

Evaluation of Water Efficiency and Crop Yield by Adopting Drip Irrigation Technique for Upper Bhadra Project in Chitradurga

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Abstract:

This research assesses the effect of the implementation of drip irrigation technology on water use efficiency and crop yields in the Upper Bhadra Project area of Chitradurga. The study intends to compare the efficiency of drip irrigation with other traditional systems in water savings, productivity of crops, and economic returns. The method focuses on analyzing crop water use, examining water usage trends, and quantifying yield increases in different crops. Findings show that drip irrigation greatly enhances water use efficiency with measured crop yield and cost benefit increments of 25% to more than 100% in some instances. In spite of these advantages, high initial investment, maintenance of the system, and technical inadequacies still act as hindrances to its widespread use. The report concludes that encouraging drip irrigation, through subsidies as well as farmer training, can promote sustainable agriculture and boost food security in desert areas.

Keywords — Drip Irrigation. Water Use Efficiency. Sustainable Agriculture. Crop Productivity. Water Management.

I. INTRODUCTION

A scarce and precious natural resource, water is essential to agriculture, life, and economic development. Since agriculture uses about 70% of the world's freshwater supplies, it is more important to use water efficiently. To ensure efficient use of water and improved crop production in the face of growing water shortages, climate change, and food demand, advanced irrigation technology must be developed.

In view of the Indian monsoon's intermittent and seasonably uncertain character, irrigation systems serve as a valuable complement to nature's rainfall. This enables farmers to grow crops year-round, particularly during dry spells. India's irrigation history is rich, ranging from ancient tanks, wells, and canals to contemporary multi-purpose river valley projects. The nation has one of the biggest and most extensive irrigation systems in the world, with major,

medium, and minor irrigation schemes. The schemes include surface water such as canals and reservoirs and groundwater such as wells, tube wells, and boreholes India's irrigation industry is typical of regional heterogeneity, with each state following different techniques according to geographical, climatic, and socio-economic factors. Canal irrigation, for example, dominates Punjab and Uttar Pradesh, while groundwater-based irrigation dominates Maharashtra, Gujarat, and Tamil Nadu. Sub-Surface irrigation uses a pipe network with drip nozzles and water supplied directly to the root area of crops. Drip Irrigation is a form of irrigation technique also known as micro-irrigation or Trickle Irrigation. Drip irrigation includes the control head, network piping, and emitters. The control unit, in essence, consists of an overhead tank, a pumping unit, a water-measuring unit, a filter, and a pressure control unit. Water from the overhead tank passes through the main line pipe under regulated

conditions. Water use efficiency (WUE) is a crucial metric in agriculture that portrays the linkage between crop yield and water utilization. It may be described as the amount of crop yield per unit of water consumed or applied. Based on Perry (2007), enhancing WUE in irrigated farming is among the most effective options for managing water scarcity in water-scarce areas. Bucks et al. (1982) observed that drip irrigation systems are specifically suited to arid and semi-arid areas, where water resources are scarce and high evapotranspiration occurs.

The systems provide accurate control of water and fertilizer application, enhancing plant health and yield. Various studies have established the efficacy of drip irrigation systems in enhancing water use efficiency. Narayanamurthy (2004) empirically studied drip irrigation effectiveness compared to traditional surface irrigation in grape vineyards in Maharashtra, India. The results projected water conservation of 40% and raised crop yield by approximately 23%. Economic evaluation is a critical factor when measuring the viability of drip irrigation systems, especially for resource-poor rural agricultural communities. Narayanamurthy (2005) made a detailed cost-benefit comparison of drip irrigation in India and found that even though the investment costs were more, the systems were economically sustainable in the long term considering savings in water, manpower, fertilizers, and higher yields. The parameters of drip irrigation technology will be compared to those of traditional irrigation methods in order to determine whether it can promote sustainable agricultural development.

II. STUDY AREA

Economic analysis plays a crucial role in determining the viability of drip irrigation systems, particularly in resource-poor rural agricultural communities. Narayanamoorthy (2005) carried out an extensive cost-benefit analysis of Indian drip irrigation and established that although the systems were more expensive in initial investment, they were economical feasible in the long term because of water, labor, fertilizer, and crop yield savings. Chitradurga district lies between 13°34' N to 14°39' N latitudes and 75°58' E to 77°01' E longitudes in the central region of Karnataka, India. This is depicted in Figure 1. It has a geographical coverage of 8,440 square kilometers. The district is surrounded by

Tumkur and Hassan districts in the south, Davanagere in the west, Ballari in the north, and the Anantapur district of Andhra Pradesh in the east. Chitradurga town is the administrative district headquarters. Geologically, Chitradurga is part of the Dharwar Craton and is characterized by Archaean to Proterozoic age formations of granitic gneisses, schists, and quartzites. The district is situated in Karnataka's eastern transition zone and is part of the Deccan Plateau. Elevation varies between 450 and 1,200 meters above mean sea level (MSL).

