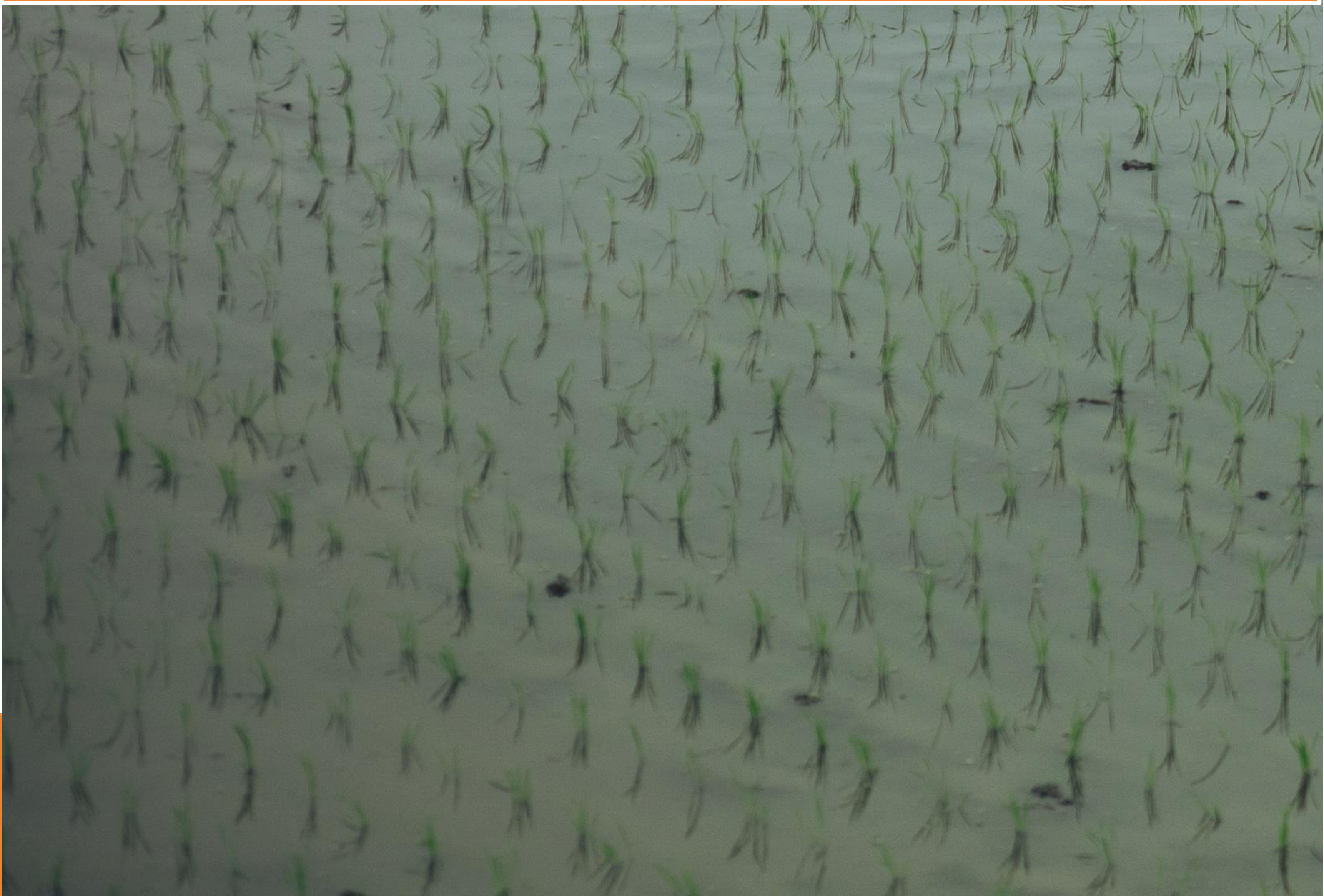
Draft Pre-Feasibility Report for implementation of solar pumps scheme in Uganda



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List of Abbreviations

AC	Alternating Current
AfDB	African Development Bank
BfZ	Berufliche Fortbildungszentren der Bayerischen Wirtschaft gemeinnützige GmbH
CIF	Climate Investment Funds
cm	Centimetre
DC	Direct Current
DfID	Department for International Development
DFIs	Development Finance Institutes
EAC	East African Countries
EAENet	East Africa Energy Access and Efficiency Network
ERA	Electricity Regulatory Authority
FAO	Food and Agriculture Organization of the United Nations
FBMO	Farmer Based Management Organization
FIP	Forest Investment Program
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GOU	Government of Uganda
Ha/ha	hectare
HH	Households
HP	Horsepower
ICT	Information and Communication Technology
INR	Indian Rupee
IPPs	Independent Power Producers
JEEP	Joint Energy and Environment Projects
JICA	Japan International Cooperation Agency
kg	Kilogram
km	kilometre
kV	kilovolt
kWh	kilowatt hour
kWh/m2/day	kilo-Watts Per Square Meter Per Day
LV	Low Voltage
m	Meter
m^3	Cubic meter
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
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MEMD	Ministry of Energy and Mineral Development
MFIs	Micro Finance Institutes
mm	Millimetre
MNRE	Ministry of New and Renewable Energy
MOFA	Ministry of Foreign Affairs

MOLG	Ministry of Local Government
MW	Megawatt
MWE	Ministry of Water and Environment
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NFP	National Focal Point
NGO	Non-Governmental Organization
PPA	Power Purchase Agreement
PPCR	Pilot Program for Climate Resilience
PV	Photovoltaic
PVP	Photo Voltaic Pump
RATP	Trade and Productivity Project
SDGs	Sustainable Development Goals
Sida	Swedish International Development Cooperation Agency
SPIS	Solar Powered Irrigation System
sq. km	Square Kilometer
SREP	Scaling Up Renewable Energy Program in Low Income Countries
SSIS	Small Scale Irrigation systems
SWPS	Solar Water Pumping Systems
UEDCL	Uganda Electricity Distribution Company Limited
UEGCL	Uganda Electricity Generation Company Limited
UETCL	Uganda Electricity Transmission Company Limited
UKAID	United Kingdom Aid
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USD	United States Dollar
VFD	Variable Frequency Drive
W/m^2	Watts per square meter
WfP	World Food Programme
WUAs	water user association
Y-o-Y	Year-on-Year

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1. Executive Summary

- Uganda derives **nearly 90% of its energy supply from biomass**. Owing to the effects of climate change and deforestation, firewood availability in the country is decreasing.
- Hydropower contributes to more than 83% in the electricity generation; grid connected solar capacity is 50 MW.
- With vast arrays of fertile land, Uganda is **one of the largest agriculturally rich nation in Africa**. However, the sector is yet to meet its enormous potential.
- The irrigation is **primarily rain fed** and is carried out using labor intensive farming techniques.
- Climate change has led to increasing uncertainties regarding rainfall patterns leading to lower yields and dwindling crop productivity.
- Uganda's ratio of cultivated area under irrigation to the irrigation potential is only 5%.
- Majority of the farmers rely on rain government led large irrigation schemes to meet their crop water requirements.
- Major international development and funding agencies have increasingly started implementing projects to ensure sustainable agricultural practices and irrigation schemes.
- The **Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)** is acting as the nodal ministry for locally managing and coordinating international development projects.
- The **average solar radiation in Uganda is 5.1 kWh/m^2/day**. The solar energy resource in Uganda is high and is available throughout the year.
- Majority of the farmers have land holding less than 1 hectare and therefore small sized pumps shall be more suitable for deployment
- There are **limited sources of financing** available with the government of Uganda for solar pumps and external financing through donor agencies, MFIs and DFIs shall be required.
- Uganda has submitted demand for 30,000 Nos. solar water pumping systems. At an average price of USD 5045.5 per 5 HP pumpset, Uganda requires financing of **USD 151.37 Million to roll out deployment of 30,000 Nos. solar water pumping systems** across the country.

2. Introduction

Uganda is one of the few sub-Saharan African countries to have liberalized and financially viable energy markets, with generation, transmission and supply segments unbundled since 2001. There is an independent Electricity Regulatory Authority that undertakes sector regulation and oversight[1]. Following are the roles of various institutions in the power sector:

S.No.	Institution	Role
1.	Ministry of Energy and Mineral development	Policies
2.	Rural Electrification Agency	Extension and distribution of electricity
3.	Electricity Regulatory Authority	Licenses and permits
4.	Uganda Investment Authority	Investment license – license obtainable in one day
5.	Uganda Revenue Authority	Taxes collection
6.	Uganda Energy Credit Capitalization Company	Provide vendor loans and end-use credit for solar systems, biogas systems, electricity connection etc.
7.	Transmission and Generation company	
8.	Independent power producer	Private Sector led power generation project

Table 1: Role of various institutions involved in the electricity sector in Uganda

2.1 Energy Sector Overview

Energy plays a crucial role in the development and sustainability of a nation's economy and it drives all other sectors of the economy, such as food, health, the environment, and water, etc.[2] Likewise, electricity is one of the most significant forms of energy that provides essential input into all the other sectors of the economy. Uganda's energy mix is predominantly dependent on Firewood and constitutes 78% of all energy generation in the country as shown in the figure below.

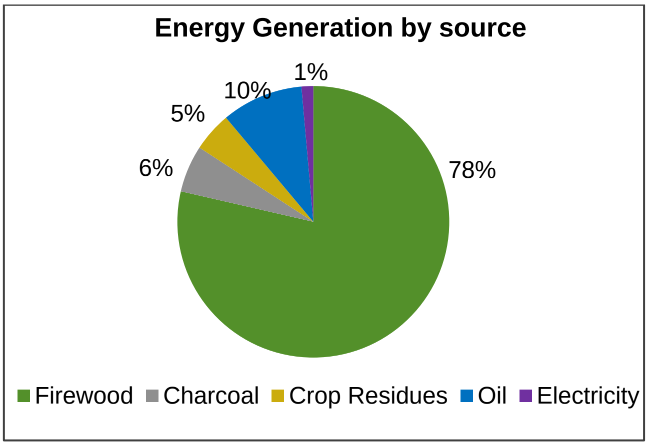


Figure 1: Source wise energy generation

[1] US Agency for International Development

[2] https://www.mdpi.com/2571-8797/1/1/3/htm#B45-cleantechnol-01-00003

The electricity access in Uganda is very low, at 22% national[3] and 11.4% in rural areas[4]. Uganda has one of the lowest per capita electricity consumption rates in the world with 215 kWh per capita per year (Sub-Saharan Africa's average: 552 kWh per capita; World average: 2975 kWh per capita)[5].

