RESEARCH PROGRAM ON Dryland Systems

CGIAR

"Economics of new energy efficient methods with micro irrigation in dryland system"

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1. Introduction

The quantitative significance of the dryland agriculture is by no means small, even at their low productivity levels (Shah et al., 1998). The drylands accounts for 53% of total cropped area, 48% of the area under food crops and 68% under non-food crops. Given its large size and extremely low productivity levels, a unit rise in productivity in this sector is likely to have the largest impact on aggregate crop productivity. It is more appropriate to view the drylands as a source for future growth, a hidden potential waiting to be unlocked.

They are the home to 43% of our population. Water availability, soil conditions and the length of the growing season show wide variations. Nine states (Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Chhatisgarh, Jharkhand, Andhra Pradesh, Karnataka and Tamil Nadu) account for over 80% of the drylands. Annual rainfall in the drylands varies from less than 150 mm to 1000 mm. Soils vary from shallow skeletal soils of the deserts to medium to deep black soils.

The drylands are caught in a low-level equilibrium trap. Both private and public investments are required to enable them to break out of this trap. Private investments need to concentrate on the demand based and location specific issues and public investment in drylands has to be substantial, multi-directional and sustained over a long period of time. At present both these investment levels not increasing and even at national level, there has been a decline in public investment in agriculture since the mid-1980s.

Hence, addressing the challenge of dryland agriculture involves implementation of a package of several interlinked components:

- Soil and moisture conservation practices
- Water storage and management related investments through private and public investments

Learning from local contexts about possibilities and limitations of different interventions will improve the overall productivity in dryland systems.

2.Objectives

The CRP1.1 Dryland Systems research is designed to pursue new knowledge about dryland agro-ecosystems of the developing world and to develop technologies and policies that will improve the livelihoods of poor agricultural communities in target regions. The overall goal is to identify and develop resilient diversified and more productive dryland agricultural production systems that have the potential to be scaled-up, especially in dry areas where water is scarce. The Program targets the poor and highly vulnerable populations of the dry areas. It aims to develop technology, policy and institutional innovations to improve livelihoods, using an integrated agro-ecosystems approach to research-for-development.

As a part of this program and to contribute to the aforesaid overall goal, it is important to identify the feasible irrigation related investment opportunities in the dryland systems in order to compliment the agricultural production livelihood opportunities. The present study was undertaken in CRP1.1 action sites, viz., Bijapur district of Karnataka State and Ananthapur district of Andhra Pradesh state (India) mainly to assess and suggest suitable irrigation and energy related investment options both at farm level and community level.

Hence, two irrigation investment options (farm pond integrated with micro irrigation and Solar pumps with micro irrigation and flood irrigation) were proposed to examine the economics of interventions in the dryland system.

3. Interventions in the action sites

a. Farm pond integration with micro irrigation:

Anantapur and Kurnool Districts are in the southern part of State of Andhra Pradesh on the Deccan Plateau. The two Districts cover an area of 17,600 to 19,200 km2. They are well connected by rail and road to the major cities of Hyderabad in the north and Bangalore in the south. Topography is mainly flat with small hills and uneven terrain. Kurnool District falls under the Deccan Plateau, hot and arid sub-region (ICAR classification) with an annual average rainfall of approximately 670 mm. Anantapur is under the Karnataka Plateau Rayalaseema sub-region with an annual rainfall of 560 mm. The CV% for rainfall in Anantapur (1911-2004) is 28% and this District experiences drought once in every 5 years. The Length of Growing Period (LGP) is on average 119 days and the probability of a dry spell occurring is >50% for 15 weeks of the season. Kurnool also has variable rainfall but receives more rain during the SW monsoon period. The number of rainy days is between 45 and 53. Weather data specific to the action villages is not available. But from field observation and discussion with farmers it was possible to judge that the action villages' weather tends to be similar with the districts.

