Estimation of Crop Evapotranspiration Using the Thornthwaite Method: Case Study of Raichur District, Karnataka, India

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***Abstract*:**

This research delves into the use of the Thorn Thwaite method for estimating evapotranspiration, an extensively adopted empirical technique in hydrology and agriculture. By relying on temperature data, this method is especially useful in areas with limited meteorological information. The study investigates the theoretical foundation of the Thornthwaite method and evaluates its practical implementation across diverse geographic and climatic contexts. Additionally, it discusses the method's advantages, limitations, and potential enhancements, emphasizing its importance in water resource management and agricultural planning. Through an extensive review of existing literature and case studies, this abstract offers insight into the effectiveness and dependability of the Thornthwaite method for estimating evapotranspiration, thereby contributing to the progress of hydrological modelling and resource management practices.

***Keywords*:** Evapotranspiration, Hydrology, Thornthwaite method, Agricultural planning;

1. Introduction

Evapotranspiration, which involves the transfer of water from the Earth's surface to the atmosphere, is a crucial part of the water cycle. It significantly influences the distribution and availability of water resources, impacting both natural ecosystems and human water management. By directly affecting crop water needs and irrigation scheduling, understanding evapotranspiration patterns helps farmers enhance water use efficiency, manage droughts, and boost crop yields. Acting as a vital link between the land surface and the atmosphere, evapotranspiration has profound effects on environmental, agricultural, and societal systems. Grasping its importance is essential for sustainable water resource management, climate adaptation, and ecosystem conservation.

1.1 Classification of Evapotranspiration

Evapotranspiration, the combined process of evaporation and plant transpiration, is categorized into three main types:

- Potential **Evapotranspiration (PET):** Maximum evapotranspiration with unlimited water, influenced by solar radiation, temperature, humidity, and wind.
- Actual **Evapotranspiration (AET):** Actual water loss from surfaces and plants, dependent on vegetation, soil moisture, and energy.
- Reference **Evapotranspiration (ET0):** Standard measure for comparing water use, calculated with the Penman-Monteith equation.

1.2 Need for Studying Evapotranspiration

- **Water Resource Management:** Essential for efficient water management, aiding in irrigation, reservoir management, and water allocation.
- **Agricultural Planning:** Helps optimize irrigation schedules and crop selection, maximizing yields and minimizing waste.
- **Climate Studies:** Influences water and energy balance, aiding in climate modeling and prediction.
- **Environmental Monitoring:** Provides insights into ecosystem health and impacts of land use changes.
- **Hydrological Modelling:** Crucial for simulating water cycle dynamics and assessing management practices and climate variability.

1.3 Benefits and Beneficiaries

- **Agriculture:** Optimizes irrigation, conserving water and increasing yields.
- **Water Resource Management:** Aids in planning and sustainable resource use.
- **Environmental Conservation:** Helps manage ecosystems, especially sensitive areas.
- **Urban Planning:** Guides efficient landscaping and infrastructure design.
- **Climate Studies:** Enhances climate models and understanding of water cycles.
- **Hydrology:** Assists in calculating water balances, predicting floods, and monitoring droughts.
- **Engineering:** Informs design of water supply systems and infrastructure.
- **Research:** Supports studies on vegetation dynamics and hydrological processes.

2.0 Review of Literature

Thornthwaite Method: Estimates evapotranspiration using temperature and daylight hours. Simple but less accurate in varying conditions. Hargreaves-Samani Method: Uses temperature data, effective in arid regions, less accurate in humid areas. Blaney-Criddle Method: Uses temperature and daylight, requires region-specific calibration. Jensen-Haise Method: Uses temperature and solar radiation, accuracy depends on reliable data. Modified Penman-Monteith Method: Adapted for simplicity and precision, needs ancillary data.

Traditional methods like lysimeters and eddy covariance systems are used for direct measurement. Remote sensing technologies provide valuable data for large areas. Empirical models like Penman-Monteith and Hargreaves-Samani are widely used. Climate and soil properties, along with vegetation types, significantly affect evapotranspiration rates.