Uganda's electricity sector is, regulated by The Electricity Regulatory Authority (ERA), in three segments, namely:

- **The Uganda Electricity Generation Company Limited (UEGCL),** manages the electricity generation
- **Uganda Electricity Transmission Company Limited (UETCL),** manages electricity transmission and deals directly with the independent power producers (IPPs) for executing power purchase agreements (PPAs).
- **Uganda Electricity Distribution Company Limited (UEDCL),** manages electricity distribution.

The total installed capacity of Uganda is 1182.2 MW (as of May 2019). With 89% of electricity generated (2018) form hydro, around 6% of increment is observed as compared to 2017's generation. The table below gives the source wise installed capacity for both the On-Grid and Off-Grid power plants.

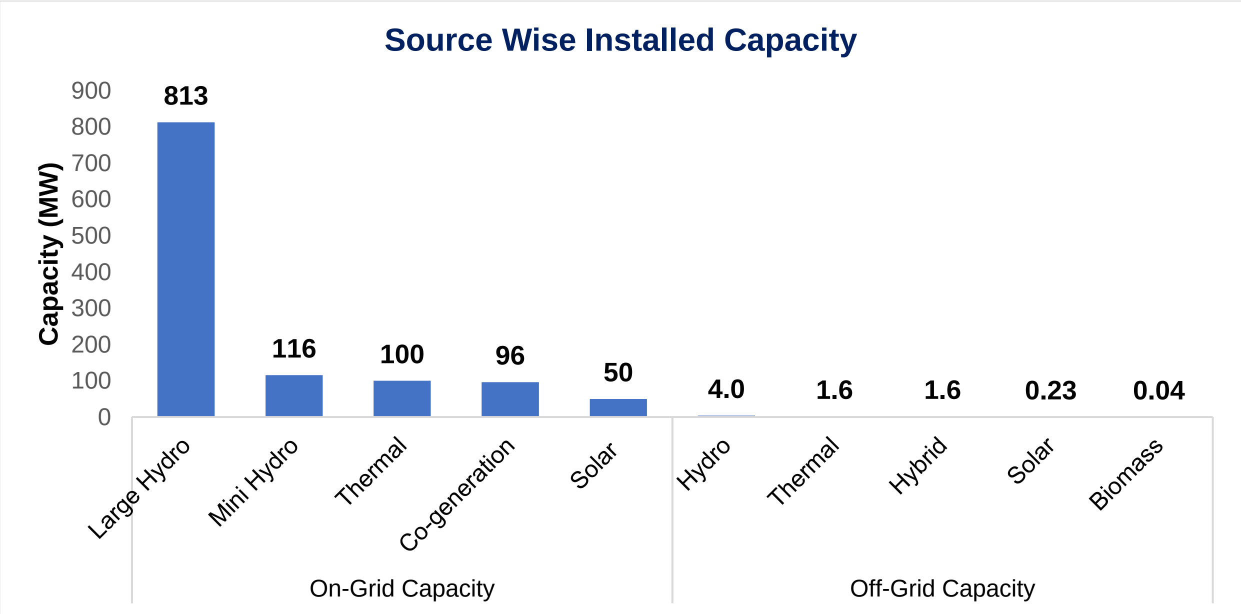


Figure 2: Uganda's total installed capacity of power plants[6]

The GOU is working to expand its power supply by constructing a number of micro-hydro projects along the Nile River and is promoting the development of other sources of renewable energy, such as off-grid solar power systems. Uganda's transmission line length (in 2018) is increased by 942.9 kms (58%) as compared to 2017 and has approximately 2569 km of total transmission and 45423 km of distribution lines.

[3] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=UG&view=chart
[4] https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=UG&view=chart
[5] Export.gov
[6] https://www.era.or.ug/index.php/stats/generation-statistics/installed-capacity

Transmission Lines Length (in kms)[7]				Distribution Lines Length (in kms)[8]			
Capacity/Year	**220kV**	**132 kV**	**66kV**	**Streetlights**	**LV**	**11 KV**	**33 kV**
2018	1,008	1526	35.2	612	24,066	6,114	14,426
2017	150	1,441.7	35.2	N/A	N/A	N/A	N/A

Table 2: Uganda's transmission and distribution lines status

Uganda has set a target to rapidly increase the uptake of renewable energy from current 4% to 61% for meeting the energy needs of the population in a sustainable manner.

It is noted that rising population and growth of incomes have increased the demand for food and agro-processed products. This is putting increased pressure on the environment amid frequent and severe climate conditions, made worse by the continued dependence on rain fed agriculture. Combined with poor agricultural practices, low technological adoption, and insecurity over land ownership, poor access to extension services, low quality inputs, and lack of credit, the agriculture sector continues to be hindered from realizing its full potential. Challenges notwithstanding, Ugandan agriculture has enormous potential to transform the economy and make farming much more productive and profitable for Ugandan smallholder farmers. In stark opposition to supply-side constraints, demand-side opportunities for agriculture and food for Uganda and its neighbors are the strongest they have ever been. Booming domestic and regional demand for higher-value foods arising from income growth, urbanization, and dietary shifts offer massive opportunities for Ugandan farmers and for value chains beyond farm production, and better jobs in agriculture. Other areas of potential identified are developments in agricultural technology and ICT, and various successful agribusiness models that could be up scaled.

Strengthening the institutional base of agriculture, removing identified distortions, facilitating trade, and enhancing resilience through climate-smart agriculture and low-cost irrigation systems can help closing the potential-performance divide of Ugandan agriculture.

[7] https://www.era.or.ug/index.php/transmission/transmission-network-length
[8] https://www.era.or.ug/index.php/electricity-distribution-statistics/distribution-network-length

3. Geography

Uganda is bordered by South Sudan to the north, Kenya to the east, Tanzania and Rwanda to the south, and the Democratic Republic of the Congo to the west. The capital city, Kampala, is built around seven hills not far from the shores of Lake Victoria, which forms part of the frontier with Kenya and Tanzania.

Figure 3:Map of Uganda

Most of Uganda is situated on a plateau, a large expanse that drops gently from about 1500 meters in the south to approximately 900 meters in the north. The limits of Uganda's plateau region are marked by mountains and valleys. To the west a natural boundary is composed of the Virunga Mountains, the Ruwenzori Range, and the Western Rift Valley. The volcanic Virunga Mountains rise to 4125 meters at Mount Muhavura and include Mount Sabinio, where the borders of Uganda, the Democratic Republic of the Congo, and Rwanda meet. Farther north the Ruwenzori Range rises to 5109 meters at Margherita Peak, Uganda's highest point; its heights are often hidden by clouds, and its peaks are capped by snow and glaciers. Between the Virunga and Ruwenzori mountains lie Lakes Edward and George. The rest of the boundary is composed of the Western Rift Valley, which contains Lake Albert and the Albert Nile River.

The northeastern border of the plateau is defined by a string of volcanic mountains that include Mounts Morungole, Moroto, and Kadam, all of which exceed 2,750 meters in elevation. The southernmost mountain—Mount Elgon—is also the highest of the chain, reaching 4,321 meters. South and west of these mountains is an eastern extension of the Rift Valley, as well as Lake Victoria. To the north the plateau is marked on the South Sudanese border by the Imatong Mountains, with an elevation of about 1800 meters.

Uganda's Lake Victoria, in the southeastern part of the country, is the world's second largest inland freshwater lake by size after Lake Superior in North America, although Lake Baikal in Siberia is larger by volume and depth. Victoria is also one of the sources of the Nile River[9]. Five other major lakes exist in the country: Edward and George to the southwest; Albert to the west; Kyoga in central Uganda; and Bisina in the east. Together with the lakes, there are eight major rivers. These are the Victoria Nile in central Uganda; the Achwa, Okok, and Pager in the north; the Albert Nile in the northwest; and the Kafu, Katonga, and Mpongo in the west. The southern rivers empty into Lake Victoria, the waters of which escape through Owen Falls near Jinja and form the Victoria Nile. This river flows northward through the eastern extension of Lake Kyoga. It then turns west and north to drop over Karuma Falls and Murchison Falls before emptying into Lake Albert. Lake Albert is drained to the north by the Albert Nile, which is known as the Al-Jabal River, or Mountain Nile, after it enters South Sudan at Nimule. Rivers that rise to the north of Lake Victoria flow into Lake Kyoga, while those in the southwest flow into Lakes George and Edward.

Except for the Victoria and Albert Niles, the rivers are sluggish and often swampy. Clear streams are found only in the mountains and on the slopes of the Rift Valley. Most of the rivers are seasonal and flow only during the wet season, and even the few permanent rivers are subject to seasonal changes in their rates of flow. The soils, in general, are fertile (and primarily lateritic), and those in the region of Lake Victoria are among the most productive in the world. Interspersed with these are the waterlogged clays characteristic of the northwest and of the western shores of Lake Victoria.

[9] ResearchGate

4. Climate

The tropical climate of Uganda is modified by elevation and, locally, by the presence of the lakes. The major air currents are northeasterly and southwesterly. Because of Uganda's equatorial location, there is little variation in the sun's declination at midday, and the length of daylight is nearly always 12 hours. All of these factors, combined with a fairly constant cloud cover, ensure an equable climate throughout the year.

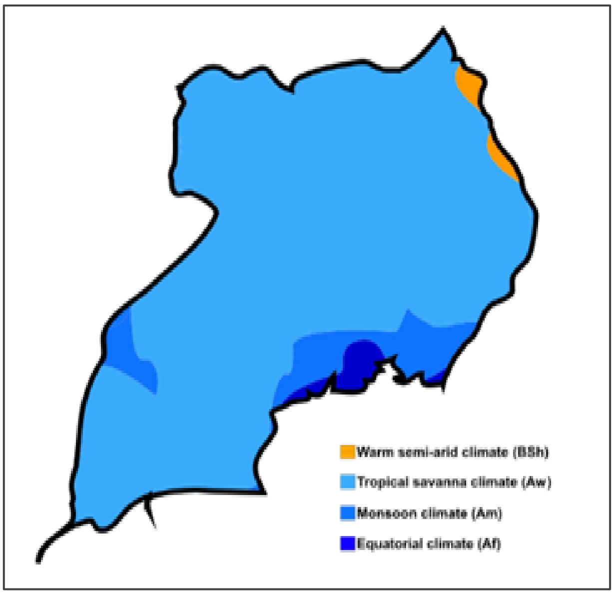


Figure 4: Climate Classification Map of Uganda[10]

The figure given below shows the average temperature pattern in Uganda. Uganda climate is a warm tropical place with temperatures around 25-29°C. With the hottest days in December to February, but even so evenings can feel around 17 -18°C. Temperature in Uganda averaged 23.04°C from 1850 until 2015, reaching an all-time high of 26.50°C in February of 2005 and a record low of 21.03°C in December of 1860.

