Final Report

"Utilization of Treated Wastewater in Forage Production" Project

Project Time Frame:
Dec. 2008 to Dec. 2010

Leader Coordination:

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Forward:

In tune with H.M. Sultan Qaboos bin Said progressive direction of innovation in Agriculture for sustainable development, it is with pleasure and privilege; I present this final report in a summary format on "Treated Wastewater Utilization for Fodder Cultivation" at Saham. The project started in collaboration with L.N.G. Co. and the Ministry of Regional Municipality and Water Resources in Dec. 2008. The project was completed successfully by the end of Dec. 2010 in scheduled time.

The focus of the project was exploration of non-conventional water resource for agriculture development and enhancement of productivity and in turn to reduce the pressure on groundwater resources. This was a unique feat to experiment and to facilitate favorable economic and social impact.

The project on the test of "techno-economic analysis" at every stage and for all the three selected crops – viz. barley, sorghum and maize revealed most encouraging results and economic viability of the project. This will unfold new vistas of attracting private sector investment along with the availability of treated wastewater in Sultanate of Oman.

This achievement would not have been possible without the generous support of from H.E. the Minister and H.E. the Undersecretary of Ministry of Agriculture and the supporting company like L.N.G. Company.

I take this opportunity to place on record deep appreciation of all the committee members and in particular Eng. Saif AlKhamisi, Head of Field Crops Research and Dr. V.S. Gosavi, Economics Expert Advisor, Planning and Investment Promotion for their extensive effort, excellent work contribution and continued commitment.

I am confident that the encouraging results of this project on possibility of utilization of treated wastewater will go long way in developing sustainability and cultivation of fodder corps to meet cattle feed security in the near future.

Thank you,

Dr. Ahmed Al Bakri
Director General of Agricultural &
Livestock Research
Ministry of Agriculture

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Contents

1. Preamble:

Oman is a land of diversified nature with variety of climatic conditions throughout the year. The country is located over the hot and dry region of the globe creating vital challenges of providing water for irrigation as well as for domestic consumption.

His Majesty Sultan Qaboos Bin Said attaches profound importance to the water resources and emphasized on several national occasions the need to conserve water, develop its resources, both conventional and non-conventional, and efficient use of water in the interest of the nation and citizens of the country. Exploring new sources of water sustainability to tackle imbalances in supply and demand is, therefore, of paramount importance in the water stressed region like Oman.

In the recent symposium held in Nov. 2009 under the direction of H.M. the Sultan on sustainable development of Agriculture Sector, once again emphasis was laid on development of water resource, integrated management and encouraging private sector to be involved in Agriculture.

In tune to the above directions, Ministry of Agriculture initiated the 'Pilot Project' exploring the possibilities of treated wastewater utilization at Saham Treatment Plant for the cultivation of selected fodder crops. A unique step to reduce the pressure on groundwater resources and trying to bridge the gap on water scarcity.

H.E. the Minister and H.E. the Undersecretary of Ministry of Agriculture encourage the pilot project on experimenting the treated wastewater utilization project at Saham, which was executed under the leadership of Dr. Ahmad Al Bakri, Director General of Agriculture and Livestock Research. The project was sponsored by Oman Gas Company (LNG) Company and experiments on various crops were undertaken for a period of 2 years.

A special committee of fifteen staff was established with close association representing Ministry of Agriculture, Ministry of Regional Municipalities & Water Resources and Ministry of Environment & Climatic Affairs which extended their valuable cooperation for this project. The project initiated in Dec. 2008 was successfully completed with all observations on selected three crops by the end of Dec. 2010. The possibility to continue this experiment for some other suitable crops is on table.

2. Central Theme:

Water is one of the most precious and scarce resource in Sultanate of Oman. With increase in the population as well as emphasis on developing sustainable agriculture, the demand for water is increasing and is under pressure. Developing alternative non-conventional water resources, therefore, became critical which can be productively used for the cultivation of suitable crops.

LNG company came forward to sponsor the experimental project while Ministry of Regional Municipality supported by providing availability of treated wastewater at Saham STP at free of cost for the project. It was an uphill task undertaken by Directorate General of Agriculture Research and Livestock and the team worked on crops like Barley, Sorghum and Maize for every season, which collected factual data and analyzed the same for testing the economic and technical viability.

2.1 The project had four objectives:

- To take advantage of the quantities of treated wastewater and areas for cultivation and production of seasonal forage crops;
- Evaluate forage crops for winter and summer (sorghum, maize, barley and any other forage crops in the future);
- Study the impact of tertiary treated wastewater on the soil at the targeted sites; and
- To evaluate the project on techno-economic parameters for future planning and utilization of treated wastewater

2.2 The project has three future components:

- Implementation of a pilot project located at Saham STP aims at using tertiary treated wastewater through the use of irrigation in forage crops.
- Follow up studies associated with the forages produced from the use of tertiary treated wastewater for animal feed.
- Expansion of the introduction of many field crops, seasonal and perennial forage using tertiary-treated wastewater irrigation.

