Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda

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Putting nitrogen fixation to work for smallholder farmers in Africa

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1. Introduction

As part of the supplementary grant received from the Bill & Melinda Gates Foundation, N2Africa is exploring the opportunities for extension of the project to Ethiopia, Uganda and Tanzania. For each of these countries, relevant background information on the importance of grain legumes, past research on legume agronomy and farming systems, as well as ongoing projects around grain legumes is gathered. This will increase N2Africa's relevance by building on key issues raised from these previous experiences. The activity falls under Milestones S 1.2.1 – 1.2.3: Prepare review and background of previous relevant agronomic, farming systems and market research in each country. This report provides background information for Uganda.

The report starts with general information on economy, poverty and malnutrition in Uganda in Chapter 2, followed by a characterization of Uganda's agriculture in Chapter 3. Chapter 4 presents information on relevant grain legumes in Uganda (common bean, groundnut, cowpea and soybean) and results of previous research on these crops. Chapter 5 lists ongoing projects around grain legumes in Uganda.

2. General characteristics

Uganda is a landlocked country in Eastern Africa, lying between latitude 4°12'N and 1°29'S and longitude 29°34'W and 35°0'E. The country occupies 241,038 km² and has a population of about 35 million inhabitants, of which 80% lives in rural areas. Population growth is high, with a rate of 3.4% per annum and an average fertility rate of 6.7 children per woman (NEMA, 2010). The share of agricultural production of total GDP has declined over the past years and growth of the agricultural sector has stagnated. Agriculture still accounts for 85% of export earnings, and 77% of total employment, however (Kabeere and Wulff, 2008). Moreover, agriculture contributes for about 40% to the manufacturing sector through food processing (NEMA, 2010). Especially among women, agriculture is an important sector: nearly 85% of economically active women in Uganda work in the agricultural sector, producing almost 75% of the country's agricultural output. Per capita income in Uganda is slightly lower than in neighbouring Kenya and Tanzania, and more people live below the poverty line than in Kenya (Table 1). Stunting, wasting and underweight prevalence is comparable to Kenya and Tanzania, but the mortality rate of children under five years old is also relatively high.

Table 1: Selected development indicators

	Uganda	Kenya	Tanzania	Source
Population (thousands)	34 509	38 765	46 219	UNDP (2011)
Gross net income (US$ per capita, PPP)	1 190	1 580	1 360	Worldbank (2011)
Population below poverty line[1] (%)	25	20	33	Worldbank
GDP (billion US$)	16.0	34.5	21.4	Worldbank
Agriculture (%GDP)	25	21	29	Worldbank
Children under 5 (thousands)	6 182	6 540	7 566	UNICEF (2009)
Stunting prevalence (%)	39	35	44	UNICEF (2009)
Children stunted (thousands)	2 355	2 269	3 359	UNICEF (2009)
Underweight prevalence (%)	16	21	17	UNICEF (2009)
Wasting prevalence (%)	6	6	4	UNICEF (2009)
Children under 5 mortality rate (per 1000)	128	85	108	Worldbank
Women with low BMI (%)	12	12	10	UNICEF (2009)

[1] Poverty line defined as people living on less than US$ 1.25 PPP per day.

3. Agriculture in Uganda

3.1 Rainfall and agro-ecology

The agro-ecological zones in Uganda are warm arid/semi-arid and sub-humid tropics (FAO/IIASA, 2000). A large part of Uganda consists of a plateau, lying between 1000 and 2500 meters above sea level. Temperatures are moderate, between 15° and 30° C. Precipitation varies from 750 mm to 1500 mm (**Figure 1**). Due to climate change, the onset of the rainy season is increasingly unreliable, and rainfall distribution is more uneven with erratic, heavy rainfall events (NEMA, 2010).

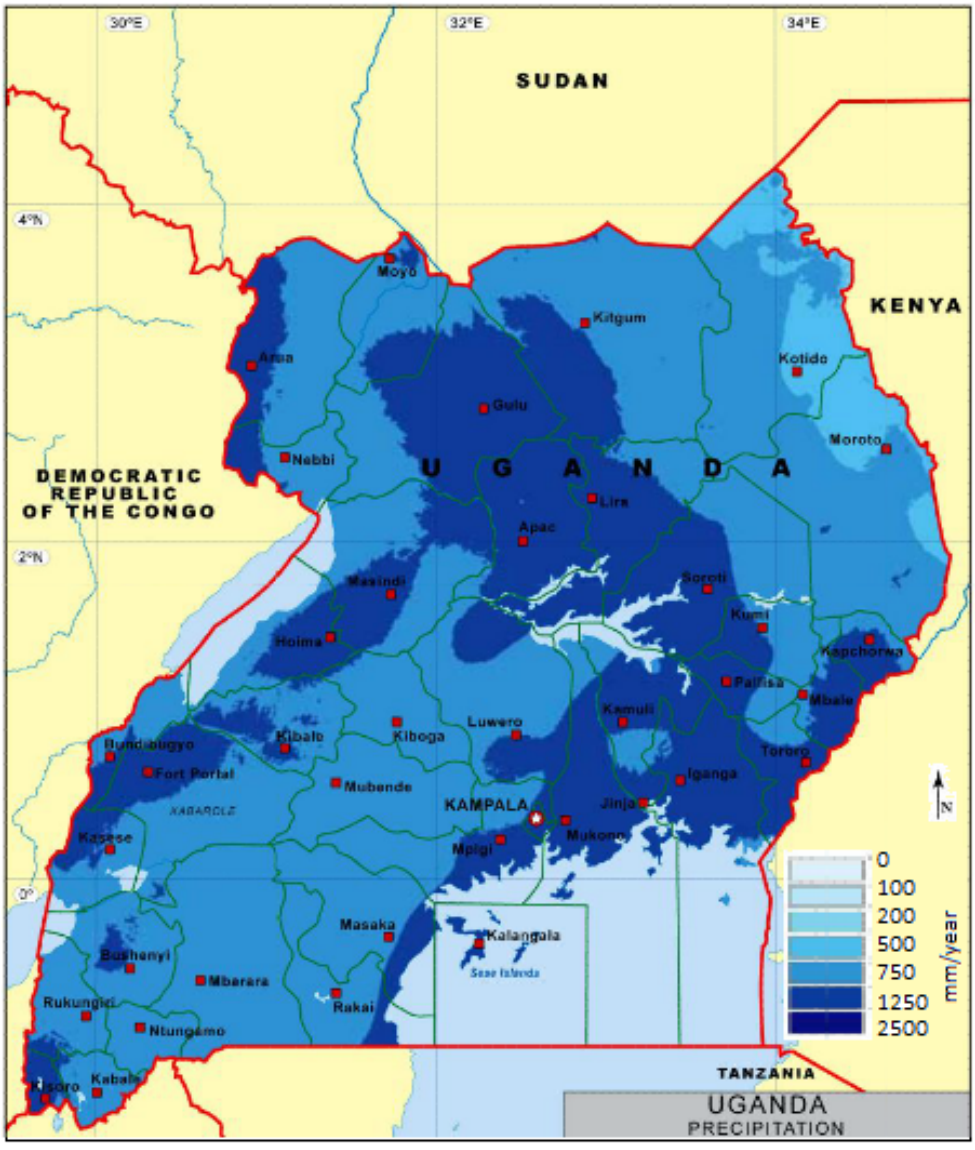

Figure 1: Average annual rainfall in Uganda
Source: World Trade Press (2012)

The central and western parts of the Lake Victoria basin and Mount Elgon are areas with relatively high rainfall. The so called 'cattle corridor' (running from the Karamoja region in the northeast to the Ankole region in the southwest) together with the western Rift Valley are distinct low rainfall areas (NEMA, 2010). In southern Uganda, rainfall is bimodal with a peak during the long rains from March to

May and the short rains from September/ October to December. This pattern allows for two crops per year. Towards the north the pattern changes into one rainy season, with longer dry periods at the end of the season (Kabeere and Wulff, 2008, FAO, 1999).

3.2 Farming systems

Agriculture in Uganda is dominated by smallholder farmers, with an average farm size of 2.5 ha. Many people live of subsistence agriculture, with 70% of the area under cultivation used for production of locally consumed food crops (Mangheni, 2007). Agriculture is mainly rainfed; irrigated agriculture comprises only 0.1% of total cultivated land. Cassava (15.3%), sweet potato (14.6%), and banana (cooking type) (14%) are the most important crops, followed by coffee (12%), maize and beans. Cassava and sweet potato are regarded as food security crops. The major cereal crops are maize, finger millet, sorghum, rice, pearl millet and wheat (for bread in urban areas). Traditional cash crops are coffee, cotton and tea, and to some extent tobacco (Kabeere and Wulff, 2008).

The country can be divided into seven agro-ecological zones/ farming systems, based on FAO (1999) and Kabeere and Wulff (2008) (see also Figure 2):

- The banana-coffee system has rainfall between 1000-1500 mm and soils are of medium to high productivity (although nutrient depletion is a problem). Land holdings are small with an average of 2-4 ha. Livestock is generally not integrated in the system. Crops: Robusta coffee, banana, maize, bean, sweet potato, cassava, horticultural crops, tea, groundnut.
- In the banana-millet-cotton system, rainfall is less stable and annual food crops are more important. Livestock is the main activity in drier areas. Crops: cotton, Robusta coffee, bean, maize. The montane system is found between 1500-1750 m.a.s.l, Population in this area is high with small land sizes of about 1.5 ha. Crops: Arabica coffee (above 1600 m), banana, cotton, maize, bean, wheat, barley, millet, rice, Irish potato, sweet potato, cassava.
- In the *Teso system*, rainfall is bimodal with a longer dry season. Soils are sandy-loams with medium to low fertility. The average farm size is about 3 hectares. Mixed agriculture of crops and livestock is practised, with free grazing of livestock after harvest in the dry season. Due to extensive rustling, nowadays fewer animals are kept. Tethering of livestock is becoming more common which limits the manure input that fields received before in the free grazing system (Ebanyat, 2009). Crops: cotton, finger millet, sorghum, maize, groundnut, sesame (simsim), cowpea, sunflower, sweet potato, cassava.
- Rainfall in the *northern system* is bimodal, but less pronounced, with about 800 mm annually. Rainfall in the far north and north-east of the country is unimodal and below 800 mm, so that only drought tolerant annuals are cultivated. The area is well-known for its semi-nomadic pastoral system. Crops: cotton, tobacco, sesame, finger millet, sorghum, cassava, sunflower.
- The *West Nile system* has similar rainfall to the northern system. Mixed cropping is common with a wide variety of crops. Livestock activities are limited by the presence of tsetse fly. Crops: tobacco, cotton, Arabica coffee, sesame, finger millet, sorghum, cassava, groundnut.
- The *pastoral system* has rainfall below 1000 mm and is characterised by short grassland with nomadic, extensive pastoralism. Crops: finger millet, cassava, sorghum, bean, maize.