Agriculture (both crop and livestock) is traditionally the major livelihood of the district and action villages' population. But with increasing frequencies of drought and depletion of ground water resources, off-farm income has increasingly become a means to augment agriculture and livelihood.

The first step to improve the dryland crop yields is the conservation of rainwater, which cannot be separated from soil conservation. Evaporation decreases with time. Water present in lower layers cannot reach soil surface to meet the evaporation rate. Therefore, under conditions of frequent small showers, more soil water is lost as evaporation. About 60 to 75 per cent of the rainfall is lost through and these evaporation losses can be reduced by applying mulches. The in situ soil moisture conservation practices viz., contour bunding, border trenches and deep trenches, and ex situ practices such as check dams, percolation tanks, farm ponds etc. are important.

Farm pond is a proofed concept of water conservation which can be implemented across the action villages. In arid and semi-arid regions, rains are sometimes received in heavy down pours resulting in runoff (Singh, 1983. The percentage of runoff ranges from 10 to 30 % of total rainfall. Alfisols (major soils in the action villages) have high runoff generating potential than vertisols with deep cracks at the commencement of the monsoons. Runoff starts earlier and more frequently during rainy season in alfisols compared to vertisols. On alfisols even with contour bunds, there is atleast 20 to 30 per cent runoff. Simple treatment of the land such as shaping, removing obstructions etc. enhance the harvesting efficiency of runoff water.

Small farm ponds of size 100-300 m^3 can be dug for storing runoff water. The size of the farm pond depends on the rainfall, slope of the soil and catchment area. The dimensions may be in the range of 10m x 10m x 2.5 m to 15m x 15m x 3.5 m (Yellamanda Reddy and Sankara Reddi, 2010). The side slope 1.5:1 is considered sufficient. A silt trap is constructed with a width of slightly higher than the water course and depth of 0.5 to 1 m and with side slope of 1.5:1.

The problem associated with farm ponds is high seepage loss. This can be reduced by lining walls. Some of the traditional methods for seepage control are: use of bentonite, soil dispersants and soil-cement mixture (Maheswari and Turner, 1986). Farm pond technology is economically viable. Studies done in Ananatapur, and Kurnool regions showed that water harvesting in a farm pond of size 271 m^3 and utilizing the water for supplemental irrigation is economically viable (Goyal et al, 1995). The cost benefit ratio was 1.7.

Based on the reviews, farm pond with 10x10x3 m was developed in the action site of Kurnool (Yerraguntla village). A micro irrigation with vegetable crops was planned to study the economics of the micro irrigation integrated with farm pond. The total rainfall received during the Kharif season (June-December 2015) is 287 mm. Public private partnership (PPP) with Jain irrigation system limited (JISL) was proposed for implementing the farm pond micro irrigation. The design proposed for the farm pond can be seen in figure 1.

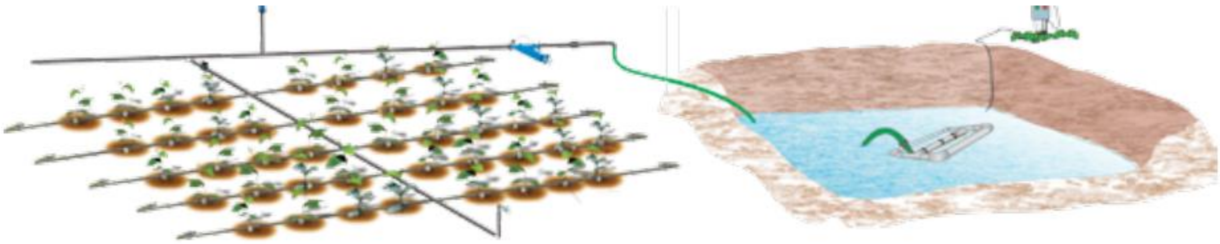

Figure 1: Schematic farm pond integrated with micro irrigation
Source: Jain irrigation system ltd (JISL), 2015

Figure 2: Farm pond with drip system equipment at Kurnool district, Andhra Pradesh