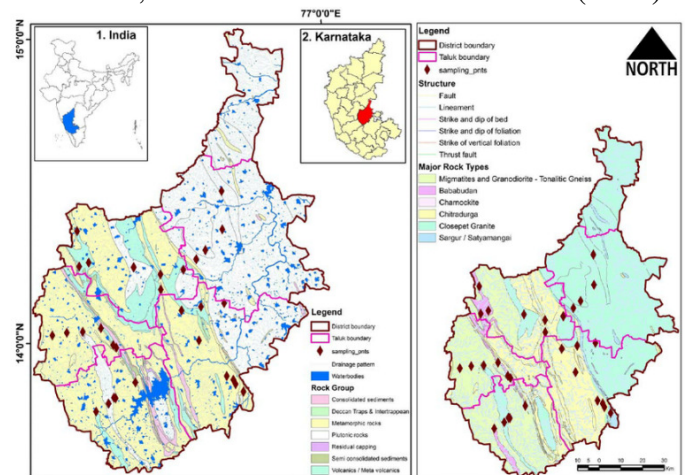


Fig. 1: Study Area

The drainage system of Chitradurga is predominantly seasonal and non-perennial in nature, with rivers flowing only during the monsoon season. The prominent rivers passing through the district are the Vedavati River, a tributary of the Tungabhadra, Suvarnamukhi River, and minor streams like Janagahalla and Bennihalla.

Land in Chitradurga is mostly agricultural, with dry farming being the predominant practice owing to lack of irrigation facilities. The major crops are: Ragi (finger millet), Jowar (sorghum), Groundnut, Sunflower, and pulses.

III. METHODOLOGY

An overview of the methodology is illustrated in the flowchart shown in Figure 2

Crop water requirement can be defined as the water required for the healthy growth of the crops. The required amount of water is defined as the amount of water needed to meet the loss of water through evapotranspiration. While calculating the crop water requirement of various crops in a basin, the water requirement to be met by the surface irrigation needs to be considered.

Evapotranspiration is influenced by climatic factors, such as sunshine, temperature, humidity and wind speed. Out of the total evapotranspiration, evaporation account for about 10% and plant transpiration for the remaining 90% (Phociades A, 2001). Hence the crop water requirement includes all losses like:

- (a) Transpiration loss through leaves (T)
- (b) Evaporation loss through soil surface in cropped area (E)
- (c) Amount of water used by plants (WP) for its metabolism.

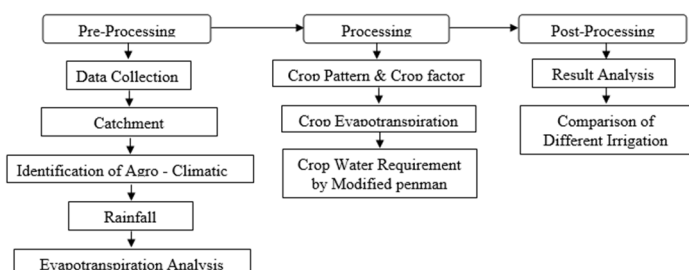


Fig. 2: Flow Chart of Methodology

FAO-24 Modified Penman (1977) Method:

$$PET_0 = W \cdot R_n + (1 - W) \cdot f(u) \cdot (e_s - e_a)$$

Where

PET = potential evapotranspiration (mm/day).

W = Temperature related weighing factor.

Rn = Net radiation (mm/day).

f(u) = wind related function.

($e_s - e_a$) = difference between saturation vapor pressure (SVP) at mean air temperature and mean actual vapor pressure of air (mb).

c = correction factor.

IV. RESULTS AND DISCUSSIONS

The major crops which are grown in Chitradurga were selected for this study and the crop water requirement for these crops was calculated. The selected crops include Sorghum (Jowar), Maize, Pulses, Sunflower, Groundnut, Vegetables, Fruits and Arecanut. The crops selected for the study purpose include six major crops of the Kharif season and one major crops from Bi-season. The crop water requirement for these seven crops was computed by FAO-24 Modified Penman method.

