IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. I (Jul. - Aug. 2015), PP 59-65
www.iosrjournals.org

Assessment of Economic Viability of Different Irrigation Methods: A Case Study of Chaar-Ghare, Lalitpur, Nepal

Subik Shrestha and Khet Raj Dahal
Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal

Abstract: *In the Chaar-Ghare village of Chapagaun, Lalitpur, Nepal, furrow irrigation is a primary source of water for growing crops. A study was conducted in order to know the economic viability of surface (furrow) and sprinkler irrigation during the period of 2013-2014 in Chaar-Ghare, ChapagaunVillage Development Committee (VDC), Lalitpur. A topographic survey of Chaar-Ghare area was conducted. The crops Solanumly copersicum (tomato), Alliumcepa (onion), Allium sativum (garlic), Zeamays (corn) were chosen for economic analysis. The case of water requirement was analyzed in three scenario of optimistic, pessimistic and normal in the significant level of 5% with the hydrological parameters, which were normally distributed. It was found that the lowest water requirement was for Zeamays (17400 cu. m) and Alliumcepa (32375cu. m) and the next was Allium sativum (33135 cu.m).The highest water requirement was for Solanumly copersicum with water requirement of 210345cu. m. The study concluded that sprinkler irrigation was almost one and half fold economical than the furrowirrigation.*

Key words: *Chaar-Ghare, Furrow Irrigation, Sprinkler Irrigation,Water Requirement, and Economic Return*

I. Introduction

Irrigation is the art of applying water artificially to the field in accordance to the crop requirement throughout the cropping period for the full fledge nourishment of the plant for better yield ability **(NARC, 2011).** The need of food is inevitable till the cycle of life exist on the planet. Time and modernization are paramount parameter related with each other and have brought today's burning issues of climate change which demands a better irrigation system where we can optimize the use of water and Irrigation Engineers, while designing an irrigation system that tries to maximize Irrigation Efficiency (IE) and economic return. The rational use of water is another thing for optimization we either follow consumptive use or conjunctive use of water. From our traditional cultivation method of surface irrigation to today's modern method of irrigation, we are assessing the economic viability of different irrigation methods **(Ortiz Romero et al., 2006)**.

Government policy makers are usually interested in achieving higher yield for a unit of water applied and consequently interested in more economic return. It is obvious that water used in surface irrigation is more than that used in sprinkler irrigation but the question is how much of water in excess. We surveyed on different literatures and found, the average efficiency of surface irrigation in the inner mountain west is probably less than 50 percent as compared to the higher sprinkler efficiency of 70 percent **(Robert, 2001)**, using raingun sprinkler irrigation system, 30.8% and28.3% higher water use efficiency and 21.1% and 9.0% more water application efficiency was achieved as compared to basin and furrow irrigation system, respectively (**Rana et al.,2006).**A good irrigation system should give a better return, and the general prosperity of farmer is based on the yield of crops. About 5.64% and 1.71% more yield was obtained in raingun sprinkler irrigation system as compared to basin and furrow irrigation systems, respectively **(Rana et al., 2006).** Irrigation Water Used Efficiency (IWUE) (t/ha/mm), is defined as the ratio of crop yield to seasonal irrigation water in mm including rain **(Howell, 1994)**. Both IE and IWUE can be increased by practicing deficit irrigation in part of field receiving the minimum water application depth **(Al-Jamal et al., 2001)**. The most economical deficit irrigation level depends on the uniformity of application of the irrigation water and the associated cost of the irrigation water, any cost of remediation treatment on the drainage water, and the value of a unit of the crop **(Wu, 1998).** Previous research shows a higher IWUE for sprinkler systems (from 0.0044 to 0.0659 t ha^{-1} mm^{-1}) compared with furrow irrigation (from 0.0086 to 0.056 t ha^{-1} mm^{-1}) **(Sammis, 1980; Bogle et al., 1989).**When growing Allium Cepas has also shown higher IWUE values sprinkler irrigation (0.049 t ha^{-1} mm^{-1}) compared furrow irrigation (0.044 t ha^{-1} mm^{-1}) is seen **(Ellis et al., 1986).**

Farmers are usually interested in the economic return per unit of the water applied. Consequently, deficit irrigation is not economical at current water cost in US **(McGuckin et al., 1987)**, but changing from furrow to sprinkler irrigation which can increase both IE and IWUE is economical for high value crop.

