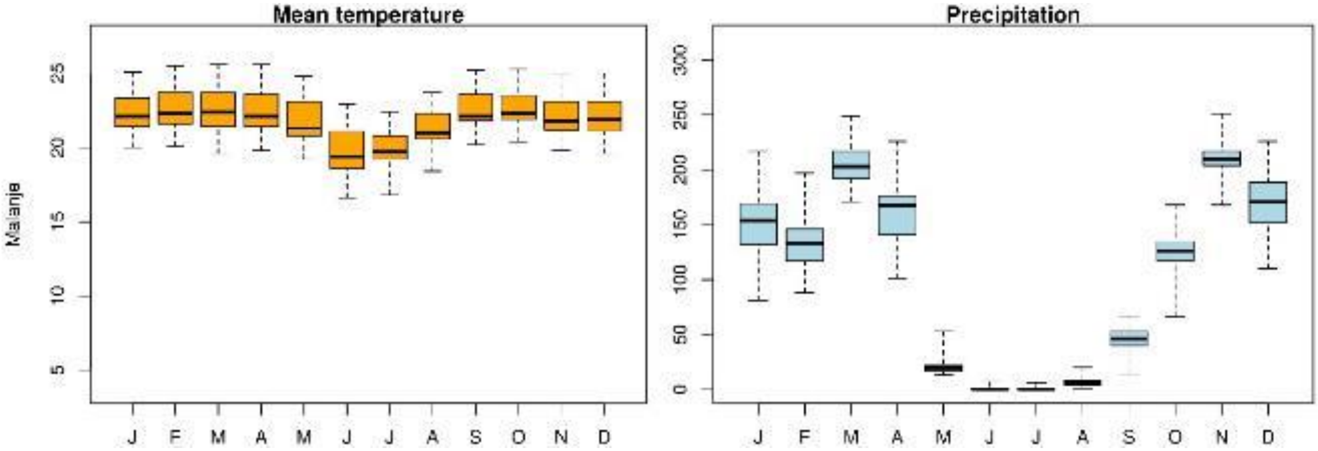

Figure 4.7.a Mean monthly temperature and precipitation in Malanje province

5. Modelled crop suitability

Chapter 4, above, summarises the annual climatic variability within and between the studied provinces. The following chapter will summarise the spatial variation of crop suitability scores within each of the studied provinces, including quantification of the optimum production areas for each of the individual crops.

The approach used to describe and visualise the spatial and temporal distribution of crop suitability (below) includes maps, graphs and tabulated summaries. The analyses below have summarised 'crop suitability index' scores into discrete categories of suitability, namely "excellent" (Suitability Index score of 0.9–1), "highly suitable" (score of 0.7–0.9), "suitable" (score of 0.5–0.7), "marginally suitable" (score of 0.3–0.5), "very marginally suitable" (score of 0.1–0.3) and "unsuited" (score of 0–0.1).

As a result of the assignment of these categories, the proportional and absolute spatial extent of each category of crop suitability can be estimated in each province, and is presented in summary tables for each crop. The results presented in the summary tables in sub-chapters 5.1–5.10 are for the month of October, which coincides with the onset of the rainy season and which is assumed to represent the optimum time for establishment of rainfed crops. Therefore, all tabulated summaries of crop suitability presented in the following analyses assume the month of October as the time of planting/crop establishment.

In addition to providing a tabulated summary of the distribution of each category of crop suitability, the use of colour-coded maps and graphs provide visual demonstrations of the distribution of crop suitability categories across each province. Each of the six categories of crop suitability (ranging from "unsuited" to "excellent" suitability) are depicted visually through the assignment of a colour code, ranging from dark and light green ("excellent" and "high" suitability, respectively), yellow and orange ("suitable" and "marginally suitable", respectively), to pink and grey ("very marginal" and "not suited", respectively). These colour codes and categories are used in all subsequent graphs and maps presented in this report. To assist in the interpretation of crop suitability maps and graphs presented in the sub-chapters below (5.1–5.10), an example of each is presented and discussed in Figures 5.a and 5.b, below.

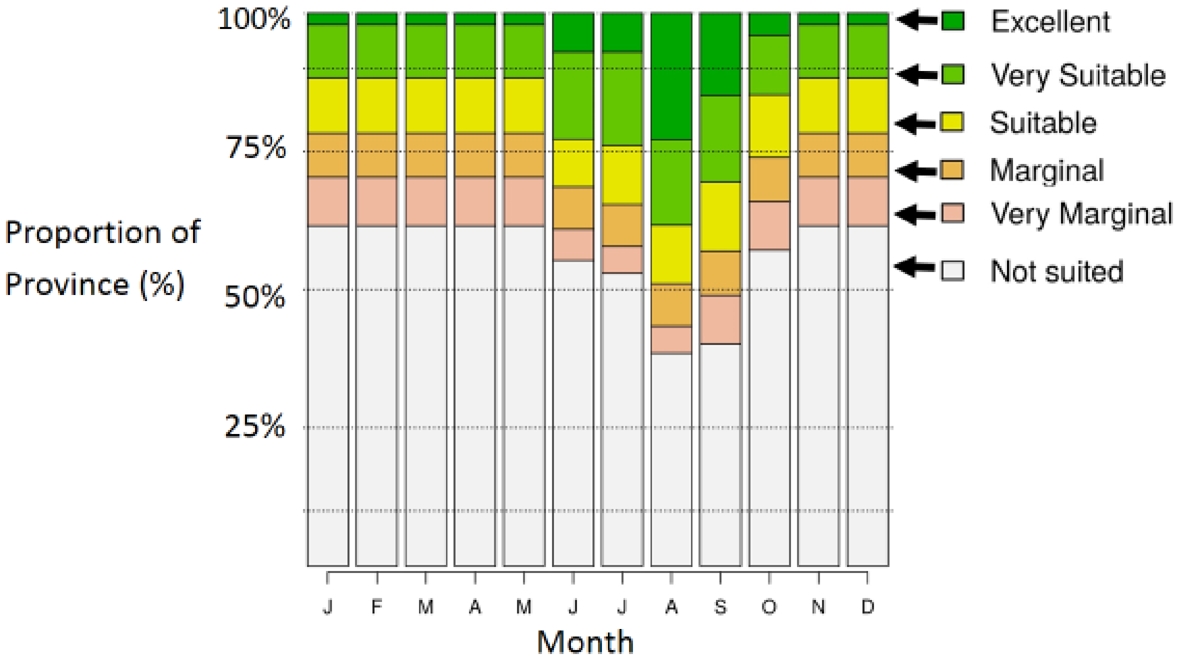

Figure 5.a Example demonstration of monthly variability in crop suitability index scores within a single province

Figure 5.a, above, can be considered a hypothetical example of seasonal variation in crop suitability index scores within a single province (or study area). The Y-axis indicates the 12 months of the year, from January to December. The X-axis depicts the spatial proportion of the hypothetical province covered by each respective category of crop suitability (i.e. where '100%' indicates the entire spatial extent of the province). The relative size of each coloured bar is proportional to the geographic extent of the corresponding category of crop suitability.

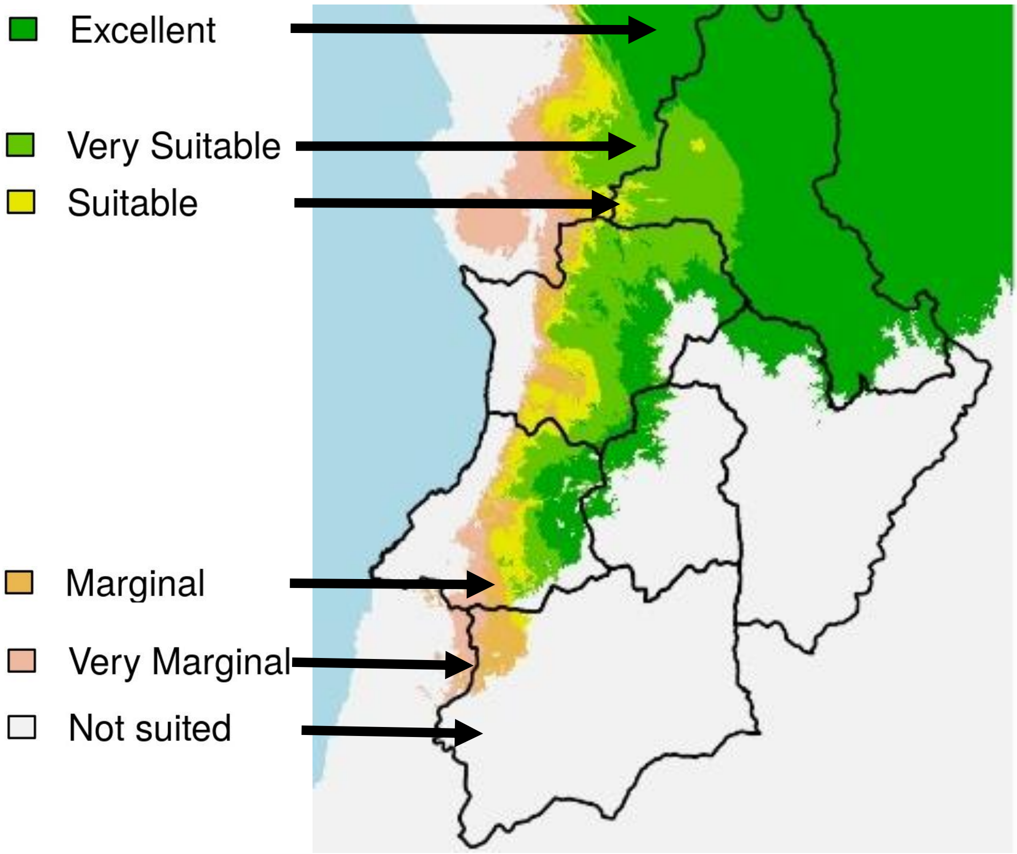

Figure 5.b Example demonstration of spatial variability in crop suitability index scores

Figure 5.b, above, is an alternative approach to depicting the data presented in Figure 5.a, where the relative proportion of each colour-shaded area indicates the spatial extent of each corresponding category of crop suitability.

The same approach and specific categories of crop suitability scores are adopted in each of the crop-specific analyses described in 5.1–5.10, below.

5.1 Cassava (*Manihot esculenta*)

As described in the literature review, cassava is the main staple crop of Angola's northern regions and, in terms of total production area, is the largest crop in Angola. Analysis of crop suitability models affirm the statements in literature that cassava production, while practiced across the country, is particularly well suited to the extended rainfall and high temperatures of Malanje province and the midlands of Benguela and Cuanza Sul provinces. The highlands in the interior of the country, including much of Bie, Huambo and Huila, are considered unsuitable for optimum production of cassava, while the aridity and heat of the coastal plains limits the extent of suitable production zones along the west of Benguela and Cuanza Sul provinces. Figure 5.1 a (below) depicts the spatial variability of cassava suitability across the study area while Figure 5.1.b (below) indicates the proportional distribution of crop suitability within each province.

One of the primary advantages of cassava as a climate-resilient crop is the aseasonal production patterns, which allow for cassava to be grown throughout the year and harvested according to household needs. Furthermore, the ability to propagate cassava vegetatively (i.e. without seed, as compared to cereal crops) allows the ability to plant and harvest cassava independent of the rainy season. However, in all six provinces (including the comparatively 'marginal' provinces of Bie, Huambo and Huila), EcoCrop models indicate that the optimum period for establishment of cassava (based on a 365-day growing period) coincides with the onset of the rainy season in August–September. As can be seen in the Figures below, the annual distribution of crop suitability is quite uniform with the exception of the months of August – September, and as a result these latter months are not included in the crop suitability scores summarised in Table 5.1 below. Rather, Table 5.1 summarises crop suitability data for October, which is interpreted as more closely aligned with traditional cropping practices and the onset of the rainy season in the study area.

As can be seen in Table 5.1, over 18% of Malanje is considered to be 'highly suitable' (~2,930 km^2) or 'excellent' (~17,570 km^2). Benguela and Cuanza Sul provinces also have extensive areas considered 'highly suitable' (~4,000 and 7,220 km^2, respectively). Bie, Huila and Huambo are not considered suitable for cassava production, except for a small area (~2,300 km^2) in the north of Huila.

Table 5.1 Proportional and absolute area of cassava suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela			0.1	3 982.6	0.11	4 380.9	0.08	3 186.1	0.09	3 584.3
Bie										
Cuanza Sul			0.13	7 228.0	0.12	6 672.0	0.07	3 892.0	0.03	1 668.0
Huambo										
Huila							0.02	1 580.5	0.01	790.2
Malanje	0.18	17 568.4	0.03	2 928.1	0.02	1 952.0				

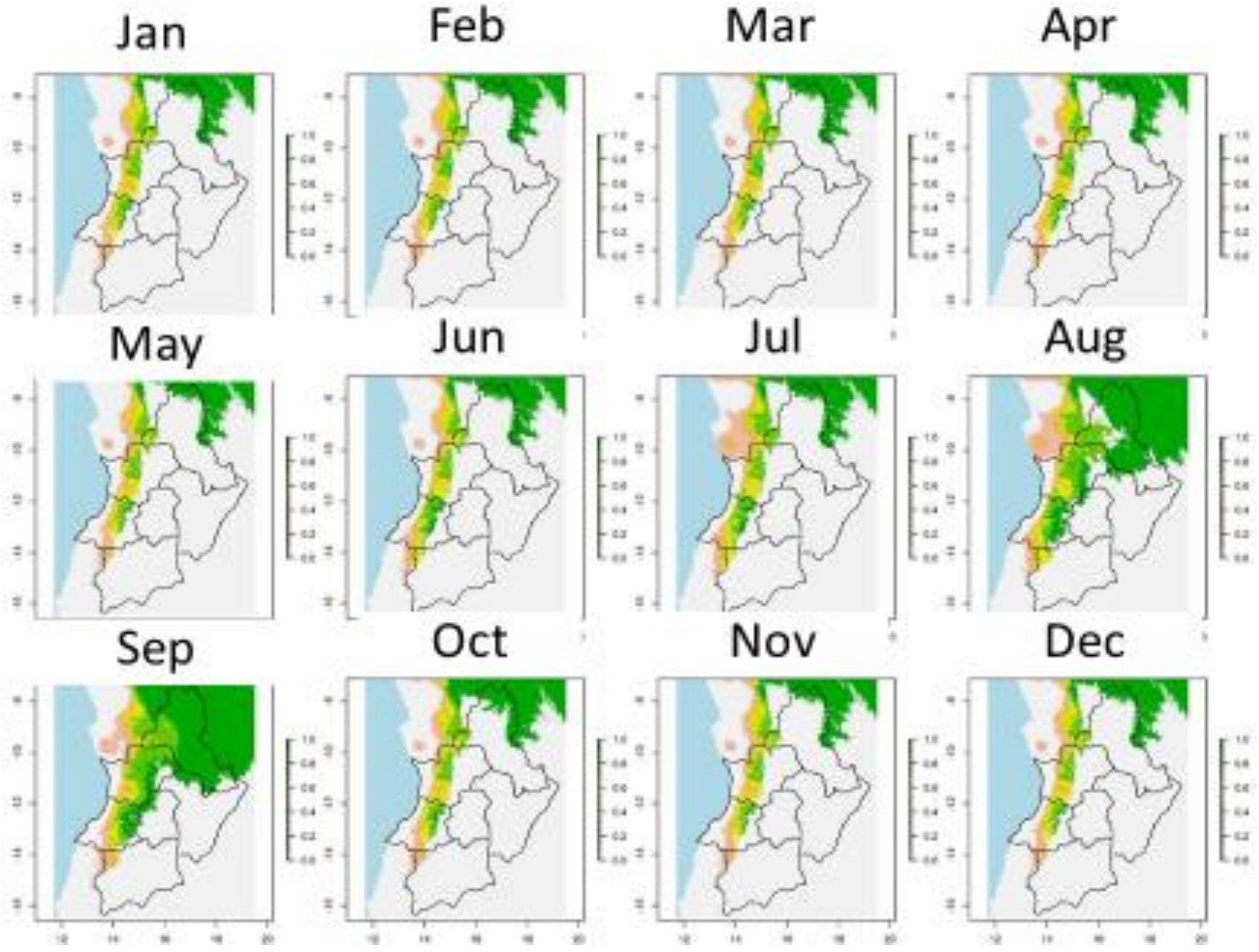

Fig 5.1.a Spatial variation in crop suitability of cassava in the Planalto region, by month.

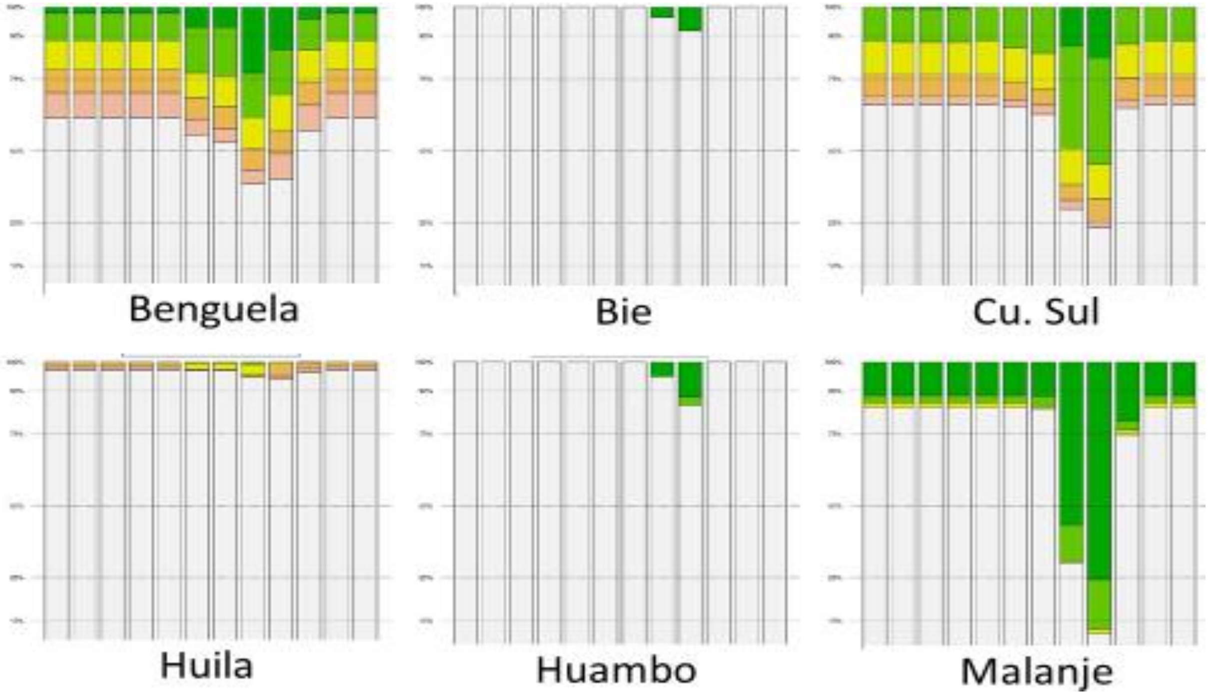

Figure 5.1.b Monthly variation in modelled cassava suitability in the Planalto region.

