Modernizing Agriculture in Uganda: Providing Access to Electricity to Farmers from Small Hydroelectric Power Plants

Carlos Elias
Radford University and DHC Consulting

Linda Lee Bower
Consultant

This paper presents an economic analysis of the impact on farmers' income of providing electricity generated by small hydroelectric power plants in rural Uganda. Facilitating private investments in power generation from hydro sources would increase the supply of power to the country and provide electricity to farmers. Farmers would be able to use powered equipment at all phases of the production cycle and also for irrigation. A cost-benefit analysis for Kapchorwa, in rural eastern Uganda, shows that providing electricity to farmers that grow coffee, maize and beans, may result in an annual income increase of 50%.

INTRODUCTION

About 84% of the population of Uganda lives in rural areas, and agriculture is the most important sector of the economy; agriculture represents 73% of total employment, accounts for about one-fourth of Gross Domestic Product (GDP), and provides most of the raw materials used by the mostly agricultural-based industrial sector. Although coffee is the major export earner, the country also produces many other agricultural products including maize, beans, tea, cotton, tobacco, cassava, and potatoes, among others. A large proportion of agricultural production goes into feeding the local population, and a significant number of farmers practice subsistence farming or grow most of their products for self-consumption.

Agriculture has the potential to significantly increase its contribution to economic growth and poverty reduction in Uganda if energy is used to modernize agricultural practices. The United States Agency for International Development (USAID) has found that electricity is integral to economic development in developing countries; it underpins agriculture, as well as industry, transportation, and commercial enterprises. Energy is not sufficient by itself to achieve economic growth, but it is an important prerequisite. As developing countries seek to sell their agricultural products in the world marketplace, energy is important to power the chain of farm-to-shelf production (USAID, undated).

For countries such as Uganda, transformation of the economy cannot occur without a broad-based increase in productivity and incomes in the agricultural sector. According to the Food and Agriculture Organization (FAO), extending electricity distribution networks into rural areas can bring social and economic benefits because of the positive impact of mechanizing processes on productivity, including post-harvest activities such as storage, drying and milling, among others (FAO, undated). According to FAO, each unit increase in agricultural activity may lead to 1.5 units of economic growth (FAO, 2010).

Currently in Uganda, most post-harvest processes are done by hand. Because of the lack of adequate power in rural areas, farmers are forced to employ traditional, but inefficient, methods for drying, which in many cases result in high post-harvest losses. In addition to being inefficient, these traditional methods affect quality—such as discoloration and lack of uniformity—and result in lower prices. Further, improper or incomplete drying may leave moisture in the product, resulting in spoilage. The use of power equipment could make these procedures and processes more efficient, reduce losses in post-harvest handling, increase productivity, and yield a superior product with higher market value. Simple, inexpensive electric equipment is available, and in some cases farmers can even build their own (Hassan, 2007). Electricity supplied to farmers would also allow for modern irrigation practices with an impact on output and productivity. Irrigation has proven its potential to increase levels of agricultural productivity, and the returns on investment in irrigation are high, not only in terms of greater production of export-quality produce, but also in terms of greater food security (Svendsen, 2009).

However, the supply of electricity in Uganda is insufficient to meet the demand for all uses, in spite of abundant opportunities for power generation from hydro sources. The vast majority of potential sites for building hydroelectric power plants are located in mountainous rural areas that also produce the majority of agricultural goods, especially coffee for export. Uganda's ample potential for generating electricity from water can play a significant role in economic growth and development. Uganda possesses potential hydropower estimated at 3000MW, but less than 10% is being exploited (Federation of Universities, undated).

Within this context, this paper makes a contribution by presenting the economic analysis of the impact, on farmers' income, of supplying electricity to farmers in Kapchorwa, a rural region in eastern Uganda. The paper focuses on the most common crops produced in this region: coffee, maize, and beans. Mechanization offers significant opportunities for increasing productivity for these crops.