The major interest of this research paper lies in exploring the net profit per cubic meter of water for surface and sprinkler irrigation.

II. Material And Methods

Study Area

Chaar-Ghare area is a small remote area of Chaar-Ghare, which lies in Chapagaun VDC,Lalitpur district of Nepal with bounding coordinates of maximum 27°35'28.6210", 085°19'08.9770" and minimum 27°35'14.5194", 085°18'50.5572" (Fig. 1). The rain and canal fed irrigation system, serves 264.4 Ha areas in total extending up to Thecho of Lalipur district. The study was limited to gross command area of 9.27 ha having cultivable command area of 9 ha **(www.googleearth.com).**

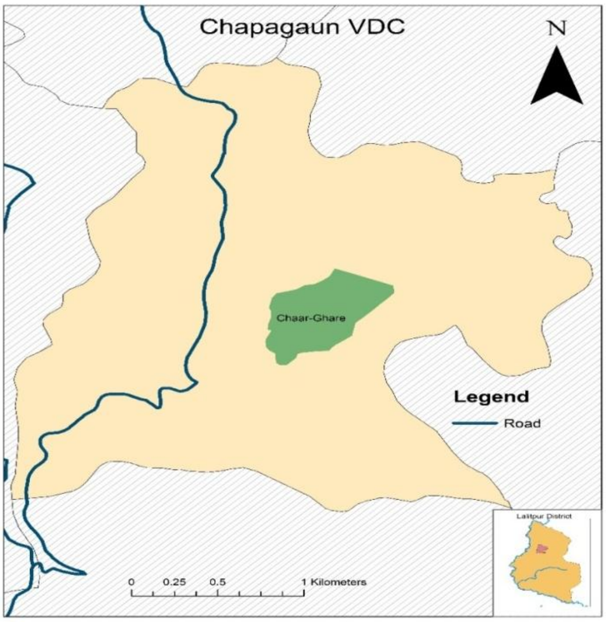

Fig. 1: Study area

Data collection technique at preliminary design stage was through focused group discussion (FGD) in Chaar-Ghare (Fig. 1). It provided basic information for further design. FGD also helped to know the problems regarding water and its quality with their annual yield and market economics. The discharge of canal and field properties like field capacity and wilting point were measured. The discharge measurement technique was leaf floatation in a straight and uniform section of length 7.5m and cross-sectional dimension of 1.38m width and 0.3m depth while for field capacity and wilting point, soil sample were collected after 24 hours of rain had stopped and also after 10 days. Samples were weighted separately and fed to oven for 24 hours and weighted again to get dry weight. Weight of water in soil sample divided by weight of dry soil gives the water content which are field capacity and wilting point respectively. Other necessary data for calculating crop water requirement was collected from Department of Hydrology and Meteorology(DHM),Nepal,which was of 20 year long time series. The data was first analyzed if they follow normal distribution. The central limit theorem was also applied and concluded they do follow normal distribution of probability. The formula used for this study was:

$$\text{Normal distribution (z)} = \frac{\text{Variable} - \text{mean}}{\text{Standard Ddeviation}}$$

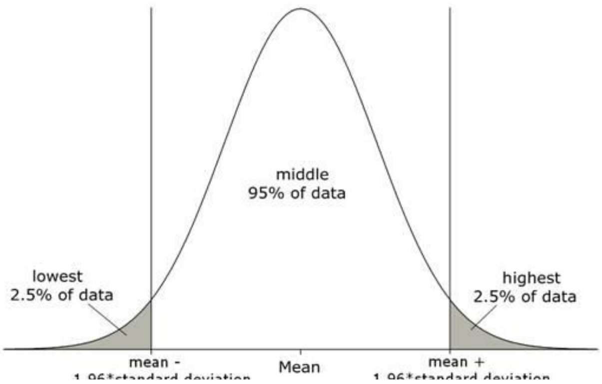

Figure 2: Normal distribution graph at 95% confidence level

For 5% level of significance z = ± 1.96 which is multiplied by standard deviation and added to mean to find the variable value.