3. Experimental Focus:

The Ministry of Agriculture, represented by the Directorate General of Agriculture and Livestock Research, has the activities in using such water for agriculture through research and studies on different crops, especially forage crops. It has implemented a series of experiments for the use of tertiary treated wastewater on forage crops like barley, maize and sorghum in different seasons (winter and summer) as well as analysis of soil and irrigation treated wastewater pH, salinity and micro-elements or heavy elements to find out their suitability for animal feeding which will be reflected on human nutrition and health.

The Ministry of Agriculture initiated the 'Pilot Project' exploring the possibilities of tertiary treated wastewater utilization at Saham STP for the cultivation of selected fodder crops, a unique step to reduce the pressure on groundwater resources and trying to bridge the gap on water scarcity. According to information provided by Oman Wastewater Services Company (OWSC), there are 11 wastewater treatment plants of the company in Muscat with average production to about 41,800 and 42,750 and 94,740 $m^{3/}$day during the years 2008, 2009 and 2010, respectively. The forecast for the period 2011-2016 is expected to increase output of treated wastewater by an increase in demand by the Muscat Municipality as a result of which the estimated average quantity of surplus water would be between the 17,943 m^3/day in 2011 and 21,993 m^3/day in 2016. However, there are 48 wastewater treatment plants in other governorates of the Sultanate supervised by the Ministry of Regional Municipalities & Water Resources.
Figures from the Ministry of Regional Municipalities and Water Resources show that the total capacity of the current number of stations (48 stations) was expected to be 38,010 m^3/day whereas the average amount of water as treated effluent from 48 stations was estimated to be only 8,665 m^3/day taking advantage of municipal needs and landscaping as 4,204 m^3/day which accounts for 48.5% of the average amount of treated wastewater.

A team of techno-economic experts worked on this project collected all the technical data as well as detailed information on cost inputs, yield outputs initial investment for estimating project cost for techno economical analysis (with blending of crops in cyclic manner – barley, sorghum and maize), the results of the study are most encouraging.

A detailed study feasibility study was undertaken for three corps – barley, sorghum and maize proved that there is high possibility of investment opportunities for the expansion of such projects using tertiary treated wastewater keeping in view of the project profitable income return (IRR) after a entire two years of experiments on these three corps was to the tune of 26%.

Utilization of treated wastewater for selected fodder crops would be possible and may prove to be attractive for large scale commercial farming for the private sector investment. An opportunity exists for exploring the utilization of treated wastewater productivity. Considering a number of wastewater collecting and treatment plants, this field provides scope for further exploration. Investors will have to assess the cost benefit analysis based on the large scale commercial farming before entering this field.

The project assumes prime importance in view of "food security" concern for fodder and livestock population. Fodder cultivation and fodder availability are both crucial due to higher water consumption crop and increasing demand for fodder. There is a need to conserve water resources and explore new possibilities for renewal. Keeping this important aspect in mind, the "treated wastewater utilization project" funded by Oman Gas Company (LNG) and undertaken jointly by the Ministry of Agriculture and Ministry of Regional Municipalities & Water Resources is most appropriate for the sustainable growth in Agriculture. Eng Saif Alkhamisi appointed

as a coordinator of the project and Dr V.S. Gosavi as techno- economics analysis expert.

4. Crops & Site Selection:

4.1 Barley, sorghum and maize were the three crops selected for cyclic plantation as fodder crop on which all the observations were undertaken throughout the 24 months of project period ending in Dec. 2010.
Three cross-sections were practiced for the soil in the selected site to examine the soil validity for cultivation.

At the farm site "Saham" entire fencing is undertaken as well as civil and mechanical work related to pumping system, drip irrigation system and crop programming for cultivation was completed by the technical team and necessary manpower was also deployed. The area of cultivation was six Feddan* while the total area of the plot selected was eight Feddan. The site was adjacent to Sewage Treatment plant (STP) of Regional Municipalities &Water Resources of Saham.
*(1 Feddan = 4,200 sq. m)

