"Spatio-temporalVariability of Reference Evapotranspiration and Trend Analyzeof CropWaterRequirement"

ABSTRACT: -

The study was aimed to analyse the trend of Reference Evapotranspiration(ETo) for estimation of Crop Water Requirement(CWR) for Rice (*Oryza sativum*) cultivation in Manipur from 2011-2021 in 16 districts (Bisnupur, Churachandpur, Jiribam, Imphal East, Kamjong, Senapati, Imphal West, Tengnoupal, Ukhrul, Thoubal, Noney, Pherzwal, Chandel, Kakching, Tamenglong and Kangpokpi)ETo and CWR was estimated using CROPWAT. Spatial trends of climate variables were analysed using Mann– Kendall test and Sen's slope estimator.

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KEYWORDS: Crop Water Requirement, CROPWAT*,*Rice,Reference Evapotranspiration,16 districts of Manipur.

1. INTRODUCTION: -

It is essential to estimate the CWR of diverse crops in order to accurately build an irrigation system and conserve the most water feasible. For irrigation planning and water management, precise measurement of the crop's water needs is vital.Using crop coefficient (Kc), the amount of water a crop needs to grow may be determined from the reference evapotranspiration.The rate at which readily accessible soil water evaporates from certain vegetated surfaces is the definition of evapotranspiration (ETo), which is the term used here. After rainfall, ET is one of the most significant factors in the hydrological cycle that influences the amount of water that crops need in certain locations. The FAO Penman-Monteith method was approved by the FAO experts as the industry standard for defining and calculating reference evapotranspiration (ETo) and crop water requirements. In all climates and regions, the FAO Penman-Monteith approach yields constant ETo values.(Gautam*et al*., 2019)

For its best use, a methodical and scientific planning process is essential. Modern irrigation methods will go a long way toward reducing water consumption and saving water, bringing more regions under control and ultimately increasing agricultural productivity. The CROPWAT model is used to calculate the water requirements and irrigation planning for major crops including sugarcane, rice, tobacco, etc. (Kumari *et al*.,2017)

The CROPWAT model plays a crucial role in enhancing crop yield in water-scarce conditions, particularly for major crops like sugarcane, wheat, cotton, and rice. By determining water requirements and aiding in irrigation planning, CROPWAT enables the development of recommendations for optimizing irrigation practices. This includes managing schedules based on varying water needs and estimating productivity in rainfed or limited irrigation scenarios. Climate and water pressure significantly impact anticipated yield losses, with the primary drop occurring during the growing stage in both rainfed and irrigated scenarios. Scientists widely employ CROPWAT for estimating Crop Water Requirements (CWR), crop evapotranspiration, and irrigation planning, utilizing software tools introduced by the Food and Agriculture Organization (FAO). (Hussain *et al.,* 2023)

2. METHODOLOGY

STUDY AREA:

The study covered all districts of Manipur, situated between latitudes 23°83'N – 25°68'N and longitudes 93°03'E – 94°78'E, spanning 22,327 square km. The valley slopes from North to South, and the surrounding mountain ranges shield it from cold winds and cyclonic storms. Manipur climate, influenced by its hilly topography, is generally mild at 790 meters above sea level.The climate of Manipur is moderate. Climate in the western part of the state is tropical whereas the rest part of the state experiences sub tropical climate with distinct summer, winter and rainy seasons. The valley gets the reflection of the heat of the summer and the cold of the winter from the hills. Average annual rainfall ranges from 1250 mm to 2700 mm. The months of November, December, January and February remain dry and the remaining eight months are more or less rainy. January is the coldest month and May-June are hottest months.The maximum temperature in the summer months is 32 °C (90 °F).

Fig.1. Map of study area (Manipur)

CROPWAT

Computermodel simulation is an emerging trend in the field of water management. CROPWAT is a powerful simulation tool which analyzes complex relationships of onfarm parameters such as the crop, climate, and soil, for assisting in irrigation management and planning. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT facilitates the estimation of the crop evapotranspiration, irrigation scheduling and agricultural water requirements with different cropping patterns for irrigation planning.