As described by e.g. Ebanyat (2009) and Fermont et al. (2008), however, these systems are dynamic, and farmers constantly adjust their strategies to cope with population pressure as well as external political and economic factors. In the Teso system, for instance, cotton and millet are largely replaced by cassava for economic reasons, but also due to declining soil fertility. Traditionally, fallows formed part of the system. With increased pressure on land, cassava is used as 'imitation fallow' on poor fertility soils, as nutrients are recycled in cassava litter.

A more detailed map of Ugandan livelihoods is presented in Appendix 1. Soil types in Uganda are found in Appendix 2.

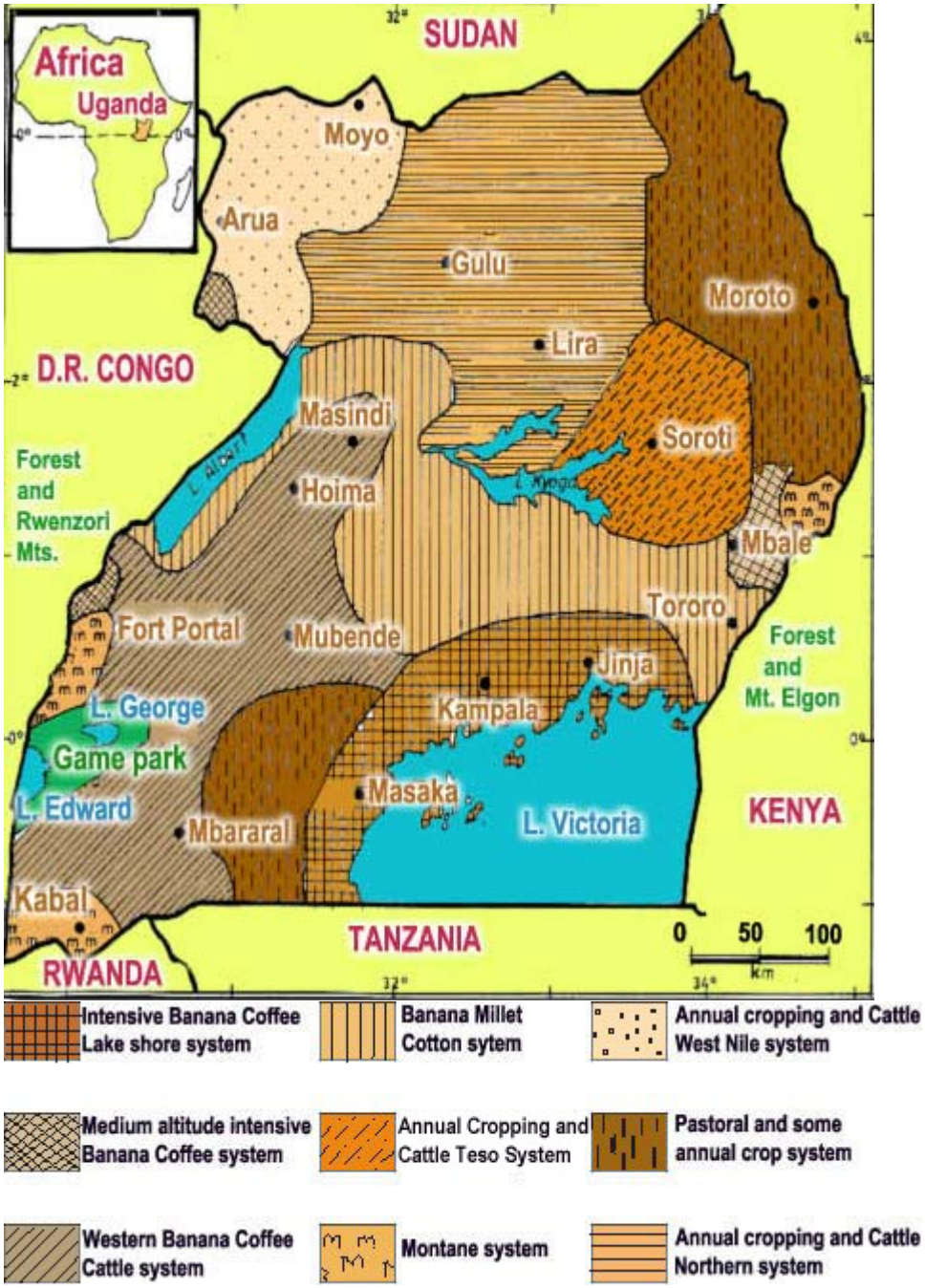

Figure 2: Farming systems in Uganda
Source: FAO (1999)

3.3 Population density and market access

Populations are most dense in districts around Lake Victoria, and in the highlands of the south-western part of the country (). The Eastern region has the highest population density with an average of 143 rural persons per km^2, although locally population densities can be much higher (Figure 3). The districts with the highest population densities coincide with good agricultural potential and high rainfall (Kabeere and Wulff, 2008).

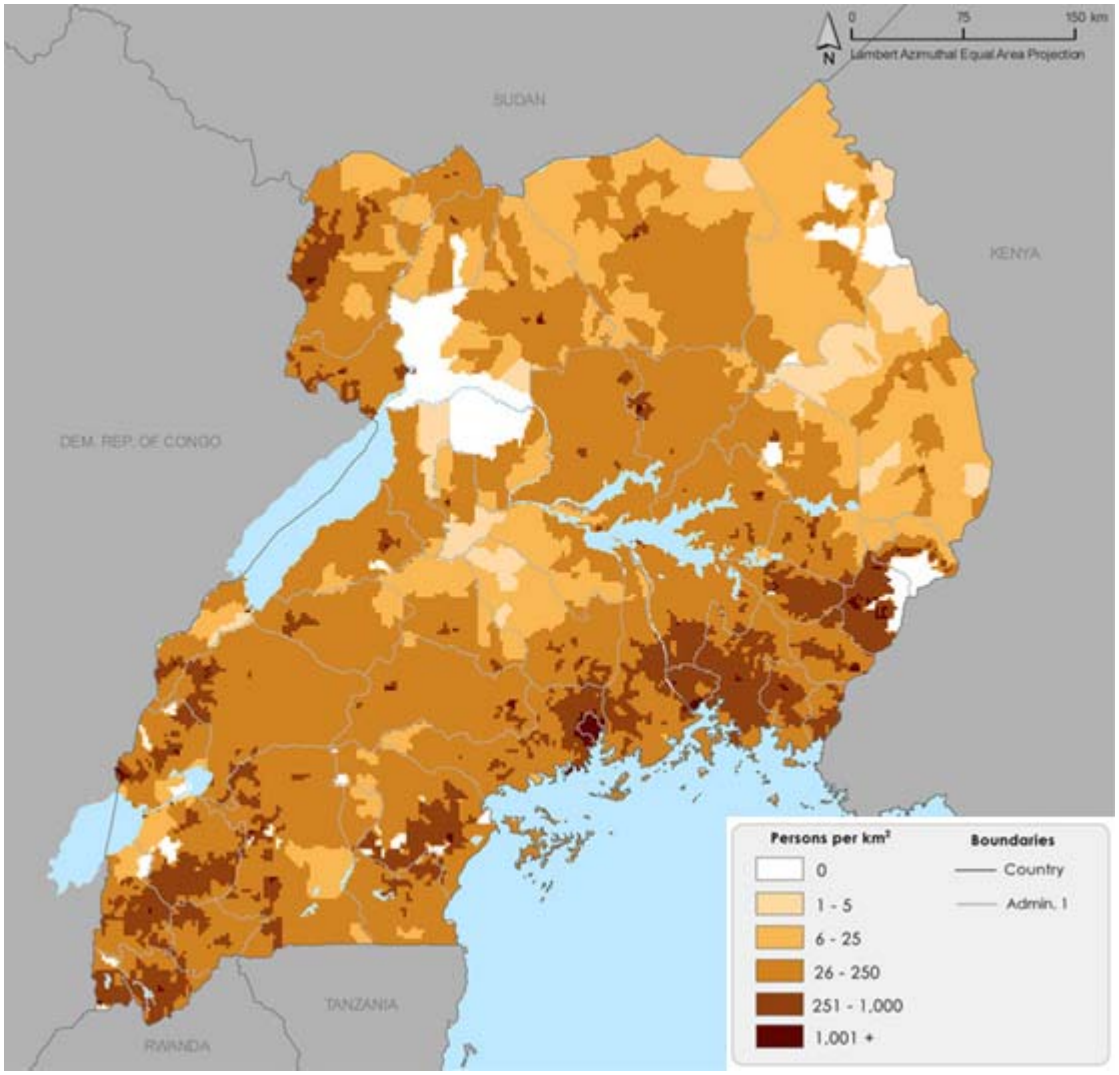

Figure 3: Population densities in Uganda
Source: NASA (2000)

High population densities resulted in land fragmentation, reduced fallow periods and continuous cultivation of land in these areas (NEMA, 2010, Nkonya et al., 2004). At the same time, Benin et al. (2002) found that in Uganda, population pressure and smaller farm sizes are associated with greater use of fertilizer, manure, pesticides, and incorporation of crop residues so high population pressure also leads to intensification of agriculture.