5.2 Coffee (*Coffeea robusta*)

The analysis of crop suitability included consideration of both *Coffeea robusta* and *C. arabica* (5.3, below). As can be seen in Figure 5.2.a, overleaf, the primary zone of suitability for *C. robusta* production is the hot humid interiors of Malanje province and further north. Although Bie and Huambo are not considered to be suitable for production of *C. robusta*, the remaining provinces of Benguela, Cuanzal Sul, Hula and Malanje all collectively include some areas of moderate suitability.

Table 5.2, below, summarises the relative distribution of crop suitability in the month of October. Approximately ~21% of Malanje is considered to be 'highly suitable' (~1,120 km^2) or 'excellent' (~7,170 km^2). Benguela and Cuanza Sul provinces also have extensive areas considered to be 'highly suitable' (~4,000 km^2 and 5,180 km^2, respectively). Therefore, the *Planalto* region has an area of at least 16,000 km^2 which is highly suitable for 'Robusta' coffee production. In addition to these areas, the remaining area of 'suitable', 'marginal' and 'very marginal' zones cumulatively totals an additional ~21,900 km^2.

Table 5.2 Proportional and absolute area of *Coffeea robusta* suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela			0.1	3 982.6	0.11	4 380.9	0.08	3 186.1	0.09	3 584.3
Bie										
Cuanza Sul			0.13	5 177.4	0.12	4 779.1	0.07	2 787.8	0.03	1 194.8
Huambo										
Huila							0.02	796.5	0.01	398.3
Malanje	0.18	7 168.7	0.03	1 194.8	0.02	796.5				

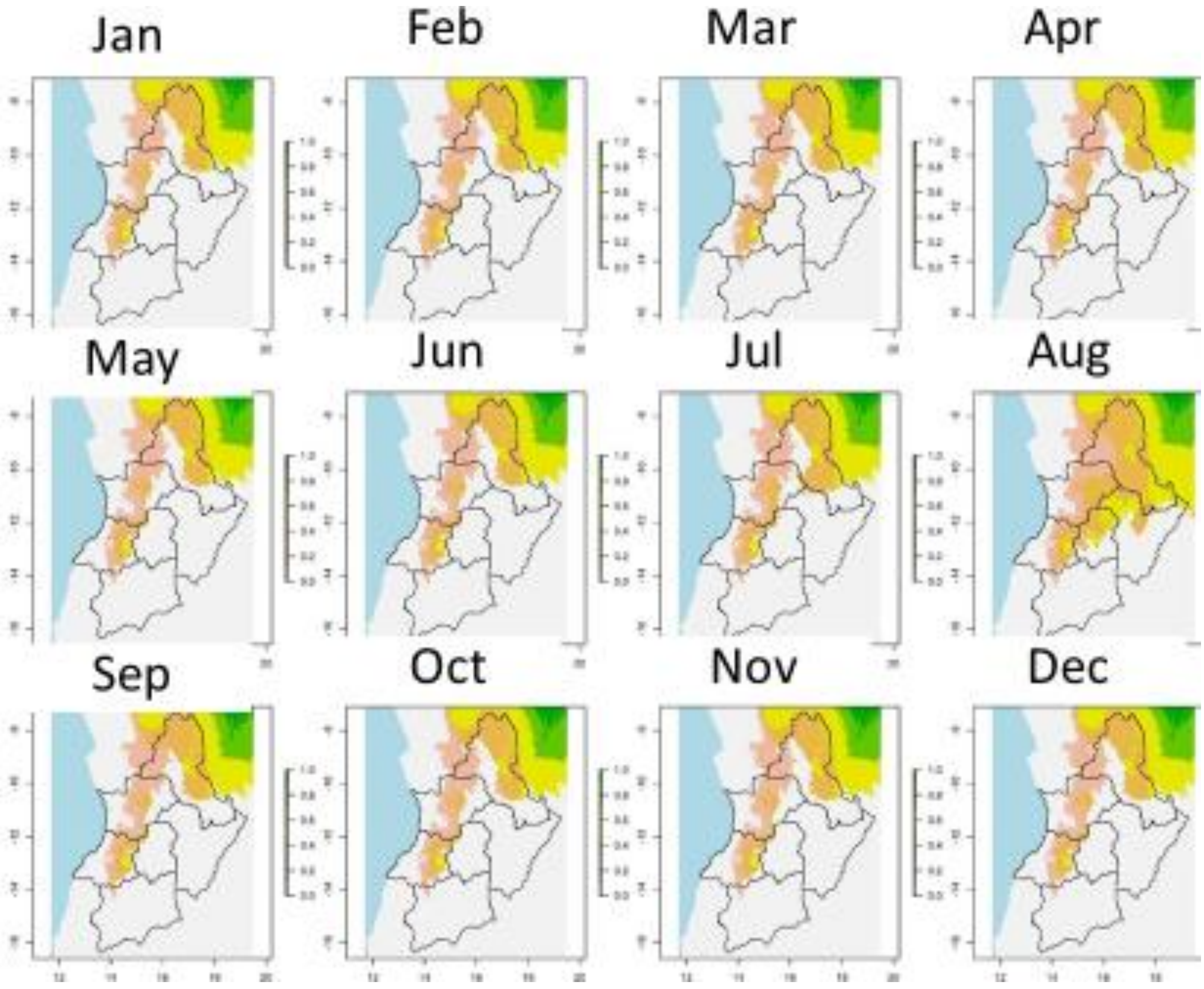

Figure 5.2.a Spatial variation in crop suitability Coffee (sp. *C robusta*) in the Planalto region

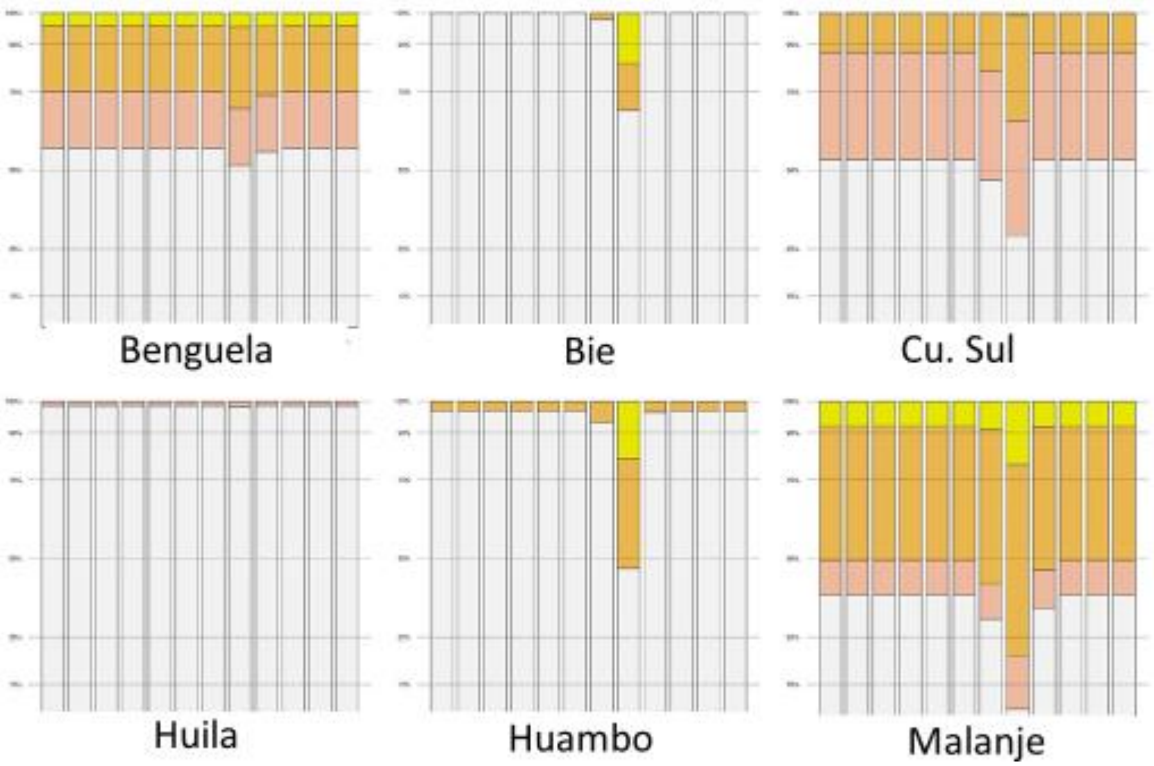

Figure 5.2.b Monthly variation in modelled Coffee (sp. *C robusta*) suitability in the Planalto region

5.3 Coffee (*Coffeea arabica*)

As noted previously, Angola produces *C. arabica* as well as *C. robusta* (5.2, above). The provinces of Bie and Huambo, while considered unsuitable for 'Robusta', include extensive areas which are considered to be 'very marginal', 'marginal', and 'suitable' for '*Arabica*' coffee production. Model results indicate that there are no areas which can be considered 'highly suitable' (in contrast to *Robusta*), however there is a total area of ~170,000 km^2 which can be considered marginally to moderately suitable for *Arabica* particularly in Bie, Huambo and Malanje.

Table 5.3 Proportional and absolute area of *Coffeea arabica* suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela							0.22	8 761.7	0.23	9 160.0
Bie					0.3	21 094.2	0.47	33 047.6	0.18	12 656.5
Cuanza Sul					0.01	556.0	0.29	16 124.0	0.36	20 016.0
Huambo					0.13	4 455.1	0.81	27 758.7	0.05	1 713.5
Huila							0.01	790.2	0.22	17 385.1
Malanje					0.26	25 376.5	0.55	53 681.1	0.18	17 568.4

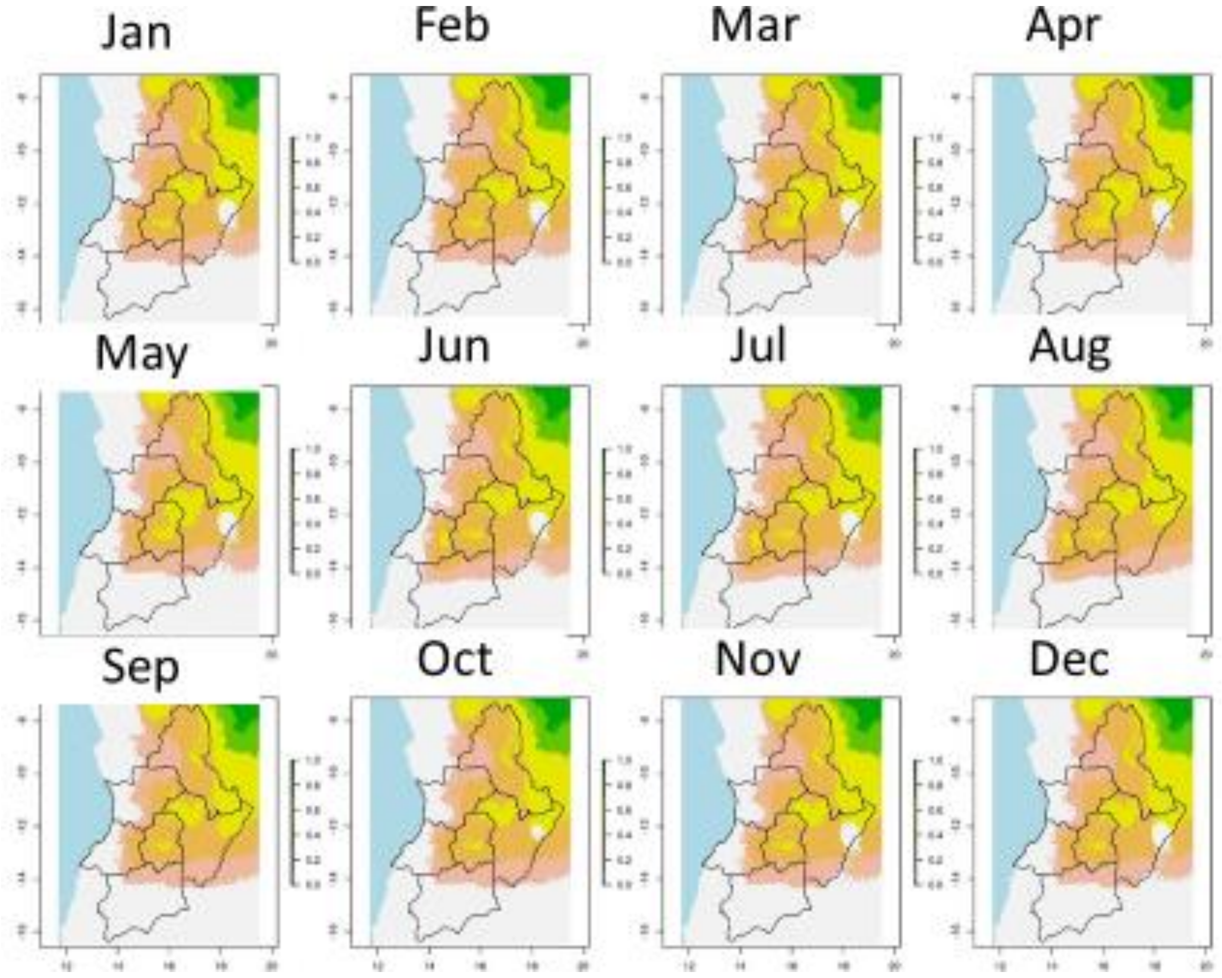

Figure 5.3a Spatial variation in crop suitability of Coffee ‘Arabica’ (sp. *C arabica*)

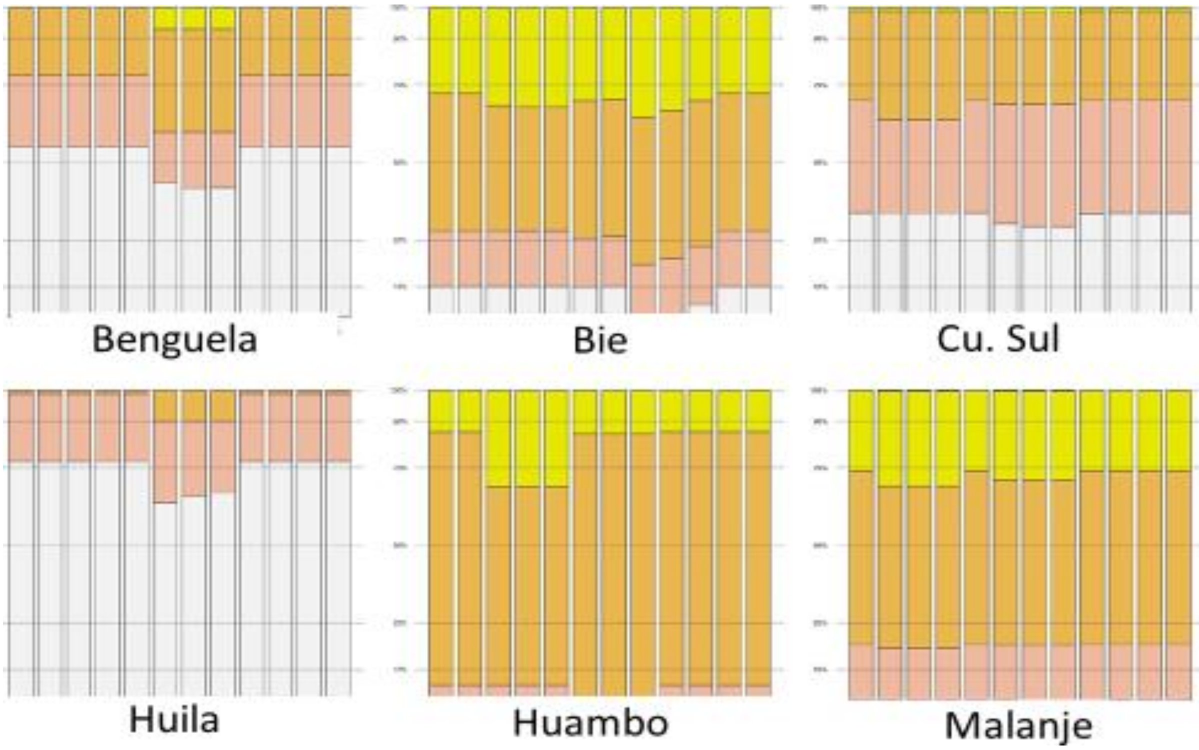

Figure 5.3.b Monthly variation in suitability of Coffee ‘Arabica’ (sp. *C arabica*)

5.4 Sugar cane (*Saccharum officinarum*)

With the exception of Huila, all provinces include areas of moderate suitability for sugar cane production. As a result of the high water demand for this crop, the southern and coastal regions are unsuitable for sugar cane. Suitability increases northwards in proportion to temperature and precipitation, following a pattern similar to banana (*Musa* sp., described further below). Malanje province has the largest total of 'suitable' (19,500 km^2) and 'moderate' (52,705 km^2) zones for sugar cane production. Table 5.4, below, summarises the relative distribution of crop suitability in the month of October.