REFERENCE CROP EVAPOTRANSPIRATION (ETo)

The Evapotranspirationvalues calculated using the Penman-Monteith equation.Its rate from a well-watered reference surface is known as reference Evapotranspiration (ETo), symbolized as ETo. It is calculated using the Penman-Monteith Model (Allen *et al.* 1998), which employs directly measured or easily calculated parameters from weather data. This model allows for the direct calculation of crop Evapotranspiration (ETC). The concept of ETo, based on a hypothetical grass reference crop, ensures consistency in studying atmospheric evaporative demand, independent of crop type and management practices. The FAO Penman-Monteith equation represents the physical and physiological factors influencing Evapotranspiration. ETo provides a universal reference, eliminating the need for separate ET levels for different crops and growth stages. As water availability is ample at the reference surface, soil factors do not influence ET. ETo values from different locations or seasons are comparable, offering a standardized measure for different surfaces. The mathematical expression is simplified for ease of calculation.

$$\mathrm{ETo} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where,

ETO = Reference Evapotranspiration (mm per day)

Ra = Net radiation at the crop surface (MJ/m² per day)

G =Soil heat flux density (MH/m² per day)

T =Mean daily air temperature at 2m height (°c)

u_2 = Wind speed at 2m height (m/s)

E_s = Saturation vapor pressure (kPa)

e_a = Actual vapor pressure (kPa)

e_s-e_a = Saturation vapor pressure deficit (kPa)

γ= Psychometric constant

Δ = Slope vapour pressure curve [kPa °C-1]

ESTIMATION OF CROP WATER REQUIREMENT (ETc)

Crop Water Requirement is the amount of water needed to meet the water loss through Evapotranspiration Estimation of the crop water requirement is derived from crop Evapotranspiration (crop water use) which is the product of the reference Evapotranspiration (ETo) and the crop coefficient (Kc)The reference Evapotranspiration (ETo) is estimated based on the FAO Penman-Monteith method, using climatic data (FAO, 1998)

ETc=ETo × Kc

Where, ETc = Actual Evapotranspiration by the crop (mm/day),

ETo= Reference crop Evapotranspiration (mm/day),

Kc =Crop coefficient at a certain growth stage.

TREND ANALYSIS MANN-KANDELL TEST

In the present study, trend analysis has been done by using non-parametric Man-Kendall test. This method tests whether there is a trend in the time series data. It is a statistical test widely used for trend analysis, used for detection of statistically significant trend in variables like rainfall, temperature and stream flow. According to this test, the null hypothesis Ho assumes that there is no trend and this is tested against the alternative hypothesis H1, which assumes that there is a trend Ndayisaba *et al.*,(2017)

SEN'S SLOPE ESTIMATOR

Sen's slope estimation (Sen 1968) is another non-parametric method for trend analysis of precipitation data. It is used to detect the magnitude of the trend.
Where is the data values for j and k times of a period where j>k. Median is computed from N observations of the slope to estimate the Sen's Slope estimator.

3. RESULTS AND ANALYSIS

SPATIO TEMPORAL VARIATION OF TEMPERATURE AND RAINFALL FOR DIFFERENT DISTRICTS OF MANIPUR.

The value of annual variation in temperature and rainfall for all 16 districts of Manipur during the period of 2011-2021 has been shown in Table.1 Generally in Manipur the highest temperature is observed in the month of June and lowest in December. The minimum temperature out of 16 districts of Manipur was observed in Senapati and maximum temperature in Bisnupur. From the Table.1 it has been observed that minimum average temperature is lowest in case of Senapati (11.00°C) and Ukhrul (12.16°C) stations. While the highest average maximum temperature has been observed in Bisnupur (34.64°C) and Tengnoupal (33.42°C) station. The overall range of average maximum temperature for different 16 districts lies between 28.44°C to 34.64°C and average minimum temperature lies between 11.00°C to 17.10°C

Table no.1. Spatio Temporal variation of temperature and rainfall for different of districts of Manipur.