Fencing

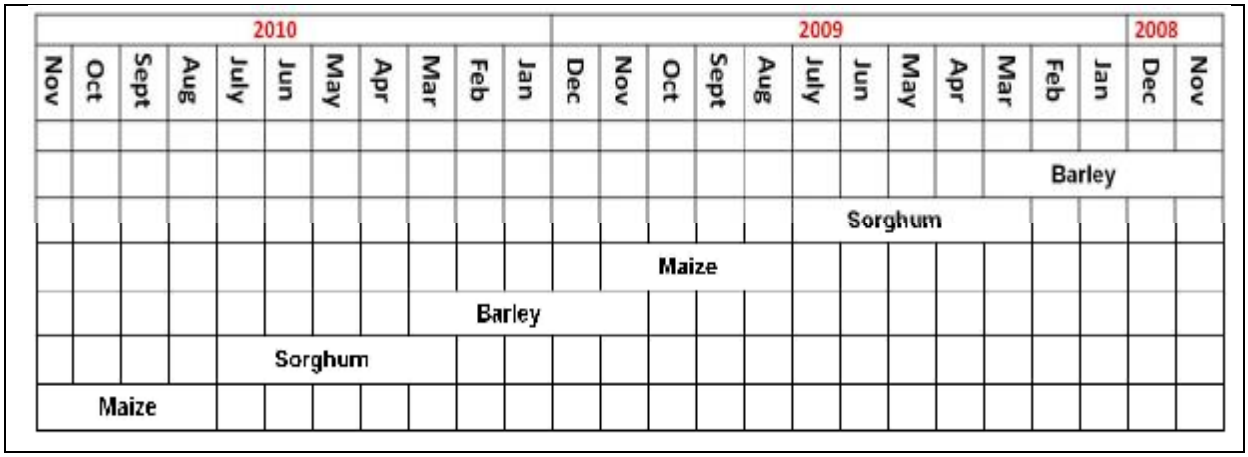
Irrigation system installing

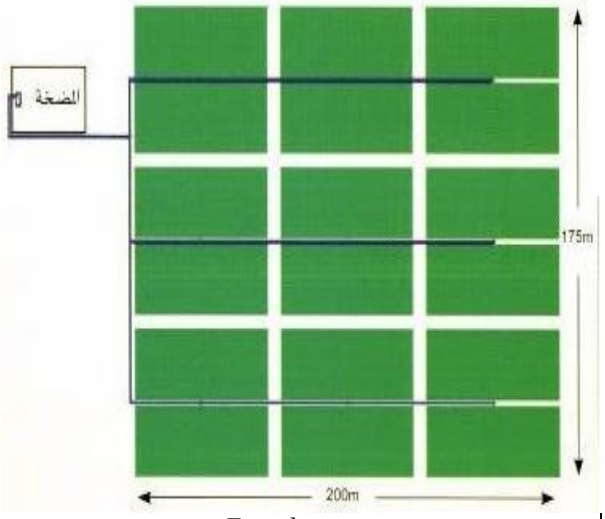
Irrigation time setting

Planting

5. 1 Data Collection and Observation:

- Data on forage green yield, water consumption were collected.
- Samples of plants and soil at three depths (15cm, 30cm and 45cm) were taken and subjected to chemical analysis.
- Visits to the cultivation farm were undertaken by all the members of committee from time to time and detailed action plan was chalked out for various points of project operation were also discussed.
- All the input and output data was gathered and analyzed for monitoring purpose.
- Objectives, action plan and scope of work were briefed to each of the members.
- At every crop rotations techno-economic analysis was made and presented to committee and all such observations of six report on crops were used for averaging the results.





Farm layout

Project committee visit location

5.2 Techno-Economic Analysis Modeling:

The **"Final Report"** on techno-economical analysis on cultivation of crops by reuse of tertiary treated wastewater aims at providing broad comparison of two scenarios.

(i) The results of cultivation of Barley, Sorghum and Maize crops of the first year (all 3 seasons) with

(ii) The results of cultivation of new plantation of Barley, Sorghum, Maize along with Sorghum for the second year (Three Seasons) to observe change if any in economic results in terms of yield and profitability.

Recommendations are based on common average working on economic viability considering all variation on corps and season

For all the three selected crops planted twice, six independent techno-economic analysis models were developed and for the final results blended together to observe variations and economic viability in totality.

6. 2 Technical Analysis

The actual yield and the water consumption for all the four crops is presented in Table 1, while the selling prices as per the market response were considered for estimating sales realization of crops.

Table 1. Yield (t/ha) and quantity of water consumption of fodder crops cultivated at Saham STP

Sr. No.	Crop cultivation	Season	Yield Actual (tons/feddan)	Water Consumption M^3
1	Barley	1st season of 1st year	21	10,295
2	Sorghum	2nd season of 1st year	32.5	30,923
3	Maize	3rd season of 1st year	26	24,479
4	Barley	1st season of 2nd year	16	26,448
5	Sorghum	2nd Season of 2nd year	39	24,055
6	Maize (2.7) with Sorghum (3.3) Feddan	3rd Season of 2nd Year	28 44	43,025

*** Yield reduced – may be due to soil exhaustion**

The project began with the first crop of barley, which was planted during the first week of Nov. 2008 till March 15th 2009, where in production reached 125 tons of green fodder for an area of 6 feddans (Table 2), and the rate of water consumption was 10259 m^3 to irrigate the crop during the cultivation period (Table 1). The

following cultivation was the fourth crop of barley (variety J 98) on Nov. 18th 2009 who planted and harvested is during the first half of the month of February 2010. Second season produced 96 ton green forage yield per 6 feddan (16 t/fed). The WUE of barley in the first season was higher (2.09 kg DM/m^3) in comparison to the second year barley (1.09 kg DM/m^3). This was due to the lower water consumption in the first season (rainy season).