Table 5.4 Proportional and absolute area of sugar cane (*Saccharum officinarum*) suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Moderate		Very marginal	
Benguela							0.22	8 761.7	0.2	7 965.2
Bie							0.08	5 625.1	0.51	35 860.1
Cuanza Sul							0.11	6 116.0	0.48	26 688.0
Huambo							0.01	342.7	0.55	18 848.5
Huila									0.02	1 580.5
Malanje					0.2	19 520.4	0.54	52 705.1	0.21	20 496.4

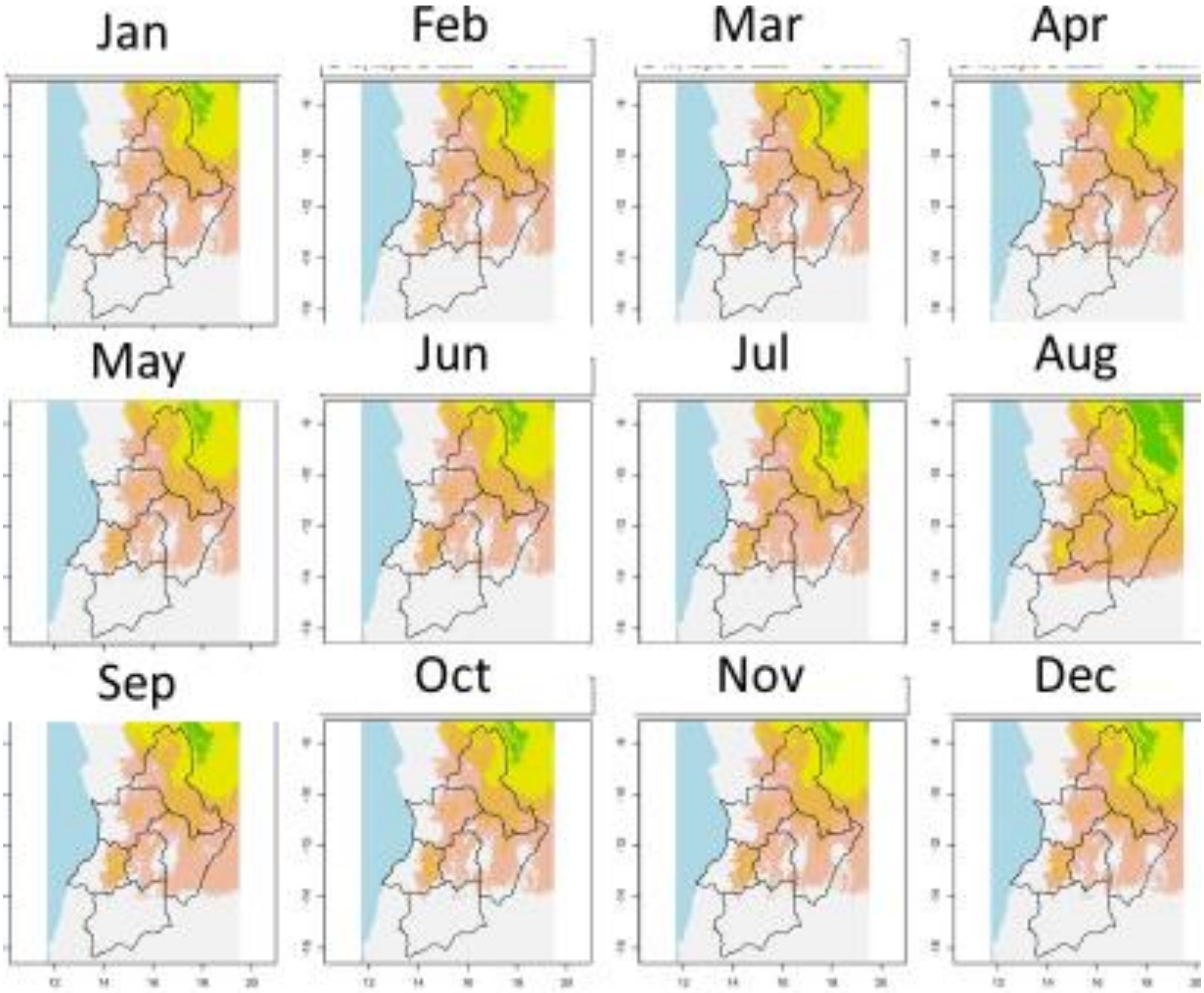

Figure 5.4.a Spatial variation in crop suitability of sugar cane in the Planalto region, by month

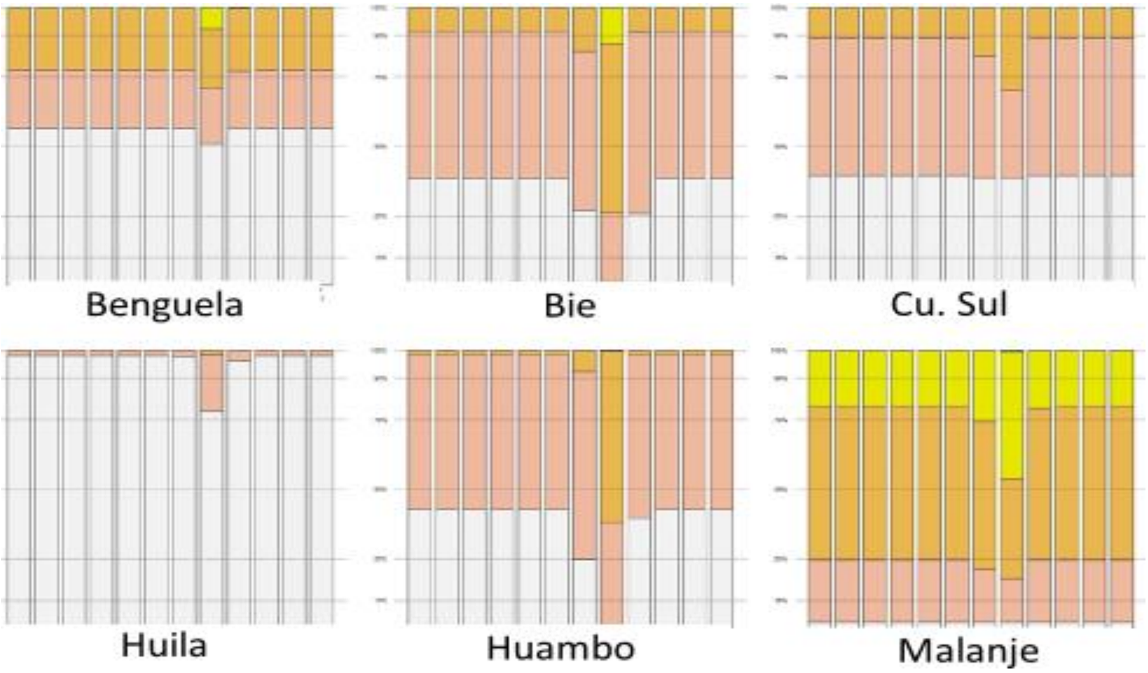

Figure 5.4.b Monthly variation in modelled suitability of sugarcane in the Planalto region

5.5 Sweet potato (*Ipomoea batatas*)

Sweet potato appears to be one of the most widely adaptable and versatile crops assessed during this study. With the exception of the semi-arid zones at the southern extent of the study area (lower Huila province) and the coastal plains of Cuanza Sul and Benguela, sweet potato can be grown throughout the six provinces assessed. The optimum area for sweet potato production falls across the interior highlands, particularly Huambo, Bie, and the southern interior of Malanje. In contrast with cassava (5.1, above), which can be planted and cultivated perennially, EcoCrop analyses indicate that the preferred timing for planting of sweet potato is at the onset of the rainy season in September – October. Table 5.5, below, summarises the relative distribution of crop suitability in the month of October.

Table 5.5 Proportional and absolute area of sweet potato (*Ipomoea batatas*) suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela	0.27	10 753.0	0.08	3 186.1	0.06	2 389.6	0.05	1 991.3	0.05	1 991.3
Bie	0.98	68 907.7								
Cuanza Sul	0.29	16 124.0	0.21	11 676.0	0.07	3 892.0	0.07	3 892.0	0.2	11 120.0
Huambo	1	34 270.0								
Huila	0.13	10 273.0	0.1	7 902.3	0.13	10 273.0	0.17	13 433.9	0.19	15 014.4
Malanje	0.84	81 985.7	0.07	6 832.1	0.03	2 928.1	0.01	976.0	0.01	976.0

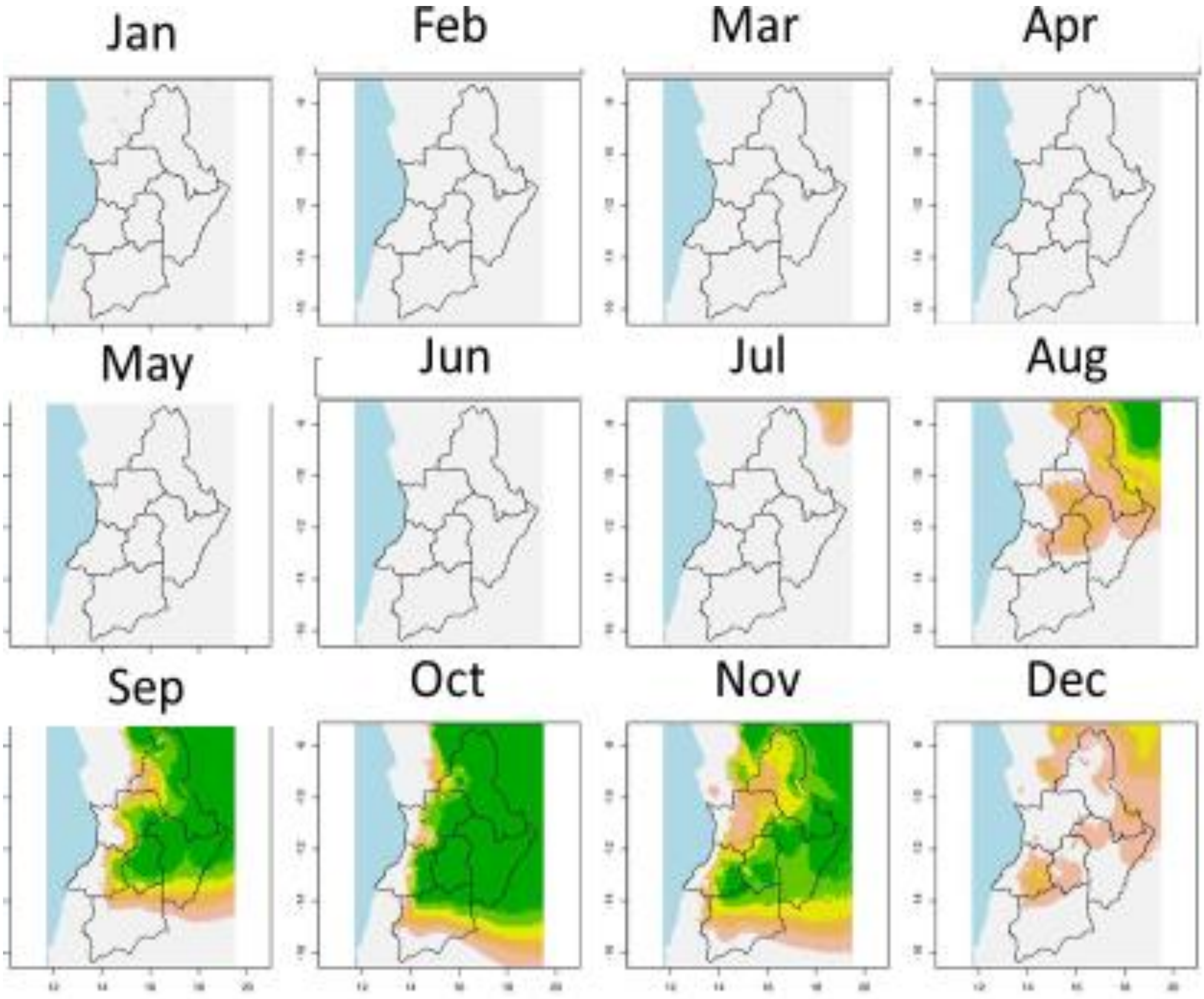

Figure 5.5.a Spatial variation in crop suitability of sweet potato

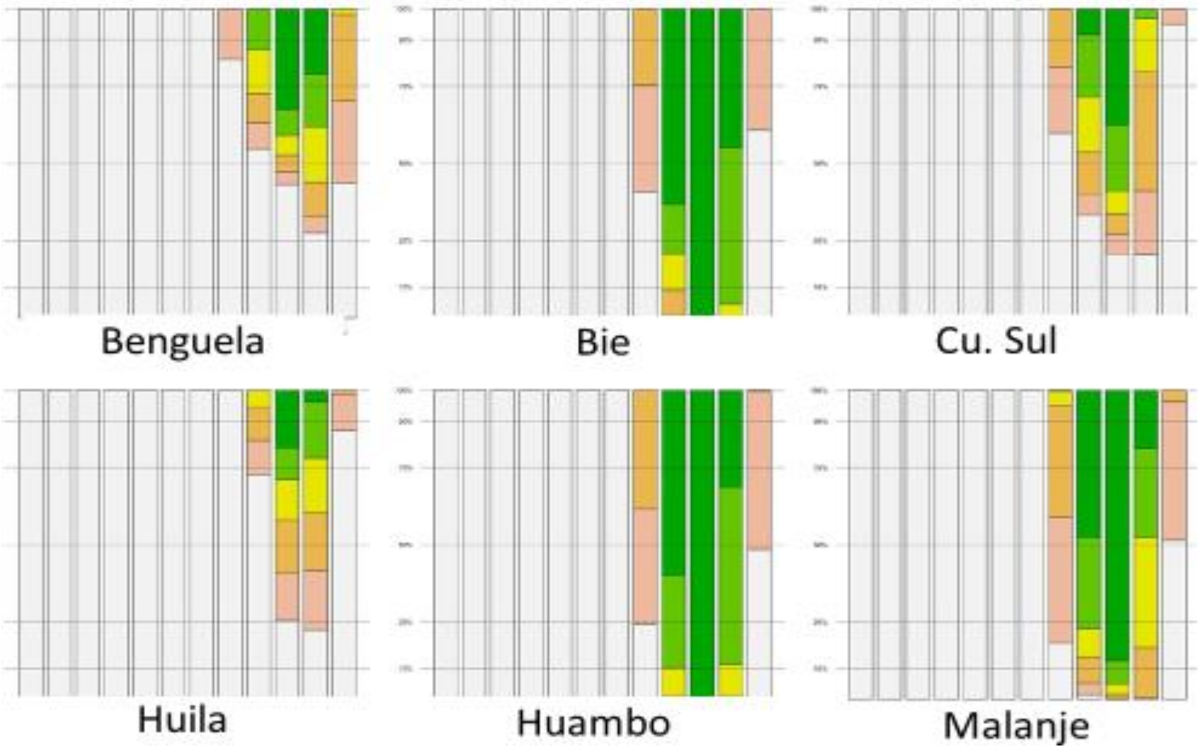

Figure 5.5.b Monthly variation in modelled sweet potato suitability in the Planalto region

5.6 Banana (*Musa* spp.)

Banana is one of the most widespread crops in Angola and accounts for the second-largest production area after cassava. As there are multiple landraces and commercial varieties of banana, including both ‘table’ banana as well as plantain ‘cooking’ banana, these analyses are restricted to three common varieties which are known to be grown in Angola currently: *Musa acuminata* (AAA-genome, commercial Cavendish variety), *M.* (BB-genoma, cooking plantain variety), and *M. acumiata x balbisiana* (AAB, improved cooking plantain variety).

5.6.1 Banana (*Musa acuminata*, AAA Cavendish variety)

Banana is one of the most widespread crops in Angola and accounts for the second-largest production area after cassava. As there are multiple landraces and commercial varieties of banana, including both ‘table’ banana as well as plantain ‘cooking’ banana, these analyses are restricted to three common varieties which are known to be grown in Angola currently: *Musa acuminata* (AAA-genome, commercial Cavendish variety), *M.* (BB-genoma, cooking plantain variety), and *M. acumiata x balbisiana* (AAB, improved cooking plantain variety).

Although a review of literature indicates that bananas are widely grown in vicinity to most homesteads around the country, the EcoCrop model are focused on identifying those areas of optimal suitability for commercial-scale production. This study assessed the commercial ‘Cavendish’ table banana, *Musa accuminata*, the *M. balbisiana* plantain, and a hybrid of *M. accuminata x balbisiana.*

Of the three varieties analysed, the AAA-genome ‘Cavendish’ variety is the most widely adaptable cultivar, where all provinces included some zones of marginal to moderate suitability. The extended rainfall and high temperatures of Malanje province are well-suited for Cavendish banana production and a relatively large proportion of the province (20% or ~19,520 km^2) was found to be highly suitable (Table 5.6.1, below, where results indicate the month of October). All other provinces, except for the arid extents of southern Huila and western (coastal) Benguela and Cuanza Sul, include large extents of land which are ‘moderately’ suitable for Cavendish table banana production.

Table 5.6.1 Proportional and absolute area of Cavendish banana suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela					0.17	6 770.4	0.23	9 160.0	0.14	5 575.6
Bie					0.13	9 140.8	0.78	54 844.9	0.03	2 109.4
Cuanza Sul					0.22	12 232.0	0.42	23 352.0	0.12	6 672.0
Huambo					0.04	1 370.8	0.87	29 814.9	0.05	1 713.5
Huila							0.17	13 433.9	0.27	21 336.2
Malanje			0.2	19 520.4	0.59	57 585.2	0.19	18 544.4		

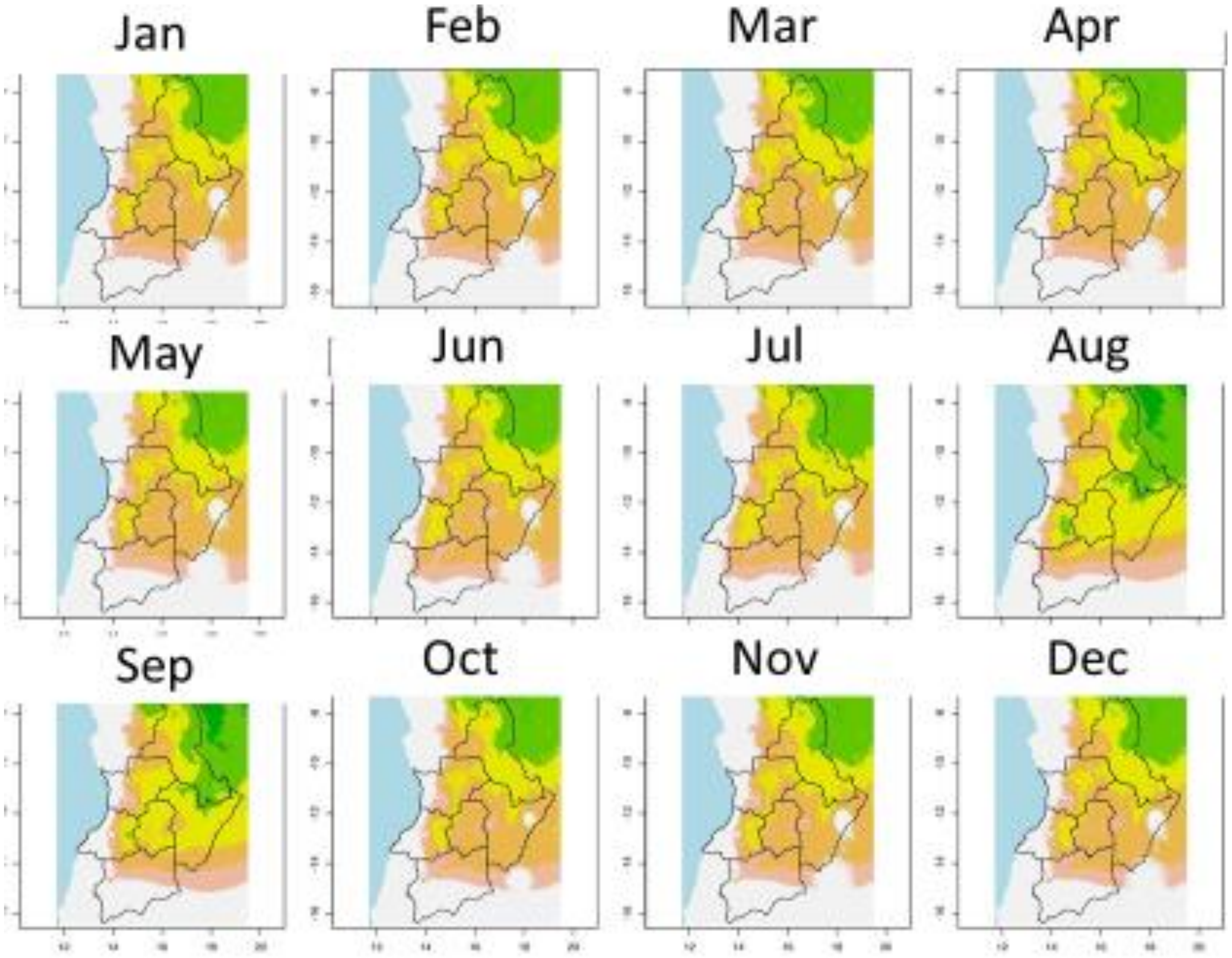

Figure 5.6.1a Spatial variation in crop suitability of banana (*M. accuminata*, AAA Cavendish variety)