However, due to the constraints in availing the equipment from the supplier the study is still in progress. The impact of critical irrigation with the farm pond was studied by ICRISAT, Acharya N G Ranga agricultural University (Andhra Pradesh) and Darwad Agricultural University, Bijapur. But integration of farm ponds with micro irrigation is not field tested to study the efficiency of irrigation and energy for pumping. Hence, there is a need to continue the study and analyse the impact/economics of the farm pond with micro irrigation.

b. Solar Energy with drip and flood irrigation:

Electricity is one of the essential requirements for all facets of our life. It has been recognized as a basic human need. It is a critical infrastructure on which socio-economic development of the country depends. Since independence electricity has been placed in concurrent list in the constitution of India. In India, power generation is mostly performed by government entities and is controlled by central public sector corporations like National Hydroelectric Power Corporation, National Thermal Power Corporation and various State Electricity Boards (SEBs). The parliament and the state governments have authority to legislate on the subject. Of the total installed capacity (274,818 megawatt) in the country, 35 percent of the current installed base is from state sector, 26.6 percent from central and 38.4 percent from private sector (Ministry of Power, 2015). In thermal power plants, coal based thermal power is about 61 percent, gas 8.4 percent and oil 0.4 percent (Table 1). Hydro power is 15.3 percent of the total installed base, Nuclear 2.1 percent and renewable energy is of 13 percent. With the available power sources, India is producing electricity of 1048 billion kWh by 2014-15 and the ministry of power is trying to produce additional power (88,425 MW) by the end of 12th five-year plan.

Table 1: Installed power sector in India

S.No	Energy	Megawatt		Percentage	
		2007	2015	2007	2015
1	Thermal power	86,935.8	191,264	64.5	69.6
i)	Coal	71,932.3	167,208	53.4	60.8
ii)	Gas	13,801.7	23,062	10.2	8.4
iii)	Oil	1,201.7	994	0.9	0.4
2	Hydro Power	33, 485.7	41,997	24.8	15.3
3	Nuclear Power	4,120.0	5,780	3.1	2.1
4	Renewable Power	10,175.0	35,777	7.6	13.0
	Total	134,716.6	274,818	100.0	100

Source: Ministry of Power, 2007 and 2015

Electricity consumption was also increased with the increasing population and economy over the years (Figure 3). Electricity is playing a major role in industrial and agriculture sectors. Agriculture is the second largest consumer of electricity after industry competing with the domestic consumption. Electricity consumption in agriculture sector has been increased significantly due to rural electrification. Especially in southern part of India, 99.6 percent of the villages are electrified. In total 84.3 percent of the villages were electrified by the end of 2004 in India.