FAO Eto calculator was used for calculatingPotentialEvapotranspiration which feds the parameters like Temperature(Max and Min), relative Humidity(Max and Min), wind velocity at 2 m above the ground surface and solar radiation. The obtained Eto was multiplied by Crop Coefficients (Kc) (listed by FAO) to get water requirement in millimeter/day. It was checked by manual method of calculating Eto of Penman Monteith and was found almost the same. Crop water was analyzed in different scenario of Optimistic, The Normal and The Pessimistic with the significant level of 5% as the data follows Normal distribution of Probability. And the rainwater was again analyzed in to effective rain water at different former explained scenarios. The formula used for this study was:

$$Eto=\frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}u_2(es-ea)}{\Delta+\gamma(1+0.34u_2)}$$

Where,

Eto	Potential Evapotranspiration
Rn	Net Radiation at crop surface
G	Soil heat flux density
T	Mean daily air temperature at 2m above the ground surface
U2	Wind velocity at 2m above the ground surface
Es	Saturation vapor pressure
Ea	Actual vapor pressure
Δ	Slope vapor pressure curve
Γ	Psychrometric Constant

And the effective rainfall (Pe) was calculated using the following formulae:

$Pe = 0.8 P - 25$ if $P > 75$ mm/month

$Pe = 0.6 P - 10$ if $P < 75$ mm/month

Topographic survey of Chaar-Ghare area was conducted by Total Station (Topcon). The arbitrary coordinate of 1000, 1000, 1000 (N,E,Z) was given for the bench mark (BM) and detailing was carried out. The recorded data were plotted using Digital Terrain Modelling**(**DTM**)** with the contour interval of 0.5m. The optimal alignment (Cut = Fill) for canal was plotted at Topo-map and longitudinal and cross section was extracted from plotted alignment with vertical and horizontal scale of 1:1000 both. GIS map was prepared with the help of Google Earth control points and were marked at the required boundary of Chaar-Ghare and was mounted to Arc GIS.

Canal section was designed by using the Lacey's Formula and special considerations (as suggested by Irrigation Manual of Government of Nepal) were also undertaken (Fig. 2). The field was divided in to 3 parts (2 ha, 3 ha, and 4 ha)and canal section was designed for 4 ha land.For preventing seepage and percolation losses the canal section was lined brick masonry. The canal section was kept constant throughout the length. The canal section was 1.2m wide and 0.8 m deep including 0.15m freeboard.

For every 10 m, cross-section of ground level was prepared with required formation level and canal section. The cascade was provided wherever necessary with concrete floor. At the 4 ha area a PVC pipe, 30cm diameter was provided. It was found more economical than others considering the annual maintenance and replacement cost.

Usually furrows are aligned down the main slope of land and supplied form head ditch. A tail ditch at the end of the run collects water for reuse at lower levels.

Cross slope: It is not essential for furrows to run down the main slope. Cross-slope are used or row crops on the land slopes of up to 12% **(Withers and Vipond, 1974)**.

Corrugation: A form of furrow, shallow and broadly spaced, is used to irrigate pasture and small grain crops, and as such is called a corrugation. The system is down slope on land from 0.4% to 8%, and cross slope up to 12%. Land levelling on the steeper slopes can be limited to the removal of minor irregularities by land plane **(Withers and Vipond, 1974).**

The water rotation for field was divided in such a way that the frequency of frequently water requiring plant would not get disturbed. The water was not allowed to deplete more than Optimum Moisture Content (OMC), so water division and distribution was made with reference to Allium Cepa.