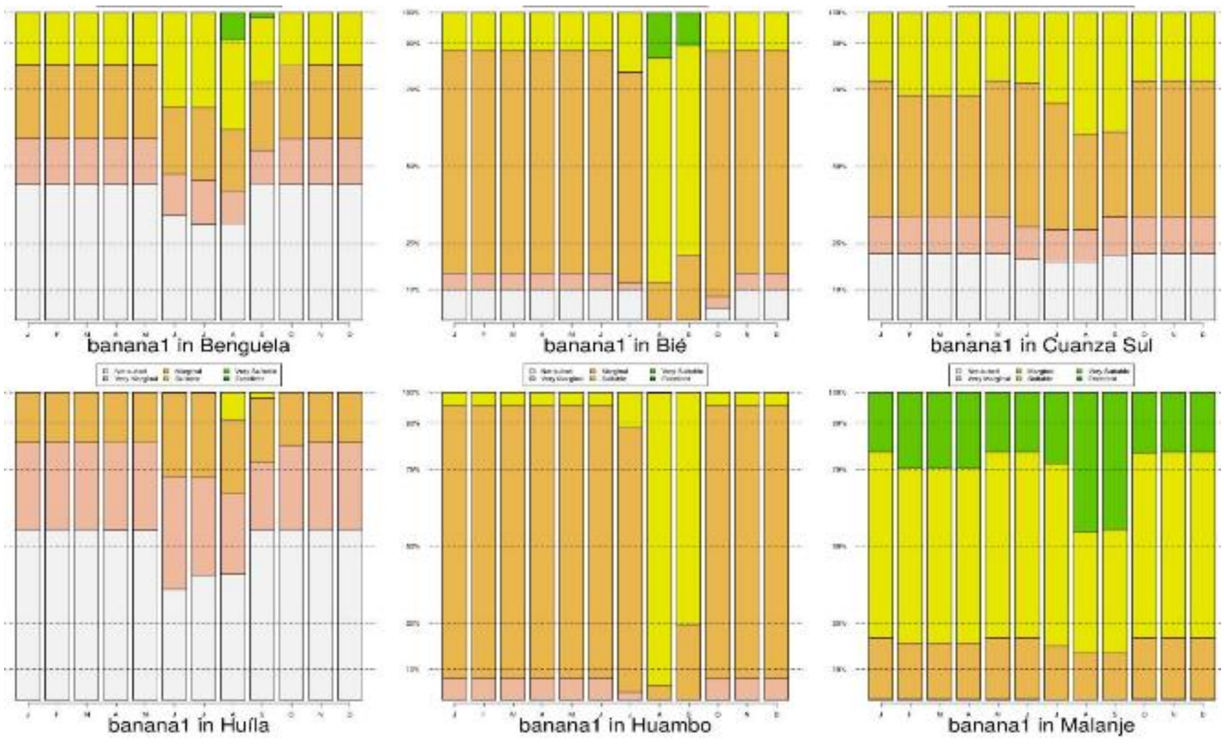

Figure 5.6.1.b Monthly variation in suitability of banana (*M.acuminata*, AAA Cavendish variety)

5.6.2 Banana (*Musa balbisiana*, BB cooking plantain)

The second banana variety analysed, *M. balbisiana* plantains, exhibited a pattern of crop suitability most closely aligned with the banana production zones described in the FEWSNet livelihood zones analysis of Angola. In the latter resource, banana production is described as characteristic of the low-altitude inland areas of the coastal provinces (Benguela and Cuanza Sul) below the slopes of the *planalto* escarpment. According to EcoCrop models of BB genome plantains, the majority of the study area is completely unsuitable for plantain production, except for a narrow band of marginal-to-moderate suitability, extending from south to north in parallel to the coastline and inland escarpment of Benguela and Cuanza Sul towards Malanje. This area of modest suitability corresponds with the optimal zones for 'Cavendish´ *M. accummunita* (5.6.1, above). Table 5.6.2, below, summarises the relative distribution of suitability zones assuming October as the month of planting/establishment.

Table 5.6.2 Proportional and absolute area of plantain banana (*M. balbisiana*) suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela							0.03	1 194.8	0.04	1 593.0
Bie										
Cuanza Sul							0.01	556.0	0.05	2 780.0
Huambo										
Huila										
Malanje			0.01	976.0					0.01	976.0

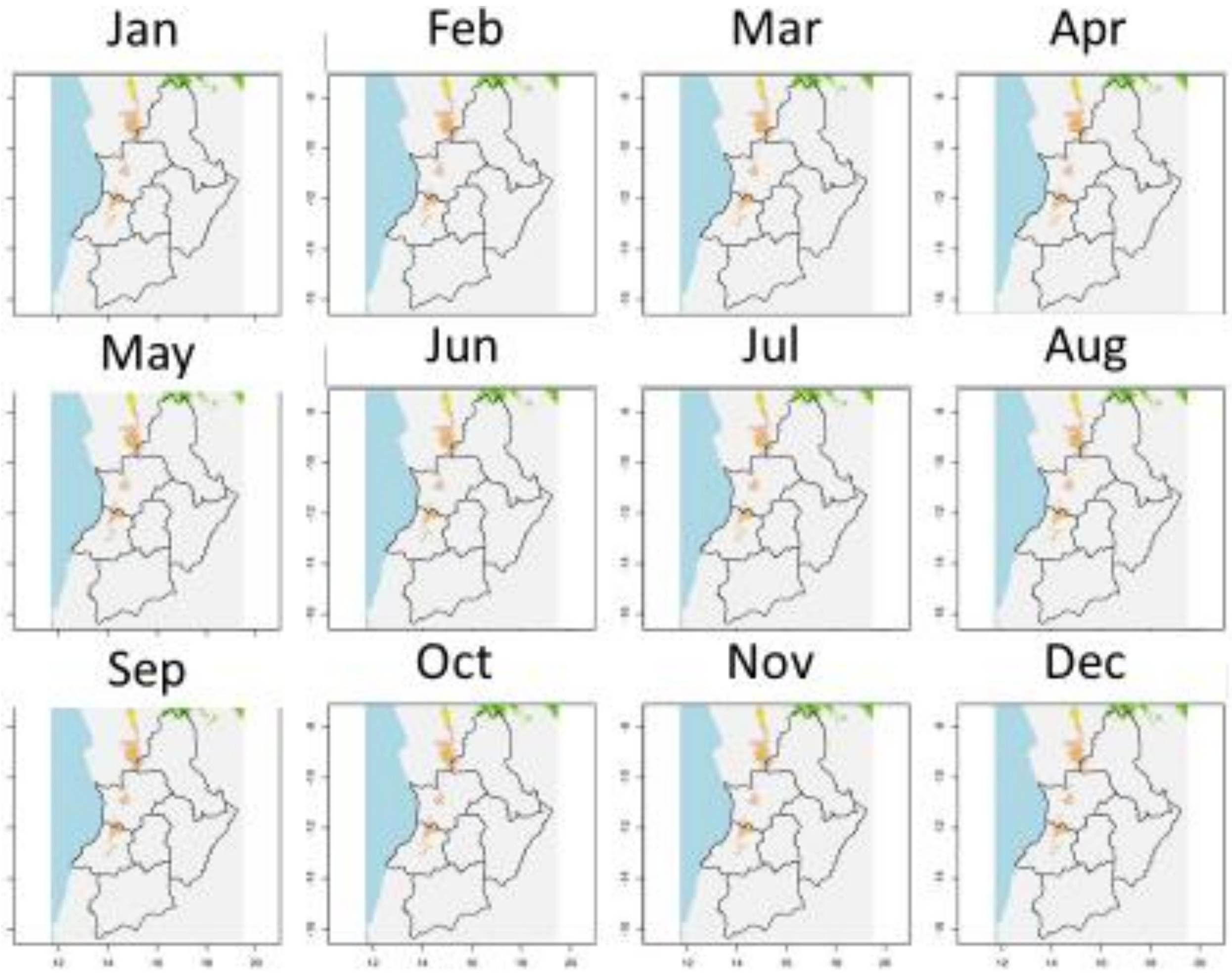

Figure 5.6.2.a Spatial variation in crop suitability of banana (*M. balbisiana*, cooking plantain)

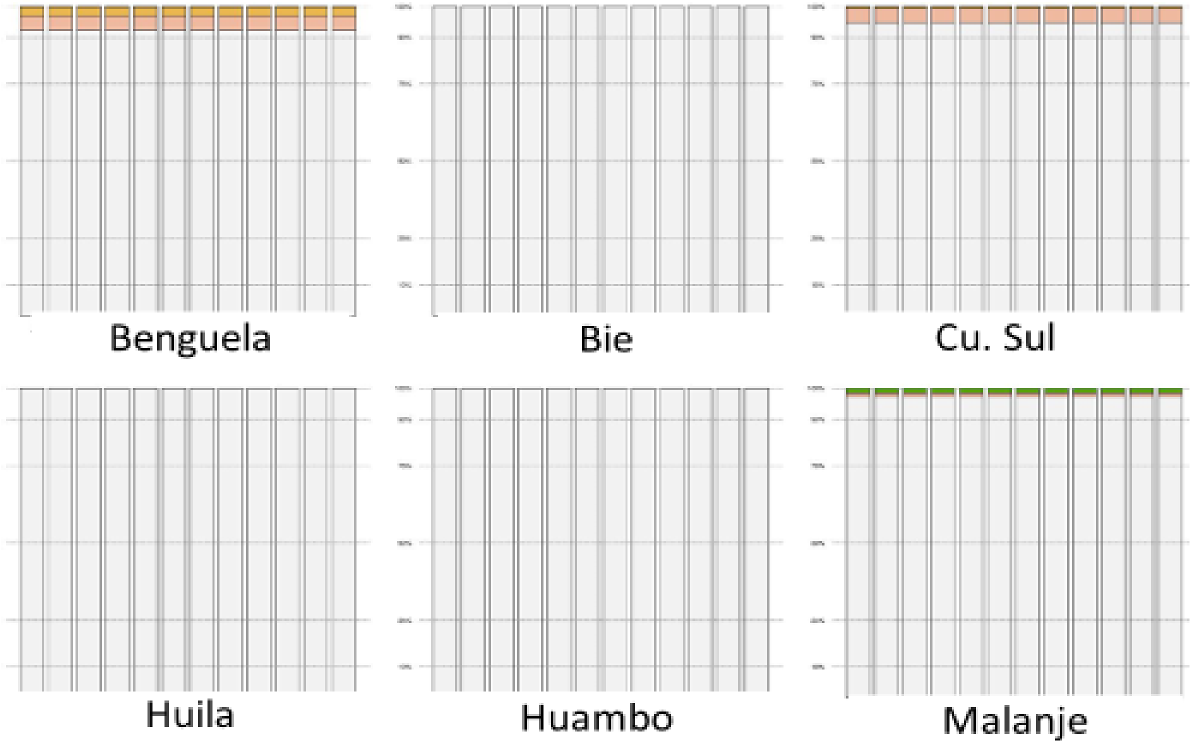

Figure 5.6.2.b Monthly variation in suitability of banana (*M. balbisiana*, cooking plantain)

5.6.3 Banana (*Musa acuminata x balbisiana*, cooking plantain)

The third cultivar of banana analysed, a hybrid of *M. accuminata x balbisiana*, exhibits a suitability range moderately between the previous two varieties. The AAB-genome banana is moderately suited to some areas of northern Malanje and the central-to-northern extents of Bie and Huambo. While the BB-genome plantain banana was found to be mainly appropriate for the comparatively arid midlands of Cuanza Sul and Benguela, the AAB-hybrid plantain is likely to be more appropriate for moderate-to-high altitude, humid sub-tropical climates in the *planalto* provinces. Table 5.6.3, below, summarises the relative distribution of suitability zones assuming October as the month of planting/establishment.

Table 5.6.3 Proportional and absolute area of hybrid plantain banana (*M. balbisiana x accuminata*) suitability zones in the *Planalto* region, Angola

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela									0.01	398.3
Bie									0.3	21 094.2
Cuanza Sul									0.04	2 224.0
Huambo									0.2	6 854.0
Huila										
Malanje							0.04	3 904.1	0.39	38 064.8

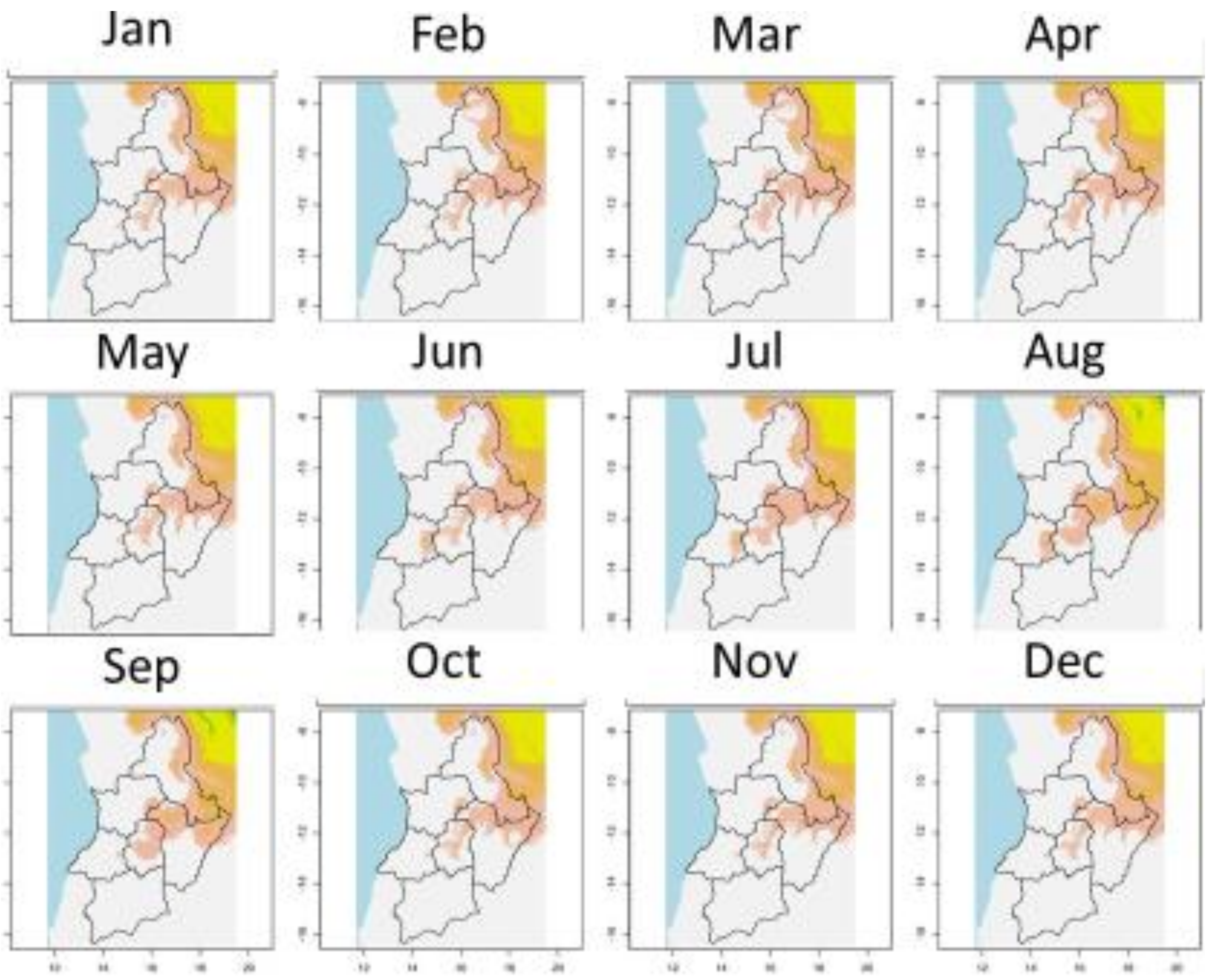

Figure 5.6.3.a Spatial variation in crop suitability of banana (*M. acuminata* x *balbisiana*, hybrid cooking plantain)

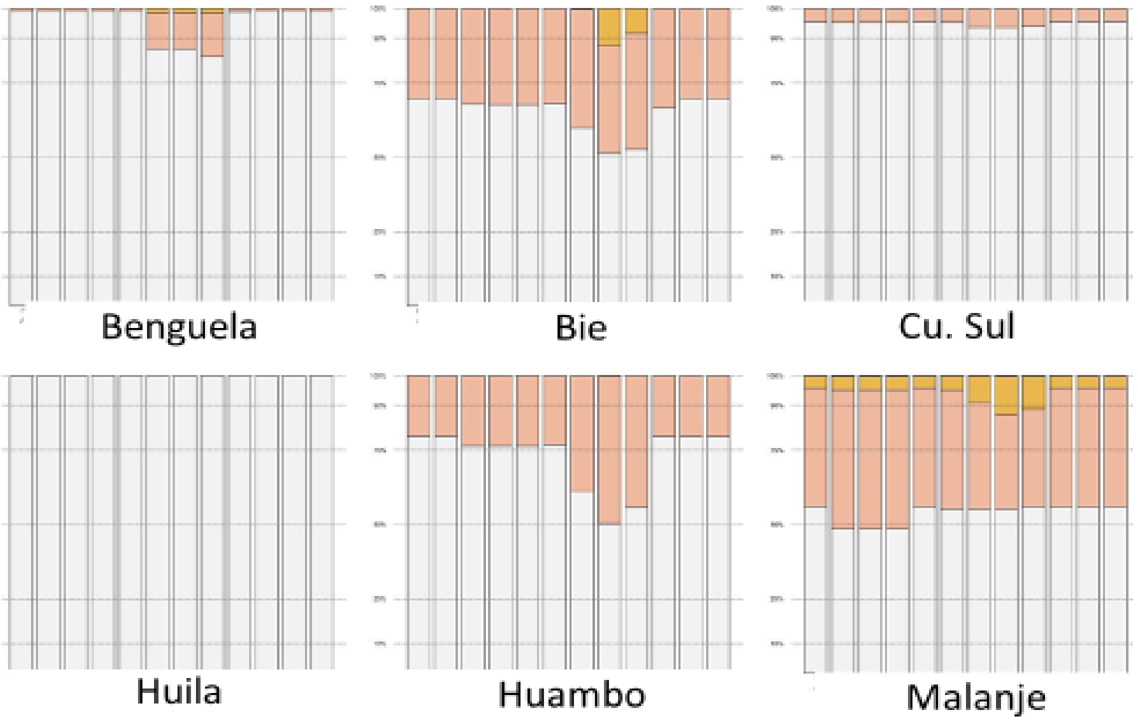

Figure 5.6.3.b Monthly variation in suitability of banana (*acuminata* x *balbisiana*, hybrid cooking plantain)

5.8 Maize (*Zea mays*, various subspecies)

Maize is the most widely grown and largest cereal crop by volume in Angola. However, as a result of the genetic diversity of the commercial cultivars and landraces of maize grown worldwide, there are multiple varieties of maize that can potentially be included in the EcoCrop suitability analyses. Furthermore, as a result of the wide variety of landraces that are traditionally grown in Angola, as well as a number of improved cultivars that have been promoted by development organisations, there is a need for crop suitability analyses to include consideration of a diverse range of maize cultivars. Consequently, this analysis considered three models of maize suitability: i) *Zea mays* L. *mays*, interpreted as open-pollinated white maize grown for food and fodder; ii) Flint maize and dent maize, *Zea mays v. indurata* and *Z. mays indentata*, both of which are modelled on identical parameters in EcoCrop, and which are interpreted as high-starch improved maize for flour production and fodder; and iii) Soft, popcorn and pod maize varieties (*Z. mays v. amylacea, everta, tunicata*, respectively), all of which are modelled on identical parameters in EcoCrop and are assumed to be improved maize varieties for specific applied industrial or agroprocessing purposes. Sections 5.8.1, 5.8.2 and 5.8.3 summarise the aforementioned analyses of maize varieties. The variability between these three analyses reflects the diversity of modern maize genetics, and emphasises the need to strengthen modelled analyses with field observations and local-level data. Therefore, these analyses should be interpreted as a demonstration of a small selection of maize varieties.