3.0 Methodology

The Thornthwaite method, developed by C.W. Thornthwaite in 1948, is a popular technique for estimating potential evapotranspiration (PET) using temperature data. This approach is especially beneficial in areas where only temperature data is accessible. The methodology adopted is described in detail with the help of a flowchart shown in Figure 1.

Serving as the foundation of this project, the literature review was given significant importance. An extensive review provided clarity on the implementation of the analysis techniques. Monthly temperature data was sourced from the power access data collection website and the Directorate of Economics and Statistics for analysis purposes. The gathered data was thoroughly analysed using the Thornthwaite method. The test results were compiled and analysed. Based on the study's findings, conclusions were drawn regarding the implications for evapotranspiration.

Figure 1 Methodology for the present study

4.0 Estimation of Evapotranspiration

This method involves following steps:

- Begins by computing monthly heat index:

i= $i=(t/5)^{1.514}$ monthly heat index

t=temperature

- Sum the 12 monthly heat index into annual heat index(I):

$$I= \sum_{m=1}^{12}(t/5)1.514$$

I=Annual heat index

m=month (1=January …12= December)

t=temperature

- Calculate ET

$$E=1.6b\ (10t/I)\ a$$

i=Monthly heat index
I=Annual heat index
ET=Evapotranspiration
b= (total monthly daylight hours)/360)

$$a=(I^3 x\ 6.75\ x\ 10^{-7}-I^2 x\ 7.71\ x\ 10^{-5})+(I\ x\ 1.792\ x\ 10^{-2})+0.49239$$

Table 1 gives the ET computation details

Table 1 ET computation year wise

sl no	Month	Temperature in ◦c	i	ET non adj	Adj.factor	ET (mm/year)
1	Jan	35.15	19.15536	596.6191	0.86	513.0924
2	Feb	36.33	20.1373	860.6994	0.77	662.7386
3	Mar	41.08	24.2547	3366.104	1.03	3467.087
4	Apr	41.73	24.83809	4006.795	1.11	4447.542
5	May	42.83	25.83604	5348.2	1.24	6631.768
6	Jun	38.18	21.70996	1493.667	1.25	1867.083
7	Jul	36.73	20.47392	971.9214	1.27	1234.34
8	Aug	35.53	19.46976	672.2428	1.18	793.2465
9	Sep	35.9	19.77755	754.1563	1.04	784.3225
10	Oct	36.02	19.87772	782.6112	0.96	751.3068
11	Nov	35.34	19.31234	633.4048	0.83	525.7259
12	Dec	34.79	18.85912	532.202	0.81	431.0836
		I(total)	253.7019		ET	22109.34
Sl No	**Crops**	**Coef**	**Area in m^2**	**ET**	**ETCrop**	-
1	wheat	1.15	3090000	22.109	785655.4	-
2	maize	1.2	6870000	22.109	1822693.9	-
3	rice	1.15	1.41E+09	22.109	358630076.8	-

4	jowar	1.18	1.11E+08	22.109	28948377.92	-
5	ragi	1.08	0	22.109	0	-
6	other cereals	1.29	300000	22.109	85563.14	-
7	bajra	1.23	89820000	22.109	24426089.3	-
8	barley	0.9	0	22.109	0	-
9	Gram	0.72	0	22.109	0	-
10	other pulses	0.72	260000	22.109	41388.68448	-
				Total ET	414739845.2	-

5.0 Results and Discussions

By analysing 20 years of temperature and land use data from 2001 to 2020 using the Thornthwaite method, we obtained evapotranspiration data for the entire 20-year period and also determined the evapotranspiration for each crop. Figure 2 to Figure 11 represents the results related to ET for various crop patterns year wise.