In case of second crop of sorghum (Sorghum), planted during middle April 2009 until June 22nd 2009 with two high yielding varieties viz. Super Dan and Sweet Jumbo at the project site, the production was 193 tons of green fodder for an area of 6 feddans (32.5 t/fed), while it was 234 tons per 6 feddans (39 t/ha). The consumption of water has reached 30923 m^3 and 24055 m^3 to irrigate the crop during the cultivation period (Table 1 and 2).

Table 2. Harvesting dates, total green forage production (ton) and water use efficiency (kg DM/m3) of fodder crops cultivated at Saham STP

CROP	Year	Harvesting Date	Total Green Forage (tons)	Water Use Efficiency (kg DM/m^3)
Barley	**First**	15/03/2009	125	2.06
	Second	18/03/2010	96	1.09
Sorghum	**First**	22/06/2009	193	1.90
	Second	13/06/2010	234	2.24
Maize	**First**	29/10/2009	154	1.50
	Second (Maize+2nd –cut of Sorghum)	29/09/2010	148	0.90

For third crop i.e. maize (Hyb533, Hyb756IT), which was grown on Aug. 19th 2009 and harvested by end of Oct. 2009, the total production of green fodder was 154 tons for the area of 6 feddans against water consumption of 24479 m^3 /6 feddans in irrigating the crop during the cultivation period (Table 1).

In the last season for the second year, the whole area was divided into two parts. A 3.3 feddan was left for the second cut of sorghum, however 2.7 feddan of the area was planted with maize crop. The yield of the 2nd cut of sorghum 44 t/fed, whereas maize produce a green forage yield of 28 t/ha. The total consumption of water was 43,025 m^3 (Table 1).

Sorghum crop was superior in water use efficiency at the second year (2.24 kg DM/m^3) followed by barley in first year (2.06 kg DM/m^3). Maize in the second year was the lowest in WUE (0.9 kg DM/m^3) (Table 2).

6.2 Chemical Analysis

In depth chemical analysis was undertaken on both plant analysis and soil analysis for all the three crops for all the seasons on sample basis. The depth, EC dS/m, pH and fertilizer were observed and data related to the technical analysis presented in "appendix 2"

6.3 Economic Analysis

The economic analysis is carried out on the basis of information made available on input costs, output yield per crop per season and response on sale prices consulted through main fodder markets.

With certain assumptions, the economic indicators for testing the viability of the project were worked out and on this basis it is safe to conclude that the project indicates strong economic viability. The practices followed for cultivation, scale of operation and farm management are critical parameters for obtaining successful results while considering commercial application of such experimentation.

Table below presents the Crops considered and the economic analysis main indicators for viability of the project.

Table 3. Crops results considered for comparison

Sr. No.	Description	Year No. 1 (completed)	Year No. 2 (completed)
1	Project location	Saham	Saham
2	Area under fodder crop	6 Feddan	6 Feddan
3	Crop considered for analysis (For one year season) (i)	Barley	Barley (new plantation)
	(ii)	Sorghum	Sorghum (new Plantation)
	(iii)	Maize	Maize (2.7) & Sorghum (3.3) (new plantation

Table 4. Economic Indicators

S. No.	Description	1st year	2nd year	Average	Remarks
1	Project cost (RO.)	49,000	49,000	-	-
2	Fixed Assets	42,700	42,700	-	-
3	Working Capital	6,300	6,300	-	-
4	Return on Investment	34%	46%	40%	Attractive
5	Return on Capital Employed	44%	61%	52%	Attractive
6	Breakeven Point	52%	44%	48%	Most Reasonable
7	I.R.R.	28%	44%	36%	Good/Attractive
8	I.R.R. Sensitivity (-20%)	19%	33%	26%	Attractive
9	Payback period (years)	2.11	2.00	2.6	Reasonable

Note: in principle the project is economically viable with the assumptions considered in the analysis.

7. Conclusion

(1) The treated wastewater utilization pilot project at Saham is undertaken to assess broadly the economic viability of the concept that such treated wastewater can be used productively for cultivation of suitable fodder crops and in turn reduce the pressure on scarce ground water resources.

