

Performance Evaluation of Fixed dome and Floating type Biogas Digesters for Tubewell Operation with Dual Fuel Approach in Pakistan

Abdul Wahab Siyal¹, Muhammad Yasin², Irfan Ali³, Zakir Hussain⁴, Muhammad Aslam⁴, and Matiullah Khan⁴

¹Senior Engineer, Climate Change, Alternate Energy and Water Resources Institute,
National Agricultural Research Centre, PARC, Islamabad, Pakistan

²Chief Scientist, Climate Change, Alternate Energy and Water Resources Institute,
National Agricultural Research Centre, PARC, Islamabad, Pakistan

³Senior Scientist, Natural Resources Division,
Pakistan Agricultural Research Council, Islamabad, Pakistan

⁴Principal Scientist, Climate Change, Alternate Energy and Water Resources Institute,
National Agricultural Research Centre, PARC, Islamabad, Pakistan

Copyright © 2015 ISSR Journals. This is an open access article distributed under the **Creative Commons Attribution License**, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT: The idea of biogas as a diesel fuel substitute is not new. It is a very attractive alternative, especially in countries rich in agricultural products and poor in petroleum resources. It can be concluded from the study that while running a diesel engine in dual fuel mode i.e. on diesel and biogas saved almost 62% to 64% diesel fuel, and consequently showing an annual saving of Rs. 3486/m³ and 3379/m³ capacity when run on dual fuel mode with respect to gas produced from fixed dome and floating drum biogas digesters respectively. The less saving in floating type biogas digester is due to gas losses from plant as compare to fixed dome biogas digester where system is air tight. Fixed dome biogas digester not only save the money but also the environment. Running engine through floating type biogas digester consumed 6.35% more diesel than fixed dome biogas digester in dual fuel mode. A 16 hp dual fuel diesel engine pumped 14 % more water from fixed dome biogas plant as compared floating drum biogas plant. It is therefore recommended that fixed dome biogas digester may be installed in such agroecological zones like Islamabad.

KEYWORDS: Biogas, fixed dome and floating type biogas digesters, diesel engine, centrifugal pump, dual fuel.

1 BACKGROUND

Pakistan is an energy deficient country that's why the interest in use of alternative energy and energy conservation has skyrocketed. The rapidly escalating fuel costs have compelled to move toward renewable and sustainable energy sources. The agriculture sector continues to be an essential component of Pakistan's economy contributing 21% to GDP. Agriculture generates productive employment opportunities for 45 % of the country's labor force and 60 % of the rural population [1]. The agriculture sector is not the largest energy-consuming sector of Pakistan however; it is in transition from the traditional i.e. low energy inputs methods of farming to higher level of energy inputs, of cope the food requirements of the country's population growing at a rate of almost 3% [1]. The price hike in fuel products are increasing the input cost of production, making agriculture as an unprofitable and unattractive business in the country. Shortage of water and energy are two major issues currently faced by irrigated agriculture in Pakistan [2]. Water is very important factor in agricultural productivity and production. In Punjab province, around 60% water available at farm level is from groundwater, whereas at the national level it is around 46%. Thus groundwater contributes significantly for irrigated agriculture in Pakistan [3]. The distribution of Tubewells based on size of power indicated that majority of electric operated Tubewells are in range of 10-20 hp. The diesel

operated Tubewells are in the range of 16-20 hp. Population of diesel operated tubewells in Pakistan was around 87% of the total population during 2005-06, whereas this percentage was around 88% in the province of Punjab [3]. Hence it is very advisable to work on diesel operated tubewells to be converted on biogas as dual fuel mode. The idea of biogas as a diesel fuel substitute is not new, but it is supposed to be a very attractive alternative, especially in countries rich in agricultural products and poor in petroleum resources. There have been continuing efforts in research, development and demonstration to utilize biogas to provide power agricultural engines at farms within the country for the past two decades. Biogas can be used as an alternative to the partial or total substitution of gasoline and diesel fuels without requiring extensive engine adjustments or modifications. These research efforts are therefore directed to evaluate the performance of two biogas digesters in biogas production to use it as fuel on a diesel engine. The literature says that the durability test of an agricultural engine operating on biofuel may be of great satisfaction to the farmers in Pakistan. In this investigation, long term water pumping discharge tests for engine operation on dual fuel was carried out at the National Agricultural Research Center (NARC), Islamabad during 2010-2012.