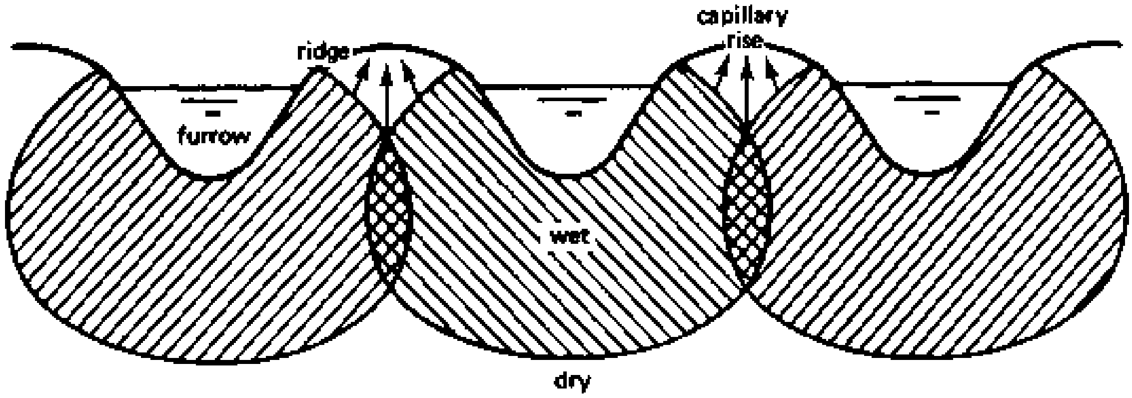

Figure 3: Furrow Irrigation and its wetting pattern **(FAO, 1988)**

Sprinkler is versatile method of applying water to any crop (except field crops like paddy), soil and topographic condition. It is particularly useful in areas where there is a shortage of water; hill slopes are steep and can erode with other methods of irrigation.

In sprinkler irrigation, surface ditches and prior land preparation are not necessary, but it was to get the required head through gravity (Fig. 4). It was known earlier that for medium head of 20 -50 m, the sprinkler work good with uniformity of coverage, which wasaffordable and suitable for most of the terrains and eventually it was found the head of 20 meter withallowable head variance of 4m. The lateral of 63mm and distributaries of 75 mm were selected and grid of each sprinkler was selected on the basis of wind direction. Pressure and wetted land overlapping and canopy effect, 15m *15m was selected with 5 sprinklers in each lateral of 2 m riser. Water hydrant was kept at each 15 meter interval and distributaries were kept at center of field acquiring both sides. The filed size was 110m wide and 180 m long. The field was again divided in former 3 parts and water for larger field crop was selected. Required numbers of portable lateral was calculated, and 40 laterals were found to be required. All material in sprinkler was made from Poly Vinyl Chloride (PVC).

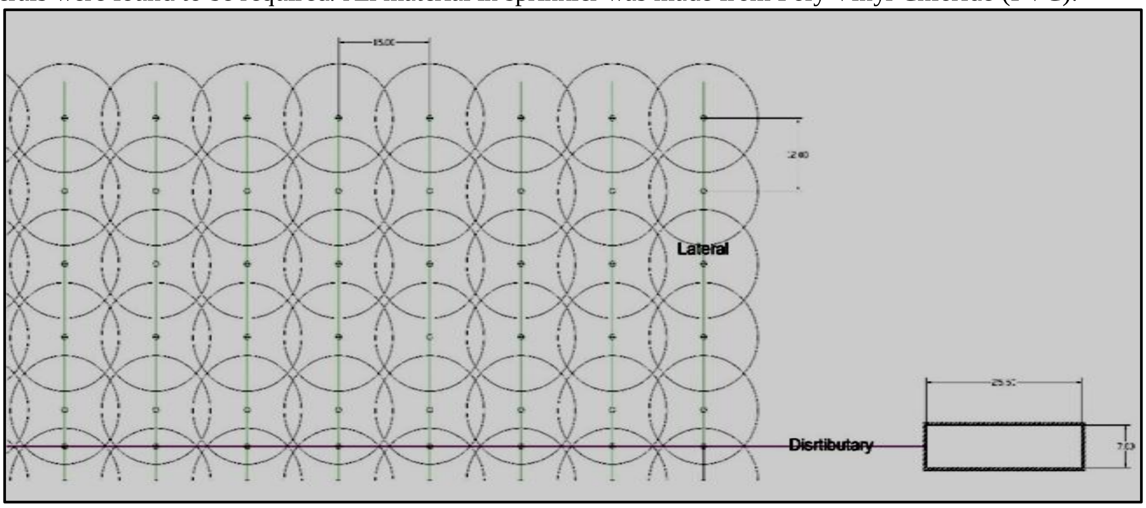

Figure 4: Lateral and Distributary Distribution

Agricultural considerations for better productivity regarding soil and their compatibility with crops, access to scheme in terms of provisions of input and marketing of produce, provision of facilities for agro-processing, the possibility of crop diversification in future was carried out simultaneously.

III. Results And Discussion

Surface Irrigation (Furrow Irrigation)

Many agricultural crops can be grown in beds separated by furrows. When irrigation is required, water can be run into the furrows. This system works well if the furrow hydraulics are correct for uniformity along the run and if water movement within the soil is predominantly horizontal into the plant root zone.It may be undesirable for water to rise within the bed by capillarity until the ground surface is wet. Compared to other surface irrigation practices, there is less open water surface and therefore less evaporation from furrow, the risk of pudding soil is reduced, and farmers can work on the field sooner after the end of water application.Corrected

mean discharge was found 0.161 cumecs with field capacity (FC) 0.331 and permanent wilting point (PWP) 0.123.
Eto was found 0.95 mm/day for the month of December (Minimum) and 5.73 mm/day for month of May (Maximum). Such variation was due to higher Temperature, lower percentage of Relative Humidity in the month of May than that of December.