Market access is highest in Lake Victoria crescent, in parts of the highlands and around the highways in the rest of the country (Figure 4).

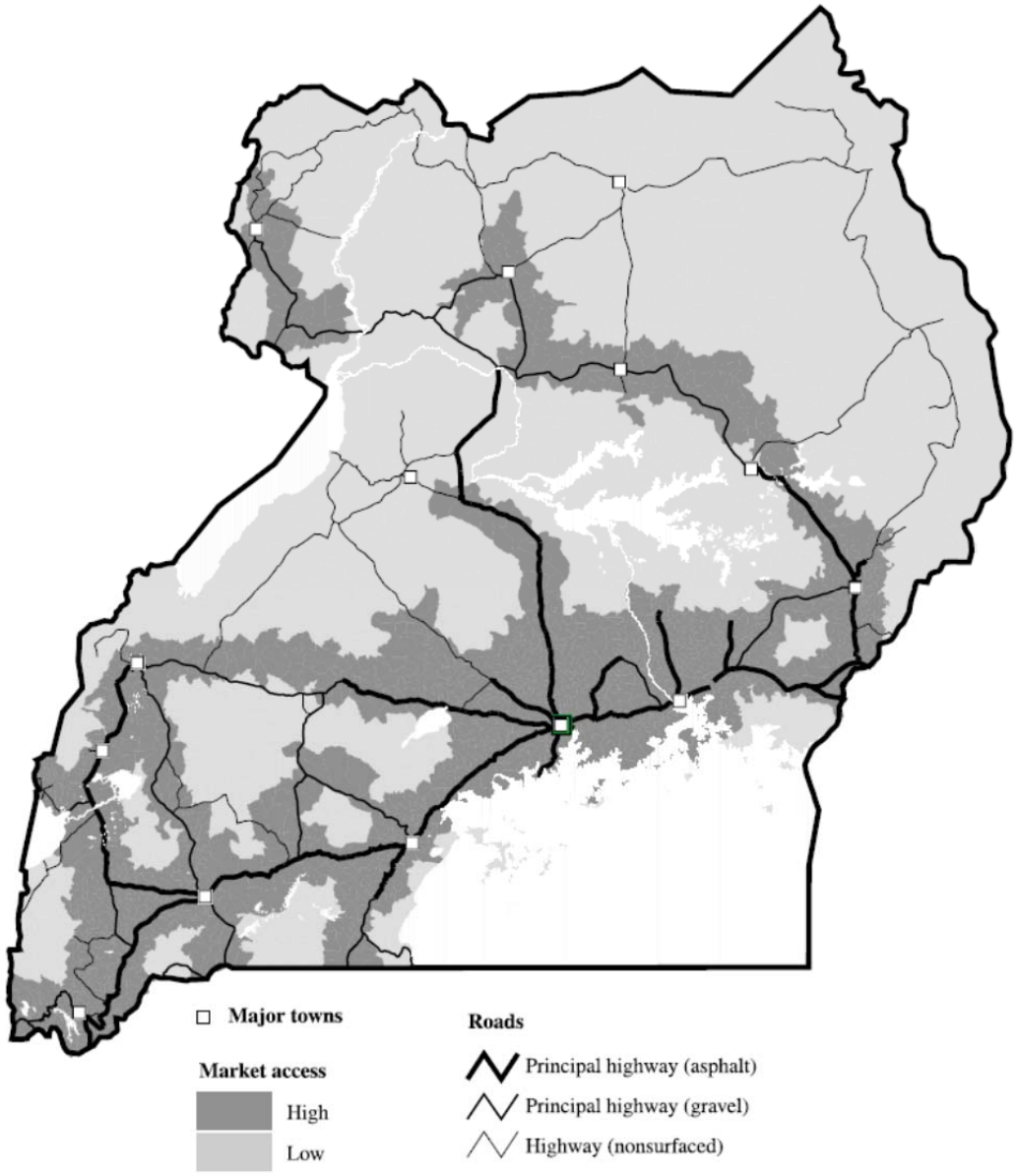

Figure 4: Classification of market access in Uganda
Source: Nkonya et al. (2004)

Access to input and output markets is especially important for cultivation of cash crops. However, market access also increases the opportunities for non-farm income, which is found to have a negative influence on labour investments in agriculture (Nkonya et al., 2004).

3.4 Agricultural productivity

Generally, agricultural productivity in Uganda is low with both crop and livestock yields being a quarter or half of potential yields. Per capita food production is declining despite an increase in acreage (NEMA, 2010). Land degradation is one of the major problems in Ugandan agriculture. Continuous cultivation and low use of external inputs cause soil erosion and nutrient depletion, resulting in diminishing crop yields (Nkonya et al., 2005). Soil erosion and infertile soils are particularly problematic in the Southwestern highlands, Lake Victoria Crescent, the Northwest and the Eastern

highlands as well as the cattle corridor. In these areas N, K and P were estimated to be lost at the rate of 85, 75 and 10 kilograms per hectare per year respectively. Soil erosion is estimated at more than 5 tons per hectare per year (NEMA, 2010). In the drylands, overgrazing has accelerated land degradation and resulted in a decrease of livestock productivity.

Despite ongoing nutrient depletion, fertilizer is estimated to be used by only 10% of smallholder farmers, mainly on maize in the Eastern Highlands. Fertilizer use averaged over the country is only 1 kg/ha (Benin et al., 2002). This is also very small compared to other N2Africa countries in the region such as Kenya (29 kg/ha), Ethiopia (13 kg/ha), Mozambique (5 kg/ha) and Zimbabwe (43 kg/ha) (Sanginga and Woomer, 2009). High costs of fertilizer limit its use, and also influence profitability: fertilizer is profitable on fertile soils, but when applied on poor soils it has limited impact and hence limited profitability. A study on legume technologies by (Ebanyat, 2009) concludes that a reduction of 30-40% of P-fertilizer prices (or 15-20% increase in the value of produce) is necessary to make legume technologies profitable.

Other low-cost inputs that could be used such as manure, compost, mulch or the cultivation of legumes are only practiced by a limited number of farmers due to the labour requirements (Nkonya et al., 2004). As a result of low productivity, agricultural production is expanded to marginal areas. Forests and grasslands are converted to agricultural land, particularly in Western Uganda. Low agricultural productivity is addressed in the National Development Plan. The Ugandan government aims to improve access to inputs and for that purpose there are plans to build a phosphate plant, based on local phosphate rock, in Tororo (although it is questionable whether market demand will be sufficient at present) (P. Ebanyat, personal communication).

Another factor limiting productivity is the limited contact that most farmers have with extension services (Nkonya et al., 2005). As part of decentralization of government activities in the 1990s, Uganda also decentralized its agricultural extension services into a farmer-owned and private sector serviced system. The quality of extension services worsened, however, with only 50% of households in Uganda receiving extension support between 1990 and 2000 (Nkonya et al., 2004). Remote areas are hardly reached, and there is a lack of coherence in extension messages (e.g. promotion of use of fertilizer inputs versus a focus on low input technologies such as mulching, legume cover crops, agroforestry, etc). In addition, extension service provision is mainly conducted by men, who could be biased towards fellow men (Okoboi and Barungu, 2012). Benin et al. (2002) show, however, that Ugandan farmers who had been in contact with agricultural extension or training programs were associated with greater adoption of e.g. fertilizer, manure and mulch. They also had greater farm incomes and reduced erosion compared with farmers not reached by extension services.

Finally, the high HIV/AIDS prevalence in Uganda negatively influences agricultural productivity. In 2008 6.4% of the population was affected, whereas in 1992 this was 18% (NEMA, 2010). Prevalence is higher among women than men, and nearly 80% of those infected are between 15 and 45 years old (the most economically productive group). This has a huge impact on future labour availability, and an increasing number of households is headed by children. Impacts of HIV/AIDS on farming systems include a reduction in cultivated land and the variety of crops grown, a switch from cash to food crops and a preference for less labour-intensive crops. Moreover, agricultural knowledge and experience is lost and labour costs rise due to labour shortages. In addition, cash constraints of these households decrease the amount of money spent on agricultural inputs and equipment. Adoption of improved agronomic practices is also lower among households affected by HIV/AIDS due to labour constraints. This all has a negative impact on crop yields, household food security and cash income (NEMA, 2010, Mangheni, 2007).

4. Grain legume production in Uganda

The most important grain legumes in Uganda are beans, followed by groundnut, soybean, cowpea and pigeonpea (Table 2). The country is among the top-10 producers of cowpea and common bean in the world. About 1.5 million ha is cultivated with grain legumes and beans occupy the largest share by far with almost one third of the total area. Groundnuts are grown on about 17% of the land under legume production. Yields per ha fall below the potential production of e.g. 3 t/ha for groundnut (Kaizzi et al., 2012), 1.5 to 3 t/ha for cowpea (Nabirye et al., 2003) and 4 t/ha for common bean (IFPRI, 2010). Soybean shows the most favourable productivity, while beans and chickpea have average yields of only 0.5 t/ha. According to FAO statistics import of grain legumes is limited to groundnuts, but in reality this is probably more.

Appendix 3 shows, for instance, that a large flow of beans is imported from DRC. Cross-border export of beans from Uganda is mainly to Kenya and South Sudan.

Table 2: Production, area cultivated, yield/ha and import of grain legumes in Uganda (2009)

	Production (Mt grain)	Area cultivated (ha)	Yield (t/ha)	Import (t) in 2007
Beans	452 000	925 000	0.5	0
Soybean	180 000	150 000	1.2	0
Cowpea	84 000	77 000	1.1	nd
Groundnut	185 000	253 000	0.7	1 000
Chickpea	4 000	8 000	0.5	nd
Pigeonpea	91 000	90 000	1.0	nd
Total	996 000	1 503 000		
Ranking of producers in the world	Beans 9th Cowpea 8th			

nd: no data
Source: FAOSTAT, 2011

The production of most legumes has remained rather stable over the last ten years (Figure 5). Only common bean and groundnut show a slight increase since 2006 according to the statistics.

