Title : Evaluation of different methods for evapotranspiration estimation using Automatic Weather Station data

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Background

- Reference evapotranspiration(ET_0) is widely used variable in hydrology and agriculture
- Quantitative estimation of ET_0 through empirical approach often produces inconsistent result under Agro Climatic regions
- Identification of the best suitable model for specific agroclimatic situation is important

Objective

- Estimation of ET_0 using empirical models

  FAO-Penman-Monteith
  Priestely-Taylor,
  Hargreaves-Temperature,
  Hargreaves-Radiation,
  Turc-Radiation, and
  Makkink-Radiation method using Automatic Weather Station database

- Validation against pan derived reference evapotranspiration

- Selection of the best suitable empirical models for reference evapotranspiration under present agro climatic condition

Materials and Method

Data Used

- Automatic Weather Station Data
  - Air temperature
  - Relative humidity
  - Wind speed
  - Solar radiation

  - *Data are recorded at 3 min logging interval and 30 min averaging interval*
  - *Daily total, average, maximum and minimum were estimated as per the model requirements*
  - *Vapour pressure parameters were derived (before averaging) from RH and Temperature*

- Observatory data (Daily data)
  1. Pan evaporation data

Calculation of pan Derived ET_0 (selected as a benchmark method for comparison)

- $ET_o = K_p * E_{pan}$
- $K_p = 0.108 - 0.0286\, u_2 + 0.0422 \ln(FET)$

  $+ 0.1434 \ln(RH_{mean}) - 0.000631\, [\ln(FET)]^2 \ln(RH_{mean})$

  FET = Fetch Length (200mt.)

  RH_{mean} = Mean Relative Humidity

  E_{pan} = Pan Evaporation (from observatory)

  u_2 = Wind speed

  K_p = Pan Coefficient

Expression of Mathematical Models

Model name	Formulae
Hargreaves Temperature	$HT = 0.0023Rs\,(T + 17.8)\,[T\Delta]^{0.5}$ Ra = Daily Extra Terrestrial Radiation (MJ/m^2) T = Daily Mean Temperature TΔ=Daily maximum and minimum temperature difference
Priestley Taylor Model	$PT = \alpha\left(\frac{\Delta}{\Delta + \gamma}\right) * R_n$ α =Empirical coefficient (1.56) Δ=Slope of Saturation Vapor Pressure Curve (KPa^{0}C) γ = Psychometric Constant (KPa^{0}C) Rn= Net Radiation (MJ/m^2)
Turc Radiation Model	$TU = \beta\left[\frac{T}{(T + 15)}\right] * (23.88 * Rs + 50)$ β =empirical coefficient (0.013) T= Daily Mean Temperature Rs= Solar Radiation (MJ/m^2)

Expression of Mathematical Models

Model name	Formulae
Hargreaves Radiation Model	$HR = 0.0135\,(T + 17.8)\,R_s$ T= Daily Mean Temperature Rs= Solar Radiation (MJ/m^2)
FAO-Penman Monteith Model	$ET_0 = \frac{[0.408\,\Delta(Rn - G) + \gamma\{900/(T + 273)\}U_2 * D]}{\Delta + \gamma(1 + 0.34 * U_2)}$ Rn= Net Radiation (MJ/m^2) Δ=Slope of Saturation Vapor Pressure Curve (KPa^0C) G= Ground Heat Flux (0) D= Vapor Pressure Deficit 900= Conversion factor γ = Psychometric Constant (KPa^0C)
Makkink Model	$MK = 0.61\left[\frac{\Delta}{\Delta + \gamma}\right] * \left(\frac{R_s}{2.45}\right) - 0.12$ Δ=Slope of Saturation Vapor Pressure Curve (KPa^0C) Rs= Solar Radiation (MJ/m^2)