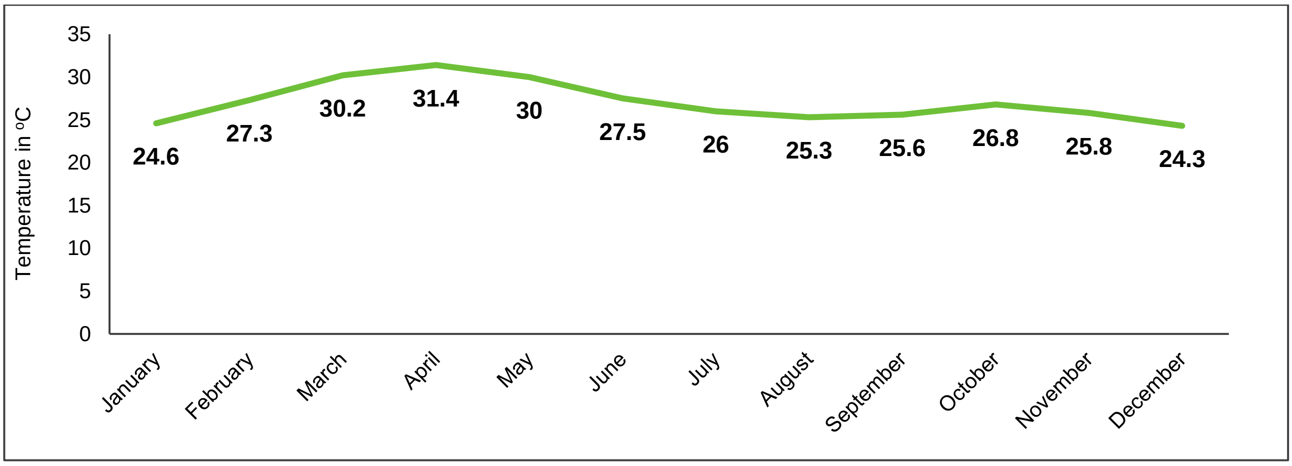


Figure 5: Monthly temperature pattern in Uganda[11]

[10] https://commons.wikimedia.org/wiki/File:Uganda_map_of_K%C3%B6ppen_climate_classification.svg
[11] Climate-data.org

5. Rainfall

Except in the northeastern corner of the country, rainfall is well distributed. The southern region has two rainy seasons, usually beginning in early April and again in October. Little rain falls in June and December. **In the north, occasional rains occur between April and October, while the period from November to March is often very dry.** Mean annual rainfall near Lake Victoria often exceeds 2100 millimeters, and the mountainous regions of the southeast and southwest receive more than 1500 millimeters of rainfall yearly. The lowest mean annual rainfall in the northeast measures about 500 millimeters. Most parts of Uganda receive adequate precipitation; annual amounts range from less than 500 mm in the northeast to a high of 2000 mm in the Sese Islands of Lake Victoria. In the south, two wet seasons (April to May and October to November) are separated by dry periods, although the occasional tropical thunderstorm still occurs. In the north, a wet season occurs between April and October, followed by a dry season that lasts from November to March[12].

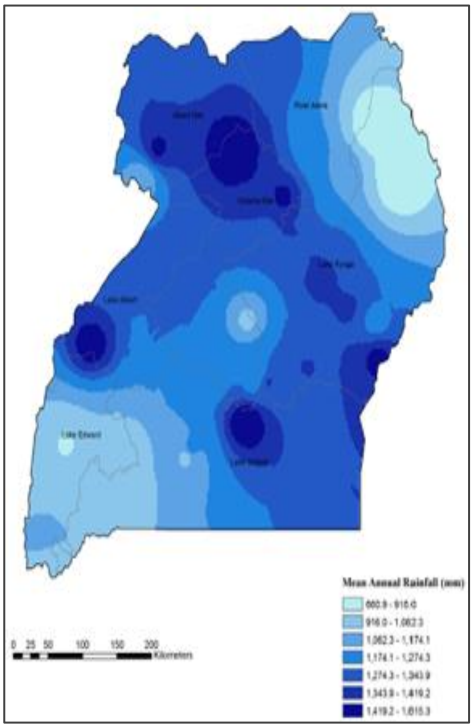


Figure 6: Precipitation Map of Uganda[13]

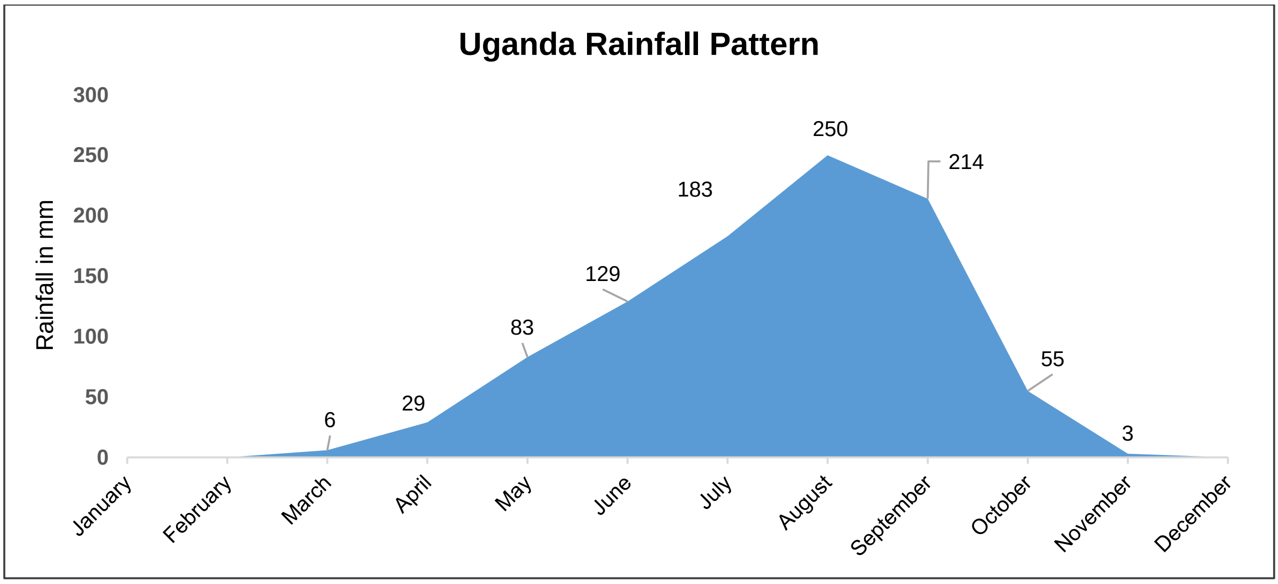


Figure 7: Monthly Rainfall pattern in Uganda[14]

[12] Source: "Water Resources of Uganda: An Assessment and Review" by Francis N. W. Nsubuga, Edith N. Namutebi3, Masoud Nsubuga-Ssenfuma

[13] World Trade Press

[14] Climate-data.org

6. Soil

The southern half of the country has rich soil which permits agriculture. Uganda's major soil types can be classified into the following categories:

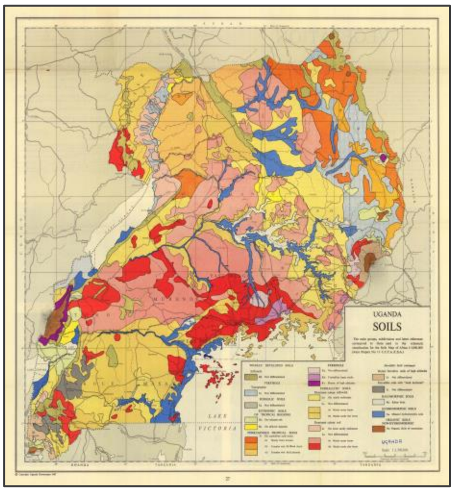


Figure 8: Soil Map of Uganda[15]

Ferralitic Soils: This is the most predominant soil group and is found spread over almost all the country. In some districts like Apac and Lira, these are almost the only soils.

Ferrisols: These are mainly found in parts of Mukono, Jinja, Iganga and Kamuli districts as well as in high altitude districts of Kabale, Kabarole and Mbale.

Eutropic Soils of Tropical Region: These are soils of volcanic origin and alluvial deposits. They are mainly found in Mbale, Kasese and Moyo districts.

Ferruginous Tropical Soils: These are scattered throughout the country, but concentrations occur in Gulu and Tororo districts.

Hamorphic Soils: Rift valley soils are found mainly along Semliki valley.

Hydromorphic soils: Distributed mostly along river valleys and western shores of Lake Victoria.

Organic Non-Hydromorphic Soils: These are mountain soils and so are found in Ruwenzori, Elgon, and Muhavura Mountains.

Podsolic Soils: These are rare and not easily differentiated, but they occur in small portion of western Bushenyi district.

Vertisols: These soils are found widely in north-eastern Uganda, but they also occur along Albert Nile in the north-western districts of Arua, Moyo and Nebbi. Small areas are also found in the Kasese, Kabarole and Hoima districts.

Weakly developed Soils: These are found along the Rift valley, Rukungiri district and along the Aswa valley in the Kitgum and Moyo districts. Areas of the Kotido and Moroto districts bordering Kenya also have concentrations of this soil group.

In general, **soils grouped as ferrisols are the most productive and fertile**. Eutropic brown soils which are relatively young and possess adequate nutrient reserves are fertile and productive. Ferruginous tropical soils are less productive and require careful usage to preserve their poorly developed top-soils. Soils in a more advanced stage of weathering such as those in ferrallitic group have little or no mineral reserves to draw on and so depend largely on bases held in clay and organic complexes for their fertility. The heavier textured soils tend to be more fertile since they're able to withstand the effect of leaching than those with a sandy texture. The productivity of ferrallitic soils depends mainly on favorable rainfall, adequate depth and maintenance of humid top-soil.