In general, all three analyses follow a similar regional and annual trend, therefore the majority of comments are focus on *Zea mays* L.s. *mays* (5.8.1, below). The primary difference between the three analyses (5.8.1 – 5.8.3, below) is that the first of these three analyses assumes the widest possible range of periods for duration of crop growth, ranging from 65 to 365 days – these parameters are broadly in line with the range of improved commercial varieties, including both 'short-' and 'long-growth' cultivars. As a result, the first of these three analyses tends to suggest that a large proportional and total of the project area is highly suitable. The second and third analyses (5.8.2 – 5.8.3, below) are based on more conservative assumptions for duration of crop growth, ranging from 90 to 140 days – therefore the latter parameters for duration of growing season have the effect of reducing the spatial extent of 'suitable' areas by reducing the potential range of growing seasons.

5.8.1 *Zea mays* L.s. *mays*

As a result of the relatively warm climate and long summer rainfall season, the majority of the study area is 'highly suitable' or 'excellent' for maize production. Similarly to most other crops analysed, the range of suitable production zones for maize is mainly limited by the aridity of the southern and coastal regions of Huila, Benguela and Cuanza Sul. Although the data shown in Table 5.8 (below) assumes October as the start of the growing season in all provinces, Figures 5.8.a and 5.8.b indicate that the northern extent of the study region benefits from a relatively 'wide' growing season as a result of the bimodal rainy season (compared to the rainfall regime of the southern region which is unimodal). As a result, much of Cuanza Sul and Benguela provinces and all of Malanje province are suitable for late-season production of maize (e.g. planting in ~December–February).

Table 5.8.1 Proportional and absolute area of common maize (*Zea mays* L.s. *mays*) suitability zones

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela	0.34	13 679.4	0.14	5 774.4	0.05	1 994.1	0.03	1 166.7	0.02	805.6
Bie	0.03	1 843.8	0.60	42 374.0	0.08	5 533.9	0.01	870.9		
Cuanza Sul	0.54	29 813.3	0.09	5 035.0	0.03	1 833.1	0.02	1 385.6	0.02	1 219.8
Huambo	0.11	3 917.4	0.56	19 051.8						
Huila	0.11	8 643.4	0.10	8 296.1	0.10	7 973.8	0.11	8 571.9	0.10	7 794.4
Malanje	0.31	30 666.2	0.33	31 725.0	0.05	5 181.7				

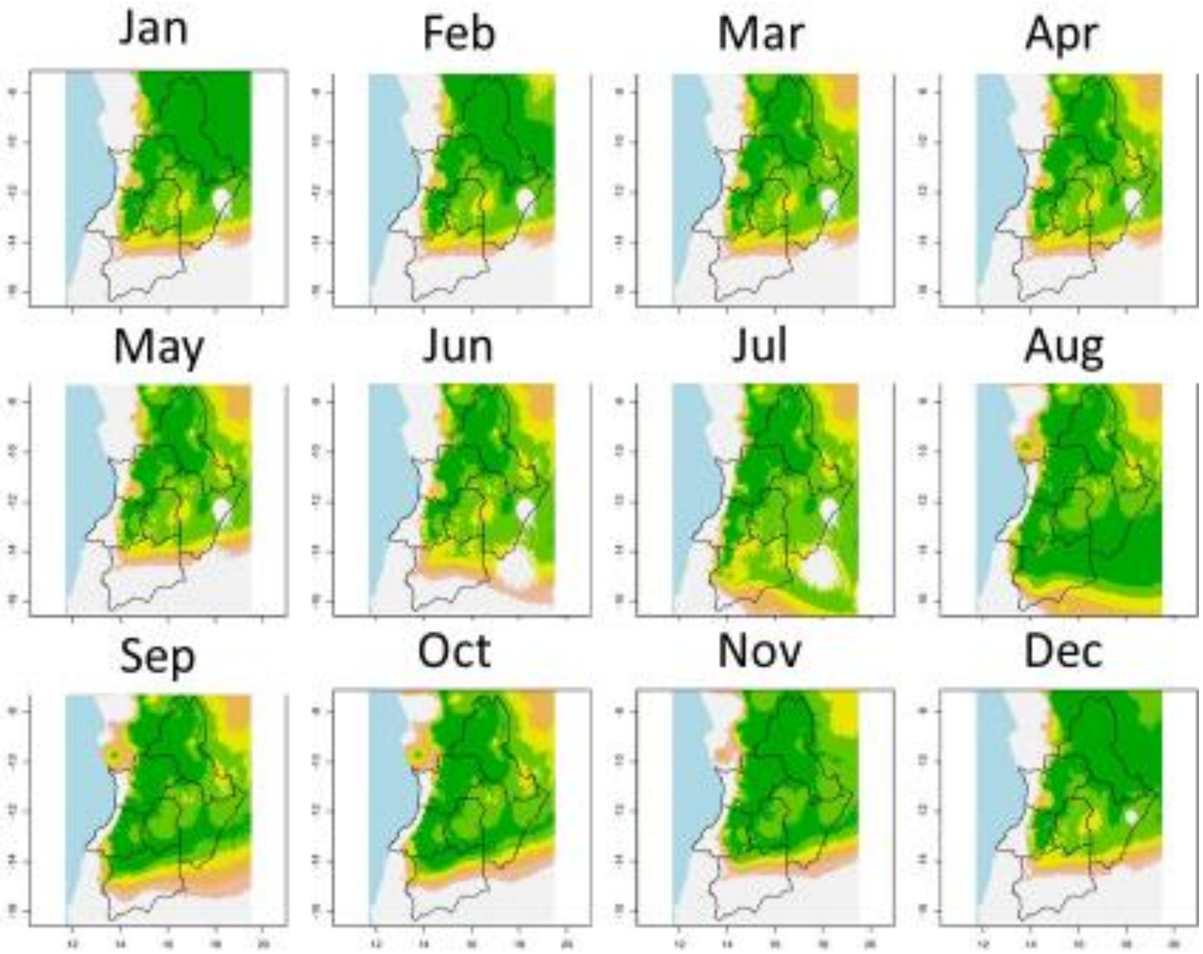

Figure 5.8.1a Spatial variation in modelled crop suitability of maize (*Zea mays L.s. mays*) in the Planalto region, by month

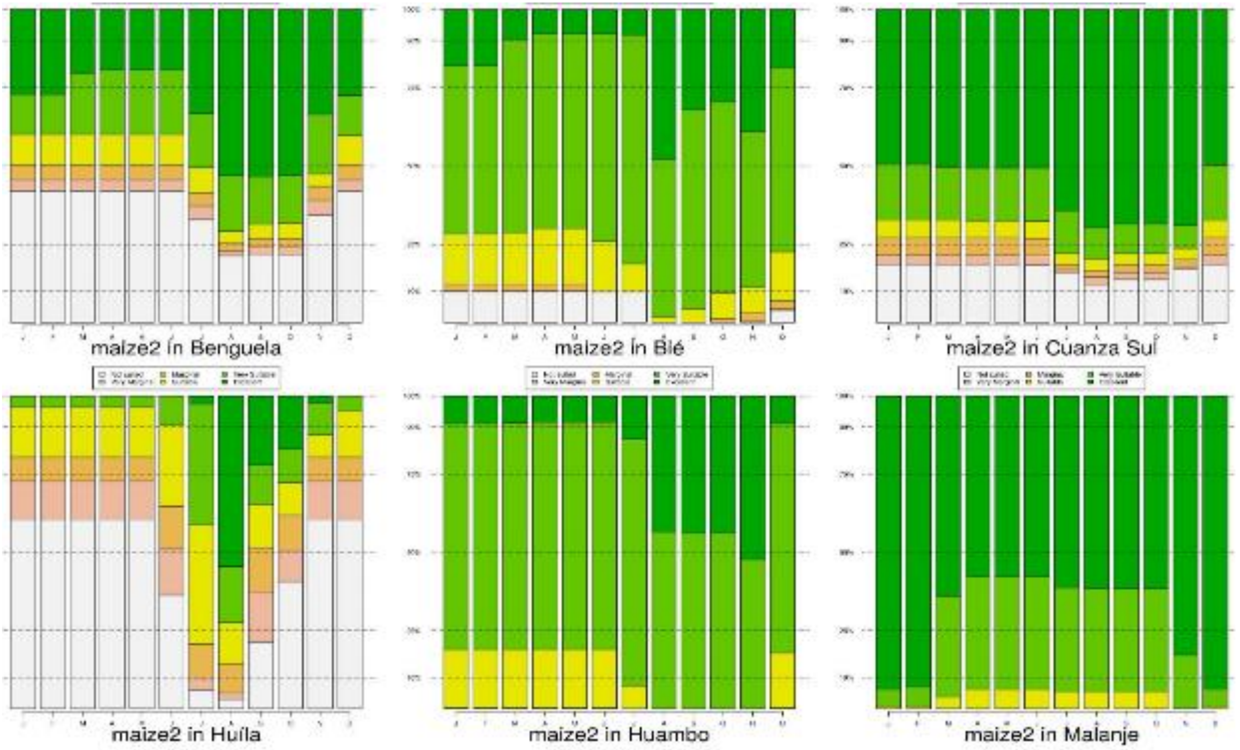

Figure 5.8.1b Monthly variation in modelled maize (*Zea mays L.s. mays*) suitability in the Planalto region

5.8.2 Maize, flint or dent (*Z. mays v. indurata* or *indentata* Sturtmays)

As noted in 5.8.1, above, the species of flint and dent maize (*Z. mays v. indurata* and *indentata* Sturtmays, respectively) considered in this analysis are similar in regional distribution to *Zea mays* L.s. *mays*, but differ in temporal (i.e. month-to-month suitability. As a result of the longer 'minimum' growth period and shorter 'maximum' growth period assumed for flint and dent maize, the optimum growing period for these varieties is restricted to planting at the first onset of rains, in September to November, indicating that these varieties of maize are unsuitable for late-season cropping. The only province which is the exception to this is Malanje, which is marginally suitable for maize production as late in the season as December – January.

As was noted in the case of *Z. mays* L.s. *mays*, the primary limiting variable for maize production in Angola is aridity. As a result, the provinces which are least suitable or most variable in suitability for maize production are Huila, Benguela and Cuanza Sul – in these provinces, the spatial extent of suitable maize zones is restricted by the aridity of the coast and the southern regions. Nevertheless, all six provinces include extensive areas which are considered to be 'highly suitable' or 'excellent' for maize production, assuming that growing season begins in October (Table 5.8.2, below).

Table 5.8.2 Proportional and absolute area of maize, flint or dent (*Z. mays v. indurata* or *indentata* Sturtmays)

	Proportional area (0-1) and total area (km^2)									
October	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela	0.39	15 505.1	0.08	3 077.5	0.02	957.9	0.02	630.5	0.02	684.3
Bie	0.73	51 297.8	0.03	2 186.3						
Cuanza Sul	0.63	35 007.4	0.03	1 447.4	0.03	1 547.2	0.02	1 389.0	0.02	904.3
Huambo	0.32	11 038.2	0.14	4 837.0	0.00	31.9				
Huila	0.40	31 843.8	0.11	8 384.2	0.07	5 333.9	0.05	4 058.8	0.04	3 528.8
Malanje	0.96	94 135.2	0.00	142.2	0.00	92.2				

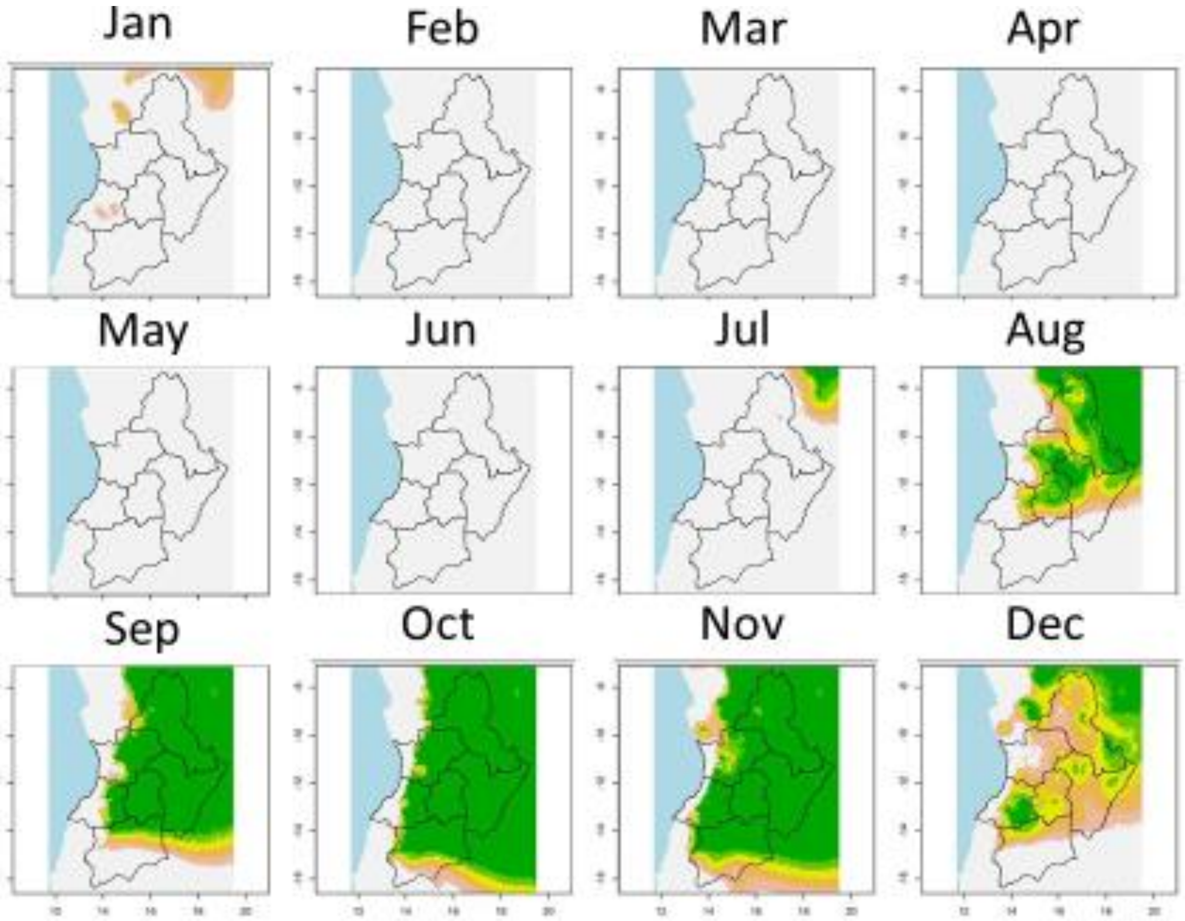

Figure 5.8.2.a Spatial variation in modelled crop suitability of maize, flint or dent (*Z. mays v. indurata or indentata* Sturtmays) in the Planalto region, by month.

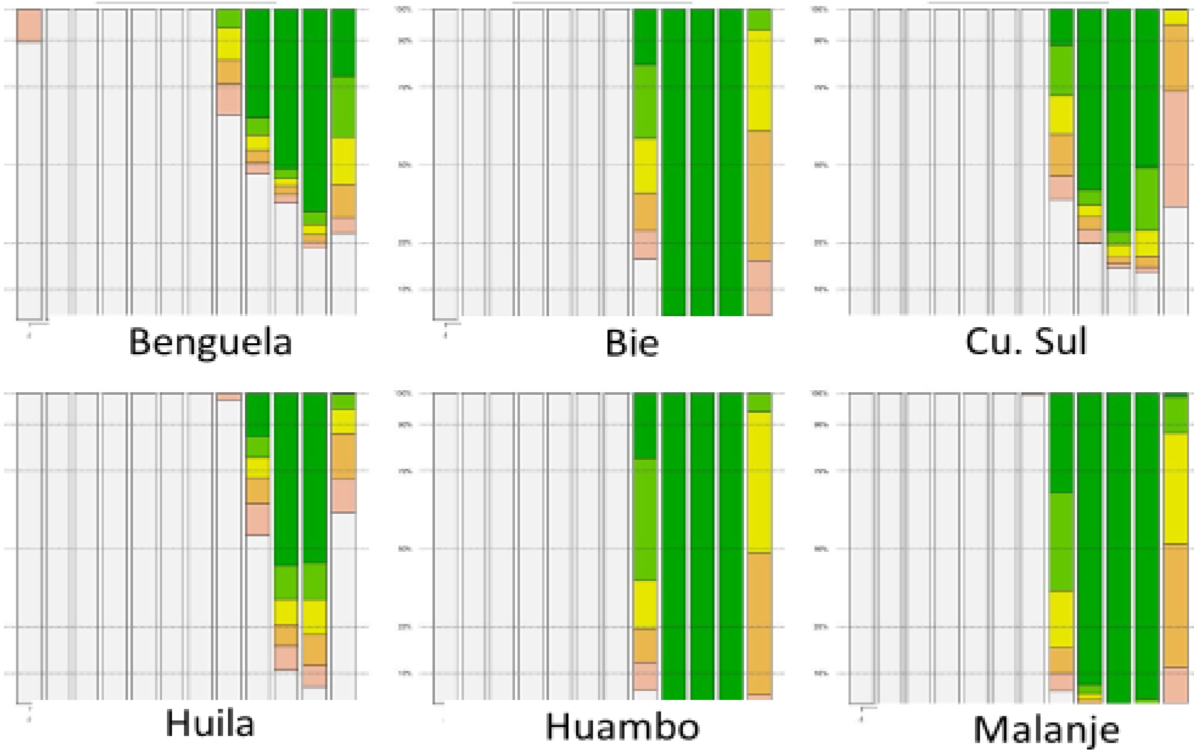

Figure 5.8.2.b Graphical depiction of monthly variation in suitability of maize, flint or dent varieties (*Z. mays v. indurata or indentata* Sturtmays)

5.8.3 Maize, soft, pop and pod (Z. *mays v. amylacea, everta, tunicata*)

The third maize model analysed can be applied to at least three varieties of maize, including soft, pop and pod maize (*Z. mays v. amylacea, everta, tunicate*, respectively). For the month of October, the proportional distribution of suitability for these varieties is identical to the results for flint and dent maize (5.8.2, above). The primary difference between these models is the temporal (monthly) distribution of suitability, where very minor differences can be discerned in the months of December and January. Irrespective of these small differences, in practical terms the defined spatial and temporal ranges of the assorted maize varieties in 5.8.2 and 5.8.3 are effectively the same. The appropriate planting season in the majority of the study area is the first onset of rainy season in October (summarised in Table 5.8.3, below).