The following section presents the estimates of the impact on the production of coffee, beans and maize of the provision of electricity for mechanizing agricultural processes and for irrigation in Kapchorwa, Uganda.

This paper is informed from a consultancy that the authors performed for USAID Uganda to analyze the costs and benefits of adding local distribution of electricity from small hydropower projects to farmers in rural areas. The objective of the project was to prepare a cost-benefit analysis (CBA) to estimate the economic rate of return, among other parameters used for project analysis and selection, for selected small hydropower generation projects that may be included in USAID's Feed the Future "Power for Rural Livelihood Activity." The authors thank USAID for the support provided for the preparation of this paper.

CASE STUDY: POTENTIAL IMPACT OF PROVIDING ELECTRICITY TO FARMERS IN KAPCHORWA

The estimates presented in this paper were prepared assuming that farmers in Kapchorwa receive electricity and use it to mechanize post-harvest practices and for irrigation. Kacofa, the main farmers' cooperative in the Kapchorwa region, was selected for the analysis because of their stated goal to develop commercial farming using modern technologies that require electricity.

Kacofa membership includes 6,300 farmers, representing about one-third of all farmers in the Kapchorwa area. Kacofa was established in 1999, and its activities and assets have significantly grown since then. Currently the association has a facility with offices, a licensed warehouse, machinery, and demo plots to experiment with various crops. Kacofa members receive technical assistance to improve production practices, and they must meet standards. Kacofa also plays a central role in marketing agricultural goods. The Kacofa warehouse is equipped to clean, dry, and sack maize, and then store it for future sales. In addition to the main warehouse, Kacofa has five depot centers and over 30 small producer centers.

Kacofa's exemplary practices have received international recognition, and it is seen as a Center of Excellence where other farmers come to learn. Its driving vision is to transform the practices of its members from subsistence agriculture to profitable and sustainable income from commercial farming. Its mission is to support farmers in the production of viable agricultural commodities that meet the demands of a competitive market. Among its achievements, Kacofa has increased household earnings, but many challenges remain (Wilson, 2013).

Kacofa would benefit from reliable access to electricity to increase efficiency and to add value by processing higher-value products. Of particular interest to Kacofa is irrigation, which would enable farmers to increase production by delinking planting seasons from rainy seasons, expanding cultivated acreage, and diversifying into higher-value crops. Further, if a reservoir were created, it could be stocked with fish to provide needed protein for the population.

Impact of Access to Electricity on Coffee, Beans and Maize in Kapchorwa

Currently, few farmers use powered equipment, with the exception of the drying facility for maize at Kacofa headquarters in Kapchorwa, which is powered by a diesel generator. This facility offers services of cleaning, drying and packing maize, but the cost of running the diesel generator is high, and not all farmers can afford to buy the service. Throughout the Kapchorwa region, electric equipment is not available for facilitating post-harvest activities of coffee, beans or other crops, and electric equipment is not used at any other stage of the agricultural cycle.

Coffee

The biggest impact of electricity on increasing productivity would be in post-harvest processing. The quality and price of coffee depends on post-harvest practices, and in particular on the timing of harvest and pulping (the process to extract the coffee bean from the cherry). Currently, pulping is done with hand-operated pulpers, which are shared by farmers. The hand-operated pulper is slow and inefficient, and it results in significant losses. Moreover, because hand-operated pulpers are slow, farmers may have to wait two or three days after harvesting the cherries, by which time their cherries begin to rot. Delays in pulping have a large impact on price because the resulting product is of lower quality. Between the inefficiency of the machine and the cherries that rot while waiting to be pulped, Kacofa estimates losses between 20% and 50% of the total harvest. Electric pulping machines could process the coffee much faster, reducing waste.

After pulping, the coffee is dried. Currently, it is usually dried on the ground under the sun, resulting in additional losses of about 2%, according to Kacofa estimates. Additional costs are related to drying coffee outside, as it needs to be brought under a roof when it rains, and set it out again when the sun comes out. Electric drying machines would enable faster and more efficient drying of coffee.