(2) The costing of the project and economic returns are bound to vary according to the type of crop, season, soil conditions, scale of operations, however, the encouraging results of the pilot project will directly provide prudent guidelines for sustainable growth of agriculture on such treated wastewater utilization for the selected crops.

(3) This economic analysis is presented on available factual information and certain assumptions for Barley, Sorghum and Maize crops in rotation, which is quite representative and the basic economical analysis shows positive results indicating economic viability of the project with average IRR 26%.

(4) Primarily it may be safe to assume that for crops like barley, sorghum and maize which can be used for fodder the project indicates fare economic returns and is techno-economically viable with its sensitivity analysis. The average IRR with (20% income reduction) sensitivity indicates 26%, payback average payback period as 2.6 years endorsing the economic viability of the project.

(5) For commercial application and private sector investment, these results are likely to be enhanced at the same time organizational efforts and management cost may also increase. Manpower cost, accommodation, transportation, market development etc. will have to be added to cost factor, but commercial yield will also be enhanced with larger area of operation, unit cost going assuring to retain the “economic viability of the project”

(6) In a nutshell the concept will have to be tested for each selected crop to be cultivated in respective season and market response needs to be monitored. There is rich potential to use TWW for fodder crop cultivation and this seems as economically viable project to attract investment from the private sector. thus the non conventional source of water such TWW may prove to new vistas for fodder and other crops cultivation

(7) The cultivation of fodder by using treated wastewater utilization is likely to have favorable environmental impact due to green land development.

(8) The economics and social impact is also likely to be most favorable due to better yield and better economic returns as per economic analysis. May be some government support would be essential to promote such cultivation and supply of treated wastewater.

(9) On view of "food security" which is top on the agenda, promotion of such project utilizing the treated wastewater for increasing fodder supply is of paramount importance on national level.

Words of Appreciation

The project team would like to appreciate Oman LNG for the financial support presented in various stages of the project. We extend our appreciation H.E. the Minister and H.E. the undersecretary for their constant encouragement and to all the committee members and Director General of agriculture and Livestock Research for their valuable guidance and cooperation.

Appendix-1

Estimation of Total Project Cost

The total cost of the project consists of the cost of fixed assets and the requirement of working capital.

Estimation of Project Cost:

S. No.	Item	Amount in RO.
1	Land development and fencing	5800.000
2	Building and civil works	1500.000
3	Plant and equipments	27270.000
4	Vehicle and transportation (lease)	--
5	Furniture and office equipment	--
6	Contingencies	2,700.000
7	Subtotal (total assets) A)	37,270.000
8	Pre operative expenses B)	5,500.000
9	Working Capital C)	6,300.000
10	Total (A + B+ C)	49,070.000
	Total capital investment) – rounded off	49,000.000
	Mode of Finance: Equity	49,000.000
	Loan	Nil
	Total project cost	**49,000.000**

Appendix-2

Barely plant and soil chemical analysis

Plant Analysis 1st Barley season

sample name	N %	P %	K %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	V mg/kg	Zn mg/kg
1 BS	5.100	0.240	0.120	0.056	0.327	4.825	9.472	249.312	26.727	0.544	4.411	1.264	0.839	33.515
2 BS	3.620	0.120	1.720	0.079	0.339	3.859	7.559	145.644	24.024	0.913	4.739	<0.001	0.916	30.833
3 BS	4.010	0.100	1.560	0.182	0.356	2.869	6.636	100.865	29.929	0.902	3.360	1.879	0.674	29.061
Avearage	**0.153**	**4.243**	**1.133**	**0.106**	**0.341**	**3.851**	**7.889**	**165.274**	**26.893**	**0.786**	**4.170**	**1.572**	**0.810**	**31.136**

Plant Analysis 2nd Barley season

sample name	N %	P %	K %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	V mg/kg	Zn mg/kg
1 BS	0.510	0.240	0.122	<0.001	0.503	4.091	8.890	108.530	42.361	4.569	1.919	1.477	1.186	20.018
2 BS	0.362	0.120	1.720	0.141	0.561	3.960	9.240	104.480	48.330	3.494	1.513	0.926	0.864	22.160
3 BS	0.401	0.100	1.560	0.115	0.479	5.270	8.453	100.930	38.130	3.714	1.438	0.955	1.491	16.200
Avearage	**0.424**	**0.153**	**1.134**	**0.128**	**0.520**	**4.615**	**8.847**	**102.705**	**43.230**	**3.604**	**1.476**	**0.941**	**1.178**	**19.180**