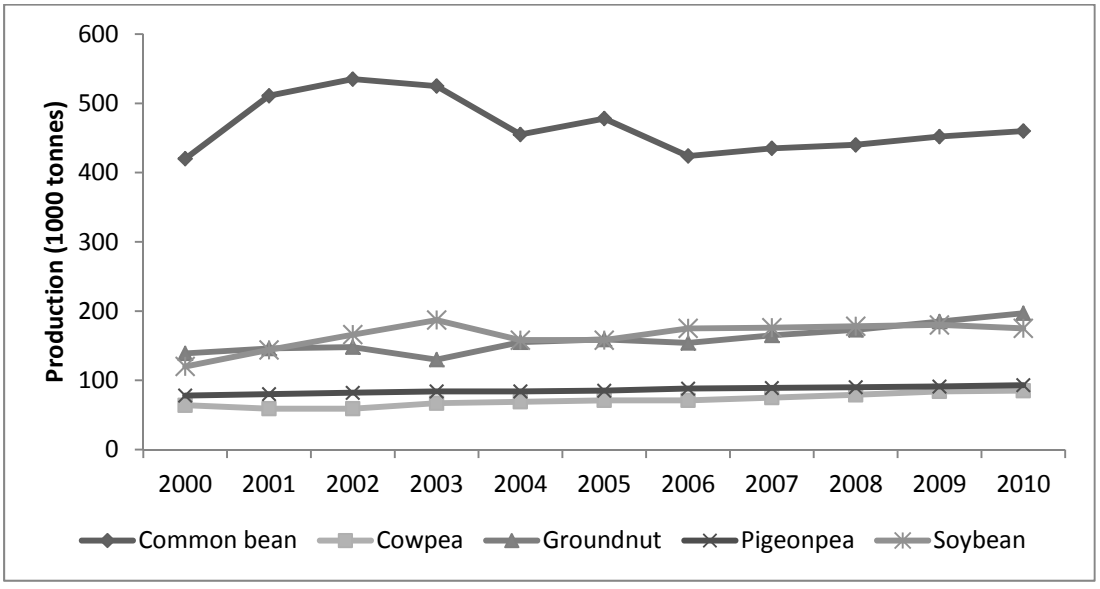

Figure 5: Production of major grain legumes in Uganda, 2000-2010
Source: FAO (2012)

4.1 Common bean

Beans form part of the traditional diet in Uganda and provide 15% of the protein sources of Ugandan families, compared with e.g. 3% by groundnut and 1% by cowpea (Kabeere and Wulff, 2008). Beans are produced throughout the country, but the main production area is the Western region (Table 3).

Table 3: Area and production of beans per region (2008/2009)*

Region	Area (ha)	Production (Mt)	Yield (Mt/ha)
Central	121,000	167,000	1.4
Eastern	108,000	99,000	0.9
Northern	147,000	251,000	1.7
Western	242,000	412,000	1.7
Uganda	**618,000**	**929,000**	**1.5**

* Data differs from Table 2 (different year and different source)
Source: UBOS (2010)

Bean production has remained more or less stable since 2006, but decreased compared to the period 2001-2003. The area harvested shows an increasing trend over the past decade, indicating that production per ha actually decreased (Figure 6).

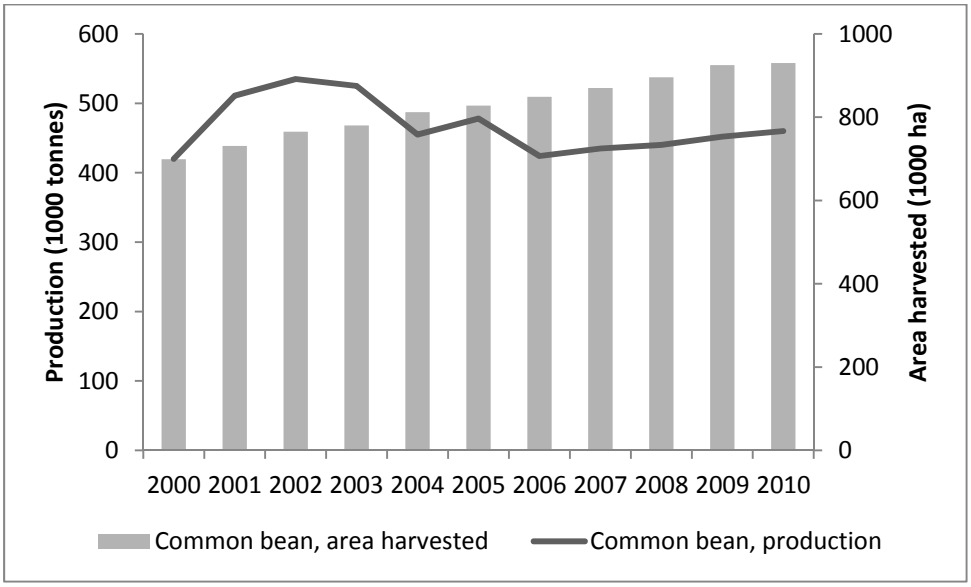

Figure 6: Production and area harvested of common bean in Uganda
Source: FAO (2012)

Beans are mostly grown as intercrops (on 2/3rd of the total plots planted with beans) with maize, cassava, cotton, bananas and groundnuts (CIAT, 2008). The mean plot size for beans is 0.3 ha. About one third of the beans produced is sold, another third is grown for consumption and the remainder is stored or used for other purposes (UBOS, 2010). There is a demand for varieties that are more suitable for export, e.g. varieties that can be used for canning. In most of Uganda, beans are planted twice a year around March/April and in August/September (Table 4).

Table 4: Characteristics of bean cropping systems in bean production areas in Uganda

Region	Major cropping systems	Sowing times	Production intensity
South-west Highlands	Sorghum, sole crop, roots and tubers	April, October	High
Western Highlands	Maize, sole crop, bananas	March, September	Medium
Mt. Elgon	Maize, sole crop, bananas	March, August	Very high
North Central	Sole crop, maize, roots and tubers	April, July	Medium
NW Tall Grass Zone	Maize, sole crop, roots and tubers	April, August	High
C and E Tall Grass Zone	Maize, bananas, sole crop	March, September	Medium
W Short Grass Zone	Sole crop, maize, roots and tubers	March, September	Medium
N Short Grass Zone	Sole crop, roots and tubers, maize	March, July	Low

Source: Wortmann et al. (1998)

The majority of bean cultivation in Uganda (80-95%) is the responsibility of women. Only on Mt. Elgon, 40% of bean production is under the responsibility of men (Wortmann et al., 1998). This is also an area where climbing beans are popular. Traditionally, cultivation of climbing beans was limited to high altitude areas (the South-west Highlands and the slopes of Mt. Elgon), but mid-altitude climbers (MACs) are introduced under the national bean programme in the Western Highlands (around Kabarole) as well. In addition, the NGO Sasakawa has trials with MACs around Gulu and Lira (Northern Region). The main stakes used are bamboo or *Eucalyptus*. *Calliandra* was promoted as staking material as well, in combination with erosion control, and e.g. in Southwestern Uganda this works well. In other areas, however, staking material is problematic (M. Abang, M. Ugen, personal communication).

Currently, climbing beans constitute 20% of the total land area under bean cultivation. Climbing beans in Uganda are grown in pure stands or intercropped with maize (CIAT, 2008). Compared with bush bean, climbing beans are less susceptible to diseases and are more productive. Higher productivity also means, however, that with low external inputs more nutrients are removed from the soil. Wortmann (2001) compared nutrient balances of uninoculated bush bean and climbing bean in rotation with sorghum in south-west Uganda, and indeed nutrient balances were more negative for climbing than for bush bean when the whole plant (pods and stovers) was removed from the field. As fallen leaves were not taken into account, however, the addition of N may have been larger for climbing bean than for bush bean when stover was left in the field.

Small amounts of inputs are found to improve bean yields considerably. An increase in grain yield of 0.77 t/ha was found with application of 15 kg N/ha, and an additional yield increase of 0.15 t/ha with application of 15 kg P/ha (Kaizzi et al., 2012). These quantities applied were shown to be profitable, considering high fertilizer prices in the country. In general, phosphorus is the most limiting nutrient in most of the bean producing areas in Uganda.

4.2 Groundnut

Groundnut is the second most important pulse crop in Uganda and is grown in most regions of the country (Kabeere and Wulff, 2008). The largest areas cultivated with groundnut are found in the Northern and Eastern region (Table 5).

Table 5: Area and production of groundnut per region (2008/2009)*

Region	Area (ha)	Production (Mt)	Yield (Mt/ha)
Central	27,000	33,000	1.2
Eastern	122,000	77,000	0.6
Northern	137,000	83,000	0.6
Western	59,000	51,000	0.9
Uganda	**345,000**	**245,000**	**0.7**

* Data differs from Table 2 (different year and different source)
Source: UBOS (2010)

In North and Eastern Uganda groundnut is grown on light, loose and sandy soils, whereas in Southern Uganda it is grown on clay loams. The latter region has two rainy seasons per year, which allows a double harvest of groundnuts (in July and in November/December). Groundnut is grown as intercrop with maize and cassava or as sole crop. Bunchy types are generally preferred since they are early maturing and easier to harvest, although spreading types are grown as well (Okello et al., 2010). Groundnut is mainly grown by smallholder farmers as source of both food and cash income. One third of the national production is used for consumption and one third is sold. Leaves and haulms are often used as animal feed. (Ebanyat, 2009) concludes that farmers often prefer to grow groundnut on less fertile soils, although biomass production was highest on more fertile soils.

Production per ha is low and the slight increase in production in the past years has mainly been the result of an increase in area under production ()Figure 7). Constraints for production include diseases, pests, droughts and lack of improved varieties. Furthermore, high levels of aflatoxins negatively influence the suitability of groundnut for regional and international markets (NARL, 2012). Farmers mention lack of access to improved seeds, lack of credit and lack of information on new varieties as major constraints for adoption of improved varieties (Kassie et al., 2011). Nkwiine and Rwakaikara-Silver (2007) report an increase of 80% of groundnuts yield with inoculation and rock phosphate in Uganda. According to (Ebanyat, 2009), however, groundnut grown on both poor and fertile soils responded only moderately to application of P-fertilizer. The amount of N_2-fixed did increase with P-fertilizer, especially on poorer soils.