Calculation of derived input

Symbol	Description
Rn	Net Radiation = **Rns-Rnl**
Rns	Shortwave Balance **= 0.77Rs**
Rnl	Longwave Balance **$=f_c f_h \sigma(T_{kx}{}^4+T_{kn}{}^4)/2$**
f_c	Cloudiness factor **$=1.35(Rs/Rso)-0.35$**
f_h	Humidity factor **$=0.34-0.14\sqrt{ea}$**
R_{so}	Clear sky radiation **= max(Rs,0.75Ra)**
R_a	Extra-terr. Radiation **$= 0.31831\ k_{sc} dr(\omega_s \sin\phi \sin\delta + \cos\phi \cos\phi \sin\omega_s)$**
K_{sc}	Solar constant
D_r	Inverse relative distance **$=1+0.033\cos(0.0172J)$**
ωs	Sunset hour angle **$=\arccos(-\tan\phi\tan\delta)$**
ϕ	Latitude
δ	Solar declination **$=4.903\sin(0.0172J-1.39)$**

Validation Methods

Statistical techniques used

Root mean square error	$RMSE = \left[\frac{1}{N} \sum_{n}^{i=1} (Pi - Oi)^2 \right]^{0.5}$
Normalized RMSE	$NRMSE = \frac{RMSE}{Range\ of\ obs.}$
Coefficient of variation of RMSE	$CVRMSE = \frac{RMSE}{Mean\ of\ obs.}$
Mean bias error	$MBE = \frac{1}{N} \sum_{n}^{i=1} [Pi - Oi]$