FAO-24 Modified Penman method uses average rainfall for a fortnight, hence, the daily rainfall data was averaged at every fortnight for all the months of the year from 1985 to 2014 as shown in the Table 4.1. Fortnightly evapotranspiration values for the basin area were collected from FAO Tool as given in Table 4.2.

A. Crop water requirement for surface irrigation:

The crop water requirement is calculated for surface irrigation considering project efficiency of 54.15% as CWC guidelines. The CWR for surface irrigation is shown in Table 4.3: Cropping pattern with water demand for surface irrigation. Table 4.3 and Figure 3.

B. Crop water requirement for Drip irrigation:

The crop water requirement is calculated for drip irrigation considering project efficiency of 81.23% as CWC guidelines. The CWR for surface irrigation is shown in Table 4.4 and Figure 4.

In comparison to conventional surface irrigation methods, drip irrigation offers a highly efficient and sustainable approach to water management in agriculture. While surface irrigation often results in significant water losses through evaporation, deep percolation, and runoff, drip irrigation delivers water directly to the plant root zone at controlled rates, minimizing these losses and enhancing overall irrigation efficiency. This precision application not only reduces water consumption but also improves crop yield and quality by maintaining optimal soil moisture conditions. Additionally, drip irrigation supports better nutrient management, reduces weed growth by limiting moisture to non-crop areas, and lowers labour requirements associated with water application. In regions with scarce water resources and erratic rainfall patterns — such as those commonly found in India — adopting drip irrigation can play a critical role in maximizing water productivity, conserving valuable water supplies, and ensuring the long-term sustainability of agricultural practices.

TABLE 4-1: AVERAGE FORTNIGHTLY RAINFALL IN MM FOR YEAR 1985 - 2014

Month	January		February		March		April		May		June	
Fortnight	I	II	I	II	I	II	I	II	I	II	I	II

Average rainfall	0.98	1.06	1.01	0.9	3.73	4.04	22.66	22.66	32.95	35.7	55.29	55.29
Month	July		August		September		October		November		December	
Fortnight	I	II	I	II	I	II	I	II	I	II	I	II
Average rainfall	102.02	110.52	88.71	96.1	54.44	54.44	67.04	72.63	28.99	28.99	6.66	7.22

TABLE 4-2: FORTNIGHTLY EVAPOTRANSPIRATION IN MM FOR 30 YEARS

Month	January		February		March		April		May		June	
Fortnight	I	II	I	II	I	II	I	II	I	II	I	II
Average ETo	74.4	79.36	87.3	75.66	94.2	100.48	105.45	105.45	105.6	112.64	99.3	99.3
Month	July		August		September		October		November		December	
Fortnight	I	II	I	II	I	II	I	II	I	II	I	II
Average ETo	86.4	92.16	87.3	93.12	82.65	82.65	82.8	88.32	74.7	74.7	70.65	75.36

TABLE 4-3: CROPPING PATTERN WITH WATER DEMAND FOR SURFACE IRRIGATION

No	Crop	%	Area (Ha)	Area (Acres)	Utilization		GIR in mm	GIR in inches
					MCM	TMC		
Khariff								
1	Sorghum (Jowar)	15%	149	367	0.628	0.022	422.55	16.64
2	Maize	10%	99	245	0.445	0.016	449.12	17.68
3	Pulses	10%	99	245	0.367	0.013	370.32	14.58
4	Sunflower	20%	198	490	0.337	0.012	339.95	13.38
5	Ground Nut	25%	248	612	0.379	0.013	382.91	15.08
6	Vegetables & Fruits	10%	99	245	0.508	0.018	512.64	20.18
	Total	90%	892	2204	2.665	0.094	2477.500	97.539
Bi- Seasonal								
1	Arecanut	10%	99	245	0.154	0.005	155.27	6.11
	Total	10%	99	244.90	0.15	0.01	155.27	6.11
Total		100.00%	991.00	2449.03	2.82	0.10	2632.77	103.65