1.1 POTENTIAL OF BIOGAS FOR TUBEWELL OPERATION IN PRESENT SCENARIO

Currently, there are over 1.0 million tubewells operated pumping systems in the country [4]. The farmers owning these systems even in shallow groundwater areas will face serious problem of cost-effectivity of water pumping with rising prices of diesel fuel. Diesel tubewells are usually installed in shallow groundwater table areas (6.0 to 15 meters). The fuel consumption of diesel engines (Chinese and slow speed diesel engines) is 1.5-2.5 liters per hour whereas the tractor operated tubewells burn 3.5-5.0 liters per hour [5]. The utilization factor of private diesel tubewells is between 10-15% (1350 hours per year). Therefore total annual fuel consumption of one million diesel tubewells (assuming 2.5 liters/hour and 1350 hours per year) would be 3.5 billion liters. Approximately 30% are electric-operated with the installed capacity of 2500 MW and consumes approximately 15-20% of the total energy delivered by the national grid. The estimated annual fuel (diesel) consumption by the diesel tubewells in Pakistan is about 950 million liters, is worth in Rs.16 billion. The electric tubewells' power consumption is currently 1.02 billion kilo watt-hours (kwh) costing Rs. 2.6 billion annually. The total energy cost of operating private tubewells is about Rs. 18.6 billion per annum. Government is heavily subsidizing electric tariff for agriculture tubewells in many areas putting additional burden on national exchequer on one hand and inducing inefficiencies in water and energy usage on the other. Agriculture sector having groundwater as the irrigation source is worst hit by present energy crises as the availability of grid electricity in remote areas is around six hours per day on an average. Therefore, a reliable, efficient, sustainable and cost effective energy option for agriculture sector in Pakistan is direly needed. Replacing/supplementing existing source of diesel power for driving tube wells with renewable energy resources (biogas) can be a viable option [6].

As per livestock census 2006, there are 59 million animal heads (buffaloes and cows,) in Pakistan owned by small and big farmers. These animals are producing 590 million kilograms of dung per day. Assuming 50 per cent collectability, the waste will produce 9 million cubic meters of gas per day which can be used for pumping ground water and other uses. There is a lot of potential of power generation from biogas in our rural areas and the economics of farmers can be improved. Utilization of biogas will also help decrease farmers electricity use and reduce the expenditure of foreign exchange required to import petroleum products. Economic performance of biogas based water pumping systems is higher as compared to the financial measures thus justifying state support in the initial phase of their dissemination [7].

2 MATERIALS AND METHOD

2.1 INSTALLATION OF BIOGAS DIGESTERS



Fig. 1 Two different type of Biogas Digesters Installed at NARC, Pakistan



Fig. 2 Dual-fuel Pumping system Installed at NARC, Pakistan

Two types of biogas plant; fixed dome of 35 m³ and Floating drum of 22 m³ were constructed at Climate change alternate energy and water resources institute (CAEWRI) field station NARC, Islamabad, Pakistan (Figure1). The feedstock used for biogas production was animal's dung. A Galvanized Iron pipe with internal diameter 19.05 mm was installed from fixed dome digester to digital gas meter for measurement of biogas volume produced. A water pumping system coupled with a 16 hp engine (2200 rated RPM) was installed at dug well for the testing and evaluation on diesel and dual fuel (Biogas + Diesel) mode. The engine was converted on dual fuel i.e diesel + biogas (Figure 2). In the dual fuel approach, the diesel engine remained essentially unmodified, except for the addition of a gas/air mixing chamber on the air –intake manifold, as the air filter can be used as a mixing chamber. A flexible bottle 1.5 liter capacity was installed and graduated cylinder was used to measure diesel consumption of the engine. A two stage centrifugal pump of (3 X 2 inch) was installed. A 3 inch water suction pipe lift water from 16 ft with 2 inch delivery head was coupled with centrifugal pump. Pump rated RPM was 2800 and with rated discharge 113 GPM (7.129 lps).

2.2 DATA COLLECTION AND ANALYSIS

The various parameters like; engine: engine and pump rpm, pump discharge, diesel and biogas consumption in diesel mode and dual fuel mode, as well as on fixed dome and floating drum, pump discharge in diesel and dual fuel mode; annual biogas production in fixed dome and floating type biogas digester; use of biogas as dual fuel on both the bio-digesters. A tachometer was used for measurement the engine and pump RPM and water flow meter of 2 inch diameter was used to measure discharge of centrifugal pump.