Table 5.8.3 Proportional and absolute area of maize, soft, pop and pod (*Z. mays v. amylacea, everta, tunicata)*

	Proportional area (0-1) and total area (km^2)									
October	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela	0.39	15 505.1	0.08	3 077.5	0.02	957.9	0.02	630.5	0.02	684.3
Bie	0.73	51 297.8	0.03	2 186.3						
Cuanza Sul	0.63	35 007.4	0.03	1 447.4	0.03	1 547.2	0.02	1 389.0	0.02	904.3
Huambo	0.32	11 038.2	0.14	4 837.0	0.00	31.9				
Huila	0.40	31 843.8	0.11	8 384.2	0.07	5 333.9	0.05	4 058.8	0.04	3 528.8
Malanje	0.96	94 135.2	0.00	142.2	0.00	92.2	0.00	38.1		

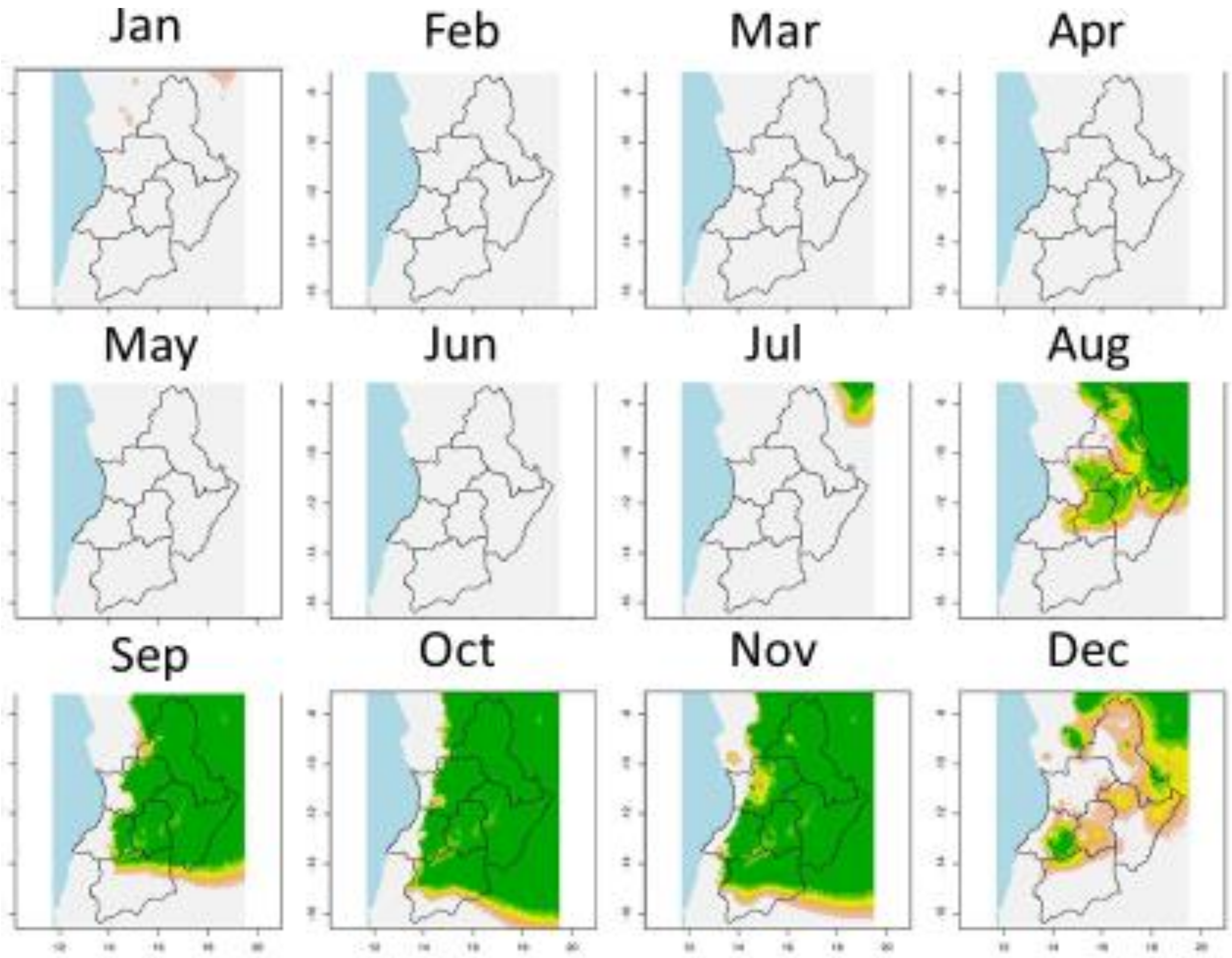

Figure 5.8.3a Spatial variation in modelled crop suitability of maize, soft, pop and pod (Z. *mays* v. *amylacea, everta, tunicata*) in the Planalto region, by month

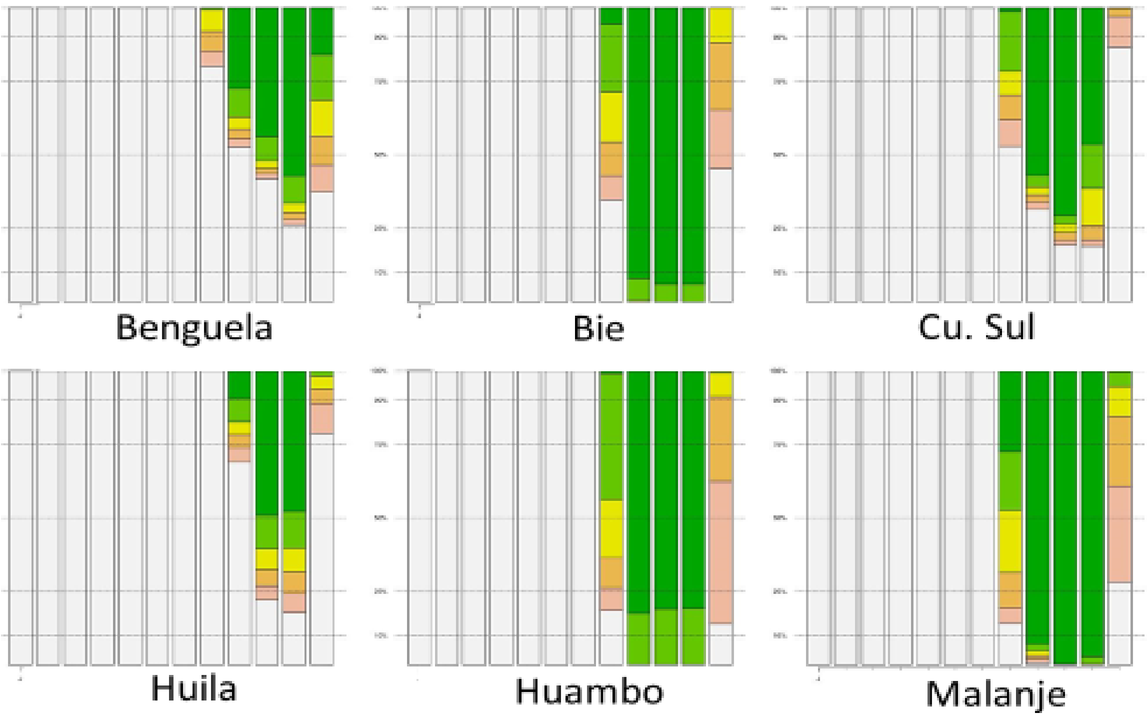

Figure 5.8.3.b Monthly variation in suitability of modelled maize, soft, pop and pod (Z. *mays* v. *amylacea, everta, tunicata*) suitability in the Planalto region

5.9 Millet (*Pennisetum glaucum* (L)R.Br.)

Millet is known to be grown widely in several provinces of Angola, both in combination with other cereals such as maize as well as in comparatively arid areas which are considered unsuitable for maize. In particular, millet and sorghum (described further in 5.10, below) are favoured in Huila province as a relatively drought-tolerant cereal crop where maize is considerably less appropriate, particularly in the south (see 5.8). EcoCrop models confirm that Huila is suitable for millet, where Huila province has a total area of ~68,000 km^2 which can be considered 'good to highly suitable' for millet production (compared to ~16,000 km^2 for maize).

Similarly, the semi-arid areas of Cuanza Sul and Benguela provinces which are poorly suited to maize production are comparatively better suited to millet. The latter provinces cumulatively include an area of ~65,000 km^2 which is 'highly to extremely' suitable for millet. The provinces of Malanje, Bie and Huambo, all of which are currently major producers of maize, are also suggested to be suitable for widespread millet production as an alternative or a complement to traditional cereal crops.

Millet and sorghum are the only cereal crops which are appropriate for cultivation across the entire study region (i.e. all six provinces), including southern Huila and the western coastal lowlands of Cuanza Sul and Benguela. In these latter areas, millet can potentially be promoted as a complement or alternative to other cereal crops, particularly where rainfall is a constraint to productivity. Traditionally millet is planted later in the rainy season than maize (~December – January), however Ecocrop analyses indicate that planting season can be extended from ~September – February in some areas. Table 5.9.1, below, summarises the relative distribution of crop suitability for the month of October.

Table 5.9.1 Proportional and absolute area of millet (*Pennisetum glaucum*) suitability zones

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela			0.44	17 523.4	0.21	8 363.5	0.07	2 787.8	0.04	1 593.0
Bie			0.28	19 687.9	0.63	44 297.8				
Cuanza Sul			0.45	25 020.0	0.27	15 012.0	0.01	556.0	0.05	2 780.0
Huambo			0.02	685.4	0.94	32 213.8	0.02	685.4		
Huila			0.5	39 511.5	0.36	28 448.3	0.04	3 160.9		
Malanje			0.59	57 585.2	0.2	19 520.4				

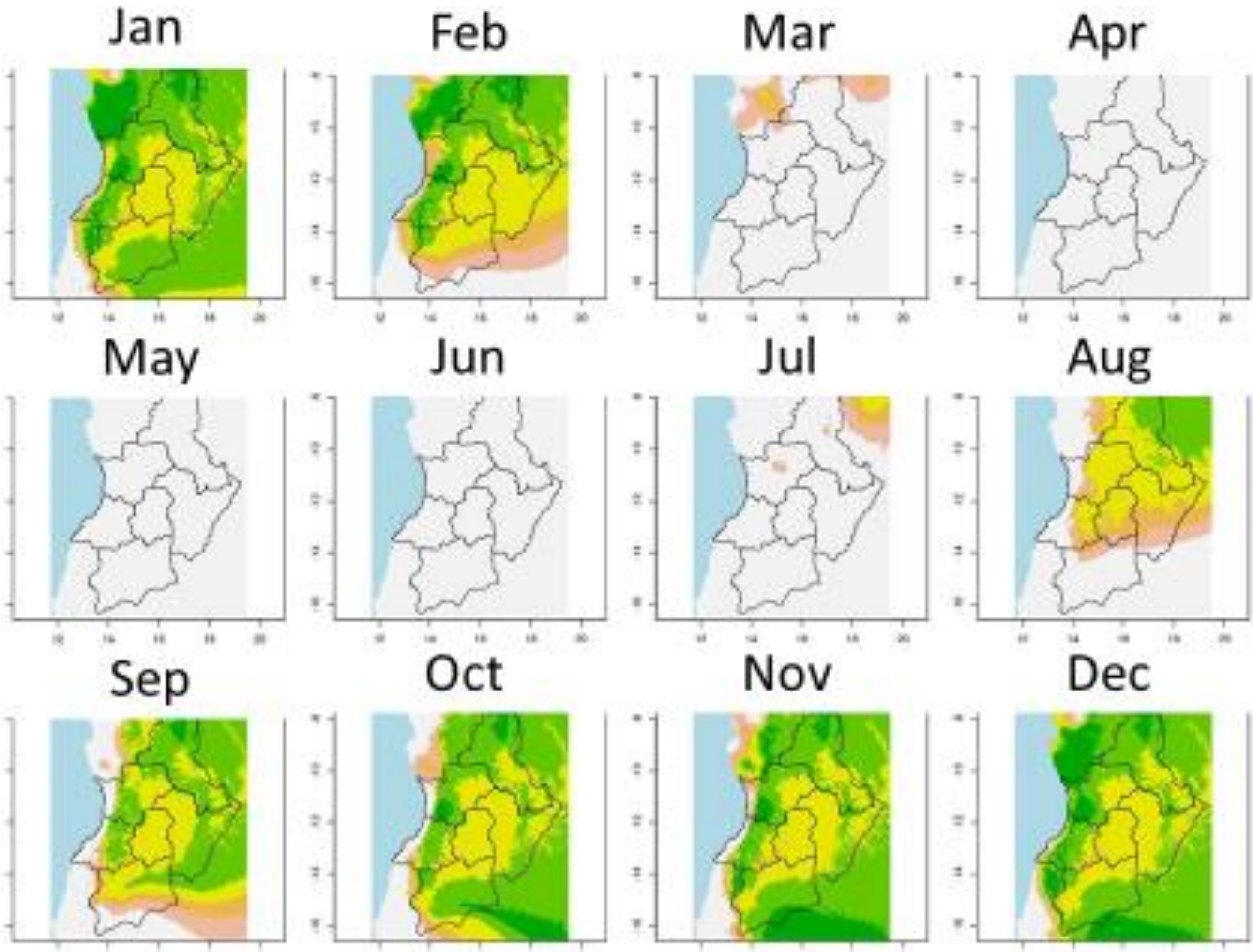

Figure 5.9.1.a Spatial variation in suitability of millet (*Pennisetum glaucum* (L)R.Br.)

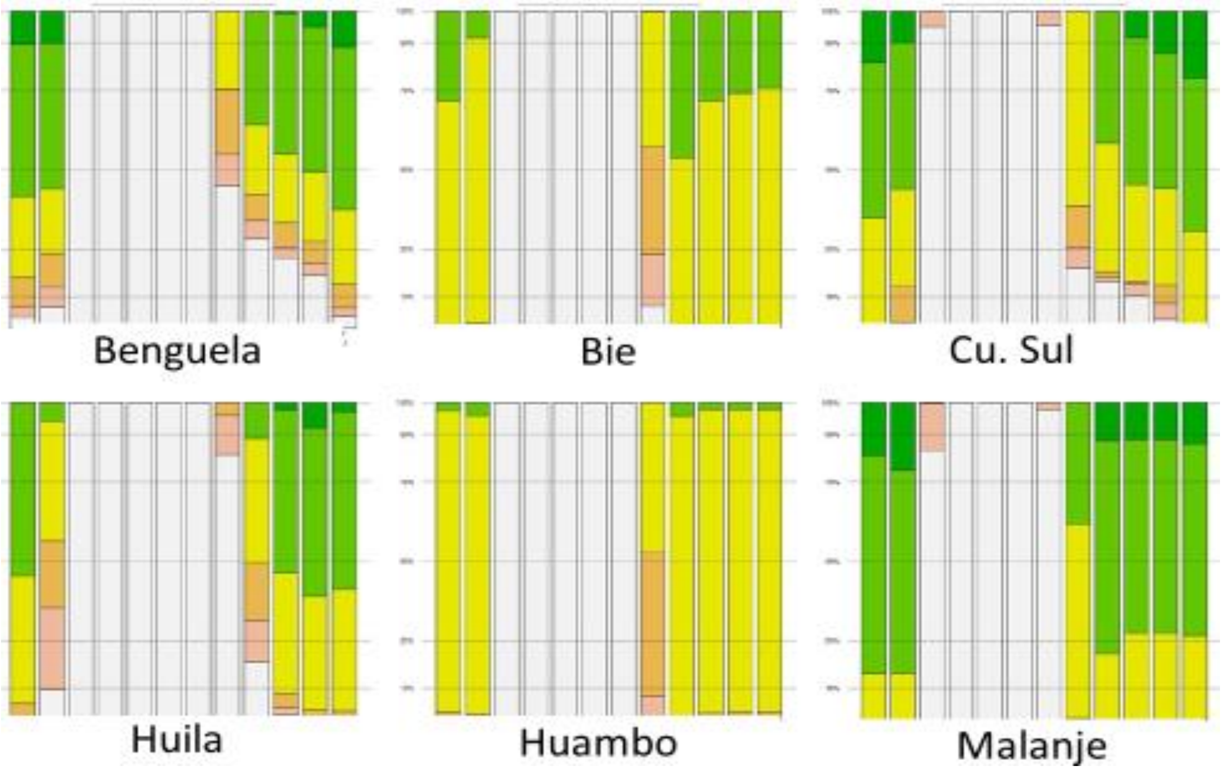

Figure 5.9.1.b Monthly variation in suitability of millet (*Pennisetum glaucum* (L)R.Br.)

5.10 Sorghum, (*Sorghum bicolor* (L) Moench)

As described previously, sorghum (*Sorghum bicolor*) and millet are widely grown as cereal crops in areas where low rainfall or unfavourable duration of rainy season limits the productivity of maize. Sorghum is reportedly grown in areas such as southern Huila and Bie provinces, and to some degree in the lowlands of Cuanza Sul and Benguela provinces. In the case of sorghum, EcoCrop distinguishes between 'low altitude' and 'high altitude' varieties, which are analysed in 5.10.1 and 5.10.2 (below), respectively.

EcoCrop analyses affirm the suitability of the aforementioned areas to sorghum, in addition to which the majority of the remaining provinces include large areas of 'high to excellent' suitability for sorghum. As a result, both sorghum and millet are considered to be appropriate cereals to be promoted as an addition or an alternative to maize production. The analyses presented in Tables 5.10.1 and 5.10.2, below, summarise the relative distribution of crop suitability in the month of October. In general, both 'low' and 'high altitude' sorghum varieties can be grown across the study area, with minor differences observed between the two analyses (below).

5.10.1 Sorghum, low altitude variety (*Sorghum bicolor* (L) Moench)

As described above, low-altitude sorghum varieties can be grown widely across areas of the study region. A relatively small area (~1,670 km^2) of Cuanza Sul province was found to be 'excellent', in addition to which an additional 70% (~39,000 km^2) is 'suitable or highly suitable'. Bie and Huambo are particularly well suited to sorghum production, where virtually the entire of each of province (~69,000 km^2 and ~32,000 km^2, respectively) is 'suitable or highly suitable'. Huila province, which is particularly dependent on drought-tolerant cereals such as sorghum, includes an area of ~50,000 km^2 which is 'suitable or highly suitable' and additional ~25,000 km^2 which is 'marginal to very marginal'. Virtually the entire Malanje province (~86%) is considered highly suitable for low altitude sorghum.

The two varieties analysed (low and high altitude, respectively) are identical in the proportion of 'marginal' and 'very marginal' zones in all provinces. The primary differences between the two varieties is in the spatial variation in 'suitable', 'highly suitable' and 'excellent' zones.