Soil Analysis before 1st Barley season

Sample	Depth cm	EC dS/m	pH	N %	P ppm	K ppm	Zn ppm	Cu ppm	Fe ppm
A	15	1.63	8.4	0.012	21.1	100	1.66	0.39	3.22
	30	1.18	8.5	0.001	15.2	220	0.21	0.59	3.44
	45	0.99	8.4	trace	15	120	0.31	0.45	2.94
B	15	2.31	8.3	0.008	4.65	450	0.38	0.65	2.9
	30	3.46	8.1	trace	15.3	150	0.39	0.47	2.9
	45	1.53	8.2	0.004	12.75	160	0.42	0.59	1.78
C	15	2.79	8.1	trace	5.25	120	0.52	0.38	3.18
	30	2.41	8.3	0.004	17.7	90	0.42	0.73	2.3
	45	2.47	8.3	0.001	12.15	480	0.32	0.56	2.62
D	15	3.68	8.3	0.004	7.95	110	0.54	0.85	2.38
	30	2.04	8.3	0.004	4.75	840	0.39	0.76	1.68
	45	2.37	8.2	0.001	12.05	170	0.02	0.81	2.08

Soil Analysis after 2nd Barley

Sample	Depth	EC	pH	N	P	K	Cu	Cr	Cd	Zn	Mn	Mo	Ni	Pb	Fe	V	Co
	cm	dS/m		%	ppm	ppm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A	15	4.07	8.1	0.0040	32.6	210	1.501	0.010	0.003	0.795	4.190	0.020	0.604	0.302	2.297	0.018	0.050
	30	2.24	8.4	0.0050	29.9	170	0.962	0.008	0.007	1.174	6.115	0.006	1.322	0.413	5.445	0.018	0.077
	45	2.65	8.2	0.0010	18.4	150	0.779	0.006	0.006	1.054	7.086	0.014	1.144	0.857	3.925	0.029	0.083
B	15	3.41	8.4	0.0000	25.1	210	0.726	0.007	0.006	0.864	6.375	0.015	1.500	0.493	4.849	0.026	0.196
	30	1.94	8.5	0.0000	18.9	170	0.893	0.008	0.005	0.974	5.607	0.009	1.181	0.521	3.923	0.019	0.073
	45	1.54	8.5	0.0000	23.2	150	0.688	0.010	0.006	1.685	4.458	0.034	1.167	0.500	3.672	0.021	0.141
C	15	0.96	8.4	0.0010	17.1	140	0.616	0.009	0.006	1.052	4.731	0.020	0.885	0.740	3.186	0.019	0.089
	30	1.19	8.4	0.0000	36.9	140	0.886	0.009	0.011	3.014	6.354	0.025	1.143	0.802	4.450	0.025	0.135
	45	0.92	8.4	0.0000	23.6	140	1.003	0.009	0.011	0.943	8.601	0.012	1.157	1.269	4.927	0.034	0.087
D	15	1.04	8.5	0.0000	23.8	120	1.331	0.008	0.017	1.393	10.072	0.016	1.369	1.307	4.609	0.034	0.104
	30	1.03	8.4	0.0000	20.3	100	0.750	0.008	0.011	1.570	3.239	0.009	1.071	0.915	4.839	0.006	0.067
	45	0.93	8.4	0.0000	14.6	90	0.815	0.009	0.007	1.104	4.579	0.013	1.395	2.118	4.220	0.014	0.096
Average	**Depth**	**EC**	**pH**	**N**	**P**	**K**	**Cu**	**Cr**	**Cd**	**Zn**	**Mn**	**Mo**	**Ni**	**Pb**	**Fe**	**V**	**Co**
	cm	**dS/m**		**%**	**ppm**	**ppm**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
	15	*2.37*	*8.35*	*0.001*	*24.65*	*170.00*	*1.04*	*0.009*	*0.008*	*1.03*	*6.34*	*0.018*	*1.09*	*0.71*	*3.74*	*0.02*	*0.11*
	30	*1.60*	*8.43*	*0.001*	*26.50*	*145.00*	*0.87*	*0.008*	*0.009*	*1.68*	*5.33*	*0.012*	*1.18*	*0.66*	*4.66*	*0.02*	*0.09*
	45	*1.51*	*8.38*	*0.000*	*19.95*	*132.50*	*0.82*	*0.009*	*0.008*	*1.20*	*6.18*	*0.018*	*1.22*	*1.19*	*4.19*	*0.02*	*0.10*