3 RESULT AND DISCUSSION

Biogas Production per day with two different types of digesters in summer and winter season was recorded round the year at ambient conditions (Figure 3). Results showed that average biogas production was 13 m³/day in June and 3 m³/day in February in case of fixed dome biogas plant of 35 m³ capacity. While in floating type biogas plant of 22 m³ capacity, production was 6 m³/day in June and 2 m³/day in December. It is illustrated from the Fig. 4 & 5 that engine consumed 1.5 litres diesel in one hour when run only on diesel operated mode, when the engine was run on dual fuel mode it consumed 0.539 and 0.569 liters diesel per hour when biogas was supplied from fixed dome and floating drum biodigesters, respectively. Maximum running time of the said engine on dual fuel mod was 6.17 hours in June and 1.46 hrs in February in case of fixed dome bio-digester, where as in case of floating drum biodigester its was 2.89 hours in June and 1.13 hours in February.

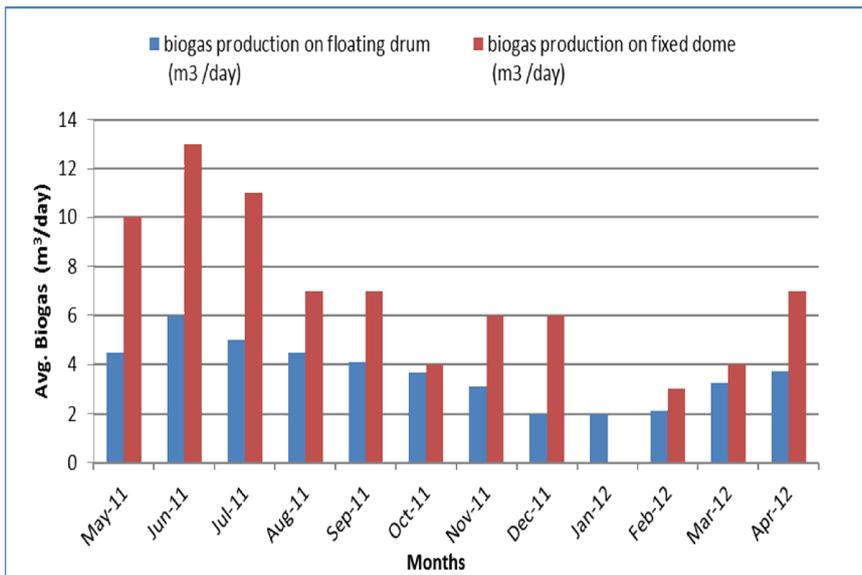


Fig. 3 Temporal variation in average biogas production in Islamabad during 2011-12