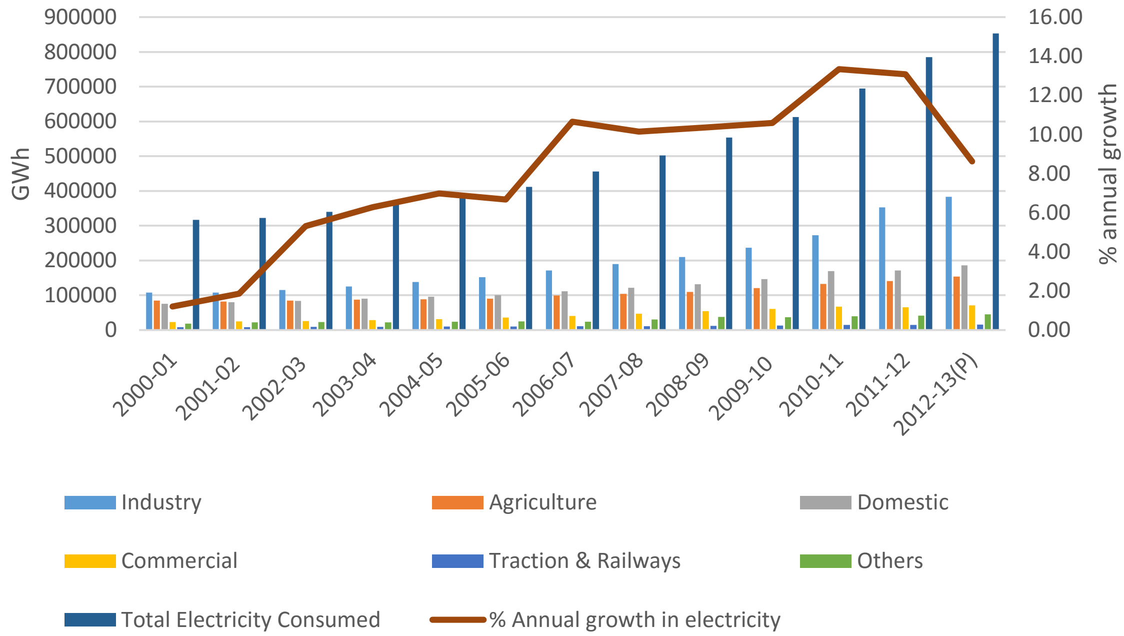

Figure 3: Electricity consumption by sector (from utility)

Source: MOSPI, 2015

Electricity consumption has been increased from 10 to 18 percent (1970-2013) in agriculture sector at country level (MOSPI, 2015). Irrigation pumpsets energized in India are 15.09 million by 2007. Southern region was on the top of its share of 42 percent in total pumpsets energized, followed by western and northern region with 33 and 21 percent respectively. Among the states, pumpsets energized are highest in Maharashtra with 2.49 million followed by Andhra Pradesh, Tamil Nadu and Karnataka with 2.31 and 1.42 million respectively (CWC, 2006).

In the first three states where higher energized pumpsets are found, the sates have announced free electricity polices or low electricity prices to gain the farmers vote bank, which are not even equal to the supply cost. In addition to this, it is believed that poor agriculturist needs this subsidy due to frequent droughts and the need to alleviate poverty. It is largely believed that the poorer sections among the agricultural areas cannot afford to pay electricity tariff as per the cost of electricity generation and supply. It is also expensive for the electricity boards to meter it for agricultural consumption. Hence, the electricity tariffs have been kept below the cost price and billing of most pumpsets has been linked to the pump capacity i.e. HP rather than the electricity use. Some states have declared free electricity policy to the agriculture sector for 7 hours to extract groundwater and written off the previous bills, which were used to charge on pump capacity. However, the electricity supply is regulated with 7 hrs per day in two phases to stabilise the extraction and efficient use of energy.

The diesel pumps are second largest source of pumping in the north-eastern states. The diesel pumps used for agriculture are higher in Uttar Pradesh (46%) of the 13.18 million in India (Rawat and Mukherji, 2012). However, the soaring diesel prices are regulating the use of groundwater in the state. The power utilities are bankrupt and supply to the villages were very poor. Hence, farmers are constrained by unreliable grid power and higher diesel cost (WLE, 2015).

Groundwater extraction is also far exceeded the net recharge in many regions of the country (Rodell et al 2009). As many as 16% of the 6,475 groundwater development blocks in the country are above critical or semi-critical thresholds with extraction exceeding natural recharge by at least 80% (Kakumanu 2009). The western and southern states are highly equipped with electricity pumps and have notified with dark blocks (CGWB, 2015). This precipitate severe environmental degradation, including drying of wet lands and streams and deteriorating quality of water and soil (Giordano 2009).

In the groundwater abundant areas and in the open well areas where recharge is good, solar irrigation pump investment option can be validated to overcome the electricity scarcity. This also reduces the marginal cost of pumping and generate massive livelihoods (Shah and Kishore, 2012).

The solar irrigation pumps with higher subsidy and zero marginal cost is attracting the farmers' attention in the recent years (Tewari, 2012, Kishore et al 2014). However, leaving it to the open market it has unique cost structure with high capital investment. This makes it similar to the electric pump investments with flat tariff at zero marginal cost.