Sorghum plant and soil chemical analysis

Plant Analysis 1

sample name	N	P	K	Cd	Co	Cu	Cr	Fe	Pb	Mn	Mo	Ni	V	Zn
	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1 Sorg	2.41	0.55	2.48	0.186	-	6.70	4.073	285.260	0.717	46.786	3.715	4.030	-	14.298
2 Sorg	1.98	0.43	3.28	0.191	-	6.50	3.383	214.307	1.329	51.938	3.415	3.365	-	17.467
3 Sorg	1.18	0.23	3.04	0.055	-	-	4.554	270.100	3.154	47.360	2.240	3.412	-	141.830
4 Sorg	1.85	0.38	3.18	0.258	-	9.62	6.750	309.181	<0.001	64.800	2.071	5.764	-	36.817
Avearage	**1.86**	**0.40**	**3.00**	**0.173**	**-**	**7.61**	**4.690**	**269.712**	**1.733**	**52.721**	**2.860**	**4.143**	**-**	**52.603**

Plant Analysis 2

sample name	N	P	K	Cd	Co	Cu	Cr	Fe	Pb	Mn	Mo	Ni	V	Zn
	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1 Sorg	2.41	0.55	2.48	0.173	0.646	11.825	4.360	510.075	1.810	73.934	5.887	6.691	1.412	36.102
2 Sorg	1.98	0.43	3.28	0.113	0.244	13.122	4.169	532.115	2.158	53.295	3.948	4.853	1.427	32.062
3 Sorg	1.18	0.23	3.04	0.194	0.396	15.501	3.849	377.780	3.139	57.267	2.592	5.540	1.074	37.236
4 Sorg	1.85	0.38	3.18	0.107	0.242	14.427	3.819	325.239	2.922	86.875	3.387	5.183	0.413	28.451
Avearage	**1.86**	**0.40**	**3.00**	**0.147**	**0.382**	**13.719**	**4.049**	**436.302**	**2.507**	**67.843**	**3.954**	**5.567**	**1.082**	**33.463**

Soil Analysis after 2nd Sorghum season

Sample	Depth	EC	pH	N	P	K	OM	Cd	Co	Cu	Cr	Fe	Pb	Mn	Mo	Ni	V	Zn
	cm	dS/m		%	ppm	ppm	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A	15	30.20	7.60	0.10	16.89	90.00	0.20	0.003	0.014	0.273	0.011	3.936	0.136	1.026	0.022	0.246	0.042	0.686
	30	5.92	7.80	0.01	5.04	60.00	0.20	0.003	0.019	0.394	0.011	4.508	0.110	1.294	0.008	0.335	0.053	0.468
	45	2.80	7.80	0.01	3.83	80.00	0.20	0.001	0.014	0.311	0.012	3.455	0.062	0.962	0.017	0.351	0.027	0.621
B	15	9.41	7.90	0.02	8.75	120.00	0.40	0.003	0.022	0.285	0.010	4.525	0.103	0.992	0.013	0.292	0.047	0.648
	30	2.92	8.10	0.02	6.04	160.00	0.40	0.001	0.016	0.273	0.012	4.455	0.064	0.828	0.011	0.214	0.036	0.385
	45	2.88	8.00	0.02	6.14	160.00	0.40	0.002	0.024	0.343	0.018	4.807	0.059	1.206	0.018	0.296	0.032	0.637
C	15	2.64	8.20	0.02	4.83	100.00	0.40	0.002	0.014	0.338	0.013	4.713	0.083	1.054	0.018	0.229	0.051	0.429
	30	15.17	7.90	0.02	8.55	100.00	0.40	0.002	0.019	0.338	0.015	5.114	0.085	1.161	0.015	0.311	0.054	0.529
	45	1.98	8.00	0.01	2.93	180.00	0.20	0.002	0.017	0.281	0.013	4.708	0.068	0.909	0.014	0.194	0.041	0.389
D	15	1.83	8.00	0.01	3.13	140.00	0.20	0.002	0.041	0.431	0.011	3.800	0.087	2.810	0.022	0.399	0.046	0.478
	30	1.20	7.90	0.00	2.02	90.00	0.00	0.003	0.060	0.411	0.013	3.782	0.085	3.996	0.015	0.475	0.039	0.564
	45	2.30	7.80	0.00	5.44	130.00	0.00	0.002	0.028	0.321	0.016	4.201	0.154	1.849	0.019	0.293	0.032	0.743
	Depth	**EC dS/m**	**pH**	**N**	**P**	**K**	OM	**Cd**	**Co**	**Cu**	**Cr**	**Fe**	**Pb**	**Mn**	**Mo**	**Ni**	**V**	**Zn**
	cm			**%**	**ppm**	**ppm**	%	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Average	***15***	*11.02*	*7.93*	*0.038*	*8.40*	*112.50*	*0.30*	*0.003*	*0.023*	*0.33*	*0.01*	*4.244*	*0.10*	*1.47*	*0.02*	*0.29*	*0.05*	*0.56*
	30	*6.30*	*7.93*	*0.013*	*5.41*	*102.50*	*0.25*	*0.002*	*0.029*	*0.35*	*0.01*	*4.465*	*0.09*	*1.82*	*0.01*	*0.33*	*0.05*	*0.49*
	45	*2.49*	*7.90*	*0.010*	*4.59*	*137.50*	*0.20*	*0.002*	*0.021*	*0.31*	*0.01*	*4.293*	*0.09*	*1.23*	*0.02*	*0.28*	*0.03*	*0.60*