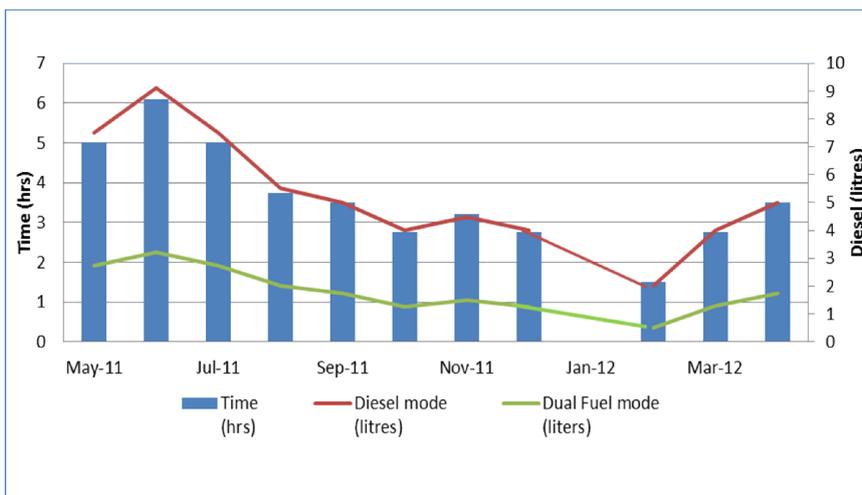


Fig. 4 Diesel consumption under diesel and dual fuel mode of fixed dome digester

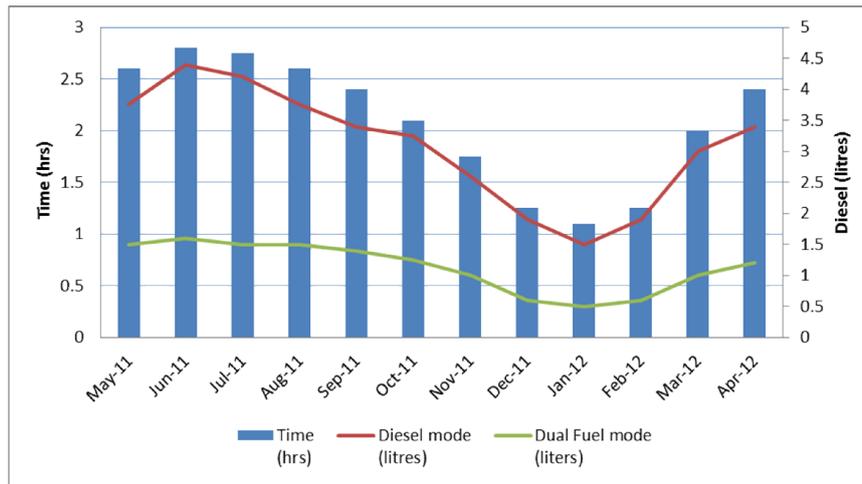


Fig. 5 Fuel consumption under diesel and dual fuel mode of floating drum digesters

It was also noted that the engine on dual fuel mode consumed 2.012 and 1.90 m³ biogas per hour from fixed dome and floating drum biodigester, respectively when it was coupled with pumps to lift water (fig 6 & 7). The discharge of pump was 18 and 16 m³/hrs when engine was operated on fixed dome and floating drum bio-digester respectively. It potentially be due to more biogas consumed in case of fixed dome than in the floating drum bio-digester. The annual biogas production was 2427 and 1350 m³ from fixed dome and floating drum digesters, respectively (Table 1). The table also shows that annual gas production based on per cubic meter capacity of bio-digester 69 and 61 m³/m³ was found in fixed dome and floating drum, respectively. Fixed dome bio-digester performed better than floating drum bio-digester and produces 13% more gas at per cubic meter of bio-digester capacity. The overall reason was leakage from the sides of floating drum bio-digester. The results showed that diesel consumed was 1807 and 1141 liters on diesel mode whereas 645 and 433 liters on dual fuel mode when operated with fixed dome and floating drum bio-digester, respectively; (Fig 8 & 9).

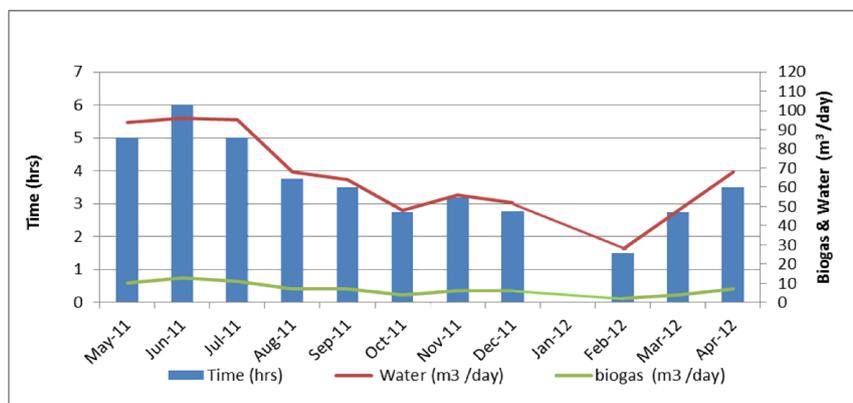


Fig. 6 Monthly average of biogas production, discharge and running of engine of fixed dome

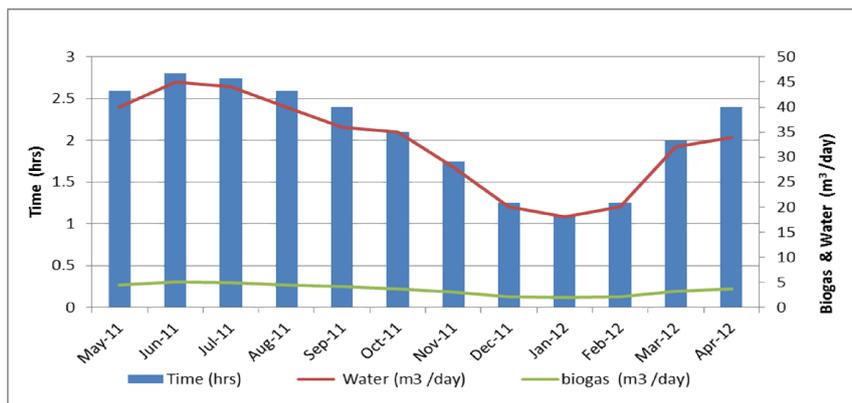


Fig. 7 Monthly average of biogas production, discharge and running of engine of floating type digester