[15] European Soil Data Centre

7. Agriculture in Uganda

Uganda has a total area of 2,41,550 sq. km with agriculture occupying more than 43% of the land. Agriculture is one of the most important sectors of the Ugandan economy contributing **about 20 percent of GDP, accounting for 48 percent of exports and providing a large proportion of the raw materials for industry. 72 percent of all working population in Uganda is employed in agriculture. About 4 million households in Uganda survive on small-holder farming. About 25% of Ugandans are poor, corresponding to nearly 7.5 million people living in 1.2 million households. Incidence of poverty remains higher in rural areas than in urban areas, with the poor in rural areas representing 27% of the population versus 9% in the urban areas.** Therefore, agriculture will be the key determinant in the country's efforts to reduce poverty in the immediate years ahead. Significantly, a considerable number of women own the land on which they work. Small-scale mixed farming predominates, while production methods employ largely rudimentary technology; farmers rely heavily on the hand hoe and associated tools and have minimal access to and use of fertilizers and herbicides[16].

58% of Ugandan farmers are having less than or equal to 1 ha of land holding, with nation-wide average land holding of 2.5 ha[17]. The agricultural sector is dominated by the production of food crops, but cash crops, livestock, fishery and forestry are also important. **Food crops accounted for 72.4 percent of agricultural GDP in 1985, falling to 65.3 percent in 2000.**

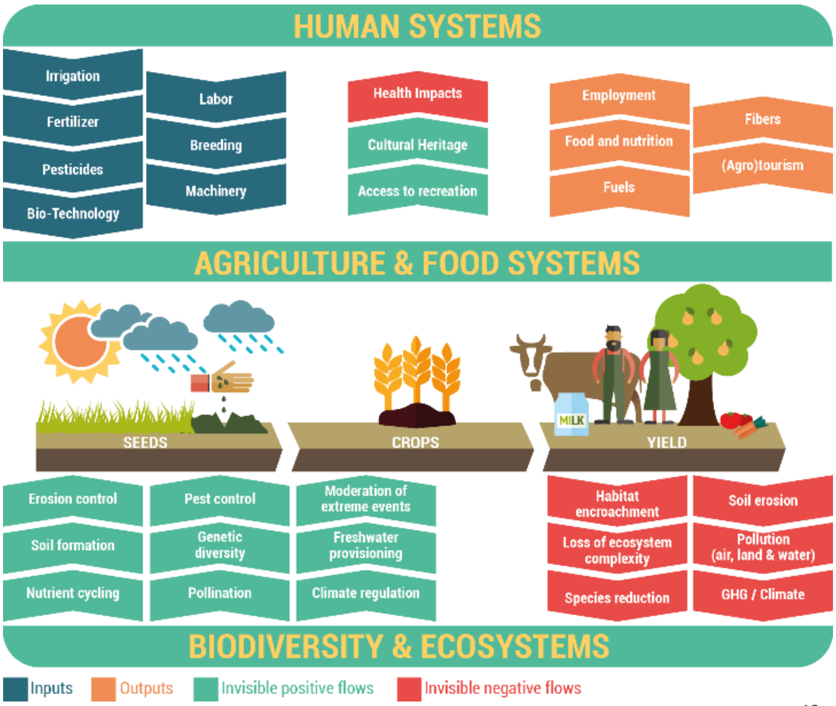


Figure 9: Agriculture impact on human, biodiversity and ecosystems[18]

Uganda's agricultural potential is considered to be among the best in Africa, with low temperature variability and two rainy seasons in the southern half of the country leading to multiple crop harvests per year. According to the Food and Agriculture Organization of the United Nations,

[16] Britannica
[17] GOU
[18] Image Source - Seea.un.org

Uganda's fertile agricultural land has the potential to feed 200 million people. **Eighty percent of Uganda's land is arable but only 35 percent is being cultivated. Two important cash crops for export are coffee and cotton.** Tea and horticultural products (including fresh-cut flowers) are also grown for export. Uganda produces a wide range of other food products including sugar; livestock; edible oils; cotton; tobacco; plantains; corn; beans; cassava; sweet potatoes; millet; sorghum; and groundnuts[19].

The subsequent section provides details on the leading sub-sectors as given below:

- **Commodities:** Most Ugandan farmers continue to produce raw commodities such as coffee, tea, cotton, maize, beans, bananas, coco and livestock. While staples such as bananas, tea, maize, and beans see strong domestic and regional demand, cash crops such as coffee and spices generate strong revenue in international export markets.
- **Agro-processing:** While Uganda traditionally exports raw commodities, the GOU is seeking foreign investment in agricultural processing in order to increase export earnings. One of Uganda's leading exports under the African Growth and Opportunity Act is casein protein, a processed dairy product.
- **Agriculture Equipment and Inputs:** As farming operations grow, Ugandans are increasingly turning to mechanization and agriculture inputs such as fertilizers, seeds and agro-chemicals to improve productivity.
- **Livestock:** It includes cattle, both indigenous varieties and those known as exotics plus experimental crossbreeds, sheep, goats, pigs, chickens, ducks, and turkeys. There have been several projects to introduce rabbits. Cattle ranching has been encouraged in the western region of the country. The average Ugandan consumes a modest amount of meat, mainly in the form of poultry. Dairy farming is another expanding sector with Uganda producing pasteurized and "long-life" milk, butter, yogurt, and cheeses.
- **Fishing:** Because lakes and rivers cover nearly 20 percent of Uganda, fishing holds considerable potential for the country. Fish and fish products are one of the most important export items for the nation.

Farmers in Uganda largely use small-scale, labor intensive technologies, dependent on rainfall that is distributed in two rainy seasons in most of the country. The hand hoe is the main production tool. Roughly 10% of farmers use animal traction, and 1.2% use tractors. The dependence of most smallholders on rain-fed agriculture without adequate water management is especially concerning in light of increasing climate variability and soil degradation that lowers the water retention of fields.

The adoption rate of new technologies such as improved seeds, inputs or mechanized traction has remained low. For instance, by 2011 only 7% of farmers rented, and 8% owned, ox-ploughs. The use of inorganic fertilizers remains concentrated on a few farms, mostly the larger and more commercially oriented ones in the Central region on which cash crops such as tea, coffee, and increasingly sugarcane or oil palms are grown. Only 8% of small farms apply inorganic fertilizer, with access to major output markets positively affecting its use rate. The least commercialized 25% of farmers sell 4% of their produce and purchase inputs worth 1% of the value of their production.

[19] Export.gov

Particulars	Unit	Net Land Operated		Gross Area Operated	
		2005/06	2015/16	2005/06	2015/16
Share of HH < 2 ha	%	74.70%	82.80%	54.10%	65.40%
Mean Operated Farm Size < 2 ha	ha	0.8	0.73	1	0.9
Mean Operated Farm Size > 2 ha	ha	4.5	3.3	5.4	3.9
National Mean Farm Size All HH	ha	1.7	1.2	3	2
Central Region rural mean farm size	ha	1.5	1.1	2.8	2.1
Eastern rural mean farm size	ha	1.8	1	3.1	1.7
Northern rural mean farm size	ha	2.4	1.9	3.7	2.8
Western rural mean farm size	ha	1.5	1	2.8	1.8
Urban based farm HH rural mean farm size	ha	1.3	0.9	2.2	1.5

Table 3: Average farmland size in Uganda[20]

Using quality inputs will increase agriculture productivity if they are accompanied by improved farming practices. Current yields for maize, millet, rice and sorghum are estimated to be only 20-33% of the potential yield for rain-fed agriculture, and even less for irrigated agriculture.

[20] World Bank

8. Irrigation

Rain fed agriculture is the most practiced land use method in the Uganda. Currently this practice is threatened with climatic variability and a fast-growing population, which are impacting on food security levels. As a result, national policy on agriculture aims at increasing agricultural production per unit area e.g. through a more efficient use of land and water resources which will improve food security. The increase in population has increased the need to raise crops in areas that do not get enough rainfall, hence requiring irrigation [21].

Uganda's ratio of cultivated area under irrigation to the irrigation potential is only 5%[22]. Uganda has enormous freshwater endowments covering about 15% of the total area, thus providing great opportunity for increased agricultural production and productivity leading to wealth creation. Of the renewable fresh water, only 1% is used for irrigation, yet world over 70% of water is used for irrigation. The current potential for irrigation in Uganda was determined based on the "Assessment of Irrigation Potential study" conducted in 2011-12 through the Regional Agricultural Trade and Productivity Project (RATP) under the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) of the Nile Basin Initiative (NBI). The irrigation potential was determined by combining five factors: Terrain suitability, Soil suitability, Water availability, Distance to water source and Accessibility to transportation.

Public irrigation schemes are owned by the government and day-to-day operations are manned by the government or delegated to the farmer cooperative societies or water user association (WUAs). Beneficiaries pay an irrigation service fee toward operation and maintenance of the irrigation scheme. Development of public irrigation schemes was initiated from the 1960s onward.

Community-based irrigation schemes are co-owned and managed by the community. The infrastructure operations and maintenance plus water distribution are the sole responsibility of the community. The majority of community-based irrigation schemes started as informal irrigated areas located on the fringes of swamps and rivers. Labor for construction of these schemes is provided by farmers with financial support from the government and development partners.

Private commercial irrigation schemes include commercial farms or estates that produce sugarcane, rice, and high-value crops such as floricultural and horticultural crops, primarily for the export market[23]. Irrigation of sugarcane farms at Kakira and Lugazi estates started in the 1970s and has continued to expand in response to prolonged droughts. Private small-scale irrigation schemes are also referred to as self-help schemes. They include small irrigated farms (less than 10 ha and typically 0.1 ha) that are owned or leased and under the complete control of the farmer. **Farmers usually have direct access to surface water or groundwater and make their own decisions about how and when they will irrigate and how much water to apply. Small-scale irrigation has been practiced informally using traditional irrigation techniques for several years as a coping mechanism against erratic rainfall.** Some of the small-scale irrigated areas belong to out-growers in the neighborhood of medium- to large-scale schemes.

[21] Source: "Water Resources of Uganda: An Assessment and Review" by Francis N. W. Nsubuga, Edith N. Namutebi3, Masoud Nsubuga-Ssenfuma

[22] Source: As per data shared by The Ministry of Water and Environment (MWE)

[23] ASCE Library

Although statistics are not available, evidence shows that the area managed by smallholder irrigators has increased over the years.

Currently, total 6 cooperatives for medium scale farms existing in Uganda. Small farmers typically do not form cooperatives, but they form water usage groups. In total 8 water usage groups with 15 farmers each are present in Uganda[24].

Several Bulk Water Systems have been constructed providing water for livestock production, Irrigation watering, aquaculture and rural industries. These include medium scale and small-scale Irrigation schemes, earth dams and valley tanks. Rehabilitation of four Medium sized irrigation schemes which include Doho in Butaleja district, Mubuku in Kasese district, Olweny in Lira District and Agoro in Lamwo district have been completed in the country, creating 2,646 hectares of irrigation potential across the country.