Beans

Electricity can have a significant positive impact on beans during the growing phase: irrigation, enabled by electricity, would allow for more crops per year. Currently, beans are planted based on the rainy season, which results in two annual crops: from March to June or July and from August to December. With irrigation, farmers would be able to plant three or four times in a year. At lower altitudes the growing time is shorter, offering the potential for additional growing seasons for beans. In addition, the acreage for beans could be expanded with irrigated land.

During harvest, beans are left out to dry in the field; or, if they are not quite ready but rains are coming, the plants may be uprooted and hung in a shed to dry. Of the three crops under discussion, beans suffer the greatest losses during harvest, which Kacofa estimates at about 15%. Additional losses during drying are also significant, due to rain and rot.

To remove the beans, pods are beaten and then winnowed. This process is inefficient and causes losses, as beans are broken and damaged during the beating. Machines could be used for threshing beans, resulting in a better quality product and lower losses.

Finally, another source of income loss is related to the timing of harvesting for farmers and the low prices that they get. Because all farmers are harvesting at the same time, prices tend to be depressed immediately after harvest. If farmers had access to cold storage, they could store their product and sell fresh beans over time, ensuring better prices.

Maize

Maize is planted in mid-March or April and is harvested in October-November. Maize may be harvested in three months in the lower belt of Kapchorwa, but a second crop is not possible because of lack of rain. With irrigation, however, farmers would be able to plant a second crop and possibly a third. Thus, electricity and irrigation could have a substantial impact on maize production.

Harvesting is still done manually: one person goes among the stalks cutting off the ears, and another person gathers them. Losses occur at this stage because the gatherer may miss ears on the ground, amounting to about 5%, according to Kacofa.

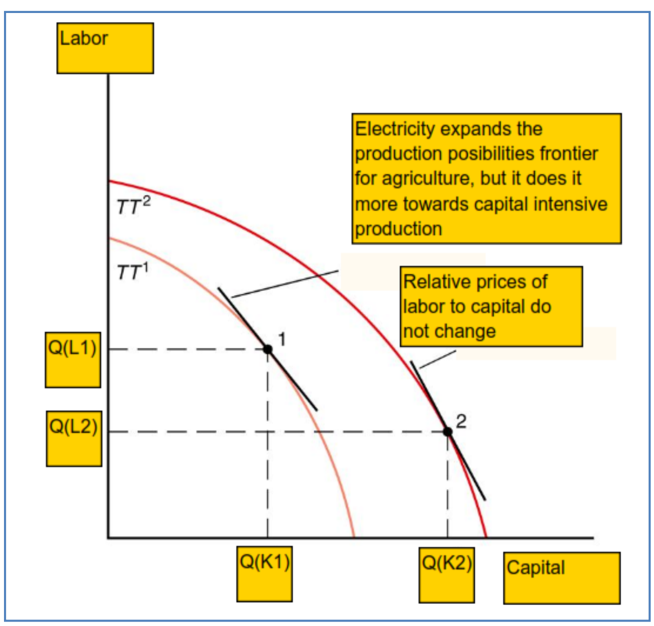
The farmers put the harvested maize in an aerated crib until it is ready to sell. According to Kacofa, losses are about 2% during this step of the process. The kernels are removed manually from the cob and are taken to market. Electricity could be used in drying and threshing.

If farmers could do their own milling, they could also add value to their product. However, only diesel-operated mills are available, but they are not satisfactory because the price of the process is high, and in many cases the maize gets contaminated with diesel.

Theoretical Economic Impact

Figure 1 shows the production possibilities frontier for agricultural production based on two factors of production, labor shown on the vertical axis and capital on the horizontal axis. The line TT^1 shows the initial production possibilities frontier; in this example, any point on this line shows the maximum agricultural production resulting from the combination of labor and capital—i.e. the combination of Q(L1) and Q(K1) result in the maximum production at point 1. When electricity is distributed to farmers, they will be able to increase overall production related to the use of equipment at all stages of the agricultural production cycle. The production possibilities frontier would expand out to TT^2, indicating that more production is now possible related to the increase in capital.