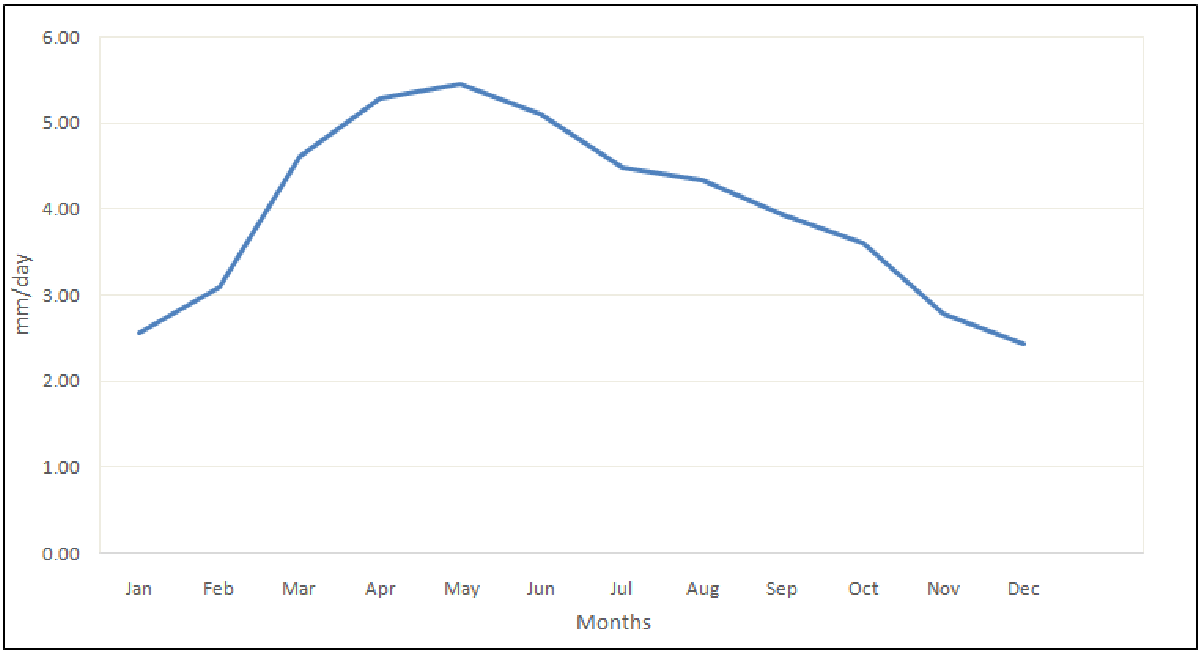

Figure 5: Potential Evapotranspiration

Separate calculation on the basis of the cropping period of plants which can be sown together in largest partitioned land of 4 ha. The water requirement for evapotranspiration is calculated and according to soil characteristic (Loamy Clay) the seepage and percolation loss was 5mm/day**(FAO, 1982, 1997, 1998)** while the water requirement for plant andthe frequency of irrigation were also calculated simultaneously. The combine discharge of plants that can be planted together were computed and then multiplied by land area to be sown giving the quantity of water in cum/month and the canal was designed for that discharge. The corrected discharge of the stream was found 0.161 cumecs.

Sprinkler Irrigation

Sprinkler system typically comprises of a water source, a piped conveyance network and a means of ejecting water into the air to fall as spray or gun. The system requires relatively high pressure to operate or a high head, which could be provided through gravity or pumping **(UNDP, 1998).**

Comparison of surface (furrow) irrigation with sprinkler irrigation

After the calculation of all field data, an overall result was obtained. The result and comparison is presented in the table (Table 1).