Currently, there are Six other medium sized schemes; (Mubuku II in Kasese district, Doho II in Butaleja district, Wadelai in Nebbi district, Tochi in Oyam district, Ngenge in Kween district and Rwengaaju in Kabarole district.) expected to create a further 3955 Ha on completion.

Through the construction of 38 small scale irrigation schemes, MWE has exploited an additional 380 acres of the country's irrigation potential. Construction of another 35 small scale irrigation schemes is also ongoing. For each of the communal WfP facilities constructed, a Sustainable Farmer Based Management Organization (FBMO) is established and trained to effectively operate and maintain the infrastructure and facilities.

The department is currently undertaking 23 No. feasibility studies and detailed designs of medium and irrigation scheme additional thirty-four (34) Small Scale Irrigation systems (SSIS) in the various districts across the country, to enable the establishment of irrigation infrastructure in a bid to boost agricultural production, food security and climate resilience.

All these interventions are aimed at meeting the implementation targets set out for the department which include; 1.5 million hectares of irrigated land by 2040 (50% of the country's irrigation potential), and 163.67 million cubic meters of water for production storage by 2030 as reported in the National Irrigation Policy (2018), and the Water and Environment Sector Strategic Investment Plan 2018-2030 respectively.

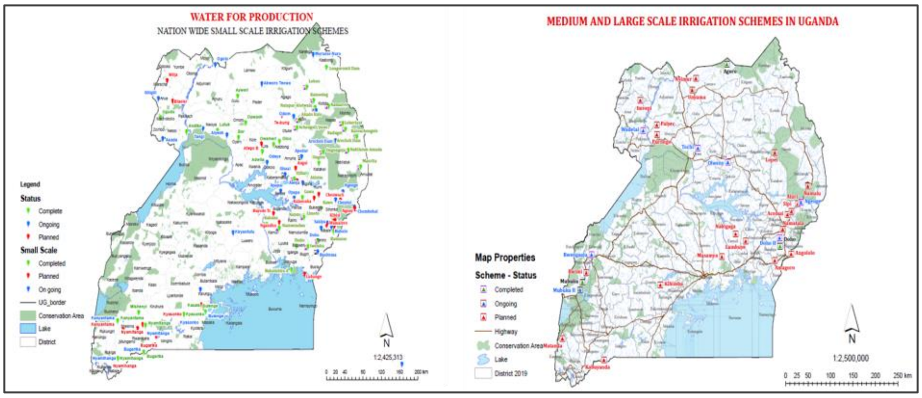


Figure 10: Irrigation schemes in Uganda

[24] Source: As per data shared by The Ministry of Water and Environment (MWE)

9. Cropping Pattern

Cereal crops grown in Uganda include; maize, finger millet, sorghum, rice, pearl millet and wheat. Other than wheat, these crops provide staple food for well over 50% of the population. They are also playing an increasing role in the provision of incomes of the rural households and the national economy. All these crops, other than wheat and rice, can be grown in most areas of the country. High potential areas for each crop are to a large extent, defined by rainfall amount and distribution. Maize requires medium to high rainfall that is well distributed throughout the growing season. As rainfall declines in duration and reliability, generally from south to north and westwards, finger millet becomes important. This in turn gives way to sorghum and finally pearl millet, as increasingly hardy crops that thrive in low rainfall environments. Wheat requires cooler temperatures and is grown in highland areas of the country such as Kapchorwa, located in the eastern and north western parts of the country, respectively.

Maize is grown in most parts of Uganda but most intensely in eastern (Kapchorwa, Mbale, Kamuli, Jinja, Iganga), central (Masaka, Mubende) and western (Masindi, Kamwenge, Kyenjojo, Kasese, Kabarole). **Over 90% of Uganda's maize is produced by smallholders, of which about 60% of the annual maize output is consumed on the farm.** The intensity of production appears to be a function of the position of the crop in the food system and the marketability of the crop. Maize can be grown twice a year (utilizing the bimodal rainfall opportunity) and continuously as long as it gives reasonable yield, and because of shortage of land to allow fallowing, this has caused a decline of soil fertility and grain yield. In many parts of the country, maize is intercropped with beans, soybeans or groundnuts.

Finger millet is the second most important cereal in Uganda after maize. Its production is concentrated in the east, north and southwest of the country. **Up to 65% country's acreage is in the districts of Apac, Lira, Gulu, Kitgum, Iganga, Kamuli, Soroti and Tororo.**

Grain sorghum is the third most important cereal crop in Uganda. It is widely grown in drier short grass areas in northern, eastern and south-western parts of the country. It is particularly important in the drought prone Karamoja region (Kotidi and Moroto districts), where it occupies 80% of the total crop acreage. It is also very important in Kabale, Kisoro and Rukungiri districts. It is more tolerant to drought than maize or finger millet, which makes it in important food security crop. It is a staple in much of eastern and northern Uganda. Sorghum plays important roles in the food security of the country and incomes of many rural households.

Rice is grown in many parts of the country, but the principal areas are Gulu, Iganga, Tororo, Kitgum, Pallissa, Hoima, Kibale, Lira and Kumi. There is an increase in acreage under rice production because of the increased demand, and stability of farm-gate and retail prices. Government policy that encourages farmers to grow rice so as to ensure food security for this commodity, alleviate poverty and reduce the need to import rice. Among the crops grown in Uganda, rice is second to none in economic returns to the smallholder farmer on the basis of labor per man-day per ha.

Lowland rice is largely distributed in areas with extensive swamp networks. High potential areas for its production are found around Lake Kyoga. The acreage under lowland cultivation is increasing at 4000 ha/yr, most of which is reclaimed permanent wetlands

Upland rice is a relatively new crop in Uganda's smallholder agriculture, but the consumption of rice is increasing due to its preference in school feeding and urbanization. Smallholder farmers consider rice primarily as a cash crop; production in 2006 was at 154000 tons; average yield was 733 kg/ha. Because the government has given increased rice production a high priority since 2000, the President launched upland rice growing in 2004, the UN's International Year of Rice.

Wheat is mainly produced in the districts of Kapchorwa, Kabale, Kisoro, Kabalore, Kasese, Bushenyi and Mbarara. Small quantities are also produced in Nebbi and West Nile districts.

Two cropping seasons exist in Uganda dependent on the rainfall, March to June and August to December with crops such as rice, maize, beans and millets grown in both the seasons. However, the rainfall during March to June is more consistent while rain is inconsistent during August to December, when the irrigation shall be required.

The table below provides details of the exports of various cash crops[25].

Cash Crop Exports (Metric Tons)	2012	2013	2014	2015	2016	2017
Coffee	162,000	221,000	207,000	216,000	213,000	287,000
Tea	55,000	62,000	60,000	53,000	56,000	N/A
Cotton	43,000	19,000	13,000	15,000	23,000	N/A
Tobacco	32,000	56,000	25,000	28,000	27,000	N/A[26]

Table 4: Major Exports of cash crops in Uganda

The typical cropping calendar for Uganda is provided below:

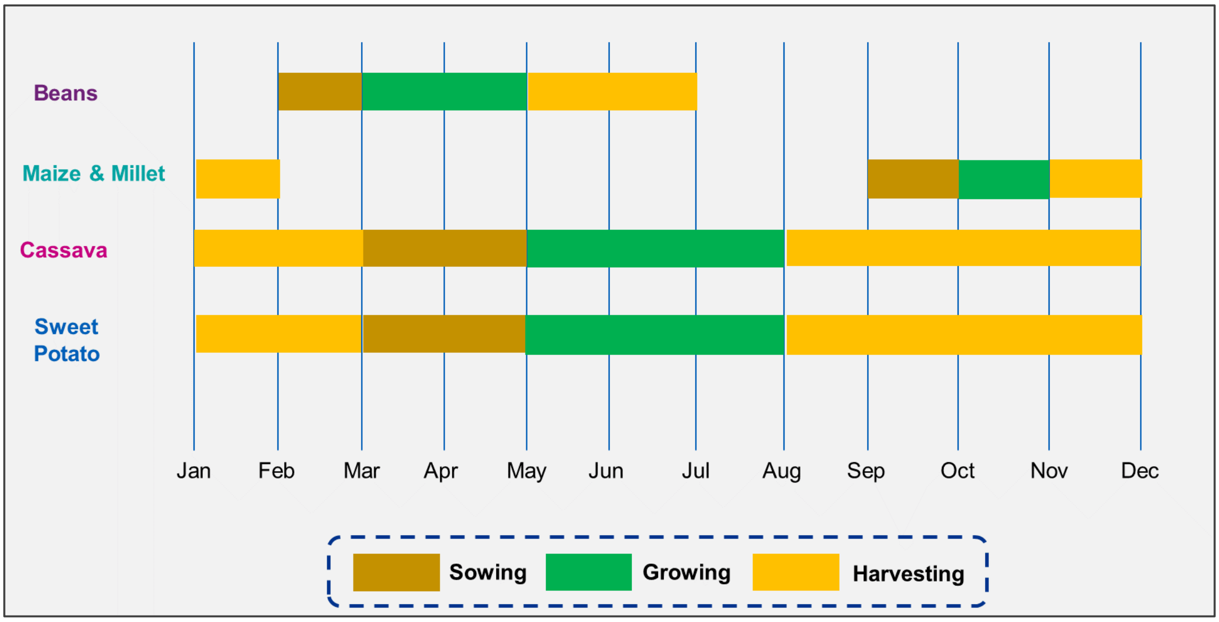


Figure 11: Cropping Calendar in Uganda[27]

[25] Yieldgap.org
[26] Exports.gov
[27] FAO/GIEWS

10. Background to solar water pumping in Uganda

Healthy rains spanning 8-9 months a year provides Uganda with an advantage to grow a variety of food and cash crops, expand livestock farming and increase investments in both capture fisheries and aquaculture. With climate change, rains have become shorter (averaging 6-7 months a year since 2010) and droughts longer. The comfort of receiving rains to sustain two cropping seasons in a year provided little impetus to invest extensively in irrigation. As a consequence, despite the advantages that the country holds in the ease of undertaking irrigation development, Uganda's level of irrigation is very low compared to its potential in relation to other East African Countries (EAC). Uganda by 2005 had recorded nil annual increase in irrigation compared to 11.4% rate of increase in Rwanda, 2.7% increase in Burundi and 4.1% increase in Kenya. Currently, the ratio of cultivated area under irrigation to the irrigation potential is only 0.5% against an irrigation potential of 15%. This compares to 3.6% for Tanzania, 2.0% for Kenya and 1.6% for Burundi. Yields from irrigated farmlands recorded much higher output compared to non-irrigated farms. For instance, irrigation enhanced maize production from 2.0 tons per hectare to 8 tons; 15.6 tons for vegetables to over 30 tons per hectare, on average, and in just two seasons.

