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Increasing productivity through irrigation: Problems and solutions implemented in Africa and Asia

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ABSTRACT

The United Nations Food and Agriculture Organization predicts that between 2005 and 2050 global food production will need to increase 70 percent to meet the demand of the world's growing population. Simultaneously, climate change threatens to disrupt growing seasons and rainfall across the globe. For food production to keep pace with population growth and resist the effects of climate change, the expansion of irrigation to non-irrigated farmland is critical. Innovative, affordable, and easy-to-implement technologies are needed for smallholder farmers to irrigate efficiently, mitigate greenhouse gas emissions, and help adapt to the effects of climate change. This paper presents three major interconnected problems inhibiting the spread of irrigation in Asia and Africa: lack of access to water, lack of access to energy, and lack of access to finance. This paper also discusses how these problems are interconnected, complicating the use of technological solutions to address these problems. Several approaches to address these three interconnected problems in Asia and Africa are presented in this paper. Through the examination of seven case studies in Asia and Africa, this paper finds that new irrigation products and services must include appropriate technology, sales, service, financing, and revenue collection in order for them to be widely adopted by underserved communities.

Background

The United Nations predicts that between 2005 and 2050 more than half of the global population growth will occur in Africa, which translates to an increase of 1.3 billion people in population [1]. In the same timeframe, Asia will have added another 0.9 billion [1]. The Food and Agriculture Organization of the United Nations (FAO) predicts that global food demand is going to have to increase by 70 percent between 2005 and 2050 just to keep up with expected global population growth with a resulting direct effect on agricultural water use [2]. Historically and globally, agricultural intensification has been largely accompanied with the increased energy and water inputs to grow, process, and distribute agricultural products. As a result, there is growing concern that increasing agricultural production will cause an even greater demand for fossil fuels worldwide and result in unsustainable water withdrawals that could contribute to greater food insecurity [3]. FAO estimates that agriculture currently accounts for 70 percent of global freshwater withdrawals [4]. With the projected increase of the world population, climate change will apply further stress on water resources in regions where water availability and accessibility are already critical limiting factors for food production. Extreme weather events such as heat waves, droughts, floods, storms, changes in temperature, and sea level rise will have significant impact on crop yields, agricultural productivity, and availability of arable land [5]. A large number of countries that depend on agriculture as a major contributor to their GDP are in Africa and Asia. Increasing water scarcity and drought resulting from climate change in these countries will adversely affect economic growth, endanger local farmers' livelihoods and threaten regional food security in the process [3]. Irrigation plays a crucial role in food production and improving food security by not only allowing achievement of full crop production potential in a given growing environment, but also by fighting pests through products diluted in water, protecting sensitive crops from frost, adding nutrients

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that are dissolved in the water, improving land physical properties, and removing excess salinity from the soil [6].

There is an enormous potential to improve agricultural productivity with irrigation in areas that depend on rainfall, such as Sub-Saharan Africa and large parts of Asia. The FAO reports that while only 20 percent of the global arable land in use is irrigated, it supplies 40 percent of the total food grown worldwide, producing more than 2.5 times the yield of rainfed crops [7]. Africa irrigates just over 5 percent of its available cultivated land, representing the lowest percentage of any continent [8]. As a result, it is also the continent with the highest potential for irrigation expansion, with about 42.5 million hectares of unirrigated land [9]. Asia's irrigation rate is higher at 41 percent, but due to Asia's size the remaining unirrigated land also represents a large, untapped demand [7]. Irrigation allows both higher yields within a crop cycle and, if climate allows, multiple crop cycles in a single growing season. As a result, large quantities of crop production occur on small areas of irrigated land.

There are multiple irrigation methods used by farmers worldwide, but most were developed for expediency and economic value generation rather than reduction of environmental impact and water efficiency. Use of pumps powered by increasingly expensive fossil fuels to flood or partially flood fields is still a common irrigation method that is water inefficient and pollutes the environment. Many of the poorest, off-grid farmers irrigate manually with buckets of water because they cannot afford to purchase or rent a fossil fuel-powered pump. Frequently, more sophisticated irrigation methods that cause little or no environmental degradation exceed the affordability of most smallholder farmers. As a result, the demand for inexpensive and clean technologies to replace traditional irrigation methods are rising in developing countries. Farmers need better access to innovative, affordable, and easy-to-implement technologies in order to irrigate efficiently, mitigate greenhouse gas emissions, and help adapt to the effects of climate change.