FIGURE 1
EXPANSION OF PRODUCTION RESULTING FROM INVESTMENTS IN ELECTRICITY DISTRIBUTION

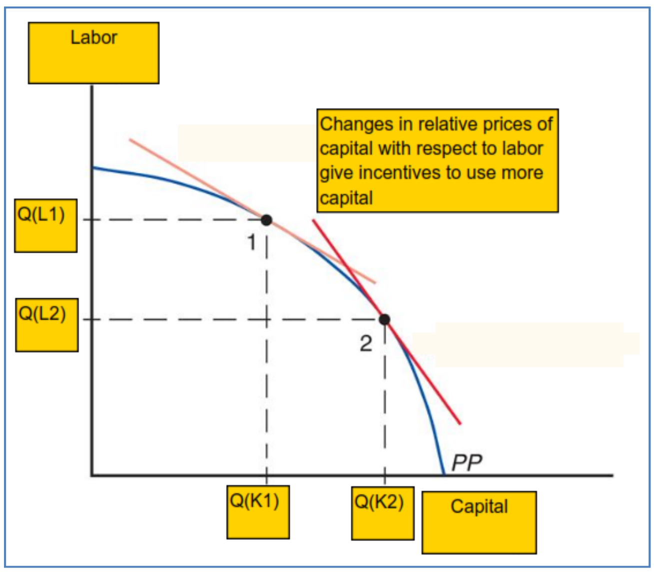


Source: Authors' construction

It is worth noting that labor as a factor of production also expands: This is related to the fact that additional production would require additional labor as the agriculture frontier expands, but also it is worth noting that the expansion of the production possibilities frontier is biased towards capital. Relative prices of labor to capital would change as capital becomes relatively less expensive than labor.

Figure 2 shows graphically the impact of changes in relative prices. At point 1, the relative price of labor to capital results in using Q(L1) units of labor and Q(K1) units of capital. When electricity is produced by hydroelectric power and distributed to farmers, the relative price of labor with respect to capital will increase. Because of the changes in relative prices, the equilibrium point moves from 1 to 2 at the new level of relative prices. The final effect of distributing electricity to farmers may be an overall increase in the demand for both factors of production, or a bias towards substituting labor for capital. Given that prices of labor are very low compared to those of capital in rural Uganda, the most likely final output would be an increase in demand for both factors, or minimal displacement of labor for capital.

FIGURE 2
CHANGES IN RELATIVE PRICES OF CAPITAL TRIGGER SUBSTITUTION EFFECTS



Source: Authors' construction.

Estimating the Impact of Providing Electricity to Farmers in Kacofa

Providing electricity would benefit farmers in the following ways:

- *Scenario A*: The initial impact: reducing post-harvest losses and increasing yields and quality of coffee, maize and beans;
- *Scenario B:* The impact from increasing the number of growing seasons per year when irrigated water is available;
- *Scenario C:* Expanding the agricultural frontier by expanding acreage under cultivation when irrigated water is available.

Costs included in the analysis are:

- Investing in the infrastructure necessary for the distribution network to farmers,
- Estimating operating and maintenance costs of the distribution network to farmers,
- Estimating costs of connections and meters to farmers,

- Estimating the investment by farmers in equipment,
- Estimating the demand for electricity and cost of using equipment,
- Estimating costs of agricultural production,
- Estimating distribution charges.

Benefits included in the analysis are:

- The subsidy that government provides for the expansion of the distribution network in rural areas of Uganda (In Uganda the Rural Electricity Authority (REA) subsidizes the expansion of electricity distribution networks in rural areas. In addition, USAID also indicated an interest in subsidizing some of the costs of the project, such as household connections),
- The impact of reducing losses,
- The impact of increasing prices and yields,
- The impact of increasing the annual number of growing seasons,
- The impact of expanding the agricultural frontier.

