FACTORS AFFECTING THE VALORIZATION OF PHOTOVOLTAIC WATER PUMPING PROJECTS FOR IRRIGATION IN THE ADAMAWA PROVINCE (CAMEROON)

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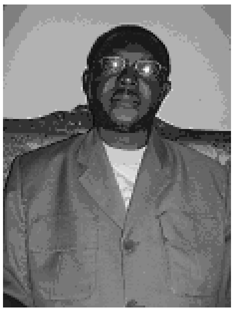
The CESAM method has been adapted to design a photovoltaic water pumping system in the state-of-the-art, according to the farmers' needs in Marza area. An experimental agricultural structure has been implemented to overcome factors affecting the valorization of new technologies for irrigation in dry season such as the lack of modern technological knowledge by farmers, the lack of affordable means by farmers, the lack of interface between the researchers and the users of research results. Convincing results revealed that the farmers could afford to invest in the photovoltaic water pumping projects for irrigation, the incomes being better than the ones in raining season.

Keywords: solar water-lifting systems, economic aspects, CESAM method, RETScreen International software



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Introduction

In the Adamawa province (Cameroon), the bulk of rural inhabitants reside in dispersed homesteads. They are poor, with irregular income from the agricultural activities. Indeed, it is estimated that 68 % of inhabitants of sub-Saharan Africa reside in rural areas [1]. In such a dispersed rural settlements, there is no conventional electric grid. Therefore, an ideal market for decentralized energy technologies that better match the dispersed rural settlements in the Adamawa province is welcomed.

The Adamawa province is known as the water tower of Cameroon, with an average groundwater level at 20 m in most plain areas [2]. These plain areas are farmable and are mainly cultivated in raining season. Unfortunately the unavoidable use a lot of herbal medicine in raining season leads to the reduction of farmers' income, even if there are high yield crops. On the other hand, in dry season the farmers' income may be higher than in raining season, due to the use of a bit of herbal medicine. However, farms have to be irrigated. As a matter of fact, most streams dry off from February to April. In this case, farmers have to select an irrigation system that best fits their incomes. For example, if farmers have access to sufficient surface water for irrigation, then it is usually the cheapest option [3]. Otherwise, in the areas were the groundwater level is less than 5 m, the use of diesel pump units could be more cheaper than other water pumping system [4]. Therefore, what is the matter for farmable areas where groundwater level is up to 20 m?

In this paper, a discussion on the specific factors affecting the valorization of photovoltaic water pumping projects in Adamawa province is presented. The CESAM method carried out at CIRAD of Montpellier (France) [5] is adapted to design a photovoltaic water pumping system which satisfies the adamawa farmers' needs in dry season, especially in the Marza area in Ngaoundere.

The CESAM method for system design

The potential utilization of photovoltaic water pumping systems for irrigation in the Adamawa province depends on factors such as the high difference in air temperature, the lack of modern technological knowledge by farmers, the lack of affordable means by farmers, the lack of interface between the researchers and the potential users of research results, etc. While the issues relating to the first factor may vary considerably from one site to another, the issues concerning the other factors really affect the development of the country. Indeed, a lot of hydraulic projects consisting of boreholes equipped with manual pump units have been carried out in the Adamawa province [2]. Unfortunately, a manual pumping system is not suitable for irrigation. In addition, the users are not qualified to maintain the system.

The CESAM method has been adapted in this paper to find out the adequate solutions to the afore-mentioned problems. This method is an approach of participatory and pluridisciplinary design, aimed to perform small scale farming equipments for sub-Saharan countries. The mean objective is to design equipments in the state-of-the-art, according to the users' needs. Therefore, the design team may be built up by researchers, manufacturers and users. They have to work together from the beginning to the end of the project. This method has been disseminated in several countries in West Africa [6-7], and has registered widespread success, mainly due to the user's satisfaction. To the best of our knowledge, this method is almost unknown in Central Africa.

Generally, the CESAM method is organized in 8 stages. Here, some of these stages have been adapted in a particular case of photovoltaic water pumping project for irrigation in the Adamawa province, especially in the Marza area. The adapted stages can be expressed in terms of the following questions. First of all, is the project profitable? Who are the partners? Who are the final users? Are the financial resources available? Is the equipment to be used local? What is the planning of the project? What is the usual agricultural technique? Etc. The answers to these fundamental questions give rise to innovative ideas which connect the technology to the market.

Within the framework of this project, inquiries have been made, where the following farmers' questions have been registered: Is the investment cost affordable? What is the rate of return on investment? How can the system be maintained and managed? Etc.

The afore-mentioned questions have enabled us to analyse and design a photovoltaic water pumping system taking into account the whole factors affecting the operation system during the dry season and its valorization. To that effect, the RETScreen International software [8] have been used and the sizing of photovoltaic pumping system have been made by the manufacturer [9]. Finally, the photovoltaic water pumping system for irrigation in the Marza area has been implemented by a team of researchers, manufacturers and farmers.

Experimental agricultural structure

There are numerous possibilities of making connexion between the technology and the market. For example, an experimental agricultural structure would be adequate for meetings of researchers and farmers. In this way, the valorization of research results may take place, particularly in the field of irrigation in dry season. This experimental agricultural structure is built up at the Mgr. Yves Plumey's foundation in Ngaoundere at the latitude of 7.3 °N and longitude of 13.3 °E, where large farmable areas and groundwater are available.