There is growing need of increasing penetration of technologies which are efficient and sustainable, and the international development and funding organizations have recognized this need and are executing projects to ensure a long-term sustainable solution to the farmers. To this effect, a number of projects are being implemented by The World Bank, African Development Bank, UNDP and other agencies for improving the efficiency of irrigation and agriculture. UK export finance, World Bank and GIZ are providing loan-based support in the country with Government of Japan also funding the projects. Uganda Energy Credit Capitalization Company. BfZ, Sida, EAENet, United States African Development Foundation are some of other agencies active in Uganda. JEEP (Joint Energy and Environment Projects) and Solar-Aid are some of the NGO's involved in the solar water pumping programme in Uganda.

The details of some of these projects are detailed below.

Funding Agency	Implementing Partner	Funding Amount (USD)	Project Title	Project Description
The World Bank	Ministry of Agriculture, Animal Industry and Fisheries	150 million	Agriculture Cluster Development Project	To raise on-farm productivity, production, and marketable volumes of selected agricultural commodities in specified geographic clusters.
The World Bank	Ministry of Finance, Planning and Economic Development, Ministry of Water and Environment	280 million	Integrated Water Management and Development Project	To improve access to water supply and sanitation services, integrated water resources management, and operational performance of water and sanitation service providers in Project areas

Funding Agency	Implementing Partner	Funding Amount (USD)	Project Title	Project Description
Not Applicable	Ministry of Water and Environment	1.3 million	Construction of Solar Powered Mini Piped Water Schemes in Rural Areas	Currently 35 solar powered mini piped water schemes have been implemented to increase agricultural productivity and institutional capacity for irrigation service delivery.
UNDP, European Union, Department of International Development, Government of Norway	Ministry of Agriculture, Animal Industry and Fisheries, NARO, Ministry of Water and Environment, Ministry of Trade, Industry and Cooperatives	0.74 million	Enhancing Adaptation to Climate Smart Agriculture Practices in the farming systems of Uganda	To increase the productivity of land through sustainable land management of soil and water resources.
Government of Japan	FAO, Ministry of Agriculture, Animal Industry and Fisheries	0.48 million	Solar powered irrigation scheme	Nearly 9000 households under Robijame Farmers' Group in Palorinya East Village, Itula Sub-county in Moyo District to use solar powered irrigation to address the challenges of water scarcity faced by the community.
USAID	Ministry of Agriculture, Animal Industries and Fisheries, Uganda National Bureau of Standards		Feed the Future	To transform subsistence farms into more commercial operations and to increase farmers' skills in improved production, post-harvest handling and storage technologies. Agricultural programs include researching and promoting biotechnology products aimed at improving the productivity and disease resistance of key food and cash crops.

Table 5: Projects in Uganda

11. Solar pump Technology Overview

A PVP (Photo Voltaic Pump) typically consists of the following main components:

1. **Photovoltaic array:** An array of photovoltaic modules connected in series and possibly strings of modules connected in parallel.
2. **Controller:** An electronic device which matches the PV power to the motor and regulates the operation, starting and stopping of the PVP. The controller is mostly installed on the surface although some PVPs have the controller integrated in the submersible motor-pump set:
   - DC controller: usually based on a DC to DC controller with fixed voltage set point operation.
   - AC controller (inverter): converts DC electricity from the array to alternating current electricity often with maximum power point tracking.
3. **Electric motor:** There are a number of motor types: DC brushed, DC brushless, or three phase induction and three phase permanent magnet synchronous motors.
4. **Pump:** The most common pump types are the helical rotor pump (also referred to as progressive cavity), the diaphragm pump, the piston pump and the centrifugal pump. Some years ago, there were PVP models on the market that operated with batteries and a conventional inverter. However, it was soon realized that the cost savings on the pump did not make up for the overall substandard efficiency and the higher maintenance cost due to battery replacements. Instead it became clear that it is more economical to rather store water in a reservoir than electricity in a battery bank.

There are currently three pumping configurations commonly utilized in Africa:

- **DC drive with positive displacement pumps**. This consists of four pump technologies: Diaphragm pump driven by brushed DC motor, Helical rotor pump driven by brushless DC motor, Helical rotor pump driven by surface mounted brushed DC motor, Piston pump driven by surface mounted brushed DC motor
- AC drive powering a submersible induction motor/centrifugal pump unit
- **AC drive powering a three-phase permanent magnet synchronous motor**. This category consists of: Positive displacement helical rotor pump, Centrifugal pump

The above technologies have specific features which make them suitable for particular applications. Some of the other key technology terms useful for understanding the functioning of a solar powered irrigation system are described in detail as per the table below.

Term	Description
Array Voltage	Some of the pumping systems have high array voltages. This has the advantage that the array may be further from the borehole without significant voltage drop (dependent on cable size and current). Array positioning may be important where there is potential for theft.
AC Motors	The motor operates on alternating current; the direct current produced by solar panels gets converted to AC using the inverter. The conversion from DC to AC leads to loss of power from generation to consumption. AC motors gain importance in applications where higher output/head combinations are required.
DC Motors	DC motors reach efficiencies of up to 80% and are therefore significantly more efficient than sub-kW three phase motors which

Term	Description
	have efficiencies in the region of 60% to 65%.
Brushless DC Motors	This combines the high efficiency of DC motors with low maintenance as opposed to brushed DC motors which require regular brush replacement (approximately everyone to two years – head and quality dependent).
Three phase permanent magnet motors	This similarly combines the high efficiency of permanent magnet motors with low maintenance.
Positive displacement vs. Centrifugal pump	Positive displacement pumps have a better daily delivery than centrifugal pumps when driven by a solar PV system with its characteristic variable power supply. This is due to the considerable drop in efficiency of the centrifugal pump when operating away from its design speed. This is the case in the morning and the afternoon of a centrifugal pump driven by a PV array, unless that array tracks the sun (which is why centrifugal PVPs effectiveness improves more with a tracking array than a positive displacement PVP). The efficiency curve of a positive displacement pump is flatter over a range of speeds. However, the efficiency of positive displacement pumps decreases with the shallowness of the borehole (the constant fixed friction losses become a more significant part of the power it takes to lift water). Therefore, it is not surprising that both Grundfos and Lorentz use centrifugal pumps for applications where the lift is less than 20 to 30m but switch to positive displacement pumps for deeper wells.
Surface pump	Surface pumps are installed at ground level to lift water from shallow water sources such as shallow wells, ponds, streams or storage tanks. Surface pumps can also be used to provide pressurized water for irrigation or home water systems. These pumps are suitable for lifting and pumping water from a maximum depth of 20 meters.
Submersible pump	Submersible pumps installed where there is a requirement for the submerged in the fluid to be pumped These pumps can be used in areas where water is available at a greater depth and where open wells are not available. Typically, the maximum recommended depth these systems can pumps is 50 meters.

Table 6: Key technology terms in a solar powered irrigation system

12. Experience and Perceptions

1. **Theft**: This is a problem for both PVP (Photo Voltaic Pump) and diesel pumping but very costly for the PVP systems due to the main portion of the capital cost being vested in the solar PV modules.
2. **Variable water demand:** Diesel pumps can pump water on demand. PVPs do not have that flexibility. A hybrid system such as solar diesel would present an attractive solution, however at a higher cost.
3. **Supply security:** PVP is considered to have less redundancy, is more difficult to repair and is susceptible to lightning strike. Diesel pumping has a more solid service infrastructure and is considered more reliable. The hybrid pumping solutions would improve supply security.
4. The diesel system is considered more flexible (flexible in moving a diesel engine to another borehole).
5. Diesel fuel is part of an existing infrastructure and the owner is able to do the minor service on the engine himself. PVP technology requires knowledge of mechanics, electrical and electronics thus making the user/operator dependent on specialized service which is often only available in Windhoek.
6. PVP are perceived to pump insufficient water.
7. **Corrosion** is a problem for both diesel and solar pumps.
8. The environmental impact of diesel pumps includes carbon emissions, possible borehole contamination, and threat to borehole sustainability. PVPs can be seen as a resource protection if it is designed for the maximum sustainable yield of the borehole.
9. The operation of PVPs is quiet.
10. PVPs are perceived to be expensive.
11. Many users on commercial farms combine the need for starting the diesel pump the opportunity for inspecting fences, checking on livestock and other farming activities. However, if a PVP is used then the frequency of these trips over the farm decrease[28].

[28] Ministry of Mines and Energy (Namibia), UNDP, GEF

13. Feasibility Analysis

The feasibility of a solar powered irrigation system depends on a wide array of factors ranging from geographic parameters such as temperature, rainfall, water table depth to site specific parameters such as cropping pattern, land size, planting date, irrigation technique etc. Any feasibility analysis of a solar powered irrigation system would involve both the technical feasibility and the financial feasibility. The technical feasibility would analyze the site-specific conditions to determine whether such system can be installed considering the different technical aspects such as solar irradiance, size availability, panel size, tracking systems, water table depth etc. The technical feasibility would also provide recommendations on the ideal pump size and type considering the dynamics of the site. Once technical feasibility for a given system is established, the costs involved, and the expected returns are calculated using financial feasibility analysis. The below figure summarizes the interplay of various parameters involved in technical and financial feasibility analysis.