Table 1: Comparison of surface (furrow) irrigation with sprinkler irrigation

S.N.	Parameter	Surface irrigation		Sprinkler Irrigation	
1	Crops	Solanumlycopersicum (tomato), Alliumcepa (onion), Alliumsativum (garlic), Zeamays (corn)		Solanumlycopersicum (tomato), Alliumcepa (onion), Alliumsativum (garlic), Zeamays (corn)	
2	Water requirement	293617 m^3		232741 m^3	
3	Yield , kg	Solanumlycopersicum	93787	Solanumlycopersicum	95832
		Allium sativum	10878	Allium sativum	11979
		Zea mays	6970	Zea mays	7986
		Allium cepa	7151	Allium cepa	7872
4	Total return	NRs. 5503200	USD 56155	NRs. 5772750	USD 58905
5	Structure cost	NRs.6938965.94	USD 72280	NRs. 1390600	USD 14485
6	Useful life	Canal	60 years	Tank	60 years
		HDPE pipe	5 years	Sprinkler	12 years
7	Return/m^3 of water	NRs.14.52	USD 0.15	NRs. 23.68	USD 0.24

Form the calculation for surface irrigation, Yield for Paddy was 107.811 ton in 9 ha with water requirement of 1858.9 mm and the IWUC was 0.019 t/ha/mm similarly or Solanumlycopersicum = 0.05, Zeamays=0.057,Alliumcepa= 0.08 t/ha/mm and in case of sprinkler irrigation,Solanumlycopersicum=0.053, Zeamays=0.059, Alliumcepa=0.082 and Alliumsativum =0.062 t/ha/mm, which was quietly satisfied with other literatures too.

The water requirement was calculated on the basis of water used by plant throughout its development stages and is presented in figure 5 for bothsurface and sprinkler irrigation respectively. The yield data were collected on the basis of 2 years survey with their local market selling rate. Sprinkler system typically comprises of a water source, a piped conveyance network and a means of ejecting water into the air to fall as spray or gun. The system requires relatively high pressure to operate or a high head, which may be provided through gravity or pumping **(UNDP, 1998).**

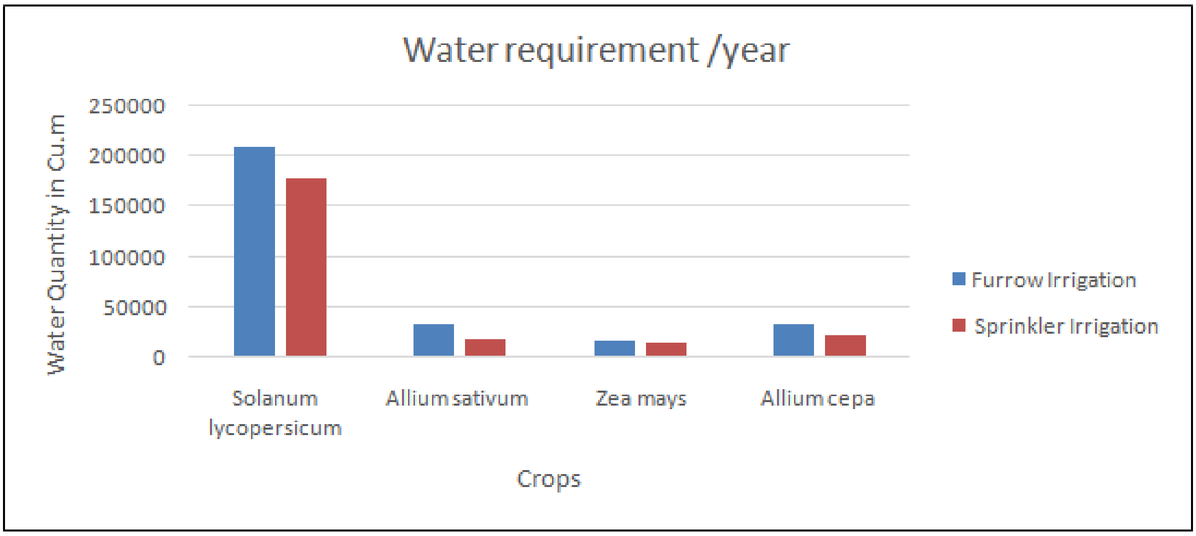

Figure 6: Water requirement for Furrowand Sprinkler irrigation

This bar chart compares the amount of water requirement per year bySolanumlycopersicum, Alliumsativum, Zeamays and Alliumcepa.The water requirement was calculated based on the pessimistic scenario of water available and hydrological parameters.

It could be clearly seen for furrow irrigation that the lowest water requirement is for Zeamays (17400 cu. m) and Alliumcepa (32375cu. m) the next isAlliumsativum (33135 cu.m).The highest water requirement is for Solanumlycopersicumwith water requirement of 210345cu. m.