S.No.	Districts	T min	T max	Rainfall

1	Imphal west	13.49	28.44	1441.36
2	Imphal east	13.49	28.44	1441.36
3	Churachandpur	13.99	29.96	1387.58
4	Thoubal	13.99	29.96	1387.58
5	Chandel	13.99	29.96	1387.58
6	Ukhrul	12.16	28.94	1311.96
7	Bisnupur	17.10	34.64	1518.68
8	Kakching	13.99	29.96	1387.58
9	Tengnoupal	15.41	33.42	1184.47
10	Tamenglong	13.49	28.44	1441.36
11	Senapati	11.00	27.25	1456.14
12	Pherzwal	15.87	32.72	1955.12
13	Noney	13.49	28.44	1441.36
14	Kangpokpi	13.49	28.44	1441.36
15	Kamjong	12.16	28.94	1311.96
16	Jiribam	15.70	31.60	1962.12
	SD	**2.084**	**1.526**	**206.97**
	MEAN	**29.973**	**13.925**	**1466.09**
	CV	**6.953**	**10.962**	**0.141**

SPATIO-TEMPORAL VARIATION IN ETO (REFERENCE EVAPOTRANSPIRATION)

ANNUAL

It is clear from the fig.2 that mean ETo was found maximum in Bisnupur and Tengnoupal 1972.05-1916.59mm/period. While, Eto was minimum for the Imphal West and Imphal east 1581.07-1581.15mm/period. Similarly,

Tadesse *et al.,* (2021)noted peak ETo in the far southern and eastern regions, with lower values in the western and southern parts. Significant temporal variations were observed, with the highest ETo (4.61mm day-1) in March during the dry season and the lowest in July during the main rainy season. The study's findings can directly aid engineers and irrigation practitioners in design efforts when data is lacking.

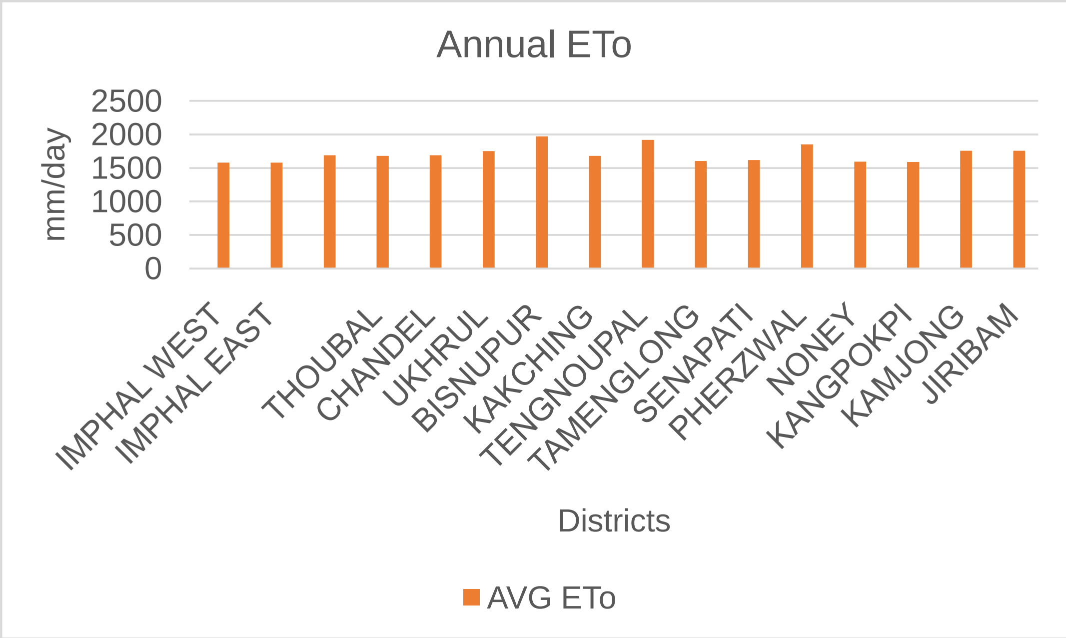

Fig.2: Variation in annual ETo (2011-2021)

SEASONAL

Fig.3 illustrates average ETo changes per season across Manipur's 16 districts from 2011 to 2021. Seasons are categorized as monsoon (June-August), post-monsoon (September-November), winter (December-February), and pre-monsoon (March-May). Tamenglong consistently had the lowest ETo across all seasons, with minimum values in post-monsoon (204.3mm/period), winter (271.5mm/period), monsoon (345.4mm/period), and summer (455.9mm/period). Ukhrul recorded the highest ETo for monsoon (676mm/period), while Bisnupur had the maximum ETo for post-monsoon (236.6mm/period), summer (680.2mm/period), and winter (360.6mm/period).