Table 5.10.1 Proportional and absolute area of sorghum, low altitude (*Sorghum bicolor* (L) Moench) suitability zones

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela			0.37	14 735.6	0.12	4 779.1	0.02	796.5	0.03	1 194.8
Bie			0.79	55 548.1	0.19	13 359.7			0.01	703.1
Cuanza Sul	0.03	1 668.0	0.61	33 916.0	0.09	5 004.0	0.04	2 224.0	0.05	2 780.0
Huambo			0.38	13 022.6	0.56	19 191.2				
Huila			0.36	28 448.3	0.29	22 916.7	0.18	14 224.1	0.13	10 273.0
Malanje			0.86	83 937.7						

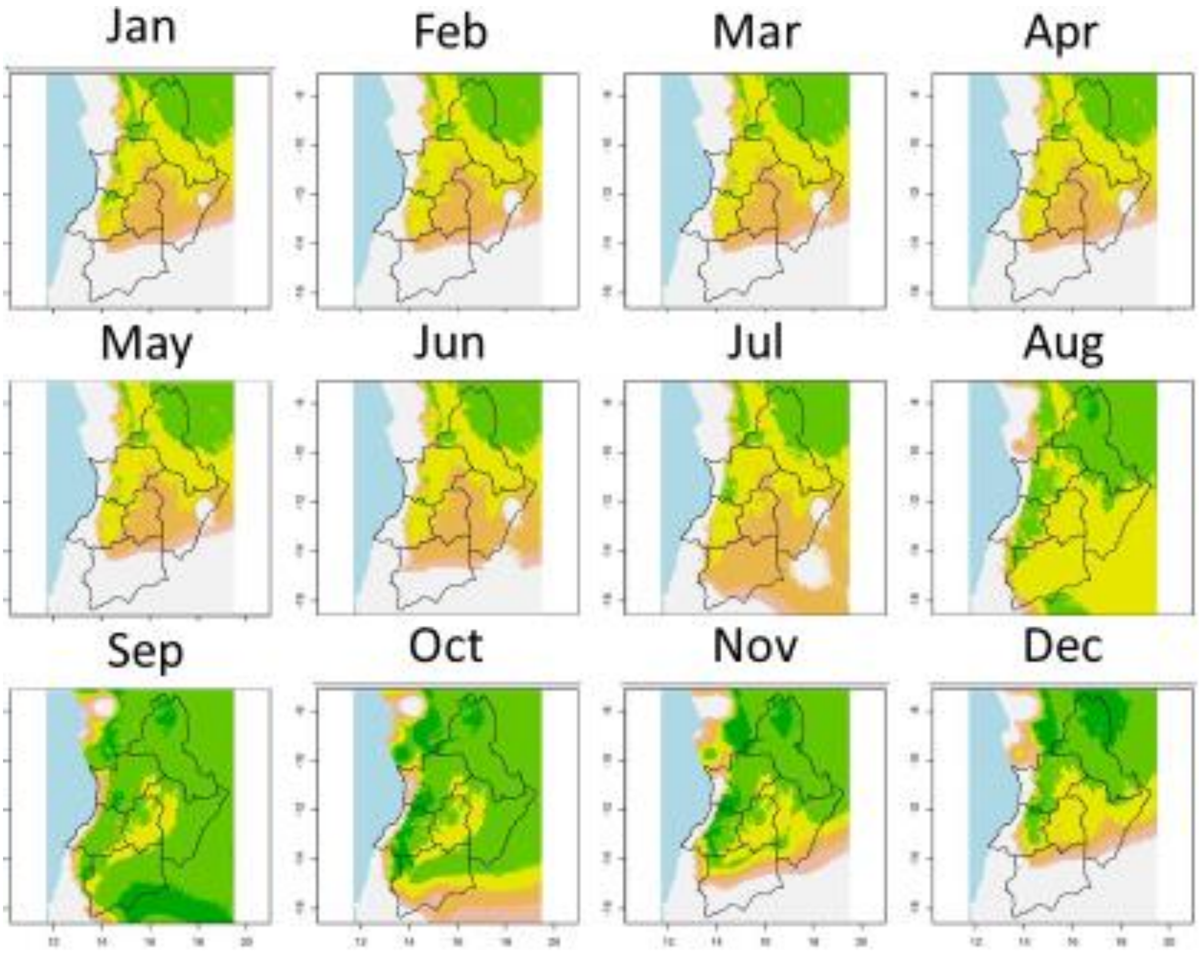

Figure 5.10.1.a Spatial variation in suitability of sorghum, low altitude variety (*Sorghum bicolor* (L) Moench), by month

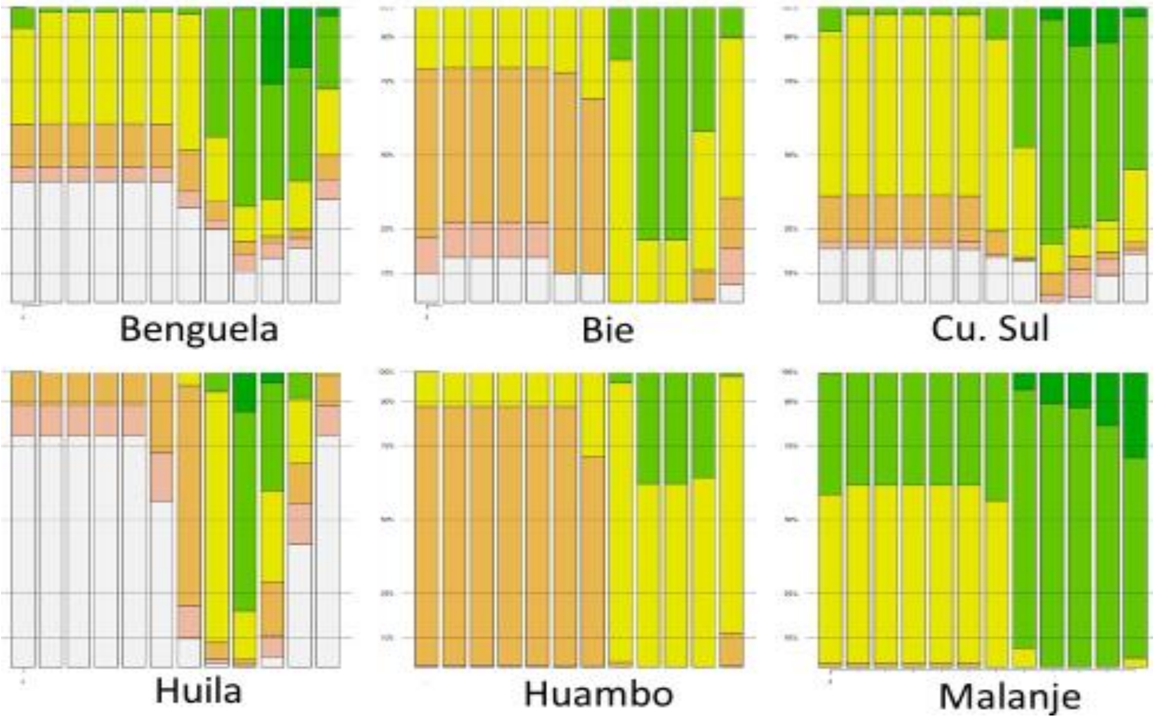

Figure 5.10.1.b Monthly variation in suitability of sorghum, low altitude variety (*Sorghum bicolor* (L) Moench)

5.10.2 Sorghum, high altitude (*Sorghum bicolor* (L) Moench)

As noted in 5.10.1, above, the primary difference between 'high' and 'low altitude' sorghum varieties is the proportion of 'suitable', 'highly suitable' and 'excellent' zones. For example, although a considerable proportion (57% or ~55,600 km^2) of Malanje province is 'highly suitable' for high-altitude sorghum, results in 5.10.1 suggest that a low-altitude variety is better suited to the province. Similarly, comparison of results for Bie province indicate that, although ~80% of the province is suitable for 'high altitude' sorghum, the remaining area of almost ~20% is better suited to 'low altitude' sorghum.

Table 5.10.2 Proportional and absolute area of sorghum, high altitude (*Sorghum bicolor* (L) Moench) suitability zones

Province	*Proportional area (0-1) and total area (km^2)*									
	Excellent		Highly suitable		Suitable		Marginal		Very marginal	
Benguela	0.14	5 575.6	0.25	9 956.5	0.08	3 186.1	0.02	796.5	0.03	1 194.8
Bie			0.8	56 251.2					0.01	703.1
Cuanza Sul	0.06	3 336.0	0.3	16 680.0	0.04	2 224.0	0.04	2 224.0	0.05	2 780.0
Huambo			0.85	29 129.5	0.08	2 741.6				
Huila	0.04	3 160.9	0.37	29 238.5	0.23	18 175.3	0.18	14 224.1	0.13	10 273.0
Malanje			0.57	55 633.1						

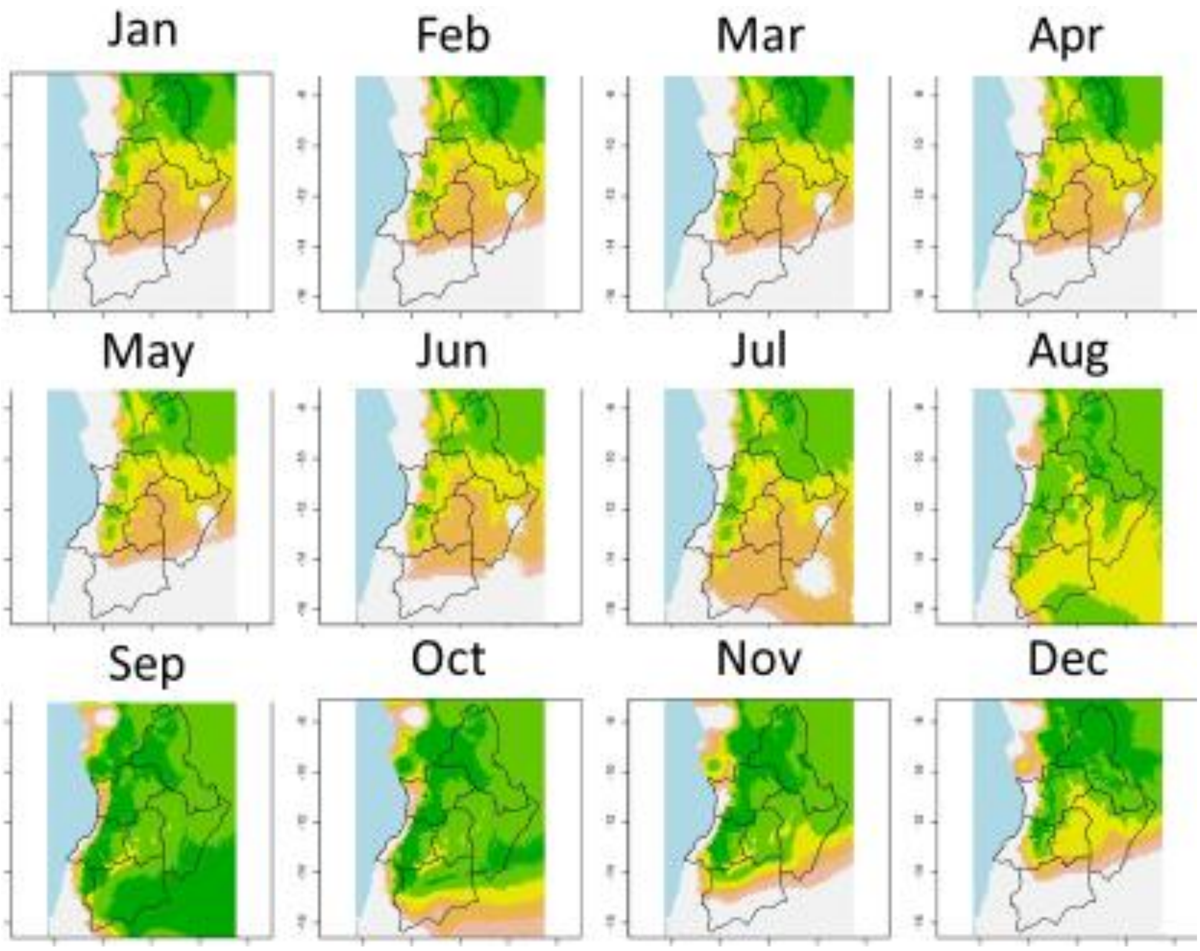

Figure 5.10.2.a Spatial variation in suitability of sorghum, high altitude variety (*Sorghum bicolor* (L) Moench), by month.

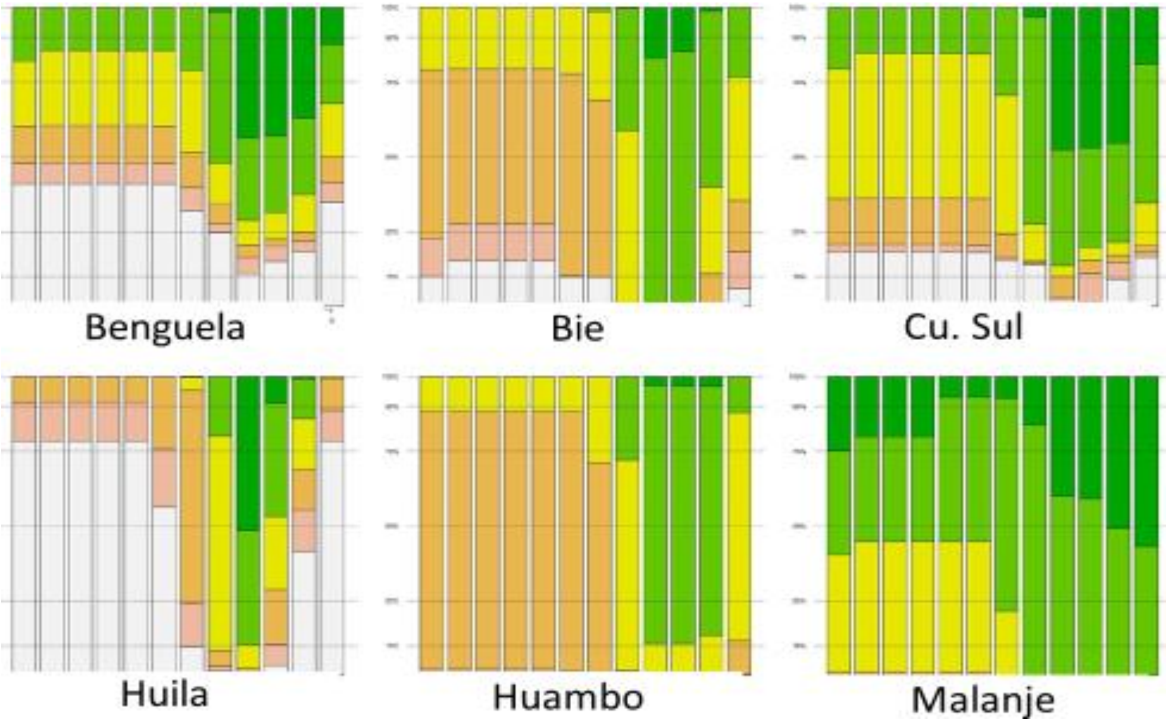

Figure 5.10.2.b Monthly variation in suitability of sorghum, high altitude variety (*Sorghum bicolor* (L) Moench)

6. Climate Risk Analysis and Recommendations

The analyses presented in Chapters 4 and 5, above, describe the current variability in climate and crop suitability across the study area. These analyses aim to guide the identification of appropriate subsistence and cash crops to prioritise in the context of the six provinces assessed in the *planalto* region. However, these analyses should be interpreted as preliminary findings to inform further investigation, rather than an absolute definition of 'suitable' and 'unsuitable' crops in each province. These results will be complemented by further analytical modelling of future climate projections, which will include consideration of multiple scenarios of future climate and the resultant impact on productivity of each of the crops analysed.

However, even in the absence of additional detailed analyses of future climate change projections, the crop suitability analyses presented in Chapter 5 can be interpreted in the context of existing predictions for climate change in Angola. As described in Chapter 2, "Angola will experience increased temperatures, more extreme weather events, an expansion of arid and semi-arid regions,…increased rainfall in the north". These effects of climate change will result in diverse impacts on agriculture including *inter alia*: crop failures due to heat and drought stress, production losses due to unpredictable onset of rains, reduced planting area due to consumption of seed stores, and increased susceptibility to pests and disease.

The maps of suitability presented for each crop in Section 5 provide a useful indication of current and future climate risks. For example, the arid and semi-arid regions in the south of Huila and the western lowlands of Benguela/Cuanza Sul are consistently noted to be the limit of the suitable range of most crops analysed. It is anticipated that future climate scenarios for Angola will become increasingly similar to the high summer temperatures and extended dry season that characterise the southern and western extents of the project area. As a result, the spatial range of suitability for a number of climate-sensitive crops such as coffee, maize and plantain bananas is likely to be reduced in low-lying, coastal and southerly parts of the study area. An additional effect of climate change on some crops will be to reduce the potential range of growing seasons, particularly in the case of maize. In these regions, the primary options for adaptation include promotion of improved, climate-resilient cultivars and the promotion of alternative cereal crops such as millet or sorghum. A final impact of climate change that is likely to reduce the productivity of certain of the crops analysed is increased incidence of pests and disease. In the case of cassava, sweet potato and banana, there are multiple soil-borne pathogens that may become more frequent or severe as a result of climate change. For example, crops are likely to be more vulnerable to *Fusarium* or *Phyophthora* as a result of increased temperature and humidity, or as a result of waterlogging during periods of prolonged rainfall.

Despite the potential negative impacts of climate change, Angola's *planalto* region nevertheless has extensive and diverse agricultural potential, with multiple opportunities to be explored in each province. As a result of the complexity of results to be interpreted (eight crops in six provinces), the analysis of crop suitability and potential climate risks are presented tabulated formats. The potential suitability, climate risks, adaptation options and opportunities for promotion of each crop are summarised in Tables 6.1 – 6.6, below, categorised according to province. In addition to the crop- and province-specific recommendations detailed below, potential adaptation options to be considered for Angola's agriculture sector may include *inter alia* promotion of rural finance, development of irrigation infrastructure, increased access to extension services, development of early warning systems, and development of rural transport infrastructure. These summaries are presented as preliminary recommendations, to be complemented by additional detailed analyses of climate change projections in a future report.