System implementation

The implementation of actual photovoltaic water pumping project for irrigation has taken into account the affordable means by farmers, their usual agricultural practice, the profit rate on investment and the system management. The configuration system drawn in Fig. 1 is not quite new. The previous photovoltaic water pumping systems for irrigation which have been the subject of numerous papers [10-11], mainly aimed to reduce the initial investment cost. For our project, all relevant system elements have been dimensioned by the manufacturer with the best up to date selling price. So, one SQFlex solar pump with internal inverter and CU 200 SQFlex controller, and three Helios Technology's solar photovoltaic modules have been purchased. The system has been designed so as to yield the surface water for irrigation in the dry season as it is shown by Fig. 1.

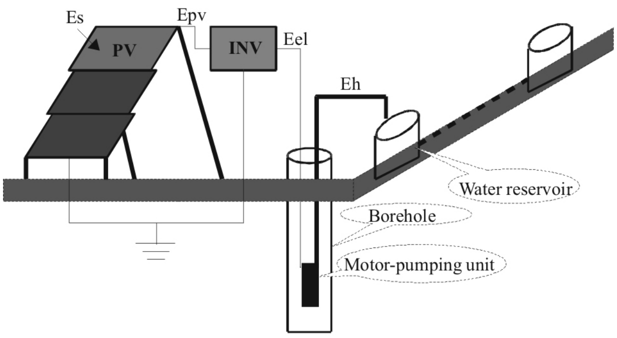

Fig. 1. *Schematic diagram of configuration system*

System analysis

The actual project has been analysed using RETScreen International software, the nominal operating cell temperature being 45 °C with efficiency of 13.3 %. The groundwater availability has been assumed to be sufficient for irrigation according to the agriculture expert's report [2]. The results are shown in Table 1 below, for the month of February.

Table 1

Performance of the system in the month of February

Mean daily production of water Q_D (m^3/day)	6
Total head lift including the head friction loss H_T (m)	24.5
Maximum flow rate Q_{max} (m^3/h)	1.1
Mean daily hydraulic energy E_H (kW·h/day)	0.4
Mean daily solar radiation on PV panel E_S (kW·h/m^2/day)	6.41
Tilt angle of the PV panel θ (deg)	9
Nominal electric power of the PV panel P_{el} (kWp)	0.18
Surface of the PV panel S_{PV} (m^2)	1.3
Total efficiency of the photovoltaic pumping system η (%)	4.6
Daily minimum temperature of photovoltaic solar cells $Tcell_{min}$ (°C)	28
Daily maximum temperature of photovoltaic solar cells $Tcell_{max}$ (°C)	65

Economic analysis

Few of the farmers in the Marza area use diesel pump units for irrigation in dry season. An inquiry has been opened on them, aimed to know if this irrigation technique is profitable; but no answer was registered. However, we assume that an assessment of the affordable means by farmers to invest in a photovoltaic water pumping project can be made by a comparison with a diesel pump unit taken as a reference within the RETScreen International software. The results are presented in Table 2 below.

Table 2

Economic analysis of the project (1 € = 655,957 XAF)

Investment cost.	
Feasibility studies (XAF)	50,000
Engineering (XAF)	350,000
Photovoltaic equipment (XAF)	852,000
Pump unit and closely related infrastructure (XAF)	2,279,745
Miscellaneous (XAF)	349,270
Total investment cost (XAF)	3,881,015
Financial parameters	
Paid-up capital (XAF)	1,552,406
Loan (XAF)	2,328,609
Loan duration (year)	4
Interest-loan (%)	15
Payment of loan (XAF/year)	815,631
Annual savings (XAF/year)	772,810
Total interest-loan (XAF)	933,915
Total payment of loan (XAF)	3,262,524
Rate of return on investment (year)	6.23

Discussion

The temperature dependence on the efficiency of photovoltaic solar cells has been the subject of numerous papers based on numerical simulations [12-16]. The high daily temperature (65 °C) of photovoltaic solar cells (Table 1) really affect the daily production of renewable energy and that remains a great preoccupation in the field of experimental research. In fact, RETScreen International software does not allow us to find out the effect of temperature higher than the nominal operating value on photovoltaic solar cells. Anyway, the manufacturer has found the same nominal electric power of photovoltaic array as the one in Table 1 for a daily water production of 6 m^3 at the head lift of 24.5 m. So, the proposed simplest configuration system for irrigation may operate well in the optimal conditions. However, a malfunction of the system could occur at the cell temperature higher than the nominal operating value.

The actual project has been awarded by the French cooperation in Cameroon (Comètes project) [17] in the frame of a call for proposal dealing with finalized research in the laboratories of the Cameroon Technology Institutes and Engineering School. The detailed expenses in the Table 2 are aimed to prove the affordable means by farmers to invest in the photovoltaic water pumping projects. It is obvious that a few group of farmers can afford 40 % of the total investment cost, the balance of 60 % corresponding to a loan with 15 % interest. The rate of return on investment is less than 7 years.

Conclusion

In the Marza area (Adamawa province), a few farmers having access to sufficient surface water for irrigation in dry season may considerably increase their income from agricultural activities. Unfortunately, large farmable areas are not worked in dry season because of the lack of sufficient surface water and also, the lack of modern technological knowledge by farmers in the field of irrigation.

To overcome these problems, the CESAM method is adapted to design a photovoltaic water pumping system for irrigation in the state-of-the-art, according to the farmers' needs. A system analysis using the RETScreen International software has yielded convincing results so that the farmers could afford to invest in the photovoltaic water pumping projects for irrigation. Another factor affecting the valorization of this technology is the lack of interface between the researchers and the potential users of research results. As a solution, an experimental agricultural structure is built up at the Mgr. Yves Plumey's foundation in Ngaoundere, where large farmable areas and groundwater are available.

In perspective, the effect of high daily temperature (65 °C) of photovoltaic solar cells which really affects the daily production of renewable energy will be a great preoccupation in the field of experimental research.

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