It is important to note that this analysis excludes the costs and benefits of building the hydroelectric power plant. This was done because government provides large incentives for the construction and operation of small hydroelectric power plants, such as the one that would provide electricity to Kapchorwa farmers. These incentives guarantee a 15% return over investment by providing long-term purchase agreements at defined prices for all the electricity produced and sold to the transmission grid. Because the financial feasibility of building the small hydroelectric power plant is guaranteed, this analysis focuses solely on the impact of selling electricity to farmers. It is noted that Kacofa may be interested in partnering with potential private sector investors to build a hydroelectric power plant in Kapchorwa.

RESULTS

Annual Impact

The annual impact of providing electricity in Kapchorwa for farmers would be measured in increased production and productivity of coffee, maize and beans. According to Kacofa leadership and their technical staff, and as previously noted, the benefits of farmers' access to electricity would be:

- Electricity would result in a significant reduction of post-harvest losses, especially of coffee, and would result in increases of productivity and quality of coffee, maize and beans.
- The power generation project in Kapchorwa is intimately linked to providing irrigation to Kacofa members, and irrigation would allow farmers to increase the number of planting seasons per year of maize (from one to two) and beans (from two to five).
- The project would result in the expansion of acreage under cultivation: Kacofa members own about 5,000 acres of land that are not currently cultivated, but that could be cultivated in the future if water from irrigation were available.

The combined impact of all factors: reducing losses, increasing yields and prices, increasing planting seasons, and expanding the agricultural frontier, is large and positive. Table 1 shows that farmers could potentially earn an additional US$5.5 million per year, a 50% increase.

TABLE 1
TOTAL CUMULATIVE IMPACT OF
THE PROJECT ON KACOFA FARMERS' REVENUES

	Land dedicated to agricultural production (acres)	Total farmers' revenues status quo (US$)	Cumulative additional farmers' revenues resulting from the project in US$ per year				
			Reducing losses	Increasing growing seasons	Increasing prices and yields	Expanding agricultural frontier	Total gains from the project (US$)
Coffee	3,600	306,073	274,681	none	none	218,001	492,681
Maize	10,800	10,111,336	63,064	2,522,579	391,000	700,716	3,677,359
Beans	1,080	721,457	67,269	1,009,031	104,267	186,858	1,367,424
Total	15,480	11,138,866	405,014	3,531,610	495,266	1,105,575	5,537,465

Source: Authors' estimates based on information collected in Kacofa, Kapchorwa, September 2013.

The largest impact of the project on the revenues of farmers is in coffee, followed by beans and maize, as seen in Table 2. If the irrigation component is included, then the potential revenues of farmers could increase up to 50%. Overall benefits, assuming that current distribution of land dedicated to coffee, maize and beans does not change, would be largest for beans, followed by coffee and maize.