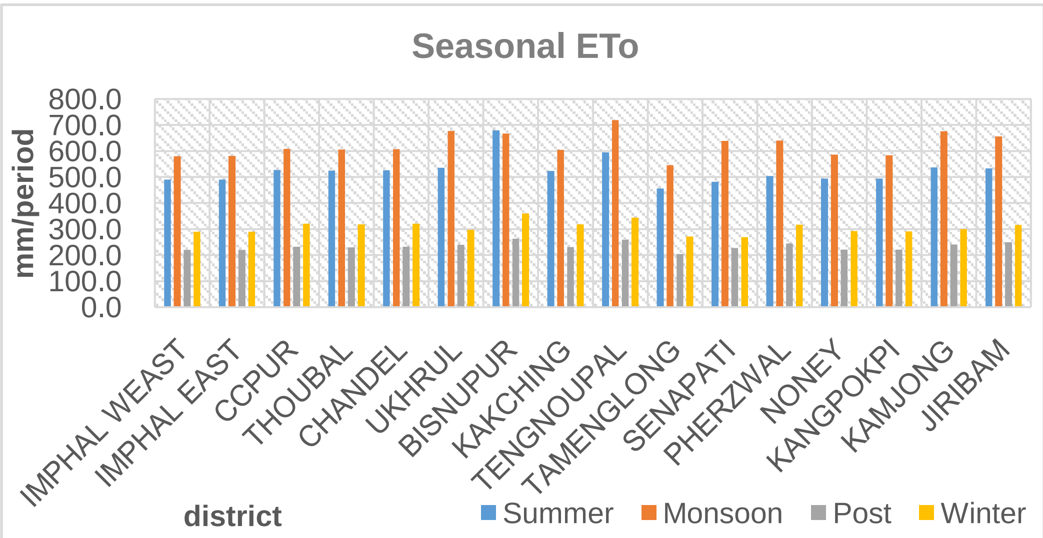

Fig.3: Variation in seasonal ETo

TREND ANALYSIS IN ETO (REFERENCE EVAPOTRANSPIRATION)

ANNUAL

The Man-Kendall test results for annual ETo (Table 2) show non-significant trends in all 16 districts, with 15 displaying positive trends and one (Bisnupur) having a negative trend.

Jhajharia *et al*. (2011) reported a significant decrease in annual and seasonal ETo across six sites in NE India, with more pronounced reductions in the pre-monsoon season. The decline is attributed to lower net radiation and wind speed, which counteracted the impact of rising temperatures, particularly in the humid region of northeast India.

Table 2: Trend analysis of annual ETo

Districts	Zc	Qi
Imphal west	0.62	3.80
Imphal east	0.78	3.89
Churachandpur	0.31	3.01
Thoubal	0.31	3.82
Chandel	0.47	3.92
Ukhrul	0.62	6.54
Bisnupur	-0.62	-3.36
Kakching	0.47	6.08
Tengnoupal	0.47	4.94
Tamenglong	1.09	6.46
Senapati	0.47	3.27
Pherzwal	0.16	2.36
Noney	0.62	3.79
Kangpokpi	0.47	4.53
Kamjong	0.62	6.43
Jiribam	0.16	4.37

SEASONAL

The results of the Man-Kendall test for seasonal ETo (Table 3) indicate significant trends at the 0.01 level of significance for Ukhrul and Kamjong during the post-monsoon and monsoon periods. Tengnoupal and Senapati also exhibit significance at the 0.05 level during the post-monsoon and monsoon seasons, while Noney and Jiribam show significance at the 0.1 level during the post-monsoon and monsoon.