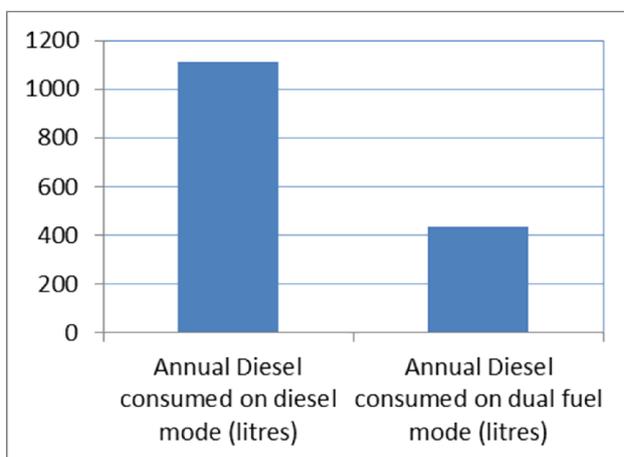


Fig. 8 Annual diesel consumption comparisons on floating drum biogas production basis

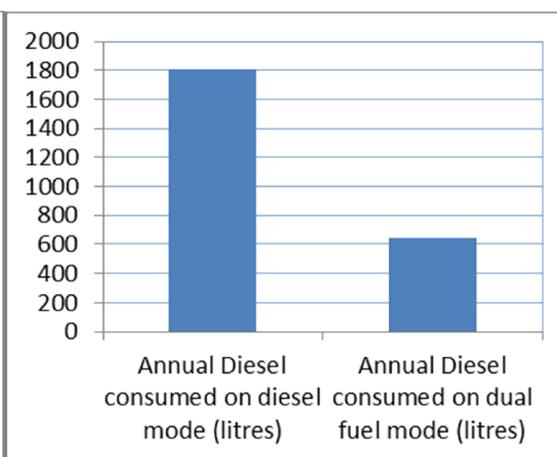


Fig. 9 Annual diesel consumption comparison on fixed dome biogas production basis

Table.1 Consumption of annual diesel and biogas fuel with two types of biogas digesters

Bio-digester Type	Biogas Production (m ³ /year)	Diesel mode operation (Lit/year)	Dual Fuel mode operation (Lit/year)	Biogas replaced 01 lit of diesel in dual fuel mode (m ³)	Annual saving of diesel (Pak. Rs.)	diesel saving in dual fuel mode (%)
Fixed dome bio-digester	2427	1807	645	2.08	122010	64
Floating drum digester	1350	1141	433	1.90	74340	62

3.1 RELATIONSHIP B/W ENGINE & PUMP R.P.M ON DISCHARGE OF PUMP IN DIESEL AND DUAL FUEL MODE

The discharge of pump was taken from 1213 to 1382 and 1607 to 1781 rpm of engine and pump, respectively on diesel mode only. However the discharge of pump varies from 19 to 22 m³/hr at variable pump and engine rpm. The average discharge was found 20 m³/hr on average engine and pump rpm of 1344 and 1747, respectively (Fig. 10). In the same way the discharge of pump was taken from 1069 to 1205 and 1400 to 1604 rpm of engine and pump, respectively on biogas dual fuel mode. However the discharge of pump varies from 15 to 16 m³/hr at variable pump and engine rpm. The average discharge was found 16 m³/hr on average engine and pump rpm of 1126 and 1462 respectively (Fig. 11).