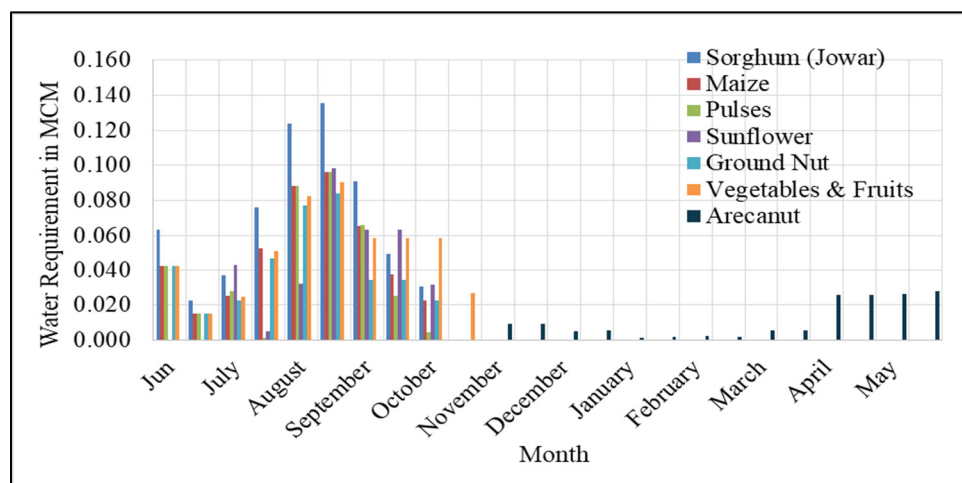


Fig. 1: Surface Irrigation Water Requirements by Month for Various Crops

TABLE 4-4: CROPPING PATTERN WITH WATER DEMAND FOR DRIP IRRIGATION

No	Crop	%	Area (Ha)	Area (Acres)	Utilization		GIR in mm	GIR in inches
					MCM	TMC		
Khariff								
1	Sorghum (Jowar)	15%	149	367	0.419	0.015	281.68	11.09
2	Maize	10%	99	245	0.297	0.010	299.40	11.79
3	Pulses	10%	99	245	0.245	0.009	246.87	9.72
4	Sunflower	20%	198	490	0.225	0.008	226.62	8.92
5	Ground Nut	25%	248	612	0.253	0.009	255.26	10.05
6	Vegetables & Fruits	10%	99	245	0.339	0.012	341.74	13.45
Total		90%	892	2204	1.776	0.063	1651.565	65.022
Bi- Seasonal								
1	Arecanut	10%	99	245	0.103	0.004	103.51	4.08
Total		10%	99	244.90	0.10	0.00	103.51	4.08
Total		100.00%	991.00	2449.03	1.88	0.07	1755.07	69.10

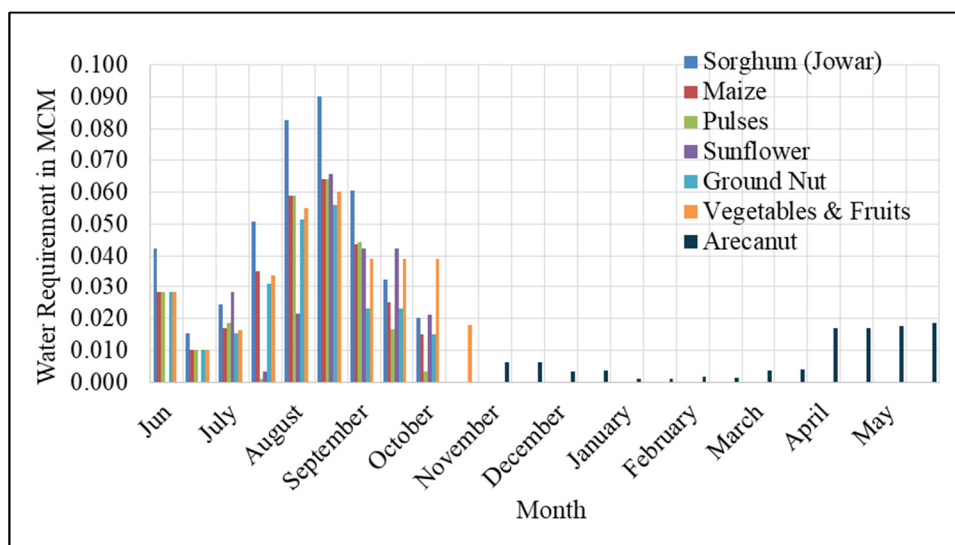


Figure 4: Drip Irrigation Water Requirements by Month for Various Crops

V. CONCLUSIONS

For the selected cropping pattern, the total gross irrigation requirement (GIR) for surface irrigation was computed as 2632.77 mm (103.65 Inches), while for drip irrigation it was notably lower at 1755.07 mm (69.10 Inches) — indicating a substantial reduction in water demand by approximately 33.33%. Furthermore, the overall irrigation efficiency for drip irrigation was estimated at 81.23%, compared to 54.15% for surface irrigation, reaffirming the operational superiority of micro-irrigation systems in water-scarce, drought-prone regions like Chitradurga.