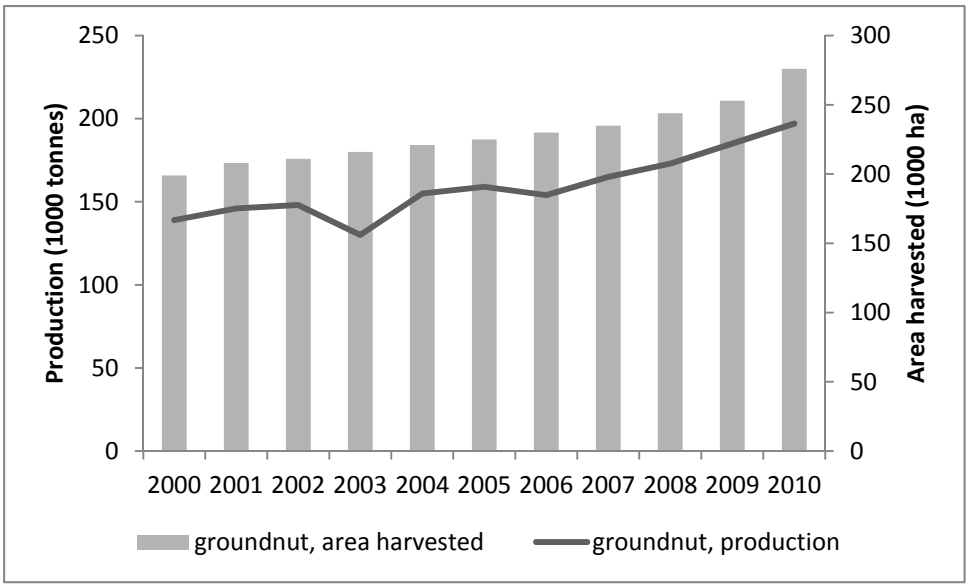

Figure 7: Production and area harvested of groundnut in Uganda
Source: FAO (2012)

4.3 Cowpea

Cowpea is an important legume in the Eastern and Northern region of Uganda. Both its leaves and grains are used as food. Cowpeas are mainly grown in pure stands (75% of plots), and mean plot size is 0.3 ha. When intercropped, cowpea is commonly grown with maize, sorghum, finger millet, cassava and green gram (Adipala et al., 2000). Half of the total production of cowpea is grown for consumption, while 20% is sold (UBOS, 2010). Productivity of cowpeas has increased over the last five years, with production expanding more rapidly than the area under production (Figure 8).

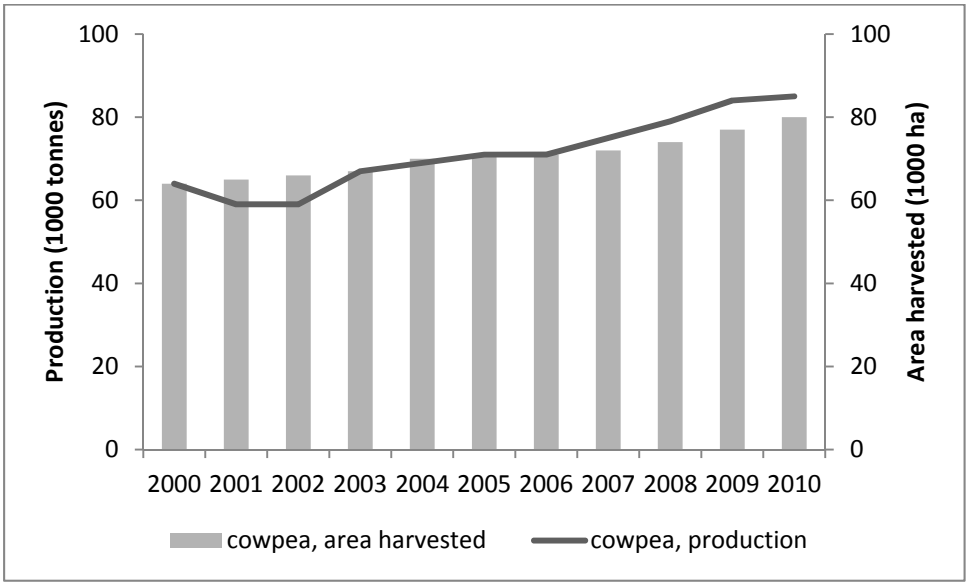

Figure 8: Production and area harvested of cowpea in Uganda
Source: FAO (2012)

Production per ha is still low, however, with an average of 0.5 t/ha (Table 6). Insect pests form a major constraint for increasing cowpea production. Apart from application of insecticides, pests could be reduced by intercropping, early planting, use of cultivars resistant to certain pests and row planting instead of broadcasting with resulting higher plant densities (Adipala et al., 2000).

Table 6: Area and production of cowpea per region (2008/2009)*

Region	Area (ha)	Production (Mt)	Yield (Mt/ha)
Central	1,000	300	0.2
Eastern	13,000	7,000	0.5
Northern	9,000	3,000	0.4
Western	300	300	0.7
Uganda	**24,000**	**11,000**	**0.5**

* Data differs from Table 2 (different year and different source)
Source: UBOS (2010)

In a study from Ebanyat (2009), cowpea shows a strong response to P-fertilizer on biomass production in fertile fields. The total amount of N_2-fixed also increased considerably. In fields of poorer fertility, however, P-fertilizer had less effect as productivity was limited by deficiencies of other nutrients.

4.4 Soybean

Soybean is mainly cultivated in the Northern (around Lira) and Eastern (around Tororo) region of Uganda (Table 7). Soybean is grown as sole crop (60% of plots) or intercropped (UBOS, 2010). The majority of soybean produce is sold, especially in the Northern region. The latter region has an oil extracting factory (in Lira). Soybean processors are found in Kampala and Tororo.

Table 7: Area and production of soybean per region (2008/2009)*

Region	Area (ha)	Production (Mt)	Yield (Mt/ha)
Central	1,000	200	0.3
Eastern	7,000	6,000	0.8
Northern	26,000	16,000	0.6
Western	2,000	2,000	0.9
Uganda	**36,000**	**24,000**	**0.6**

* Data differs from Table 2 (different year and different source)
Source: UBOS (2010)

Both production and area grown with soybean have remained stagnant over the past five years, after a steep increase between 2000 and 2003 (Figure 9).

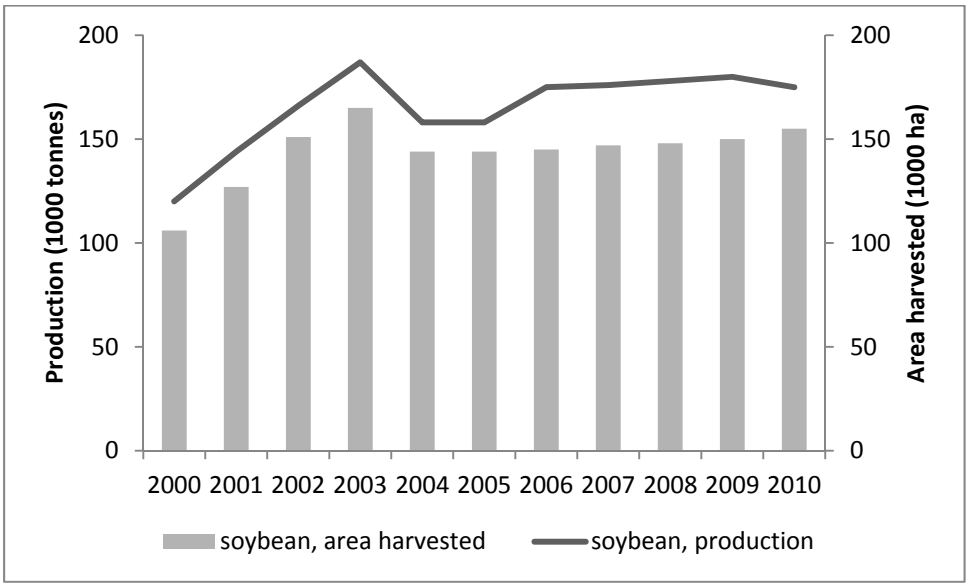

Figure 9: Production and area harvested of soybean in Uganda
Source: FAO (2012)

Soybean cultivation in Uganda was severely affected by soybean leaf rust. New varieties (Maksoy 1N, 2N and 3N, and Namsoy 4M) have been introduced in 2004 and 2010, which increased soybean yields (Makerere University, 2012). Rust remains a problem, however. Research on the use of P-fertilizer in soybean in Uganda showed that yields benefit from application of P: 15 kg P-fertilizer/ha showed a profitable increase in soybean yields by about 1 t/ha (Kaizzi et al., 2012), while in a study of Wortmann et al. (2000) yields increased only with application of TSP, not with Busumbu rock phosphate (9% P). The latter study also showed that in maize-bean intercropping after soybean, beans did relatively well (although maize performance was poorer than after other legumes like *Canavalia*, *Mucuna* or *Crotalaria*). Soybean yields in a study from Ebanyat (2009) in Pallisa, Eastern Uganda, only showed a moderate response to 30 kg/ha of P, on both more and less fertile soils. The amount of N_2-fixed did not increase with application of P-fertilizer.

Rhizobial inoculation

Uganda used to have two inoculant production facilities: Madhavani Ltd (a sugar factory with inoculant research laboratory near Jinja) and Biological Nitrogen Fixation Makerere University, established with the aid of USAID in 1990. In the 1990s, the plant at Madhavani plant produced about 8,000 kg/year in the 1990s in packs of 100 g for soybean, groundnut and bean (Bala et al., 2011). This plant no longer

exists, however, as the market for inoculants was not sufficient for commercial production. Inoculant production at Makerere is about 1,000 kg per season (2,000 kg per year), based on demand from researchers, progressive farmers, NGOs, etc.. The inoculants are produced with semi-sterile peat as carrier in packs of 150 g (hence, about 13,000 packs per year). The retail price is about $ 0.75 per pack. Inoculants are produced for soybean, common bean, groundnut, pasture legumes and tree legumes (*Calliandra*). The strains were obtained from NifTAL, and for common bean CIAT 899 is the standard strain used.