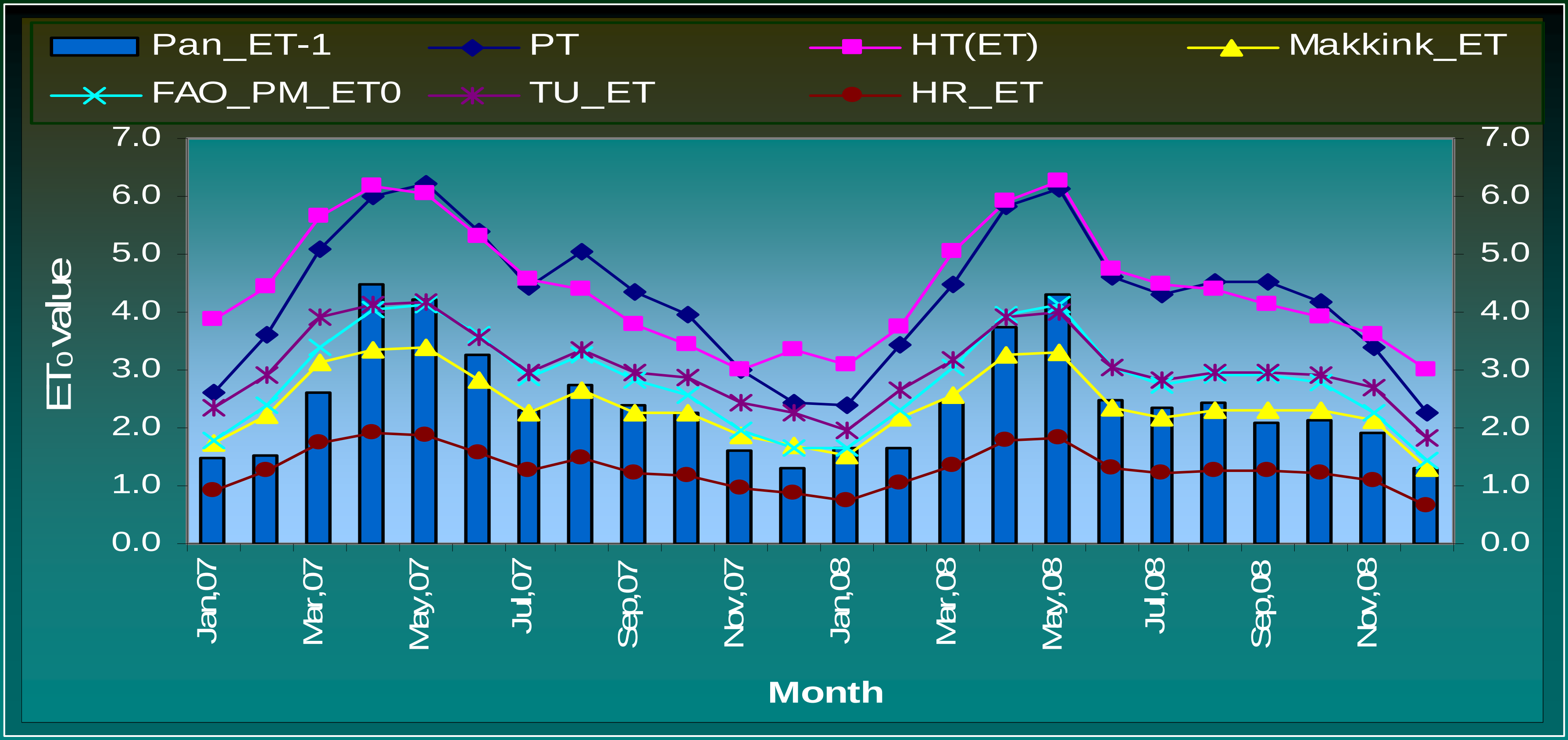


Fig: 1 Comparison of all models against Pan Derived ET

- **Hargreaves Temp** & **Priestly-Taylo**r methods overestimate ET in all months
- **Hargreaves Radiation** model highly underestimates ET