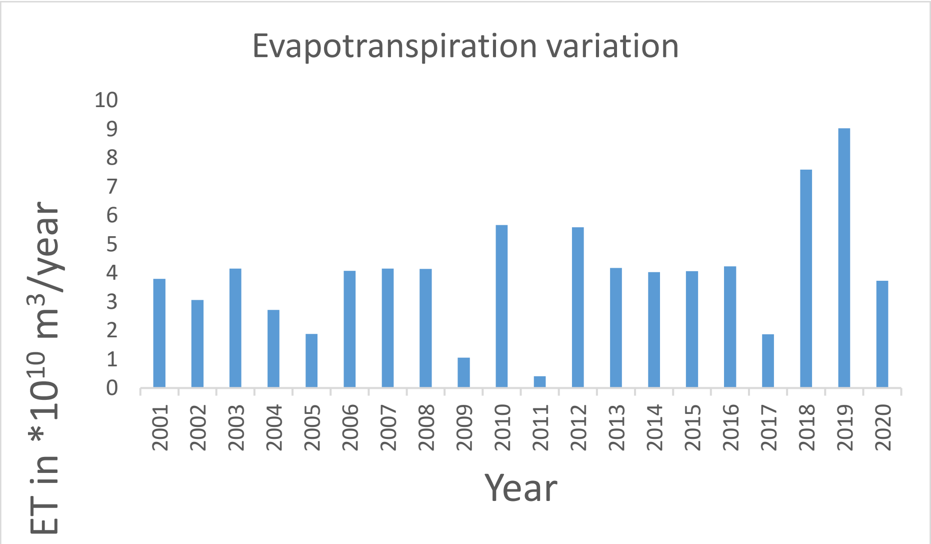

Figure 2 ET Graph year wise

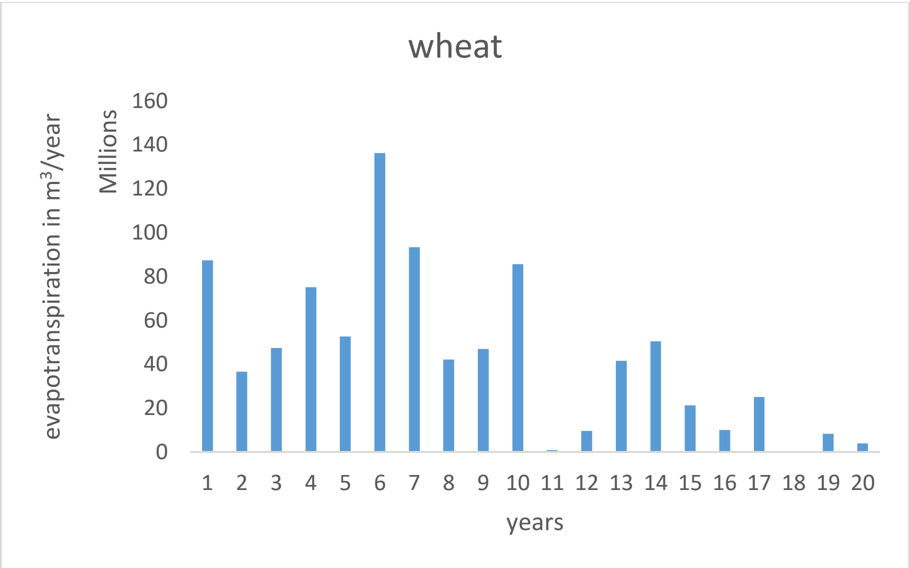

Figure 3 ET Graph for wheat

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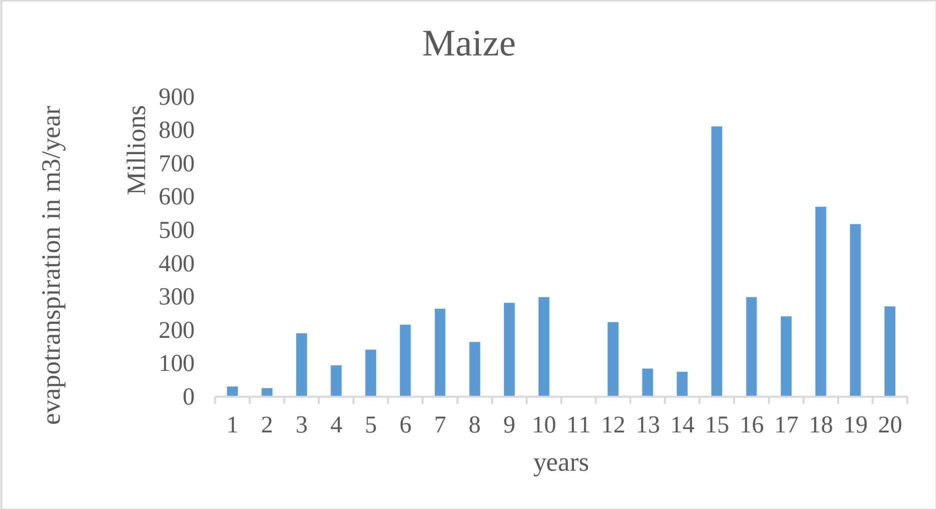