Despite in-country production facilities, farmers are little aware of the benefits of rhizobial inoculants (Rwakaikara Silver and Nkwiine, 2007). A study of Wortmann and Kaizzi (1998) in Eastern and Central Uganda showed that most farmers did not inoculate soybean, although they used non-promiscuous varieties that do not readily nodulate with indigenous rhizobia strains. In addition, due to poor availability of P, biological N_2-fixation was low. This resulted in strongly negative N-balances when N in grain and stover was removed. Some farmers removed legume stovers to feed them to livestock, others burned them. In some of the study areas residues were incorporated in the soil or transferred to banana fields. With inoculation, soybean N-balances could be enhanced, although much still depends on the use of crop residues. Nkwiine and Rwakaikara-Silver (2007) reported a 30–70% increase in soybean yield with inoculation, whereas Wortmann and Kaizzi (1998) found that even though soybean plants nodulated without inoculation, grain yields improved by an average of 600 kg/ha with inoculation (even without the use of fertilizer).

Soybean processing

In Eastern Uganda, soybean production has recently expanded through the establishment of the processing factory in Tororo, Seba Foods Uganda, which produces a low cost meat substitute (Tasty Soy Pieces (TSP)). Soybean for this processor is grown through contract farming. Minimum sales prices are guaranteed, and farmers receive technical support. Farmers were not yet familiar with soybean cultivation, but were interested in the initiative because of the guaranteed minimum price (on average the factory pays 10% above market prices). They received training in soybean cultivation, harvest and storage techniques. At the same time, marketing of the product was done through cooking demonstrations with free samples in villages, and a contract was signed for delivery to schools and health centres. So far, TSP is only marketed in Uganda, but the company sees opportunities for expanding distribution to e.g. DR Congo and South Sudan (Joosten, 2012).

Kampala also has a soybean processing factory (East African Basic Foods (EABF)), producing soybean products for e.g. supermarkets, schools, hospitals, relief organizations, orphanages and children's organizations (interview East African Basic Foods, 2012). Their supply mainly comes from the Northern (Lira), Western (Masindi, Mowende) and Central Region, through traders and middlemen, or in small quantities from individual farmers. A pilot with contract farming, whereby EABF provided seeds for free, did not work well – the crop yielded less than expected due to poor management, and some farmers withdrew from the contract. The factory considers the market outlook for soybean to be good, with more people becoming aware of the nutritious value of soybean and opportunities to use soybean in the poultry feed sector (which currently uses fish as main product).

Issues to address in soybean production and marketing

Based on the above, and interviews with NGOs, EABF and Makerere University, issues to be addressed in soybean production and marketing in Uganda include:

- Improving the quantity and quality of production through better management, timely planting, etc., and sensitize farmers to avoid mixing of varieties.
- Bulking of production from individual farmers. Establish contacts between farmers and buyers so that farmers are aware of where they can sell their output.
- Contract farming arrangements: what price agreements can be made (before or after the season?).
- Accessibility and awareness of inputs:

    - Foundation/ quality seeds: strengthen links between farmers and NARO/ community based multiplication points.
    - Network of agro-dealers is in place, but inoculants or phosphate fertilizer are often not available (only in DAP or NPK). Production of Makerere is mainly on demand, and inoculants have a limited shelf life due to the semi-sterility of the carrier.
    - Farmers are often not aware of benefits of inoculation or P-fertilizer.
- Strengthen capacity of inoculant production facilities Makerere University (training, sterility of carrier, identification of strains)
- Improving storage facilities after harvest; post-harvest handling.

5. Projects/organizations working on legumes in Uganda

5.1 National initiatives

NAROs

- National Crops Resources Research Institute (NaCRRI):
  Based in Namulonge. Involved in variety development of and research on bean and (to a limited extent) soybean. Since 1993, the centre has released 11 varieties of common bean which are higher yielding and have increased disease and pest resistance (http://www.naro.go.ug/Institute/Namulonge/index.html).
- Serere National Semi-Arid Resources Institute (NaSARRI):
  Based in Soroti district and undertakes research for semi-arid areas, including groundnut, cowpea and pigeonpea.

Makerere University/ Soybean Network

Coordinator: Phinehas Tukamuhabwa
Efforts to improve seed systems (dissemination of soybean seed through seed companies, NGOs or soybean processing factories that work with extension farmers, training of farmers for seed multiplication). Linking farmers, buyers and traders to each other. Make farmers aware of where they can sell their produce. Provide training on agronomy and on home processing of soybean.

PABRA

Coordination: CIAT, Mathew Abang and NaCCRI, Michael Ugen
Partners in Uganda: NARO, Makerere University
Objectives:

- Develop and disseminate new higher yielding bean varieties.
- Improve production through better crop, soil and pest management by farmers.
- Achieve wider impact by extending farmer access to new bean technologies to all main bean production areas in Africa.
- Improve and disseminate understanding of how communities in diverse situations can best achieve food security and improve incomes.
- Strengthen the capacity of NGOs and local agricultural providers and strengthen the research sector (NARS, farmer research groups).
- Priorities identified by PABRA are: breeding, as well as reaching the inaccessible, poor farmers and increasing the number of varieties on offer. Also try to link new varieties rich in minerals for people with HIV/AIDS with community-based health and nutrition workers

In the past, PABRA has also done a lot of work on plant breeding against pests and diseases (e.g. bean root rot disease) and/or drought (PABRA, 2006).

AGRA – Soil Health Program

Through NARO: improve fertilizer recommendations and extension packages in Uganda.
Budget: $396,380
Duration: 1 May 2009 - 30 Apr 2012

Africa 2000 Network

Activities:

- Eastern region: maize and soybean rotation (for rotational benefits, including *Striga* control).
- Southwestern region: beans (introduction of climbing beans to control root rot). Also cooperation with HarvestPlus on fortified beans.

- Northern region: groundnut, beans and sesame (simsim).

In all regions they disseminate technologies and agronomic practices. The NGO is an extension organization with a national mandate. They apply a value chain approach (establishing platforms of value chain players, links to financial partners).

For soybean: community based seed multiplication. Supervision on quality as well as training is done by the private sector. Farmers get the foundation seed from seed companies as promotion of the technology, and receive extension services (this is a grant). Farmers *have* to buy P-fertilizer and inoculants themselves, as A2N's approach is: farming as a business. There is no payback of seeds (experience is that seed loans do not work), farmers' output is bought with price established at end of season (problem: farmers may find a better buyer before).

Approach applied is comparable to lead and satellite farmer. Lead farmers get trained, and host a demonstration plot. Satellite farmers visit the field and apply what they have learned/ prefer in the following season. Same type of trials also performed for common bean in the Eastern Region.

5.2 International initiatives

CATALIST-Uganda

Funding: Embassy of the Kingdom of the Netherlands
Coordination: IFDC, David Slane
Duration: 2012-2016
Objectives: CATALIST-Uganda will help increase productivity and more effectively link farmers to input and output markets by improving value chains. Trials on fertilizer inputs, together with improvements in infrastructure for storage, soil/ water conservation, roads, etc.
Areas:

- Southwestern: climbing bean
- Eastern Uganda (Mbale to Soroti): lowland rice + sunflower + soybean
- Northern Uganda: sunflower and cassava (Lira).

2SCALE

Funding: Netherlands' Directorate-General for International Cooperation (DGIS)
Coordination: IFDC
Duration: 2012-2016
Objectives: The project's strategic objective is to develop a portfolio of 500 robust and viable agribusiness clusters (ABCs) and value chains, supplying food to regional, national and local markets as well as to the least fortunate. 2SCALE will emphasize 'going to scale' – increasing the number and size of ABCs, strengthening the role of the private sector contribution in cluster activities. The project will improve nutrition and food security through PPPs that increase productivity along agricultural value chains and sustainable connections to markets.

Integrated Seed Sector Development

Funding: Royal Netherlands Embassy
Duration: 2010-2014
Local partners: Zonal Agricultural Research Institutes (Arua, Lira, Mbarara)
Objectives:

- Facilitate public sector: supporting policies, quality assurance, support NARO in variety release, setting up multi-stakeholder platform in seed sector.
- Local seed business: farmer groups producing seeds (work with varieties with great market potential and that have been released by NARO, including beans), registration of

farmer groups, capacity building (training in business planning, agronomic practices, quality assurance).

Sasakawa Africa Association

Activities: value chain approach in different thematic areas:

- *Crop Productivity Enhancement:* provision of technical and crop management support for a.o. groundnut, beans and soybean. Help farmers developing an enterprise. Farmers receive a kit with inputs for free (for demonstration on 1 acre plot on strategic location), and in return they have to train other farmers.
- *Post-harvest Handling and Agroprocessing:* promote technologies that are aimed at reducing post-harvest losses, improving product quality, and adding value to produce for improved market access. 'One stop associations' have been formed from farmers' producer organizations, dealing with inputs, post-harvest handling, processing, organize meetings/ trainings, etc.
- *Public-Private Partnerships and Market Access:* stimulating use of fertilizers and other inputs by repacking inputs into smaller packs. Aim to strengthen agronomic practices of seed companies, and convince them to supply smaller packs of seed.

Website: http://www.saa-safe.org/www/uganda.html

VECO

Activities: mainly work with groundnut, and in new programme (2014-2019) aim to work with common bean as well. Value chain approach, with work on availability of inputs (community based seed multiplication, input revolving schemes) and organization of business meetings with partners along the value chain. Main role of VECO is to bring all actors together, as well as providing technical backstopping and training. In groundnut, focus on soil fertility and pest & disease management, in cooperation with NARO Serere and Zardi. Apart from value chains also work on promotion of crop rotations with legumes.