- **FAO-Penman-Monteith and Turc** methods slightly overestimate ET during July to Nov
- **Makkink** method closely matches with Pan Derived ET throughout the experimental year

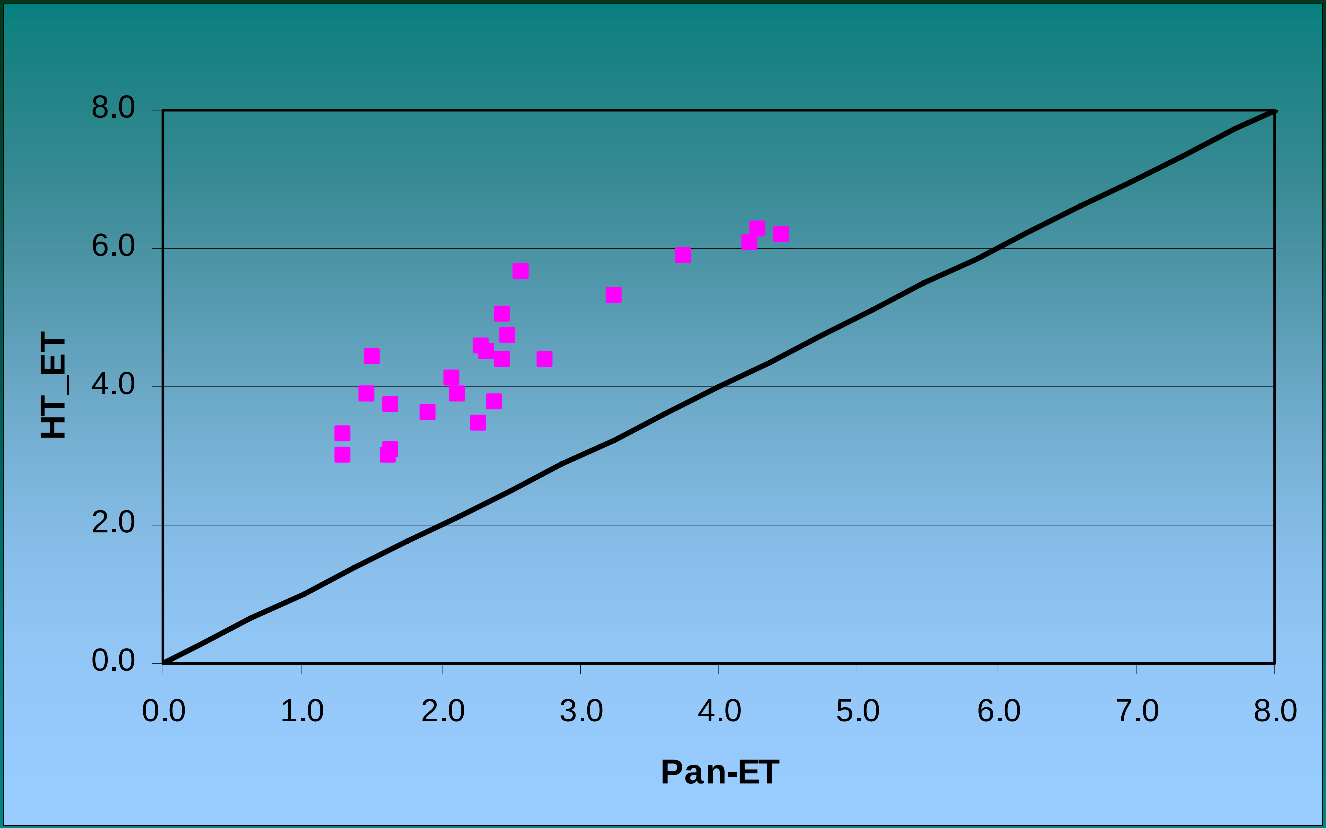
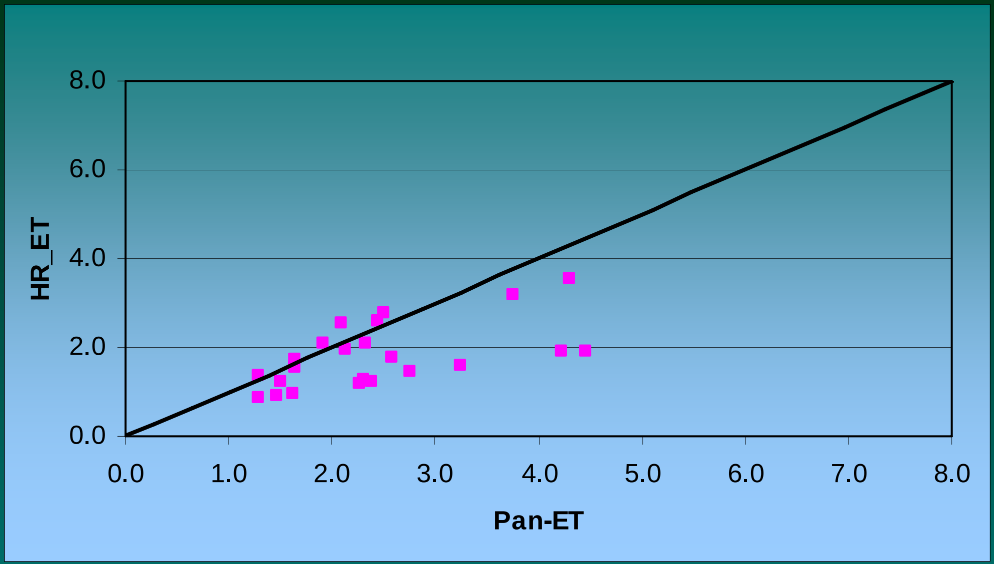