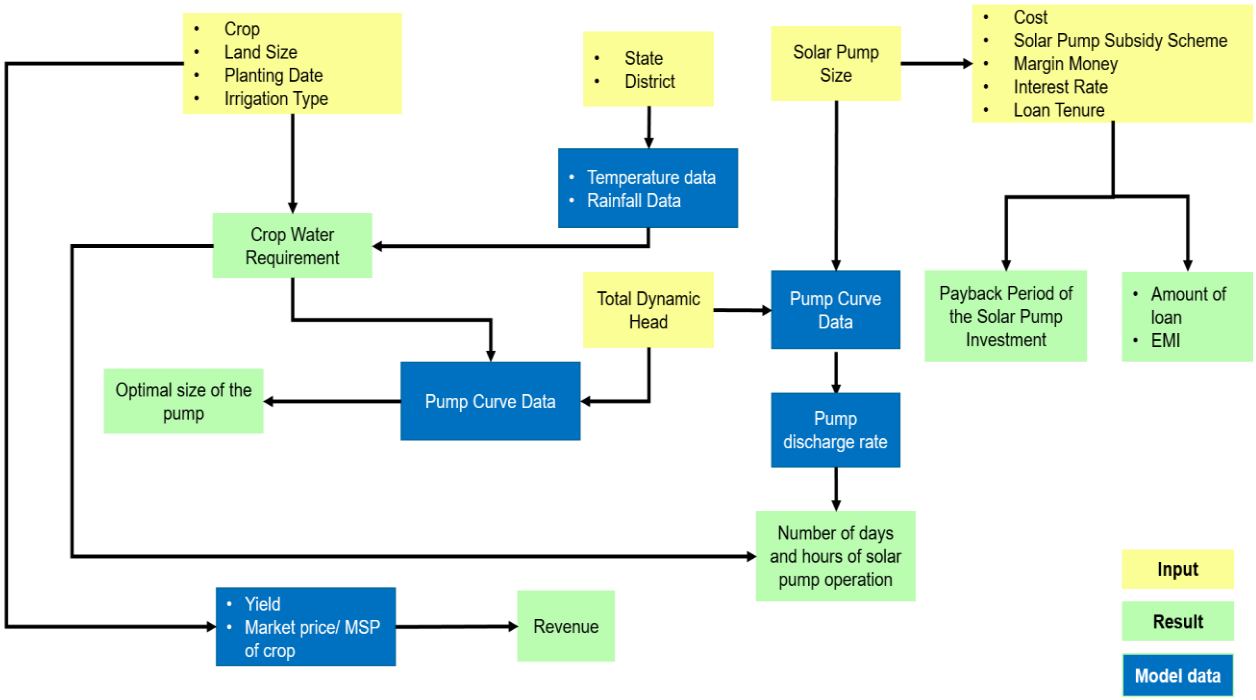


Table 7: Factors involved in feasibility analysis of a solar powered irrigation system

13.1 Technical Feasibility Analysis

13.1.1 Solar Irradiance

The efficiency of solar panels and consequently the solar energy output depends on three factors: the intensity of the solar radiation flux; the quality and the operating temperature of the semiconductor in use and the operating temperature of the semiconductor cell. Though the two latter factors may somehow, in one way or the other, be altered and improved; the intensity of the solar radiation flux however, to a great extent, is simply a given natural resource. The actual level of solar irradiance depends on the latitude and local climatic conditions. Annual solar irradiance, for instance in northern Europe is different from that noted within the sub-Saharan region. The below figure shows the long term global horizontal irradiance over Uganda.

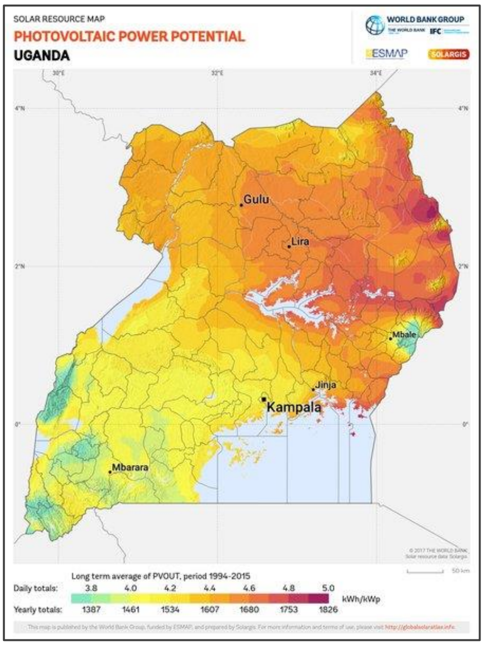


Figure 12: Solar Resource Map of Uganda[29]

The average solar radiation in Uganda is 5.1 kWh/m²/day. Existing solar data clearly indicate that the solar energy resource in Uganda is high throughout the year. The data indicate a yearly variation (max month / min month) of only about maximum 20% (from 4.5 to 5.5 W/m²), which is due to the location near the equator. The insolation is highest in the dryer area in the north-east and very low in the mountains in the east and south-west.

13.1.2 Pump Location

The pump should be located in an enclosed room called a pump pit or a pump house. Surface pumps are not waterproof and need to be kept away from water and protected from environmental conditions to prolong their lifetime and reduce maintenance requirements. Distance between the pump and the PV panels should be kept to a minimum to reduce voltage drop in the cables. Increased distance causes harmonics and would require a harmonics filter to avoid damages to the pump and the inverter/controller.

13.1.3 Pump Sizing

Oversizing would incur unnecessary costs, and under sizing would lead to insufficient performance. This is why each component needs to be properly designed and sized to meet the specific requirements of the project. It is the only way to guarantee reliability and system durability and achieve the desired performance. Similarly, when sizing a solar system, it is recommended to use the 'worst month method'. By sizing the systems for the month with most adverse conditions in the year, it will be ensured that water supply will be enough for all the other months. The worst month in the year will be that in where the gap between the energy required to supply water and the energy available from the Sun is higher. In case the daily water requirement is the same all the year round (meaning too that the energy required is the same all the year round since pump will run for the same number of hours any day), the worst month will be that with least solar radiation.

[29] https://solargis.com/maps-and-gis-data/download/uganda

13.1.4 Water Demand

Water demand is the major factor affecting the size of the pumping system. For solar systems it is calculated as a daily consumption rate (m^3/day). The storage capacity is the volume of water that need to be stored to ensure sufficient and continuous supply of water to end users. Storage tanks usually range in a volume of between 1 to 5 days of daily water requirements, depending on the location and the usage patterns

13.1.5 Total Dynamic Head

The total dynamic head is a very important parameter of a solar pumps which determines the various head losses that the pump must overcome. It is a summation of the suction head, discharge head and the friction losses. The total dynamic head and the desired flow rate of the system are applied to the pump performance curve, which is used for proper pump selection based on required electrical power input and optimum efficiency[30].

13.2 Financial Feasibility Analysis

13.2.1 Payback Period Analysis

Indicative Inputs

S.No.	Particulars	Unit	Value		Source
1	Crop to be Irrigated		Maize, Rice		
2	Land Size	hectares	0.5 (for each crop)		
3	Planting date		As per cropping calendar of Uganda		
4	Irrigation type		Flood: Lined canal supplied		
5	Annual average yield of crop	Kg/hectare	Rice	3300	JICA
			Maize	1125	FAO
6	Market Price	USD/quintal	Rice	55.74	JICA
			Maize	16.71	The Grain Council of Uganda
5	Selected Size of Solar Pump	HP	5		
6	Total dynamic head inclusive of friction losses	meters	50		
7	Cost of Solar Pump	USD	5045.5 [31]		Average of L1 prices discovered in ISA tender for Various categories of pumpsets
8	Subsidy	%	0 %		
9	Margin Money	%	10 %		
10	Loan Amount	%	90 %		
11	Interest Rate	%	19.85 %		World Bank
12	Loan Tenure	years	8		
13	Cost of diesel pump per HP	USD	1.78		
14	Cost of diesel	USD/litre	1.18		Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3%		Based on global averages

[30] ScienceDirect.com

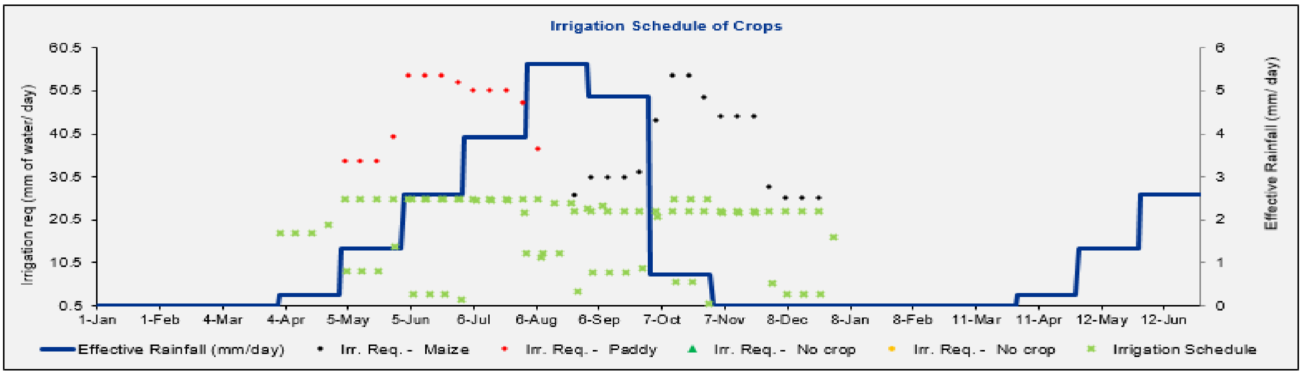
[31] Cost of Solar pumpset includes on-site Comprehensive Maintenance Contract (CMC) for 5 years but exclusive of custom import clearance, duties and local taxes as per ISA International Competitive Bid

16	Inflation rate	%	2.6%	World Bank Data
17	Living expense of the farmer (as a % of crop revenue)	%	60 %	Based on global estimates, KPMG Analysis
18	Maintenance costs for diesel pump (as a % of capital costs)	%	10 %	Based on global estimates, KPMG Analysis[32]

Indicative Crop Water Requirement

Total Crop Water Requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
92	-	-	410	655	924	629	-	-	1,208	1,157	700
Annual crop water requirement (m^3)						5,774					

Indicative Irrigation Schedule[33]



Indicative Outputs

S.No.	Particulars	Unit	Value
1	Amount of subsidy	USD	0
2	Amount of loan to be availed	USD	4541
3	Yearly installment towards loan repayment	USD	1178
4	Monthly installment towards loan repayment	USD	98
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	73
6	Number of hours of solar pump operation required	Hours	287
7	Number of days of solar pump operation required	Days	41
8	Incremental payback of solar pump w.r.t. diesel pump	years	12

Uganda has submitted demand for 30,000 Nos. solar water pumping systems. At an average price of USD 5045.5 per 5 HP pumpset, Uganda requires financing of **USD 151.37 Million to roll out deployment of 30,000 Nos. solar water pumping systems** across the country**.**

[32] The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.

[33] Note: This is just an indicative analysis to be used only for reference purposes. We have taken reasonable assumptions wherever reliable data was not available. A more accurate analysis can be arrived at once data has been obtained from the respective nations.