World Vision

Activities:

- Capacity building. Information for farmers on access to seeds, awareness of a community seed multiplication points.
- Provision of improved technologies (improved seeds, farming technologies)

Approach: seed loans, with payback through community leaders (not to NGO) and strong focus on community schemes. Linking of farmers and input dealers. Bulking of harvest at community level, for sale to middlemen/ warehouses/ factories.
Areas:

- Whole of Uganda: beans (bush bean only, no climbing beans)
- Northern (Lira, Soroti, Gulu and Kitgum): soybean
- Northern and Eastern: groundnut

Cowpea: Improving food security through participatory development of high yielding and pests resistance cowpea varieties in Uganda

Funding: McKnight Foundation
Duration: 2009-2013
Local partner: Makerere University

Objectives:
1) To conduct a baseline survey to determine the farmer/consumer-preferred cowpea attributes and identify cowpea production constraints in eastern and northern Uganda;
2) To characterize local and elite cowpea germplasm and develop improved cowpea cultivars with resistance to major pests and diseases;
3) To determine optimum agronomic practices for cowpea production in Uganda;
4) To develop an IPM strategy for major cowpea pests and diseases;
5) To develop cowpea production manual for Uganda; and
6) To develop pro-poor seed production and delivery systems through outreach, training, demonstration/farmer field schools, and community seed multiplication groups.
Website: http://mcknight.ccrp.cornell.edu/projects/ehaf_cop/EHAF_09-480/09-480_project.html

Chickpea/banana: Enhancing sustainable productivity and utilization of chickpea (*Cicer arietinum*) in the banana farming system of Uganda

Funding: McKnight Foundation
Duration: 2009-2013
Local partner: Mbarara Zonal Agricultural Research and Development Institute
Objectives: Participatory research approach to identify adaptable, high yielding and marketable chickpea varieties to be integrated in banana systems. And how can this crop be best integrated? In anticipation of increased production of chickpea in the zone, the project will determine appropriate community based storage for the crop. Similarly the project will identify, evaluate and promote markets and marketing channels for chickpea in the zone and in the country.
Website: http://mcknight.ccrp.cornell.edu/projects/ehaf_cop/EHAF_09-460/09-460_project.html

Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda

Coordinator: Robert Mazur (Iowa State University)
Funding: USAID - Dry Grain Pulses CRSP
Duration: October 2009 - September 2012
Objectives: This project produces integrated information on agronomic, post-harvest, nutritional and market factors regarding bean production and consumption, and builds a strong program of academic training and engagement in application of research findings. Continuing and new applications build on successful research outcomes and outreach activities. The team will take advantage of emerging opportunities to expand the range and depth of development impacts through improved harvested bean quality and yields, enhanced nutritional value and uses of beans, development of new markets and marketing channels, evaluating use of bean-based products for nutritional rehabilitation and continued support and development of the capacity of agriculture research institutions.
Website: http://www.srl.ag.iastate.edu/Current%20Projects.html

Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda and Tanzania

Coordinator: Mark Westgate (Iowa State University)
Funding: USAID - Dry Grain Pulses CRSP
Duration: October 2010 - September 2012
Local partners: Makerere University, Volunteer Efforts for Developmental Concerns (VEDCO), National Crop Resources Research Institute (NaCRRI)
Objectives: Low soil fertility of degraded soils and lack of access to inorganic fertilizer are major constraints for overcoming poverty and mal-nutrition of small landholder farm families in Sub-Saharan Africa. Strategic aims:

- To improve biological nitrogen fixation and grain yields of common beans significantly using novel biological inoculants through farmer-based experimentation and adoption of innovative production techniques.

- To examine the inheritance of genetic and environmental variation in BNF in the common bean, and to identify molecular markers associated with QTL conditioning for enhanced BNF.
- To improve the productivity, profitability, and sustainability of agricultural systems on degraded soils through effective dissemination of new information and technologies to small-landholder farmers through on-farm demonstrations, mass media, field schools, and local forums.

Training of numerous host-country graduate students and undergraduate interns along with enhanced farmer group training and dissemination ensures significant long-term impacts from this project.
Website: http://www.srl.ag.iastate.edu/Current%20Projects.html

Strengthening Value Chains for Maize and Soybeans for Ugandan Women Farmers

Coordinator: Mark Westgate (Iowa State University)
Funding: USAID - Farmer to Farmer Niche Project.
Duration: January 2012 - December 2012
Local partners:
Objectives: This project promotes sustainable livelihoods of small landholder women farmers in Kamuli district, Uganda. Project activities to increase production and post-harvest quality for maize and soybeans, access labor saving equipment, and improve marketing of these crops grown for commercial sales will increase profits and benefit these women and their entire families. Project volunteers will be Iowa women farm owners and operators who will mentor and train Ugandan women farmers and farmer association members. We will focus on maize and soybean production and marketing. The focus with maize is on post-harvest handling, grain quality, labour savings, and group marketing. We will teach marketing groups/associations and grain buyers to understand and adopt current maize grain grading standards. The focus with soybeans is to improve farmers' production, harvest, drying and threshing techniques. Some techniques introduced will also have application for dry beans, already grown on many Kamuli district farms. Women farmers' marketing associations will also jointly market soybeans not kept for family consumption or seed. The project accesses expertise of eight Iowa women farmers, two Iowa State University faculties and three staff members, and will impact 100 Ugandan farmers and their families. Five marketing groups/associations will be established or expanded to accommodate additional farmers and sales of maize and soybeans. Association members will establish market relationships with local and regional buyers that will provide opportunities for future marketing of additional crops and livestock.
Website: http://www.srl.ag.iastate.edu/Current%20Projects.html

P4P (Purchase for Progress – connecting farmers to markets)
Funding: BMGF, USAID
Coordination: WFP
Duration: 2008-2013
Local partners: many
Objectives: Connecting smallholder farmers to markets through market and agricultural development.
Pilot in Uganda with three components:

- Innovative Procurement Modalities
  - Pro-smallholder competitive tendering
  - Direct contracting
  - Forward contracting
- Supply-side Partners
  - Providing technical expertise in agriculture & market development
  - Building capacity
  - Empowering Women
- Learning and Sharing

Website: http://www.wfp.org/purchase-progress/overview. And:
http://documents.wfp.org/stellent/groups/public/documents/communications/wfp217495.pdf

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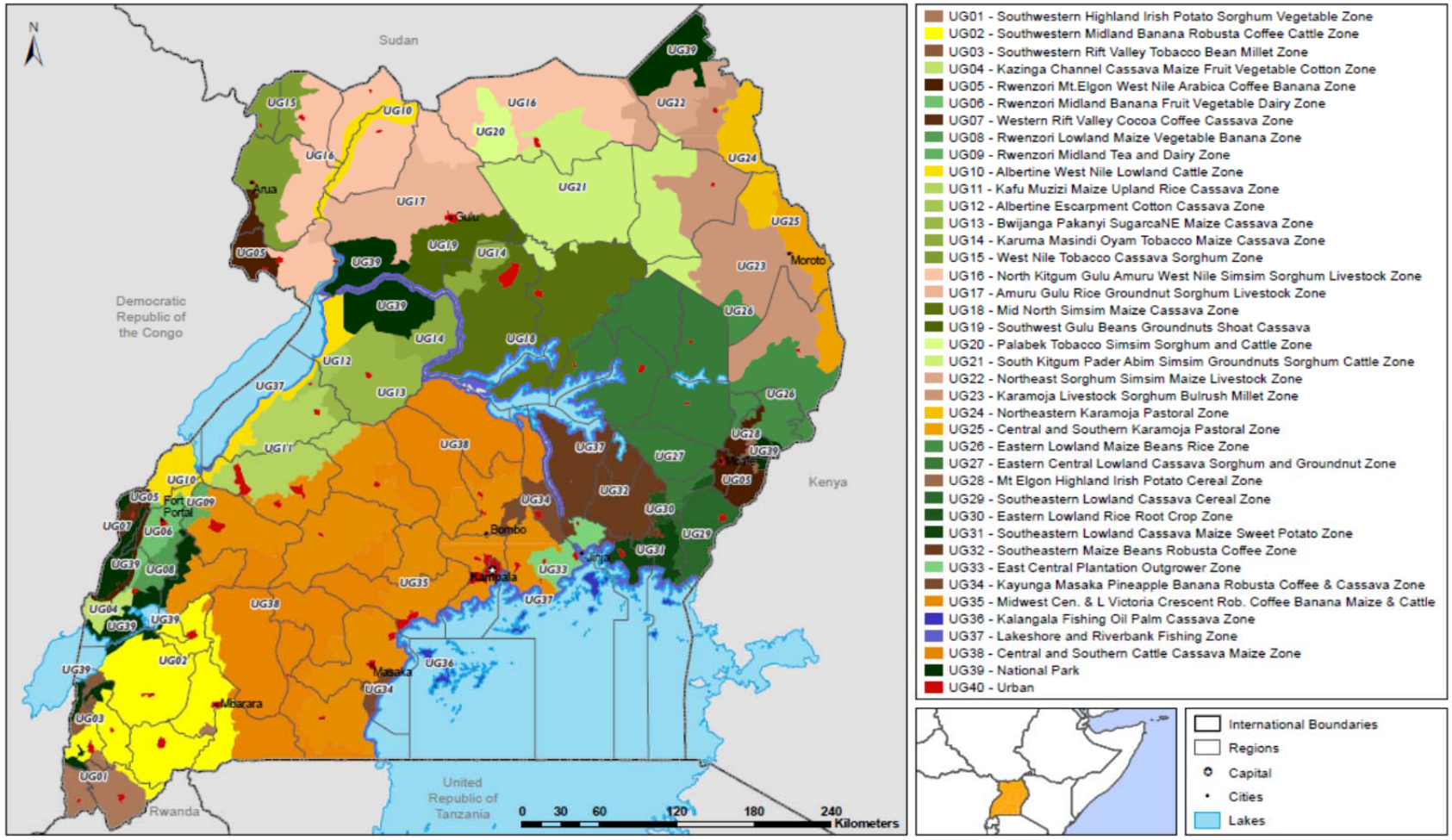
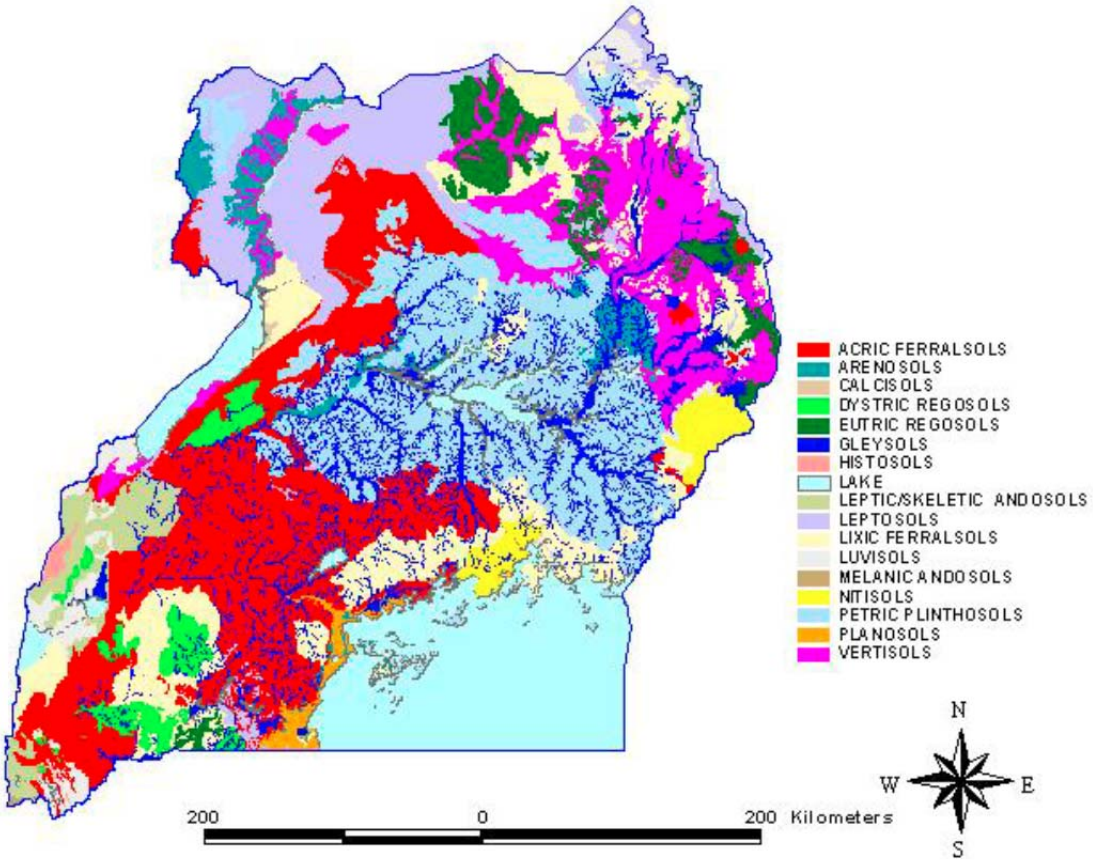
Appendix 1: Livelihood zones in Uganda