It could be clearly seen for sprinkler irrigation that the lowest water requirement is for Zeamays (14536 cu. m) and Alliumsativum (18080cu. m) the next isAlliumcepa (22735cu.m). The highest water requirement is for Solanumlycopersicum with water requirement of 177390cu. m.

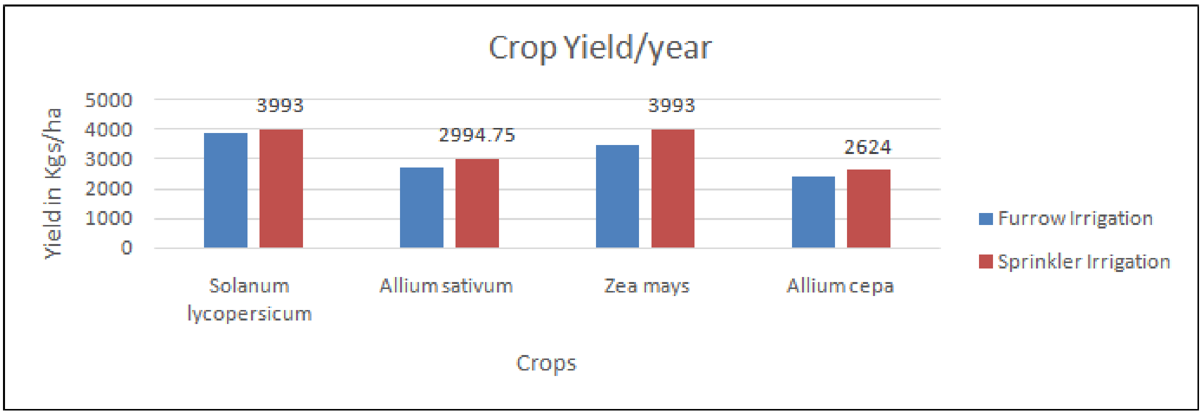

Figure 7: Yield of crops for Furrow and Sprinkler irrigation

The yield was calculated through field survey and it is presented in Figure 7. This bar chart (Fig. 7) compares the crop yield in kg per year per hector for Solanumlycopersicum, Alliumsativum, Zeamays and

Alliumcepa. It could be clearly seen for Furrow Irrigation that the lowest yield was of Alliumcepa (2383kgs/ha) and Alliumsativum(2719kgs/ha), the next was Zeamays (3485kgs/ha). The highest yield was of Solanumlycopersicum with yield of 3907kgs/ha.

While for Sprinkler Irrigation, it could be clearly seen that the lowest yield was of Alliumcepa (2624kgs/ha) and Alliumsativum (2994kgs/ha). The highest yield was of Solanumlycopersicum with yield of 3933kgs/ha and Zeamaysof 3933kgs/ha.

IV. Conclusions

For assessing economic viability,the study found out the cost of the irrigation structures such as canal, cascade, and outlet (for surface irrigation). And for sprinkler: distributaries, laterals, hydrant, and tank. Similarly, the corresponding yield of the nine ha fieldwas found out. Last but not the least, the study found out the water required for each crop to be grown in that corresponding 9 ha of field (Chaar-Ghare) and also the percolation and seepage losses. Thus, the study concluded to introduce various techniques of irrigation to the farmers which could help them to increase their agricultural productivity with consumptive use of water. The profit per cubic meter of water was found to be NRs. 14.52 and NRs. 23.68 for surface and sprinkler irrigation respectively. In this way, the study showed that sprinkler irrigation is almost one and half fold economical and profitable thansurface irrigation.

Acknowledgement

All the irrigators’ community of Chaar-Ghare helped us during field survey. Mr. Uday Bilas Panta, Mr.Deewakar Rai, Mr. Safal Lal Joshi, Mr. Ashish Khadka, and Mr. Vivek Gyawali participated in field survey. Similarly, Prof. Dr. Shanti Nath Shrestha and Dr. Narayan Kumar Shrestha guided us during field work. Thus, we would like to acknowledge all of them for their contribution.

References

[1]. Al-Jamal, M.S., Ball,S., Sammis,T.W., 2001. Comparison of sprinkler, trickle and furrow irrigation efficiencies for Allium Cepa production. Agric. Water Manage. 46:253-266.