Figure 4 ET Graph for maize

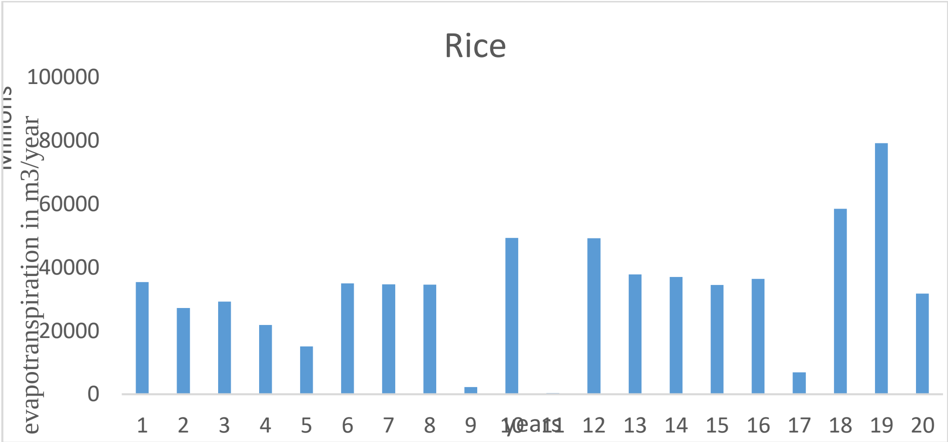

Figure 5 ET Graph for rice

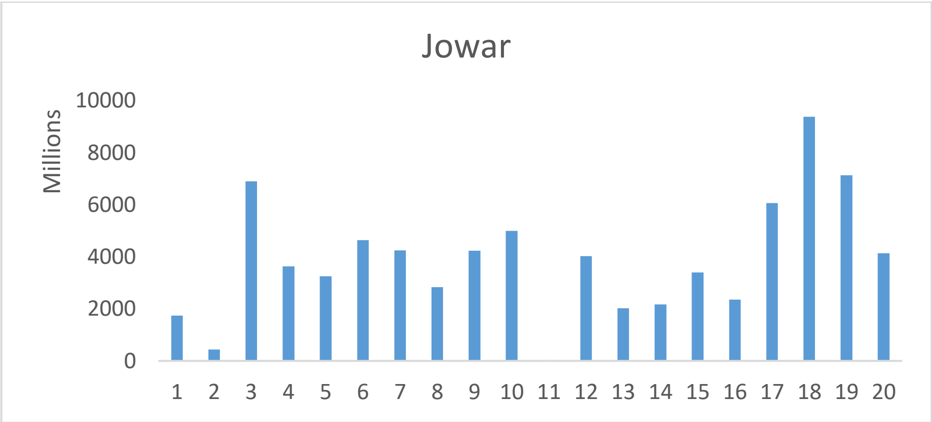

Figure 6 ET Graph for jowar

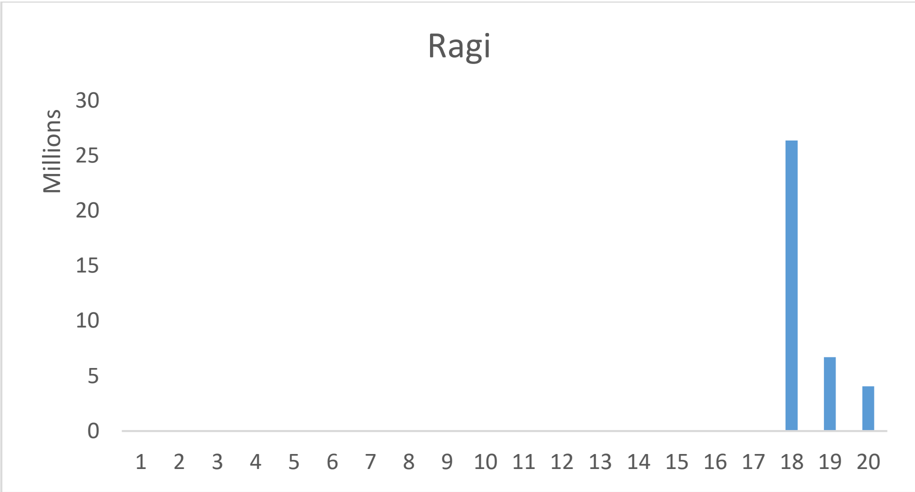