TABLE 2
PERCENTAGE INCREASE IN KACOFA FARMERS' INCOME

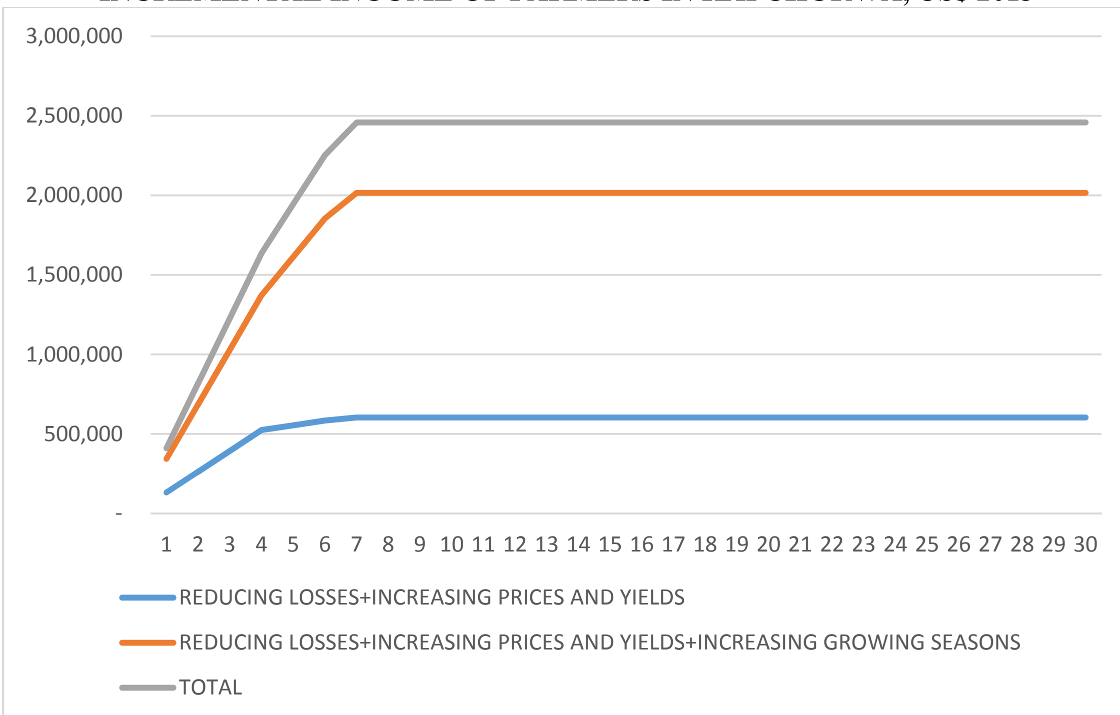
	Reducing losses	Increasing the number of growing seasons	Increasing prices and yields	Expanding agricultural frontier	Total gains from the project
Coffee	90%	0%	0%	71%	161%
Maize	1%	25%	4%	7%	36%
Beans	9%	140%	14%	26%	190%
Total	4%	32%	4%	10%	50%

Source: Authors' estimates based on information collected in Kacofa, Kapchorwa, September 2013.

30-Year Impact.

This presents the 30-year impact of providing electricity to farmers. The methodology used is the standard cost/benefit analysis (Jenkins, 2013). Figure 3 shows the net cash flow generated by providing electricity to farmers in Kapchorwa. The horizontal axis represents years, and the vertical axis total annual income, in constant US dollars, related to the reduction of losses and increases in prices and yields, the added impact of increasing the number of planting seasons, and finally the impact of expanding the agricultural frontier.

FIGURE 3
INCREMENTAL INCOME OF FARMERS IN KAPCHORWA, US$ 2013



Source: Authors' estimates

Table 3 presents the net present value of providing electricity to farmers in Kapchorwa, which in all cases is positive.

TABLE 3
MAIN RESULTS OF THE CBA, NET PRESENT VALUE, US$ 2013

Net Present Value of providing electricity to farmers in Kapchorwa	US$ 2013
Scenario A (losses reduction, increases in prices and yields)	765,550
Scenario B (A+ irrigation)	7,415,576
Scenario C (B + expansion of the agricultural frontier)	10,024,738

Source: Authors' estimates

A sensitivity analysis was performed to test the robustness of these preliminary results and applying them to the three scenarios (A, B, and C) discussed above. The sensitivity analysis included lowering the expected benefits or increasing the costs related to the assumptions on production and productivity improvements that would result from the provision of electricity to farmers; the subsidies provided to the project by government; the electricity tariff schedule; and the cost of operations and maintenance of the distribution network. The results remained positive in all but the most extreme changes.

CONCLUSIONS

The analysis presented in this paper highlights the positive impact of providing electricity to farmers in rural Uganda. The main finding is that stable power supply to rural areas in Uganda may have a large and positive direct impact on farmers' income, private sector expansion, and overall well-being, and indirectly on households and non-agriculture businesses.

It is important to note that the results presented are independent of the net benefits that would result from investing in hydro power in Uganda. When those net benefits are factored in, which would be related to selling electricity to the national grid, then the case for facilitating these investments is strengthened. Therefore, the best option, from a business perspective, is for Kacofa to invest in mechanization and also in the hydroelectric power plant.

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