Table 3: Trend analysis of Seasonal ETo

Districts	Pre-monsoon		Monsoon			Winter		Post-monsoon		
	Zc	Qi	Zc	significance	Qi	Zc	Qi	Zc	significance	Qi
Imphal West	0.31	1.23	1.56		2.08	0	0.02	1.56		2.09
Imphal East	0.31	1.23	1.56		2.08	0	0.03	1.56		2.09
Churachandpur	0.62	1.01	0.31		0.27	0	0.19	0.31		0.27
Thoubal	0.62	0.78	0.31		0.37	0	0.28	0.31		0.37
Chandel	0.62	1.44	0.31		0.58	0.16	0.2	0.31		0.59
Ukhrul	0.31	1.39	2.80	**	3.02	0	-0.26	2.8	**	3.02
Bisnupur	-0.78	-1.27	0.31		0.38	0	-0.33	0.31		0.38
Kakching	0.62	1.62	0.31		0.35	0.16	1.35	0.31		0.36
Tengnoupal	0.16	0.85	2.02	*	1.88	-0.16	-0.78	2.02	*	1.88
Tamenglong	-0.78	-6.10	0.31		0.18	-0.31	-1.59	0.31		0.18
Senapati	0.16	0.65	2.49	*	1.57	-0.62	-0.98	2.49	*	1.57
Pherzwal	0.78	2.41	0.78		1.36	-0.31	-0.33	0.78		1.36
Noney	0.16	1.20	1.71	+	2.09	0	0.06	1.71	+	2.09
Kangpokpi	0.93	2.73	1.25		1.88	-0.31	-1.77	1.25		1.89
Kamjong	0.16	1.04	2.80	**	2.98	0	0.14	2.8	**	2.99
Jiribam	0.47	0.80	1.87	+	2.14	-1.09	-0.79	1.87	+	2.14

ESTIMATION OF CROP WATER REQUIREMENT FOR RICE

Table 4 further illustrates the water requirements at different stages of the crop. In the nursery stage (May), Bisnupur has the highest water requirement (116.96mm), and Noney has the lowest (77.21mm). In the initial stage (June), Bisnupur again has the highest requirement (163.18mm), while Imphal West and Imphal East have the lowest (111.98mm). The development stage (July) sees the highest requirement in Imphal West (166.26mm) and the lowest in Tengnoupal (212.06mm). The mid-stage (July, August) has the highest requirement in Tengnoupal (293.87mm) and the lowest in Imphal West (232.96mm). Finally, in the late stage (September, October), Tengnoupal requires the most water (222.55mm), and Imphal East requires the least (170.07mm).

Table 4: Crop water requirement for Rice

Districts																	
Month	Stage	Imphal west	Imphal east	Ccpur	Thoubal	Chandel	Ukhrul	Bisnupur	Kakching	Tengnoupal	Tamenglong	Senapati	Pherzwal	Noney	Kangpokpi	Kamjong	Jiribam
May	Nurs	1.35	1.35	1.44	0.72	1.44	0.74	1.90	0.71	0.84	0.67	0.67	0.75	0.65	0.67	0.74	1.46
May	Nurs/ LPr	17.39	17.39	18.73	12.95	18.68	13.52	24.57	12.85	15.05	12.24	12.35	13.33	12.18	12.32	13.52	19.23
May	Nurs/ LPr	63.79	63.79	68.42	68.17	68.23	72.74	90.49	67.70	80.12	64.75	66.71	71.42	64.37	64.82	72.67	70.62
		82.53	82.53	88.58	81.84	88.35	86.99	116.96	81.25	96.00	77.65	79.73	85.50	77.21	77.81	86.93	91.31
Jun	Init	56.29	56.29	60.15	59.70	59.93	65.43	81.48	59.38	71.32	57.01	60.40	63.79	56.62	56.64	65.35	62.28
Jun	Init	55.69	55.69	59.29	59.04	59.03	66.25	81.70	58.78	71.45	56.63	61.36	64.12	56.24	55.97	66.13	61.69
		111.98	111.98	119.45	118.74	118.95	131.67	163.18	118.16	142.76	113.64	121.76	127.91	112.8 5	112.61	131.47	123.97