[2]. Armon, R., Gold,D.,Brodsky,M.,Oron,G., 2002. Surface and subsurface irrigation with effluents of different qualities and presence of cryptosporidium oocysts in soil and on crops. Water Science & Technology 46 (3): 115–122.

[3]. Bassoi, L.H., Hopmans, J.W.,de C. Jorge, L.A., de Alencar, C.M.,Silva,J., 2003. Grapevine root distribution in drip and microsprinkler irrigation. Sci. Agric. (Piracicaba, Braz.) 60:377-387.

[4]. Bekele, S.,Tilahun,K., 2007.Regulated deficit irrigation scheduling of Allium cepa in a semiarid region of Ethiopia. Agric. Water Manage. 89:148-152.

[5]. Bogle, C.R., Hartz, T.K., Nunez, C., 1989.Comparison of subsurface trickle and furrow irrigation on plasticmulched and bare soil for Solanumlycopersicumproduction.J. Am. Soc. Hort. Sci. 114 (1)

[6]. Bozkurt, Y., Yazar, A., Gencel, B., Sezen, M.S., 2006. Optimum lateral spacing for drip-irrigated Zea mays in the Mediterranean Region of Turkey. Agriculture Water Management 85:113-120.

[7]. Bryla, D.R., Dickson, E.,Shenk, R., Johnson, R.S., Crisosto, C.H., Trout,T.J., 2005. Influence of irrigation method and scheduling on patterns of soil and tree water status and its relation to yield and fruit quality in peach. HortScience 40:2118-2124.

[8]. Burguete, J., Zapata, N., García-Navarro,P.,Maïkaka, M., Playán, E., Murillo,J., 2009.Fertigation in furrows and level furrows systems. I. Model description and numerical test. J. Irrig. Drain. Eng. 135:401-412.

[9]. Burguete, J., Zapata, N., García-Navarro,P.,Maïkaka, M., Playán, E., Murillo,J. 2009b.Fertigation in furrows and level furrows systems. II. Field experiments, model calibration, and practical applications. J. Irrig. Drain. Eng. 135:413-420.

[10]. DHM, 2013.Official records of hydro-meteorology, Kathmandu

[11]. Ellis, J.E., Kruse, E.G., McSay, A.E., Neale, C.M.U., Horn, R.A., 1986.A comparison of ®ve irrigation methods on Allium Cepas. Hort. Sci. 21 (6), 1349-1351.

[12]. Erich, T. and Prayag, R.J., 1992. "Historical Hiti and Pokhari: Traditional Solutions to Water Scarcity in Patan"

[13]. FAO, 1997. Crop water requirement, Irrigation and Drainage Paper

[14]. FAO, 1982. Mechanized Sprinkler Irrigation. FAO Irrigation and Drainage Paper 35, 409 p.

[15]. FAO, 1998. Crop Evapotranspiration. FAO Irrigation and Drainage Paper 300 p.

[16]. Howell, T., 1994.Irrigation engineering, evapotranspiration. In: Arntzem, C.J., Ritter, E.M. (Eds.), Encyclopaedia of Agricultural Science. Vol. 2, pp. 591-600.

[17]. McGuckin, J.T., Mapel, C., Lansford, R., 1987. Optimal control of irrigation scheduling using a random time frame. Am. J. Agric. Econ. 69, 123-133.

[18]. NARC, 2011. Yearly development report, Vegetable Development Directorate, Khumaltar, Lalitpur

[19]. Ortiz Romero, J.N., Martínez, J., Martínez, R., Tarjuelo,J.M, 2006. Set sprinkler irrigation and its cost. J. Irrig. Drain. Eng. 132:445-452.

[20]. Rana, M. A.,Arshad,M., Masud,J., 2006.Effect of Basin, Furrow and Raingun Sprinkler Irrigation Systemson Irrigation Efficiencies, Nitrate-Nitrogen Leaching and Yield of Sunflower

[21]. Robert, W. H., 2001. Management of sprinkler irrigation system

[22]. Sammis, T.W., 1980. Comparison of sprinkler, trickles, subsurface and furrow irrigation methods for row crops. Agron. J. 72, 701-704.

[23]. UNDP, 1998. PSD Manual, Part –I

[24]. Withers and Vipond, 1974. Irrigation Design and Practice

[25]. Wu, I.P., 1988. Linearized water application function for drip irrigation schedules. Trans. ASAE 31 (6), 1743-1749.