Maize plant and soil chemical analysis

Maize Plant Analysis

sample name	N %	P %	K %	V mg/kg	Cu mg/kg	Co mg/kg	Cr mg/kg	Cd mg/kg	Zn mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Fe mg/kg
1 Maize	1.60	0.68	0.62	52.31	2.46	0.18	0.69	0.07	34.32	9.98	205.80	7.70	<0.004	53.35
2 Maize	1.29	0.38	1.04	7.83	4.72	0.96	4.62	0.12	34.32	11.41	25.36	7.01	0.58	284.27
3 Maize	1.39	2.21	0.68	6.35	1.99	0.40	1.15	0.06	25.94	5.97	23.67	5.73	<0.001	63.04
4 Maize	0.66	1.65	0.98	1.86	4.84	0.82	24.20	0.07	27.80	6.96	8.03	1.51	27.492	525.89
5 Maize	1.51	0.58	2.04	2.98	9.95	0.97	7.49	0.22	21.20	36.70	9.64	6.71	6.989	401.25
6 Maize	1.91	0.48	2.30	0.39	10.16	0.58	5.04	0.13	28.39	53.53	2.74	4.28	<0.001	305.80
Avearage	1.39	1.00	1.28	11.95	5.69	0.65	7.20	0.11	28.66	20.76	45.87	5.49	11.69	272.27

Soil Analysis after Maize season

Sample	***Depth***	**EC**	**pH**	**N**	**P**	**K**	**Cu**	**Cr**	**Cd**	**Zn**	**Mn**	**Mo**	**Ni**	**Pb**	**Fe**
	cm	**dS/m**		%	%	%	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
A	*15*	10.81	8.00	0.022	15.30	400.00	0.290	0.005	0.003	0.720	1.159	0.050	0.282	0.068	2.835
	30	39.50	7.50	0.002	9.56	130.00	0.271	0.006	0.003	1.016	0.837	0.006	0.245	0.067	2.924
	45	5.94	8.00	0.001	14.18	150.00	0.188	0.007	0.005	0.718	0.587	0.003	0.180	0.049	2.982
B	*15*	5.21	8.10	0.014	25.34	220.00	0.178	0.005	0.002	0.555	0.639	0.019	0.275	0.070	1.830
	30	13.95	7.80	0.009	13.08	170.00	0.191	0.006	0.002	0.569	0.561	0.019	0.253	0.096	1.876
	45	2.41	8.20	0.003	12.58	170.00	0.164	0.008	0.002	0.827	0.441	0.010	0.241	0.059	1.937
C	*15*	1.99	8.20	0.003	17.80	230.00	0.357	0.008	0.002	0.588	1.210	0.001	0.255	0.086	3.100
	30	22.10	7.60	0.000	16.10	140.00	0.224	0.006	0.003	1.186	0.707	0.006	0.181	0.097	2.289
	45	4.57	7.90	0.000	18.10	110.00	0.217	0.003	0.002	0.677	0.990	<.001	0.193	0.053	3.313
D	*15*	3.03	8.10	0.013	15.20	180.00	0.174	0.007	0.001	0.632	0.656	0.002	0.117	0.048	2.773
	30	15.40	7.80	0.003	10.80	110.00	0.146	0.009	0.001	0.846	0.669	0.007	0.138	0.065	2.892
	45	5.71	8.20	0.004	20.80	130.00	0.126	0.010	0.001	1.007	0.625	0.011	0.127	0.048	2.957
	Depth	**EC**	**pH**	**N**	**P**	**K**	**Cu**	**Cr**	**Cd**	**Zn**	**Mn**	**Mo**	**Ni**	**Pb**	**Fe**
	cm	**dS/m**		**%**	**ppm**	**ppm**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Average	***15***	*5.26*	*8.10*	*0.013*	*18.41*	*257.50*	*0.25*	*0.006*	*0.002*	*0.62*	*0.92*	*0.018*	*0.23*	*0.07*	*2.63*
	30	*22.74*	*7.68*	*0.004*	*12.39*	*137.50*	*0.21*	*0.007*	*0.002*	*0.90*	*0.69*	*0.010*	*0.20*	*0.08*	*2.50*
	45	*4.66*	*8.08*	*0.002*	*16.42*	*140.00*	*0.17*	*0.007*	*0.003*	*0.81*	*0.66*	*0.008*	*0.19*	*0.05*	*2.80*

Appendix-3