Hence, solar pump integrated with micro irrigation and supplementary irrigation to various crops was field tested for the Kharif 2015 (July-December). The present section studies the economics of such energy efficient solar energy intervention. The schematic picture and field implementation can be seen in figures 4 & 5. The total cost of the solar irrigation pump with micro irrigation for 0.4 ha is Rs.370,000. The solar pump is used for both drip irrigation and surface irrigation. The total area under cultivation is 2.8 ha with open well and canal as irrigation sources. Brinjal, Cotton and sugarcane are cultivated under the system (Figure 5). A 2hp motor is used for pumping instead of 5 hp diesel pump with consistent power supply. Six panels with 240 watts/panel is installed for 2 hp motor (Figure 5). The discharge rate of the solar irrigation pump installed is 1.2 lps with 6-8 hrs discharge.

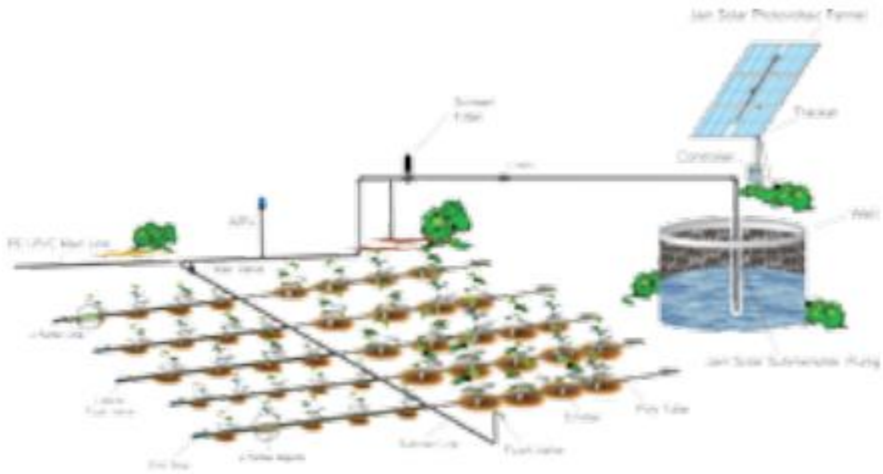

Figure 4: Schematic solar powered pump with drip irrigation
Source: Jain irrigation System Ltd, 2015



Figure 5: Solar pump with drip and surface irrigation in Bijapur District, Karnataka

Table 2: Trade off of pumping with diesel and solar energy sources

Year	2014 (Baseline data)			2015 (Pilot data)		
Particulars	**Tomato**	**Cotton**	**Regram**	**Brinjal (Drip)**	**Cotton**	**Sugarcane**
No.of irrigations	12	12	4	140	12	48
Irrigation duration (hrs)	15	15	15	226	30	30
Motor power (HP)	5	5	5	2	2	2
Diesel/solar pump	Diesel	Diesel	Diesel	Solar	Solar	Solar
If Diesel, No. of litres / irrigation	12.5	12.5	12.5	-	-	-
Total Diesel consumption (Lt/ha)	150	150	50	-	-	-
Cost of diesel (Rs/ha)	7500	7500	2500	-	-	-
Cost of cultivation (Rs/ha)	62500	50000	37500	51220	64017	75000
Annualised cost of system (Rs/ha)	6025	6025	6025	17362	17362	17362
Yield (qt/ha)	87.5	20.75	15	250	20	1125
Price (Rs/qt)	4000	4500	5000	1000	4500	220
Gross income (Rs/ha)	350000	93375	75000	250000	90000	247500
Net income (Rs/ha)	273975	29850	28975	181418	8621	155138

The baseline information from the selected farmer and the current pilot information with solar irrigation pump is presented in table 2. Diesel pump was used by the farmer for cultivating Tomato/vegetables, cotton and redgram during 2014. The operational cost for the diesel pump varies with the crop and maintenance cost. The initial findings and famers perception show that the solar irrigation pumps were able to supplement the irrigation water without any power interruptions. The higher cost of diesel for irrigation and limited supply of electricity in the study areas/ rural areas need to think of adopting to solar irrigation pump system to favour the farmer crop and environment.