Jun	Deve	55.04	55.06	58.42	58.15	58.21	64.95	74.28	57.94	70.25	55.95	60.78	64.42	55.55	55.27	64.87	61.68
Jul	Deve	55.39	55.43	58.64	58.32	58.46	64.90	66.21	58.15	70.52	56.25	61.44	66.21	55.81	55.55	64.84	62.93
Jul	Deve	55.84	55.89	58.95	58.68	58.86	65.33	59.75	58.55	71.29	56.75	62.59	68.20	56.29	55.98	65.27	64.30
		166.26	166.38	176.01	175.15	175.54	195.18	200.24	174.64	212.06	168.95	184.81	198.83	167.65	166.80	194.98	188.91
Jul	Mid	62.06	62.10	64.97	64.75	64.91	72.66	64.40	64.44	78.97	63.08	69.80	76.06	62.59	62.34	72.65	71.03
Aug	Mid	55.98	56.01	58.02	57.92	58.00	65.42	56.74	57.47	70.71	56.97	63.00	68.64	56.57	56.38	65.41	63.50
Aug	Mid	55.34	55.34	56.73	56.65	56.78	64.27	53.94	56.09	69.14	56.28	62.09	67.73	55.92	55.79	64.30	62.23
Aug	Mid	59.58	59.57	61.50	61.38	61.51	69.64	59.03	61.03	75.05	60.54	66.64	72.95	60.17	60.03	69.71	67.49
		232.96	233.02	241.22	240.71	241.20	271.99	234.10	239.03	293.87	236.87	261.53	285.38	235.25	234.54	272.06	264.25
Sep	Late	52.76	52.74	54.76	54.82	54.86	62.28	53.07	54.80	67.36	53.66	58.97	64.73	53.35	53.19	62.39	60.27
Sep	Late	49.76	49.75	51.96	52.15	52.07	59.34	50.78	52.38	64.35	50.65	55.64	61.23	50.41	50.26	59.47	57.28
Sep	Late	46.09	46.08	48.30	48.38	48.34	54.38	49.22	48.60	58.67	46.90	51.13	56.58	46.68	46.52	54.53	53.05
Oct	Late	21.51	21.51	22.67	27.10	22.65	30.07	24.27	27.25	32.17	26.21	28.31	31.56	26.09	26.00	30.18	24.82
		170.13	170.07	177.7	182.45	177.92	206.07	177.35	183.04	222.55	177.43	194.05	214.10	176.5	175.97	206.57	195.42

Total		763.85	763.96	802.9	798.91	801.94	891.93	891.83	796.07	967.26	774.55	841.89	911.69	769.4	767.74	891.99	863.85

TREND ANALYSIS OF COP WATER REQUIREMENT OF RICE

The trend analysis of crop water requirement (CWR) for rice in different districts of Manipur is presented in Table 5. The Z values of CWR exhibit both negative and positive trends across all 16 districts. Positive trends, ranging from 2.84mm/11 years to 0.56mm/11 years, are observed in 14 districts. However, Bisnupur and Pherzwal show negative trends, ranging from -0.60mm/11 years to -6.60mm/11 years. This mirrors the trend observed in ETo for Manipur. Similarly, Lolhande *et al*. (2017) noted a decreasing trend in monthly and seasonal ETo for Akola district in Maharashtra from 2005-2014, with a corresponding decrease in Crop Water Requirement.

Table 5: Trendnalysis of CWR of rice for duration 2001-2021

Districts	Zc	Qi
IMPHAL WEST	0.31	2.84
IMPHAL EAST	0.31	2.84
CCPUR	0.62	2.55
THOUBAL	0.62	2.37
CHANDEL	0.78	2.66
UKHRUL	0.62	2.65
BISNUPUR	-1.09	-6.60
KAKCHING	0.62	2.29
TENGNOUPAL	0.31	0.75
TAMENGLONG	0.31	2.49
SENAPATY	0.47	1.30
PHERZWAL	-0.31	-0.60
NONEY	0.31	2.39
KANGPOKPI	0.00	0.56
KAMJONG	0.62	2.66
JIRIBAM	0.31	2.13

4.CONCLUSION

The finding of this study also revealed that a particular crop grown in different 16 districts will require different amount of water due to varying ETo of those districts. It may also be stated that in a particular district selection of crop should be made on the basis of its CWR and ETo of the district. Water use for agriculture in Manipur is increased by poor soil and water management techniques. Understanding the water management techniques that optimize the use of water for agriculture is essential, as are adopting techniques that increase water use effectiveness in crop production.In order to save water and meet crop water requirement, farmers can use the study's findings as a guide when deciding how frequently and how much to irrigate the crops that are the subject of the study. The findings of this study need to be verified in other climatic conditions, especially in arid climates where ETo variations are crucial for water management of cultural crops.

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