Figure 7 ET Graph for ragi

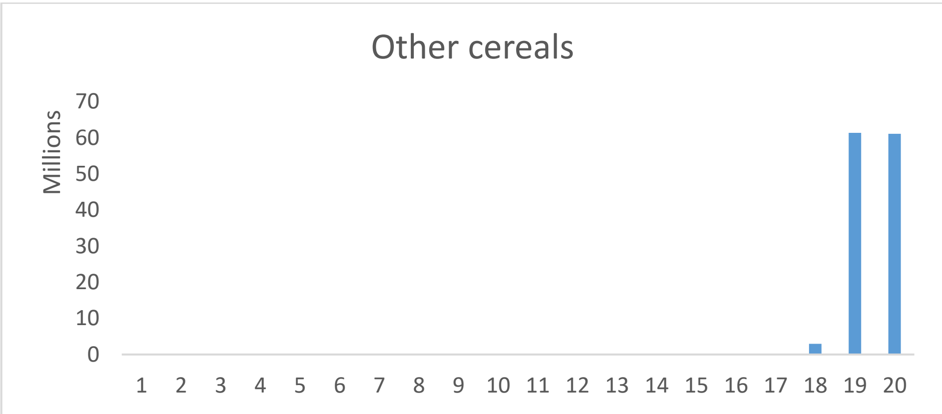

Figure 8 ET Graph for cereals

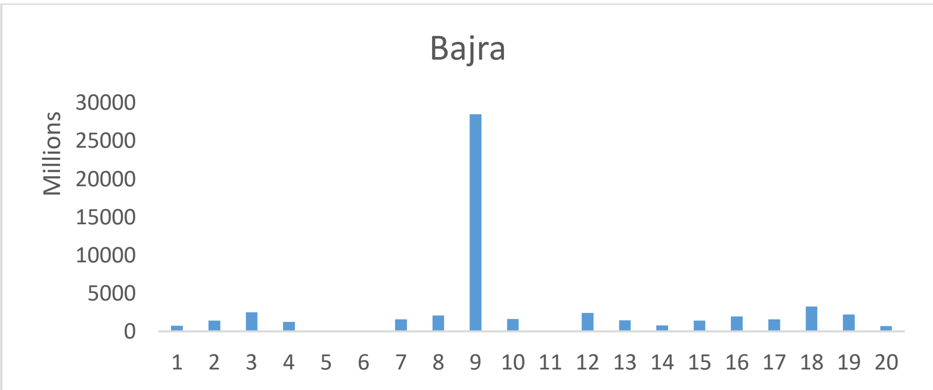

Figure 9 ET Graph for bajra

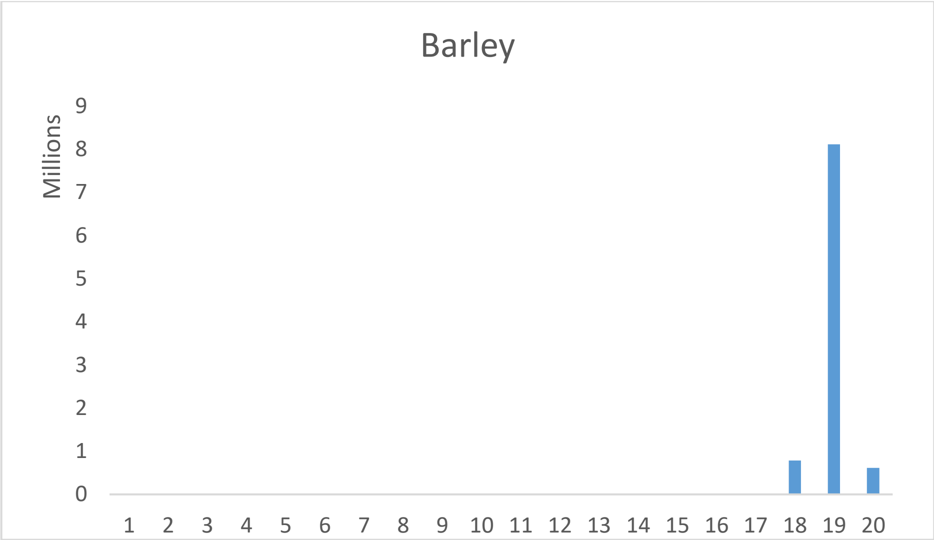