The carbon emissions contributed due to the electric pump (11.09 million tonnes) and diesel pumps (3.29 million tonnes) are high as India is the top abstractors of the groundwater (GoI 2005, Shah 2009). Many researchers estimated carbon dioxide emissions in different parts of world, where water pumping and conveyance accounts to the emissions from energy activities in the agricultural sector (Zou et al 2015, Sattenspiel et al 2009, Quershi 2014, and Reddy et al 2015). Preferring more electricity or diesel pump would increase the emissions and abatement cost to the state government.

The solar irrigation pumps can replace the emission challenges in India. But the initial capital cost is reducing the solar irrigation pump adoption in the country. Nevertheless, if the governments really think of emission cleaning costs in the developing countries like India, governments can substitute the cost of cleaning to subsidize the solar irrigation pump. For example, Uttar Pradesh alone can provide 95 thousand solar irrigation pumps with the emissions cleaning cost from diesel and electricity (Kakumanu, 2015). On the other hand, the groundwater scare states like Gujarat and Karnataka are preferring to integrate drip irrigation with solar systems to save water and energy (GGRC, 2015). Rajasthan has promoted solar energy with 86% subsidy to horticultural farmers who use drip irrigation and farm ponds (Kishore et al 2014). This has replaced majority of the diesel pumps and tractors in Rajasthan and saved the operation cost of diesel worth up to Rs 65,000. Besides saving diesel and electricity, solar also saved labour as the requirement of operators would be reduced.

The timeliness of irrigation without any shortages in the irrigation schedule also enhance water use efficiency by 5-10% (Kishore et al 2014). The tubewells that pumped 400-500 hrs/year with diesel will pump 1500-2000 hrs/year with solar (Shah et al 2014).

Conclusion:

The groundwater withdrawals are high in India to meet the domestic, agricultural and industrial demands. The withdrawals are more in the western and southern regions of India where many of the aquifers are marked as dark blocks. Studies recommend to develop *in situ* and *ex situ* soil and water conservation practices. In both *in situ* and *ex situ* cases, supplemental irrigation provided a better opportunity to increase crop income and farmer income (Palanisami et al, 2015). Further, micro irrigation based supplemental irrigation from farm ponds and percolation ponds would be investment worthy as it decreases the energy consumption (Raman and Tikadar, 2011).

Solar irrigation pumps found to be more feasible option in the long-term to meet the groundwater and energy demands with socio-ecological benefits. Establishment of Photo voltaic plants on community basis with a guaranteed long-term buy-back contracts by the state government would improve the investment and livelihoods of farmers. On the other hand, providing subsides (by state and national governments) to the solar irrigation pumps with the carbon abatement cost can enhance the adoption rate in the basin.

Nonetheless, there is a need to develop more science based evidence on the farm pond integration with micro irrigation and energy efficient methods.

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The CGIAR Research Program on Dryland Systems aims to improve the lives of 1.6 billion people and mitigate land and resource degradation in 3 billion hectares covering the world's dry areas.

Dryland Systems engages in integrated agricultural systems research to address key socioeconomic and biophysical constraints that affect food security, equitable and sustainable land and natural resource management, and the livelihoods of poor and marginalized dryland communities. The program unifies eight CGIAR Centers and uses unique partnership platforms to bind together scientific research results with the skills and capacities of national agricultural research systems (NARS), advanced research institutes (ARIs), non-governmental and civil society organizations, the private sector, and other actors to test and develop practical innovative solutions for rural dryland communities.

The program is led by the International Center for Agricultural Research in the Dry Areas (ICARDA), a member of the CGIAR Consortium. CGIAR is a global agriculture research partnership for a food secure future.

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