14. Advantages of solar powered irrigation

Socio-economic advantages		Environmental advantages
Farm level	**National level**	
Financing and cost of solar panels continue to drop, making SPIS economically viable and competitive with other sources of energy.	Potential for job creation in the renewable energy sector.	No greenhouse gas emissions.
Rural electrification and access to renewable energy, especially in remote areas.	Contribution to rural electrification and renewable energy targets.	Potential for adaptation to climate change by mobilizing groundwater resources when rains fail, or rainfall patterns are erratic.
Independence from volatile fuel prices and unreliable and costly fuel supplies.	Reduced dependence on energy exports. Energy subsidies for fossil fuels can be reduced while offering an alternative to farmers and rural communities whose livelihoods would otherwise be negatively affected.	Potential for improving water quality through filtration and fertigation systems. Less pollution resulting from inadequate fuel handling from diesel pumps.
Potential for increasing agricultural productivity and income due to improved access to water.	Food security may be improved if introduction of SPIS is accompanied by changes in irrigation technologies and agricultural practices.	
Potential for income diversification due to multiple uses of energy (e.g. feed-in to grid, lighting, cooling) and water (e.g. livestock watering, domestic uses).	Rural development through improved access to water and energy.	
Reduced cost for water pumping in the long run. If system is being modernized for pressurized irrigation, increases in energy costs are offset through the use of solar energy.		
Potential time saving due to replacement of labor-intensive manual irrigation, which can lead to other income-generating activities. Women and/or children might profit from time not spent on watering anymore.		

Table 8: Advantages of solar powered irrigation

15. Key Stakeholders

Organization/ Agency	Role
Ministry of Energy and Mineral Development (MEMD)	The mandate of the Ministry of Energy and Mineral Development (MEMD) is "To Establish, Promote the Development, Strategically Manage and Safeguard the Rational and Sustainable Exploitation and Utilization of Energy and Mineral Resources for Social and Economic Development".
Ministry of Finance, Planning & Economic Development	The Ministry's mandate cuts across all sectors of Government. Not only is it entrusted with the formulation of sound economic and fiscal policies, but it also mobilizes resources for the implementation of government programs and ensure that all public resources are disbursed as appropriated by Parliament and accounted for in accordance with national laws and international best practice. Their goal is to achieve the national PEAP targets and the Millennium Development Goals.
The Ministry of Water and Environment (MWE)	Has the overall responsibility of the development, managing, and regulating water and Environment resources in Uganda with the given roles • Developing legislations, policies and standards for management of water and environment resources • Providing sustainable safe water supply and sanitation facilities in rural areas • Providing viable water supply and sewerage/sanitation systems for domestic, industrial and commercial use in urban areas • Provision of water for production for use in agriculture, rural industries, tourism and other uses • Coordinating the national development for Water for Production (agriculture, industry, aquaculture, tourism, trade) • Promotion of integrated and sustainable water resource management • Providing effective planning, coordination and management mechanisms for water and sanitation sector • Providing sound and sustainable management of environment for optimum and social and economic benefits for the present and future generations • Promotion of effective management of forests and trees to yield increases in economic, social and environment benefits for the current and future generation, especially the poor and vulnerable • Receiving, transmitting and processing all weather data from stations nationwide and to international centers
Ministry of Foreign Affairs (MOFA)	The Ministry of Foreign Affairs (MOFA) is a cabinet-level government ministry responsible for the implementation and

Organization/ Agency	Role
	management of Uganda's foreign policy and international activity
Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)	Government Ministry charged with creating an enabling environment in the Agricultural Sector. It is commonly known as Ministry of Agriculture and carries out its role by enhancing crop production, improving food and nutrition security, widening export base and improved incomes of the farmers. The Ministry is the overseer of the Agricultural sector where it formulates, reviews and implement national policies, plans, strategies, regulations and standards and enforce laws, regulations and standards along the value chain of crops, livestock and fisheries. The Ministry of Agriculture has directorates which include: • Animal Resources • Crop Resources • Fisheries Resources • Agricultural Extension Services.
Ministry of Local Government (MOLG)	The ministry has following agenda: • Building capacity (human and physical) in the Local Governments for efficient service delivery to the population. • Ensuring that Local Governments comply with the statutory requirements and adhere to national policies and standards. • Ensuring that Local Governments are transparent and accountable to the people in the use of public resources so that development takes place. • Facilitating the implementation of the decentralization policy and enhancing democratic governance in the country through developing and reviewing systems, structures, statutory instruments and guidelines on local governance. • Providing technical assistance and backstopping to the Local Governments in Information and Communication Technology (ICT), development planning and management, among others.
Ministry of Lands, Housing and Urban Development	The ministry is responsible for "policy direction, national standards and coordination of all matters concerning lands, housing and urban development.
African Development Bank (AfDB)	AfDB is supporting a number of projects in the country in the area of energy, agriculture, transportation, water supply and sanitation through financial and knowledge support.
USAID	USAID supports Uganda's efforts to address weather-related impacts on agriculture through access to reliable climate data, development of effective climate policies, and research and education. USAID works with civil society organizations to build institutional capacity and support political advocacy on a wide variety of human rights and development issues.
World Bank	World Bank is supporting a number of projects in Uganda in the area of energy, agriculture, education, transportation, water and

Organization/ Agency	Role
	sanitation.
UNDP	UNDP is executing projects in Uganda in coordination with nodal ministries and NGOs.
Global Environment Facility (GEF)	GEF has supported around 89 projects with a grant funding of USD 491 million.
Department for International Development (DfID), UKAID	DfID is supporting Uganda in achieving the sustainable development goals (SDGs) with a focus on economic development, strengthening health and education systems and improving the water system and relief aid.
Climate Investment Funds (CIF)	CIF is supporting Uganda in designing investment plan under the SREP (Scaling Up Renewable Energy Program in Low Income Countries), PPCR (Pilot Program for Climate Resilience), and FIP (Forest Investment Program) to accelerate action in priority areas. Under the SREP, Uganda is directing $50 million in concessional financing to enhance the enabling environment and catalyze investments in geothermal, solar PV net-metering, mini-grids, and wind power technologies. It will focus on the specific institutional, financial, and economic barriers to scaling up bioenergy, hydro, solar, and wind energy.
Food and Agriculture Organization of the United Nations (FAO)	FAO's technical assistance in the country began as early as 1959 in the areas of aquaculture development and livestock disease control. Currently, the country programme comprises well over 20 projects with a combined budget of close to 80 million USD, which makes FAO one of Uganda's significant development partners. FAO projects are mainly field-based, addressing on-ground pertinent issues.

Table 9: Key stakeholders in Uganda

16. Recommendations for implementation

Following are the recommendations for the implementation of solar pumps in Uganda based on the above analysis and discussions undertaken during the visit of delegation from ISA secretariat to Uganda:

1. **Number and type of pumps**: Uganda has submitted demand for procurement of 30,000 solar water pumps. Considering the low levels of electricity access especially in rural areas, off-grid pumps are required. Further the pumps shall mainly be provided to those farmers whose fields, apart from rainfall, are not irrigated.
2. **Size of pumps:** 58% of farmers have holding less than or equal to 1 hectare. These farmers will be the primary beneficiaries of the solar pumps. Therefore, suitably smaller size pumps (<= 2 HP) may be considered in larger number while number of larger size pumps may be limited.
3. **Location of pumps:** The pumps will mainly be located in the selected districts in (Western), eastern, North, North East, West Nile, Part of Central and all cattle corridor districts[34].
4. **Need for boring:** Submersible solar pumps shall be deployed in Uganda to irrigate those fields that are far away from lakes, rivers or swamps. For submersible pumps, boring shall be required till the appropriate depth for the pumps to withdraw water and irrigate the fields. This may be initiated basis the size and specifications of the pumps, once the supplier is finalized.
5. **Financing:** There are limited sources available for the government of Uganda to fund the solar pumps and therefore subsidy shall not necessarily be available for solar pumps. Hence, the financing models envisaged should majorly consider either subsidy from external donor agencies or financing by MFIs/DFIs for the cost of the pump. The subsidy may be required for initial implementation of the solar pumps considering the technology is still new in the country. With the progress of deployment and improvement in costs, the subsidy may be reduced in a phased manner. Further, some amount may be paid by the farmers upfront while the remaining may be done on periodic basis in the form of loan repayments.
6. **Financing structures:** Considering external financing would be required as mentioned in point above, mobilization of financing should be done by the authorities and suitable financing structures should be developed to enable the deployment of pumps.
7. **Knowledge development:** Number of motorized agricultural pumps deployed in Uganda are very limited and farmers have relied on rainwater, surface water or hand pumps for irrigation. Therefore, awareness creation and knowledge development of the farmer regarding deployment of solar pumps is necessary to enable effective adoption and utilization of the pumps. Initially these activities may be undertaken by i-STARCs to be developed in Uganda under the ISA's programme.
8. **Ecosystem availability:** Solar ecosystem is to some extent developed in the country and there are retail stores in rural areas available for the solar panels. Therefore, availability of local manpower for solar and pumps should not be a challenge. However initial training may be required on the operations and maintenance aspects of the solar pumps.

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[34] Uganda's cattle corridor is a broad zone stretching from southwestern to northeastern Uganda, dominated by pastoral rangelands.

17. Proposed next steps

1. **Pre-feasibility report:** The pre-feasibility report may be shared with Multilateral Development Banks (MDBs) such as World Bank, EXIM Bank for financing solar water pumping systems in Uganda. This report assesses the feasibility of implementation of solar pumps with reasonable assumptions as detailed in the report. However, to arrive at a detailed feasibility assessment, site specific and other relevant details (such as, applicable taxes, duties, government incentives etc.) are required from the relevant Ministry.
2. **Financing arrangement:** Government of Uganda with ISA may explore suitable sources of financing for 30,000 solar pumps. The possible sources for financing will include:
    a. Government of Uganda's funds.
    b. Soft loans from bilateral like EXIM bank, AfD/GIZ/DfID/JICA/ USAID
    c. Multilateral soft loans/technical assistance from multilateral such as AfDB, World Bank.
    d. Grant from UNIDO and UNDP and private investors.
3. **Capacity building:** Post bid process and financing arrangement, capacity building of farmers and knowledge development of local technicians may be initiated by pump suppliers and through i-STARCs
4. **Implementation scale:** Considering solar pumps have not been deployed at a major scale in Uganda, implementation may be initiated at a district level which may further be scaled to the country level. The roadmap for the same may be prepared by Government of Uganda in consultation with ISA.
5. **Field preparation:** Boring activities may also be suitably initiated by farmers in the area where the solar pumps are planned to be initially implemented.
6. **Supply and project monitoring:** Regular project monitoring for supply and installation of pumps may be undertaken by ISA and NFP Uganda basis field reports and feedback from farmers, suppliers and government agencies.