Figure 10 ET Graph for barley

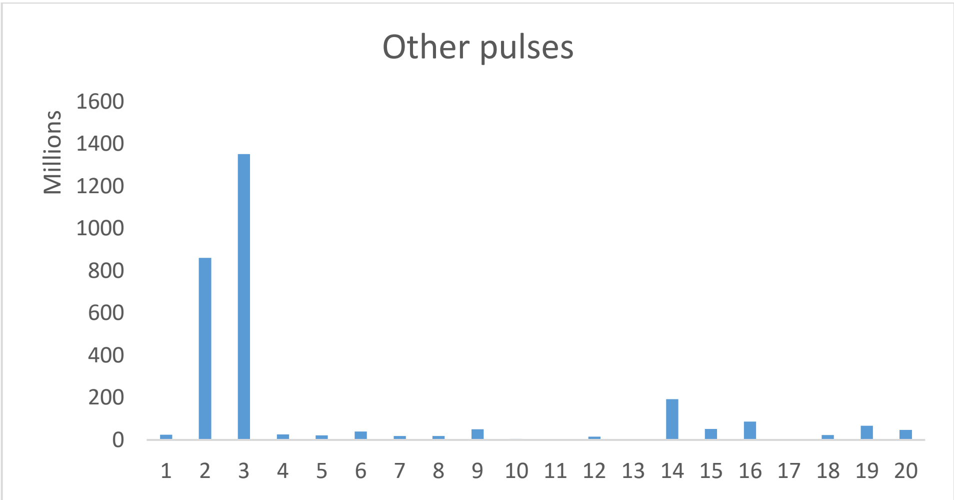

Figure 11 ET Graph for other pulses

The year wise ET for all crops in a pie chart variation is shown in Figure 12 and Figure 13.