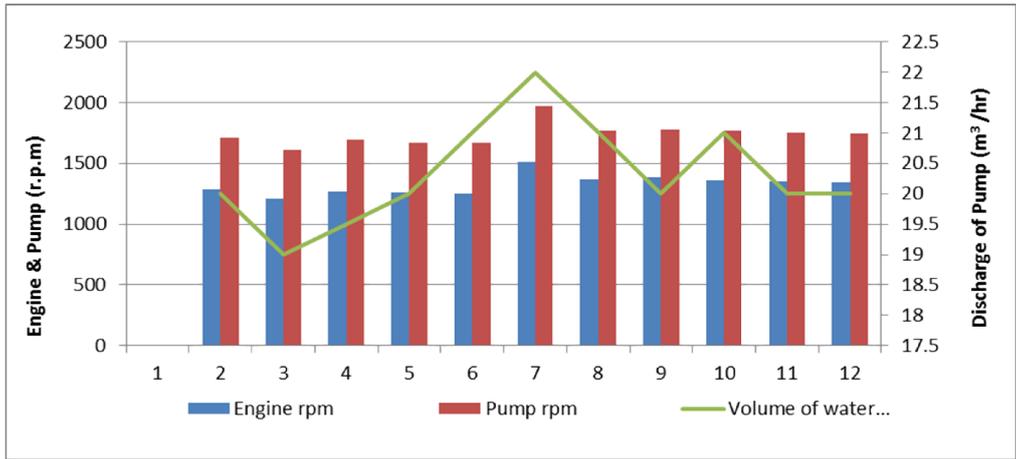


Fig. 10 Monthly average of biogas production, discharge and running of engine of fixed dome

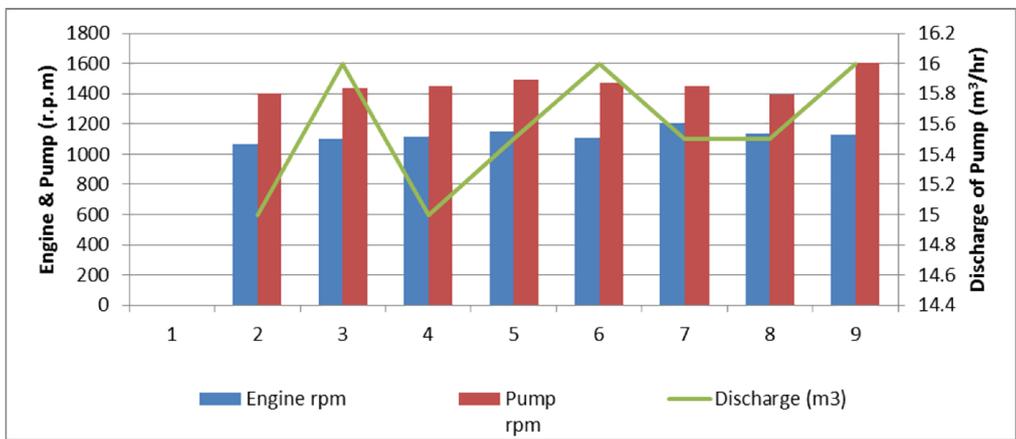


Fig. 11 Monthly average of biogas production, discharge and running of engine of floating type digester

4 CONCLUSION

On the basis of results deducted from data analysis it can be concluded that running of diesel engine in dual fuel mode saved almost 62% to 64% diesel fuel, showing an annual saving of Rs. 122010 & 74340/ when run on dual fuel mode with respect to gas produced from fixed dome and floating drum biogas digesters respectively. Running engine through floating type biogas digester consumed 6.35% more diesel than fixed dome biogas digester in dual fuel mode. A 16 hp dual fuel diesel engine pumped 14 % more water from fixed dome biogas plant as compared floating drum biogas plant.

REFERENCES

- [1] Economic survey of Pakistan, 2011-12.
- [2] Pakistan Energy Yearbook, 2006.
- [3] S. Ahmad. 2007. Growth of Agricultural Tubewells and State of Energy in Pakistan – Is Subsidy a Sustainable Option for Helping Farmers? Water for Balochistan. Policy Briefings. Vol. (3), No.(8), TA-4560 (PAK), Quetta, Balochistan, Pakistan.
- [4] Pakistan Agricultural Statistics, 2010.
- [5] Qureshi, A. S; Shah, T.; Akhtar, M. 2003. The groundwater economy of Pakistan. Working Paper 64. Lahore, Pakistan: International Water Management Institute.
- [6] Prof. Dr. Khanji Harijan.2013. Renewable Energy in Pakistan: Potentials and Prospects. Conference proceeding. Solutions for energy crisis in Pakistan. Islamabad Policy Research Institute (IPRI) and the Hanns Seidel Foundation, (HSF) Islamabad.
- [7] Pallav Purohit, Tara Chandra Kandpal. 2007. Techno-economics of biogas-based water pumping in India: An attempt to internalize CO emissions mitigation and other economic benefits Renewable and Sustainable Energy Reviews1208–1226.

ACKNOWLEDGEMENT

The author thankfully acknowledges the Agricultural Linkages Program (ALP) of Pakistan Agricultural research Council (PARC) and United states Development Agency (USDA) for financial assistance of this study.