Table 6.1 Benguela – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Extensive areas of moderate suitability.	**Moderate** Increased temperature may reduce productivity due to plant stress. Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens. Increased temperature may increase spoilage of tubers and flour.	Widespread staple crop, generally considered to be climate-resilient relative to other rainfed staples. Comparatively less vulnerable to unpredictable rainfall. Can be harvested at any time to meet short-term food security needs.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of improved post-harvest storage and processing.
Coffee *robusta*	Extensive areas of marginal to moderate suitability in the interior highlands.	**Moderate** Vulnerable to increased heat stress and drought. Suitable area may be reduced due to increased temperature at low altitudes.	Considerable area with suitable potential which is currently underexploited.	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties of robusta and arabica in the same production areas to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Coffee *arabica*	Extensive areas of marginal to moderate suitability in the interior highlands.		Already widely grown, considerable potential for expansion.	
Sugar cane	Some areas of marginal to moderate suitability.	**Low**	Prioritise engagement with private sector to support research & development, strengthening of value chain.	
Sweet potato	High to excellent in the interior, unsuitable in the arid lowlands and coastal region.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Promote as a climate-resilient, easily grown perennial crop (particularly as an alternative or complement to cassava). Promotion of improved post-harvest storage and processing.	
Banana	Extensive areas of marginal to moderate suitability for Cavendish table banana and cooking plantain.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in low-lying areas.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research &

		Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.		development, strengthening of value chain.
Maize	Extensive areas of high to excellent suitability for all varieties of maize in interior midlands and uplands. Unsuitable in the arid lowlands and coastal region. Planting season is limited to October – November.	**Moderate to high** Particularly vulnerable to variability in onset and duration of rainy season, drought.	N/A	Promotion of improved drought-tolerant varieties. Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Extensive areas of good to high suitability in interior midlands and uplands. Marginally suitable in the arid lowlands and coastal region during the late rainy season (December – January).	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Large potential area of high suitability, noted as climate-resilient alternative to maize.	
Sorghum				

Table 6.2 Bie – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Poor – EcoCrop indicates no suitable areas.	N/A Not recommended for this province	Promotion of sweet potato as a perennial starch-rich alternative.	Promotion of sweet potato.
Coffee *robusta*	Mostly or totally unsuitable.	N/A Not recommended for this province	Promotion of *arabica* coffee or other subtropical crops e.g. banana, sugarcane.	
Coffee *arabica*	Extensive areas of marginal to moderate suitability.	**Low to moderate** Vulnerable to increased heat stress and drought. Less vulnerable to temperature increases than Cuanzal Sul and Benguala.	Already widely grown, considerable potential for expansion	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Sugar cane	Some areas of marginal to moderate suitability.	**Low**	Prioritise engagement with private sector to support research & development, strengthening of value chain.	
Sweet potato	Excellent throughout the province.	**Low**	Promote as a climate-resilient, easily grown perennial crop (particularly as an alternative or complement to cassava). Promotion of improved post-harvest storage and processing.	
Banana	Extensive areas of marginal to moderate suitability for Cavendish table banana, unsuitable for cooking plantain, marginal suitability for hybrid plantain.	**Low to moderate** Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research & development, strengthening of value chain.
Maize	Extensive areas of moderate, high and excellent suitability for all varieties of maize. Potential planting season of September – November.	**Moderate to high** Particularly vulnerable to variability in onset and duration of rainy season, drought.	N/A	Promotion of improved drought-tolerant varieties. Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Good to high suitability throughout the province.	**Low**	Large potential area of high suitability, noted as	
Sorghum				

Crop	Suitability	Climate risks	Opportunities	Adaptation options
			climate-resilient alternative to maize.	

Table 6.3 Cuanza Sul – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Extensive areas of moderate suitability.	**Moderate** Increased temperature may reduce productivity due to plant stress. Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens. Increased temperature may increase spoilage of tubers and flour.	Widespread staple crop, generally considered to be climate-resilient relative to other rainfed staples. Comparatively less vulnerable to unpredictable rainfall. Can be harvested at any time to meet short-term food security needs.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of improved post-harvest storage and processing.
Coffee *robusta*	Extensive areas of marginal to moderate suitability in the interior highlands.	**Moderate** Vulnerable to increased heat stress and drought. Suitable area may be reduced due to increased temperature at low altitudes.	Already widely grown, considerable potential for expansion.	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties of robusta and arabica in the same production areas to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Coffee *arabica*	Extensive areas of marginal to moderate suitability in the interior highlands.			
Sugar cane	Some areas of marginal to moderate suitability.	**Low**	Prioritise engagement with private sector to support research & development, strengthening of value chain.	
Sweet potato	High to excellent in the interior, unsuitable in the arid lowlands and coastal region.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Promote as a climate-resilient, easily grown perennial crop (particularly as an alternative or complement to cassava). Promotion of improved post-harvest storage and processing.	
Banana	Extensive areas of marginal to moderate suitability for Cavendish table banana, marginal suitability for cooking plantain, marginal suitability for hybrid cooking plantain.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in low-lying areas.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research &

Crop	Suitability	Climate risks	Opportunities	Adaptation options
		Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.		development, strengthening of value chain.
Maize	Extensive areas of high to excellent suitability for all varieties of maize in interior midlands and uplands. Unsuitable in the arid lowlands and coastal region. Planting season is limited to October – November.	**Moderate to high** Vulnerable to variability in onset and duration of rainy season, drought in low-lying areas.	N/A	Promotion of improved drought-tolerant varieties. Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Extensive areas of good to high suitability in interior midlands and uplands. Marginally suitable in the arid lowlands and coastal region during the late rainy season (December – January).	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Large potential area of high suitability, noted as climate-resilient alternative to maize.	
Sorghum				

Table 6.4 Huambo – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Poor – EcoCrop indicates no suitable areas.	N/A Not recommended for this province	Promotion of sweet potato as a perennial starch-rich alternative.	
Coffee *robusta*	Mostly or totally unsuitable.	N/A Not recommended for this province	Promotion of *arabica* coffee or other subtropical crops e.g. banana, sugarcane.	
Coffee *arabica*	Extensive areas of marginal to moderate suitability.	**Low to moderate** Vulnerable to increased heat stress and drought. Less vulnerable to temperature increases than Cuanzal Sul and Benguela.	Already widely grown, considerable potential for expansion	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Sugar cane	Extensive areas of marginal to moderate suitability.	**Low**	Prioritise engagement with private sector to support research & development, strengthening of value chain.	
Sweet potato	Excellent throughout the province.	**Low**	Promote as a climate-resilient, easily grown perennial crop (particularly as an alternative or complement to cassava). Promotion of improved post-harvest storage and processing.	
Banana	Extensive areas of marginal to moderate suitability for Cavendish table banana. Unsuitable for plantain production.	**Low to moderate** Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research & development, strengthening of value chain.
Maize	Extensive areas of moderate, high and excellent suitability for all varieties of maize. Potential planting season of September – November.	**Moderate** Vulnerable to variability in onset and duration of rainy season, drought.	N/A	Promotion of improved drought-tolerant varieties. Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Good to high suitability throughout the province.	**Low**	Large potential area of good suitability, noted as a	
Sorghum				

Crop	Suitability	Climate risks	Opportunities	Adaptation options
			climate-resilient alternative to maize.	

Table 6.5 Huila – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Mostly poor, except for some marginal areas in the north-west.	See comments for Huambo		
Coffee *robusta*	Mostly or totally unsuitable.	N/A Not recommended for this province	Promotion of *arabica* coffee or other subtropical crops e.g. banana	
Coffee *arabica*	Extensive areas of marginal to moderate suitability in the interior highlands.	**Moderate to high** Vulnerable to increased heat stress and drought. Suitable area may be reduced due to increased temperature, drought in southern regions.	Already widely grown, considerable potential for expansion	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Sugar cane	Mostly or totally unsuitable.	N/A	Promotion of subtropical crops e.g. coffee, banana	
Sweet potato	High to excellent in the northern and western uplands, unsuitable in the arid lowlands and south.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Promote as a climate-resilient, easily grown perennial crop (particularly as an alternative or complement to cassava). Promotion of improved post-harvest storage and processing.	
Banana	Totally unsuitable for production of plantain varieties, marginal suitability for Cavendish table banana in the centre and north of province.	**Moderate** Suitable range may be reduced by temperature increases and drought in the south. Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research & development, strengthening of value chain.
Maize	Isolated areas of high to excellent suitability for all varieties of maize in the northern and western uplands, moderate to marginal	**Moderate to high** Vulnerable to variability in onset and duration of rainy season, drought,	N/A	Promotion of improved drought-tolerant varieties.

	suitability in the centre. Planting season is limited to October – November.	particularly in low-lying southern areas.		Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Extensive areas of good to high suitability in northern and western interior. Marginally suitable in the arid southern region.	**Low to moderate** Considered to be climate-resilient, however suitable range may be reduced by temperature increases and drought in the south.	Large potential area of good suitability, noted as a climate-resilient alternative to maize.	
Sorghum				

Table 6.6 Malanje – Crop suitabilities, climate risks and adaptation options

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Cassava	Extensive areas of suitability	**Moderate** Increased temperature may reduce productivity due to plant stress. Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens. Increased temperature may increase spoilage of tubers and flour.	Widespread staple crop, generally considered to be climate-resilient relative to other rainfed staples. Comparatively less vulnerable to unpredictable rainfall. Can be harvested at any time to meet short-term food security needs.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of improved post-harvest storage and processing.
Coffee *robusta*	Extensive areas of marginal to moderate suitability.	**Low to moderate** Vulnerable to increased heat stress and drought. Temperature increases may reduce the suitable range in the southwest.	Already widely grown, considerable potential for expansion.	Prioritise engagement with private sector to support research & development, strengthening of value chain. Promotion of multiple varieties of robusta and arabica in the same production areas to reduce exposure to unknown climate risks. Promotion of shade trees and other forms of intercropping and agro-forestry in new coffee plantations.
Coffee *arabica*				
Sugar cane	Extensive areas of moderate to good suitability.	**Low**	Comparatively high suitability relative to neighbouring provinces	Prioritise engagement with private sector to support research & development, strengthening of value chain.
Sweet potato	Highly suitable to excellent throughout the province.	**Low**	Promote as a climate-resilient, easily grown perennial crop. Promotion of improved post-harvest storage and processing.	
Banana	Extensive areas of good to excellent suitability for Cavendish table banana, small areas of marginal suitability for production of plantain varieties.	**Low to moderate** Inundation after heavy rainfall, increase temperature, may increase susceptibility to soil pathogens.	Considerable area with suitable potential which is currently underexploited.	Promotion of pathogen-resistant and water-tolerant cultivars. Promotion of irrigation for plantation-scale producers. Prioritise engagement with private sector to support research & development, strengthening of value chain.

Crop	Suitability	Climate risks	Opportunities	Adaptation options
Maize	Extensive areas of high to excellent suitability for all varieties of maize in a planting season. Potential planting season of September – November.	**Low to moderate** Potentially vulnerable to variability in onset and duration of rainy season, drought. Risk is comparatively less than other provinces as a result of extended rainy season in northern region.		Promotion of improved drought-tolerant varieties. Increase access to weather forecasts and early warnings. Promotion of sorghum, millet as climate-resilient alternatives to maize.
Millet	Good to high suitability throughout the province.	**Low**	Large potential area of high suitability, noted as climate-resilient alternative to maize.	
Sorghum	Excellent suitability throughout the province.	**Low**		

Appendix 1. References

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Appendix 2. Recent Climate Change-related Initiatives in Angola

GEF Initiatives

Project Title:
The LDCF-funded UNDP project Promoting Climate-Resilient Development and Enhanced Adaptive Capacity to Withstand Disaster Risks in Angola's Cuvelai River Basin
Duration: 2014–2017
Cost: US$4,416,210
Description:
This GEF project is a climate change adaptation initiative which addresses climate-related vulnerabilities through on-the-ground investments and capacity building of GoA and local communities. Components of this project include: i) transferring technologies – and related capacity building – for climate and environmental monitoring; ii) enhancing sustainable rural livelihoods; and iii) increasing understanding of climate change adaptation and practices amongst local communities and government. Component 1 of the LDCF project is aligned with the Cuvelai project, which contributes to the development of comprehensive famine and flood early warning systems in the Cuvelai Basin. Lessons learned from the Cuvelai project have been integrated into the design of the LDCF project. Moreover, the LDCF project will be emulating some of the Cuvelai project's early warning interventions in Barra do Dande. The Technical Advisor – who will be giving in-depth technical input to the CCBA under Component 3 and technical oversight on Components 1 and 2 – will be hired on a cost sharing basis between the Cuvelai project and the LDCF project.

Project Title:
Integrating and Up-Scaling Climate Resilience into Agricultural and Agropastoral Production Systems through Soil Fertility Management in Key Productive and Vulnerable Areas Using the Farmers Field School Approach.
Duration: NA
Cost: US$4,416,210
Description:
The FAO climate change adaptation project is currently at PIF stage. The overall objective of the project will be to increase the resilience of small-scale farmers to climate variability and extreme weather events, as well as the consequent degradation of ecosystems. This initiative will be based in the Central Plateau interior of Angola while the LDCF project will be based in the country's coastal areas. However, there are opportunities for engagement and sharing lessons learned between the two projects. In particular, lessons learned from this FAO GEF project will inform the design and implementation of climate-resilient agriculture interventions under Component 2 of the LDCF project.

Project Title:
Enhancing Climate Change Resilience in the Benguela Current Fisheries System.
Duration: 2012–2017
Cost: US$4,725,000
Description:
This FAO project is a GEF LDCF-funded climate change adaptation project which is currently implementing participatory adaptive strategies to promote food and livelihood security in the coastal regions of Angola. This project consists of four Components: i) integrating fisheries climate change considerations into fisheries policies and planning and into broader inter-sectoral policies and programmes; ii) piloting improved climate-resilient fisheries practices; iii) building capacity and promoting improved climate-resilient fisheries practices; and iv) monitoring and evaluation. Given that they are both implementing interventions in the coastal zone, the LDCF and FAO projects offer many linkages and opportunities for cooperation. During implementation, FAO project managers will

be consulted to promote synergies and avoid duplication of interventions. In particular, LDCF project activities to strengthen institutional capacity of local organisations – such as the Committee of the Environment – will complement similar activities under Component 3 of the FAO project.

Project Title:
Environmental Sector Support Project
Duration: 2010–2015
Cost: US$12,314,814
This is a nation-wide project funded by AfDB, with counterpart funding from GoA. Initially, this project included three components: i) environmental governance, capacity building and institutional strengthening; ii) integrated environmental conservation and natural resource management; and iii) project management. Thereafter, an additional component related to climate change – approved and funded by GEF (Climate Change) – was incorporated into this project. With GEF support, the project includes interventions to strengthen the institutional capacities of the Ministry of Environment (MINAMB), Ministry of Agriculture (MINAG), NGOs and CSOs to manage the effects of climate change. Additionally, the capacity of local communities to adapt to climate change is being strengthened through training, and dissemination of adaption technologies and guidelines. The LDCF project will develop the capacity of the CCG – which is based within MINAMB – to manage climate change adaptation at a national level.

Project Title:
Integrating Climate Change into Environment and Sustainable Land Management Practices
Duration: NA
Cost: US$6,668,182
Description:
The AfDB/GEF LDCF project has three components: i) governance, capacity building and institutional strengthening; ii) integrating climate adaptation measures into Sustainable Land Management (SLM) practices in four demonstration sites – Namibe, Huambo, Kuando Kubango and Cabinda; iii) knowledge management through a coordination mechanism with other projects; and iv) monitoring and evaluation. The LDCF project will undertake EbA and climate-resilient agriculture interventions in Namibe and Cabinda. These interventions will align with the SLM interventions of the AfDB project.

Project Title:
Umbrella Programme for National Communication to the UNFCCC
Duration: NA
Cost: US$11,330,000
Description:
This UNEP GEF-LDCF project will strengthen the capacity of the institutions involved in the development of national communications on climate change. Moreover, this initiative will enhance the base of information related to climate change and adaptation. Strengthened capacity and an enhanced knowledge base will support the integration of adaptation priorities into development strategies and programs. Additionally, the programme will promote best practices for disseminating information on climate change amongst national and sub-national institutions. Through Component 3 of the LDCF project, the technical and institutional capacity of the GoA to manage climate change – including integrating adaptation into national policies and plans – will be strengthened. Therefore, the LDCF project is aligned with the Umbrella Programme. During implementation, stakeholders from this programme will be consulted to avoid duplication of capacity-building activities.

Project Title:
Assisting Least Developed Countries (LDCs) with Country driven Processes to Advance National Adaptation Plans (NAPs)
Duration: NA

Cost: US$1,998,000

Description:

The UNDP/UNEP GEF-LDCF funded project will strengthen policies and institutional capacities at national and decentralised levels in multiple LDCs, with the objectives of promoting long term adaptation planning and therefore low carbon and climate-resilient human development through initiating the NAP process.

Project Title:

Expanding the Ongoing Support to Least Developed Countries (LDCs) with Country-driven Processes to Advance the National Adaptation Plans (NAPs)

Duration: NA

Cost: US$6,200,000

Description:

The UNDP/UNEP-LDCF project will strengthen the institutional and technical capacities of LDCs to start and/or advance their NAP process. This will be achieved by enhancing the capacity of participating countries to advance both medium- and long term adaptation planning in the context of national development strategies and budgets. These activities of these NAP projects will harness and make available the tools and approaches needed to support and implement elements of the NAPs, with a particular emphasis on planning for long-term climate change trends within ongoing national planning. This LDCF project will complement both aforementioned projects – that support adaptation planning in the medium and long term – by increasing the capacity of the GoA to adapt to the immediate and short-term effects of climate change, particularly by responding to the priorities outlined in the NAPA.

Project Title:

Land Degradation)/LDCF project Land Rehabilitation and Rangelands Management in Smallholders Agro-pastoral Production Systems in South Western Angola

Duration: NA

Cost: US$3,013,636

Description:

The objective of this FAO GEF is to enhance the capacity of South Western Angola's small holders' agro-pastoral sector to mitigate the effects of land degradation. This objective will be achieved by mainstreaming SLM practices into agro-pastoral and development initiatives. The LDCF project will be informed by lessons learned from the FAO project's integration of SLM into local initiatives.

Non-GEF-projects

Project Title:

Local Development Project (FAS)

Duration: 2010–2015

Cost: US$121,700,000

Description:

Funded by the GoA, this project has three components: i) increasing poor households' access to improved social and economic infrastructure by financing the rehabilitation and construction of basic public works and municipal grants; ii) promoting Local Economic Development by developing business skills and participation in markets of selected producer groups; and iii) strengthening capacity of local institutions, public entities and civil society to plan, manage and monitor basic public service delivery and expenditure. The FAS is being implemented in 17 provinces, four of which are provinces where the intervention sites for the proposed LDCF project are located – Bengo, Namibe, Cabinda and Kwaza Sul. The LDCF project will also promote food security and environmental infrastructure in these coastal provinces through EbA and climate-resilient agriculture activities.

Project Title:
The Climate for Development in Africa Programme (ClimDev-Africa)
Duration: 2012–2014
Cost: €14 million
Description:
The Climate for Development in Africa Programme) is a joint initiative of the Commission of the African Union (AUC), the AfDB and the United Nations Economic Commission for Africa (UNECA). Through the ClimDev-Africa, regional, sub-regional and national policy capacity will be strengthened by: i) building science and observation infrastructure; ii) enhancing working partnerships between public, private and civil society sector and vulnerable communities; and iii) creating and strengthening knowledge frameworks. The LDCF project is aligned with ClimDev-Africa in that it builds on existing climate monitoring infrastructure in Angola. Improved collection of climate data in Angola will enhance the regional understanding of climate change. Additionally, Component 1 of the LDCF project will enhance the national understanding of climate change vulnerability through a detailed vulnerability assessment of the coastal zone. This will contribute to the national repository of knowledge about climate change vulnerability and adaptation responses and will be shared with other LDCs through AAKNET under Component 4 of the LDCF project.