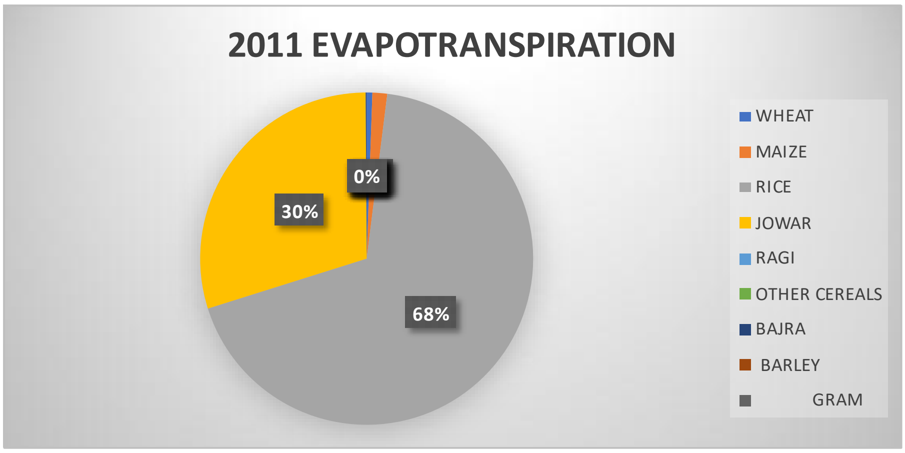

Figure 12 ET Graph variation for different crops-pie chart for year 2011

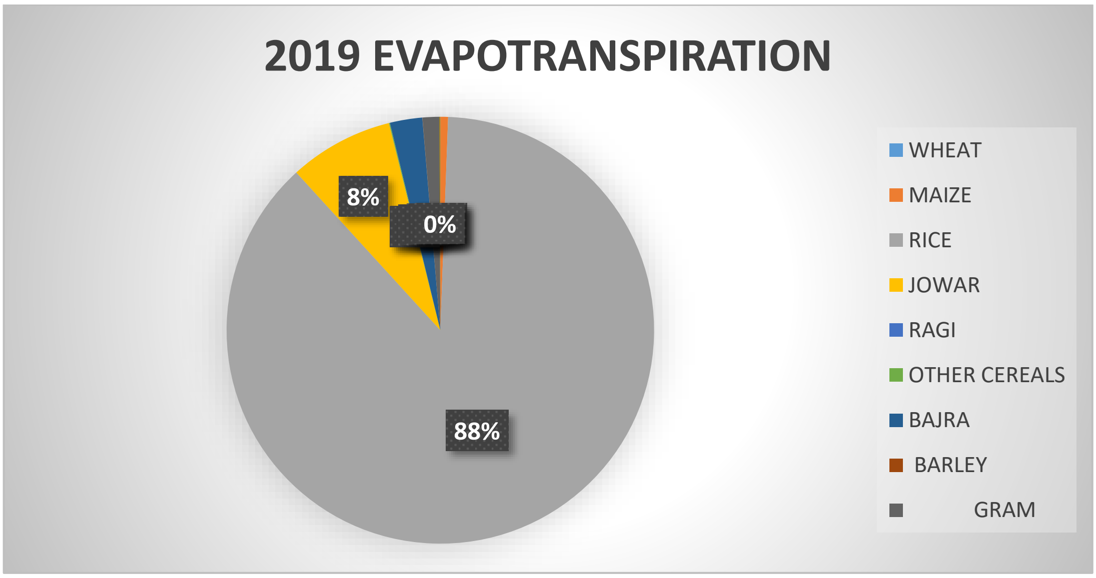

Figure 13 ET Graph variation for different crops-pie chart for year 2019

6.0 Conclusion

The Thornthwaite method is an effective approach for estimating evapotranspiration, especially in areas with limited meteorological data, relying solely on temperature information. Its simplicity and accessibility make it widely applicable, although accuracy can vary with local conditions and vegetation types. Recognizing its limitations is crucial for accurate hydrological and environmental studies. The method supports future research and improvements, and its results have significant implications for water resource management, agriculture, and environmental conservation. Thornthwaite's classification of world climates, based on precipitation and temperature indices, helps explain vegetation patterns. The method's adaptability allows it to be modified for different climatic conditions, enhancing its utility in various settings.

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