Today there is an increasing number of technology innovators working to develop products and services to address the irrigation needs of subsistence and smallholder farmers in the developing world. For example, Burney et al. discuss how solar PV drip irrigation significantly augments both farmers' income and family nutritional intake, and is cost effective compared to alternative technologies in the Sudano-Sahel region of Africa [10]. Haile et al. detail the advantages and potential pitfalls observed with smallholder drip irrigation technology being implemented in East Africa [11].

There are several barriers that have hindered the successful development, implementation, and commercialization of workable irrigation solutions with smallholder farmers in Africa and Asia. These barriers revolve around the farmers' lack of access to water, reliable energy, financing, knowledge of irrigation benefits, and training. This paper focuses on lack of access to water, reliable energy, and financing. This paper introduces each of these three problem and presents several technology innovators that are currently working on solutions to these barriers. This paper does not address problems such as lack of access to market information, good quality seeds, or reliable crop preservation techniques because these are barriers to farm profitability, not barriers to widespread irrigation usage. Where appropriate, the different technologies and their effectiveness are compared.

Methodology

This paper discusses the three most common challenges that off-grid, smallholder farmers face when irrigating their fields: lack of access to water, lack of access to reliable energy, and lack of access to financing. Each challenge is illustrated with multiple innovators who are developing appropriate technical solutions. The innovator case studies outlined in this paper are a result of the close partnership between the authors of this paper and technology innovators supported by the *Powering Agriculture: An Energy Grand Challenge* (PAEGC) initiative as described below in the Funding Section. Information on each innovator's technology and business model is collected from a variety of information and data submitted as part of their participation in Powering Agriculture. Metrics are calculated by the authors using data that was submitted by the innovators and verified by the authors through site visits, interviews, and publicly available information. Each of these brief case studies includes an introduction to the technology and subsequent challenges encountered by the technology innovators.

Lack of access to water

ECO Consult, an innovator that started developing solar PV hydroponic farms in Jordan in late 2013, and the Institute of University Cooperation (ICU), a developer of solar PV drip irrigation systems in Lebanon and Jordan, are both finding ways to maximize efficient water usage on farms in water-scarce countries.

Lack of access to energy

Both International Development Enterprises (iDE) and KickStart International are developing new low-flow, solar PV irrigation pumps that address lack of reliable energy access in off-grid farms in Kenya, Nepal, and Zambia.

Lack of access to financing

In an effort to bypass the need for farmers to access financing to purchase irrigation, both The Earth Institute at Columbia University and Claro Energy are developing irrigation service models in Senegal and India. Another model of providing financing to farmers is to connect the farmers with third-party financiers which is being pursued by Futurepump in Kenya.

Barriers to irrigation growth

Lack of access to water

Farming is particularly challenging in water scarce climates, and irrigation is a necessity when rainfed lands are not productive enough to support the population. In such locations, inefficient irrigation must be minimized. Unfortunately, traditional crop selection and irrigation practices that have developed over time in a water-scarce environment may be out of sync with current needs for water conservation. Farmers may concentrate on water-intensive, low value crops rather than maximizing the value generated from every drop of water. They may also use inefficient irrigation techniques such as flood irrigation and over-fertilization. As ground water is the most readily available source of water in these areas, inefficient irrigation and over-fertilization practices exact a heavy price on the environment through dropping aquifer levels, increased soil salinity, and nitrate contamination of surface and ground water. As the environment is degraded and farm productivity is affected, both food security and the economy suffer in a vicious self-reinforcing cycle.

In developing countries such as Jordan and Lebanon, extreme water shortages are recognized as the greatest challenge in the agriculture sector. Jordan has extremely low per capita fresh water availability and large parts of Lebanon's water resources are not exploitable [12]. Where water is available, large pumps are required