The yield data collected from various farmers across different crops under both surface and drip irrigation systems clearly illustrates the significant productivity advantage of drip irrigation. Across nearly all cases, the crop yields under drip irrigation were notably higher than those achieved through conventional surface irrigation methods.

REFERENCES

- [1] Ayars, J. E., Phene, C. J., Hutmacher, R. B., Davis, K. R., Schoneman, R. A., Vail, S. S., & Mead, R. M. (1999). Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. *Agricultural Water Management*, 42(1), 1–27.
- [2] Bar-Yosef, B. (1999). Advances in fertigation. *Advances in Agronomy*, 65, 1–77.
- [3] Bucks, D. A., Nakayama, F. S., & Warrick, A. W. (1982). Principles, practices, and potentialities of trickle (drip) irrigation. *Advances in Irrigation*, 1, 219–298.

- [4] Howell, T. A. (2001). Enhancing water use efficiency in irrigated agriculture. *Agronomy Journal*, 93(2), 281–289.
- [5] Jensen ME (ed) (1974) Consumptive use of water and irrigation water requirements. Rep. Tech. Com. OnIrrig. Water requirements, Irrig. and Drain. Div., ASCE, pp 227
- [6] Keller, J., & Bliesner, R. D. (1990). *Sprinkle and Trickle Irrigation*. Van Nostrand Reinhold.
- [7] Kishore, A., Sharma, R., & Joshi, P. K. (2013). Adoption of micro-irrigation in India: An analysis of the determinants and impact. *Indian Journal of Agricultural Economics*, 68(3), 321–332.
- [8] Kumar, S., Singh, R., & Sharma, R. K. (2012). Drip irrigation and fertigation technology for improving water productivity of vegetable crops. *Indian Journal of Agricultural Sciences*, 82(3), 241–246.
- [9] Lokhande, T. N., Patil, D. P., & Patil, S. S. (2014). Economics of drip irrigation system in pomegranate and banana crops in Maharashtra. *International Journal of Commerce and Business Management*, 7(2), 256–260.
- [10] Narayanamoorthy, A. (1997). Economic viability of drip irrigation: An empirical analysis from Maharashtra. *Indian Journal of Agricultural Economics*, 52(4), 728–739.
- [11] Narayanamoorthy, A. (2004). Impact assessment of drip irrigation in India: The case of sugarcane. *Development Policy Review*, 22(4), 443–462.
- [12] Narayanamoorthy, A. (2005). Economics of drip irrigation in sugarcane cultivation: Case study of a farmer from Tamil Nadu. *Indian Journal of Agricultural Economics*, 60(2), 235–248.
- [13] Paranjpe SV, Katpatal YB, Kadu MS (2014) Validation of SCS CN method for runoff estimation with field observed regression analysis results in Venna Basin, Central India. 2014,
- [14] Paranjpe SV, Katpatal YB, Kadu MS (2017) Suitability of spatial interpolation techniques in varying aquifer systems of a Basaltic terrain for monitoring groundwater availability. In: 2017 AGU fall meeting, 11–15 December, 2017, New Orleans, Louisiana, USA
- [15] Perrier A (1982) Land surface processes: vegetation. In: Eagleson PS (ed) *Land surface processes in atmospheric general circulation models*. Cambridge Univ. Press, Cambridge, Mass, pp 395–448
- [16] Perry, C. (2007). Efficient irrigation; inefficient communication; flawed recommendations. *Irrigation and Drainage*, 56(4), 367–378.
- [17] Phociades A (2001) *Handbook on pressurized irrigation techniques*. F.A.O, Rome
- [18] Singandhupe, R. B., Bankar, M. C., Anand, P. S. B., & Patil, N. G. (2008). Management of drip irrigated sugarcane in western India. *Archives of Agronomy and Soil Science*, 54(6), 629–649.
- [19] Singh, R., Kumar, P., & Sharma, R. K. (2010). Drip irrigation and fertigation technology for improving water productivity of vegetable crops. *Indian Journal of Agricultural Sciences*, 80(8), 660–665
- Verma, S., Upadhyay, N., & Singh, R. (2018). Constraints in adoption of drip irrigation system in India. *Journal of Soil and Water Conservation*, 17(2), 154–158.