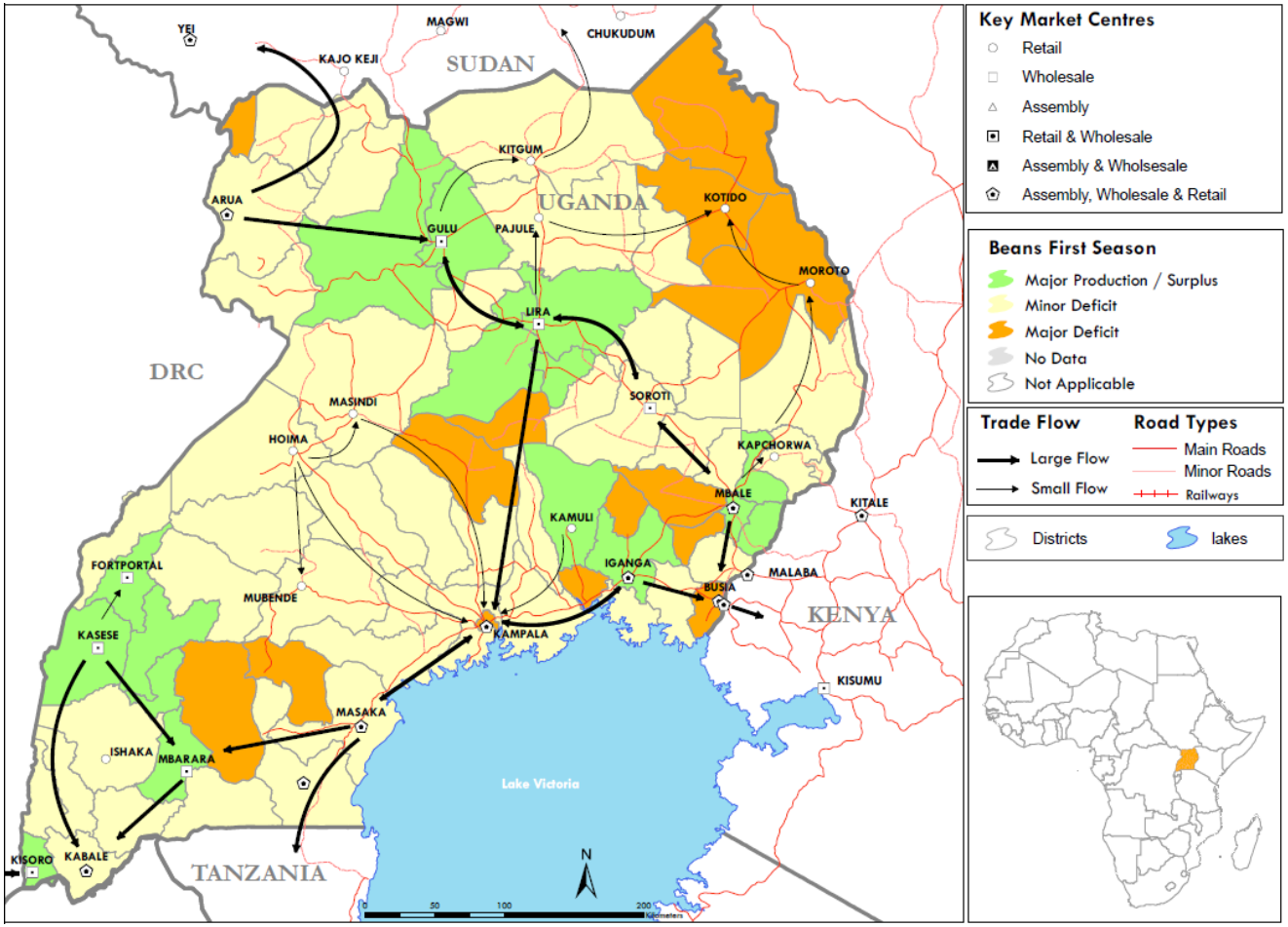
Source: USAID (2012)

Appendix 2: Soil map Uganda



Source: Kabeere and Wulff (2008)

Appendix 3: Production and market flows of common bean in Uganda



Source: USAID (2012)

List of project reports

1. N2Africa Steering Committee Terms of Reference
2. Policy on advanced training grants
3. Rhizobia Strain Isolation and Characterisation Protocol
4. Detailed country-by-country access plan for P and other agro-minerals
5. Workshop Report: Training of Master Trainers on Legume and Inoculant Technologies (Kisumu Hotel, Kisumu, Kenya-24-28 May 2010)
6. Plans for interaction with the Tropical Legumes II project (TLII) and for seed increase on a country-by-country basis
7. Implementation Plan for collaboration between N2Africa and the Soil Health and Market Access Programs of the Alliance for a Green Revolution in Africa (AGRA) plan
8. General approaches and country specific dissemination plans
9. Selected soybeans, common beans, cowpeas and groundnuts varieties with proven high BNF potential and sufficient seed availability in target impact zones of N2Africa Project
10. Project launch and workshop report
11. Advancing technical skills in rhizobiology: training report
12. Characterisation of the impact zones and mandate areas in the N2Africa project
13. Production and use of Rhizobial inoculants in Africa
18. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
19. Quality assurance (QA) protocols based on African capacities and international existing standards developed
20. Collection and maintenance of elite rhizobial strains
21. MSc and PhD status report
22. Production of seed for local distribution by farming communities engaged in the project
23. A report documenting the involvement of women in at least 50% of all farmer-related activities
24. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
25. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
26. A revised manual for rhizobium methods and standard protocols available on the project website
27. Update on Inoculant production by cooperating laboratories
28. Legume Seed Acquired for Dissemination in the Project Impact Zones
29. Advanced technical skills in rhizobiology: East and Central African, West African and South African Hub
30. Memoranda of Understanding are formalized with key partners along the legume value chains in the impact zones
31. Existing rhizobiology laboratories upgraded
32. N2Africa Baseline report

33. N2Africa Annual country reports 2011

34. Facilitating large-scale dissemination of Biological Nitrogen Fixation

35. Dissemination tools produced

36. Linking legume farmers to markets

37. The role of AGRA and other partners in the project defined and co-funding/financing options for scale-up of inoculum (banks, AGRA, industry) identified

38. Progress Towards Achieving the Vision of Success of N2Africa

39. Quantifying the impact of the N2Africa project on Biological Nitrogen Fixation

40. Training agro-dealers in accessing, managing and distributing information on inoculant use

41. Opportunities for N2Africa in Ethiopia

42. N2Africa Project Progress Report Month 30

43. Review & Planning meeting Zimbabwe

44. Howard G. Buffett Foundation – N2Africa June 2012 Interim Report

45. Number of Extension Events Organized per Season per Country

46. N2Africa narrative reports Month 30

47. Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda

Partners involved in the N2Africa project

Bayero University Kano (BUK)

Caritas Rwanda

Diobass

Eglise Presbyterienne Rwanda

Resource Projects-Kenya

Sasakawa Global; 2000

Université Catholique de Bukavu

University of Zimbabwe