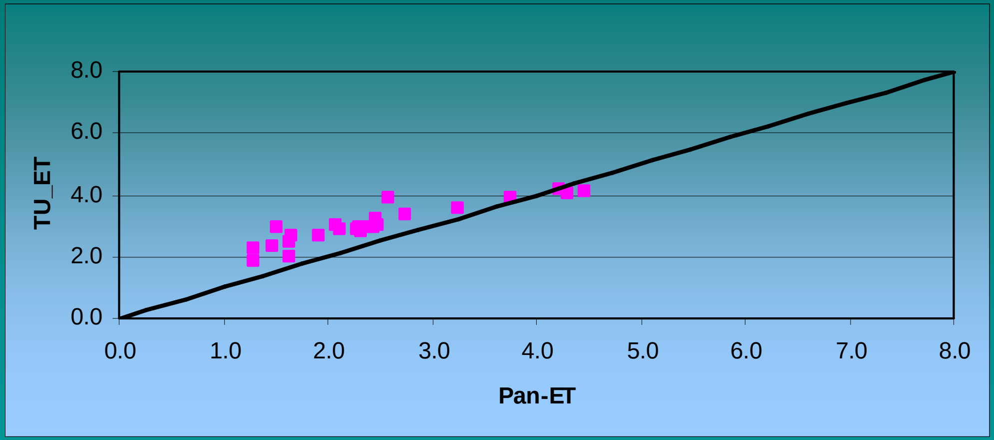
Fig:2 HT_ET vs Pan derived ET

- **Overestimation throughout the experimental period**



- Slight underestimation
- More deviation at higher range

Fig:3 HR_ET vs Pan derived ET



- Slight underestimation at higher range
- Overestimation at lower range

Fig:4 TU_ET vs Pan derived ET

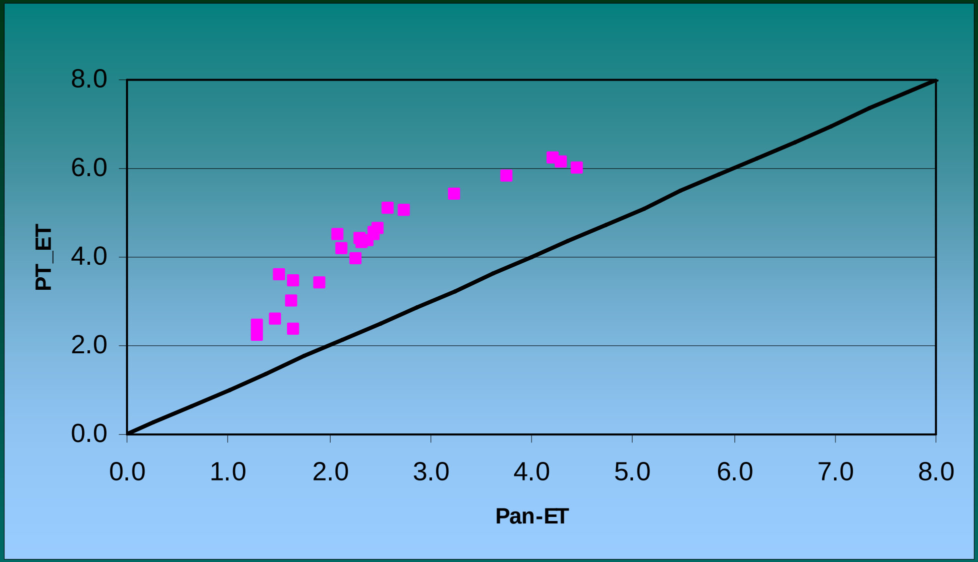


Fig:2 PT_ET vs Pan derived ET

- Overestimation throughout the experimental period
- More deviation at the middle range

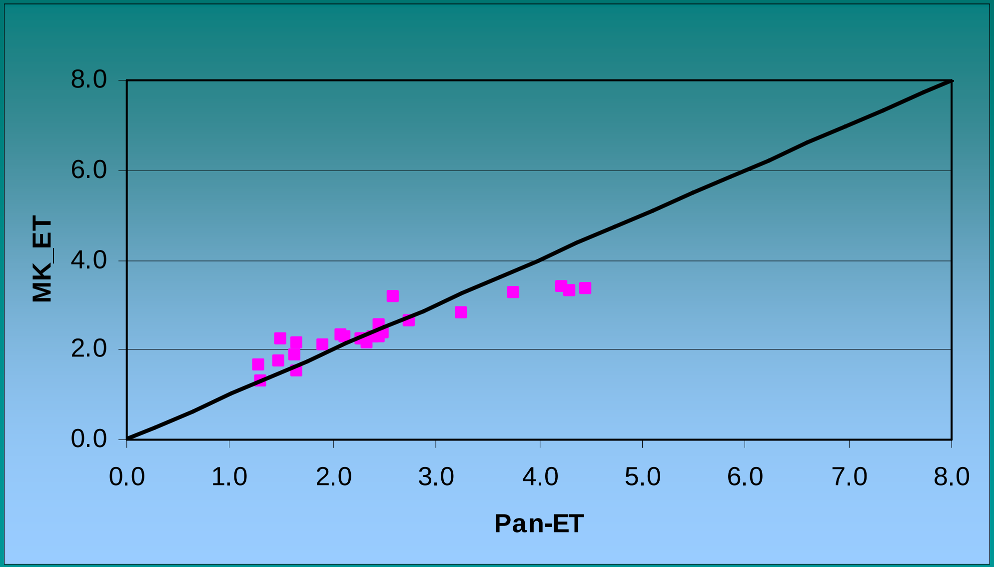


Fig:2 MK_ET vs Pan derived ET

- Gives the best predicted value
- Slight underestimation at higher range

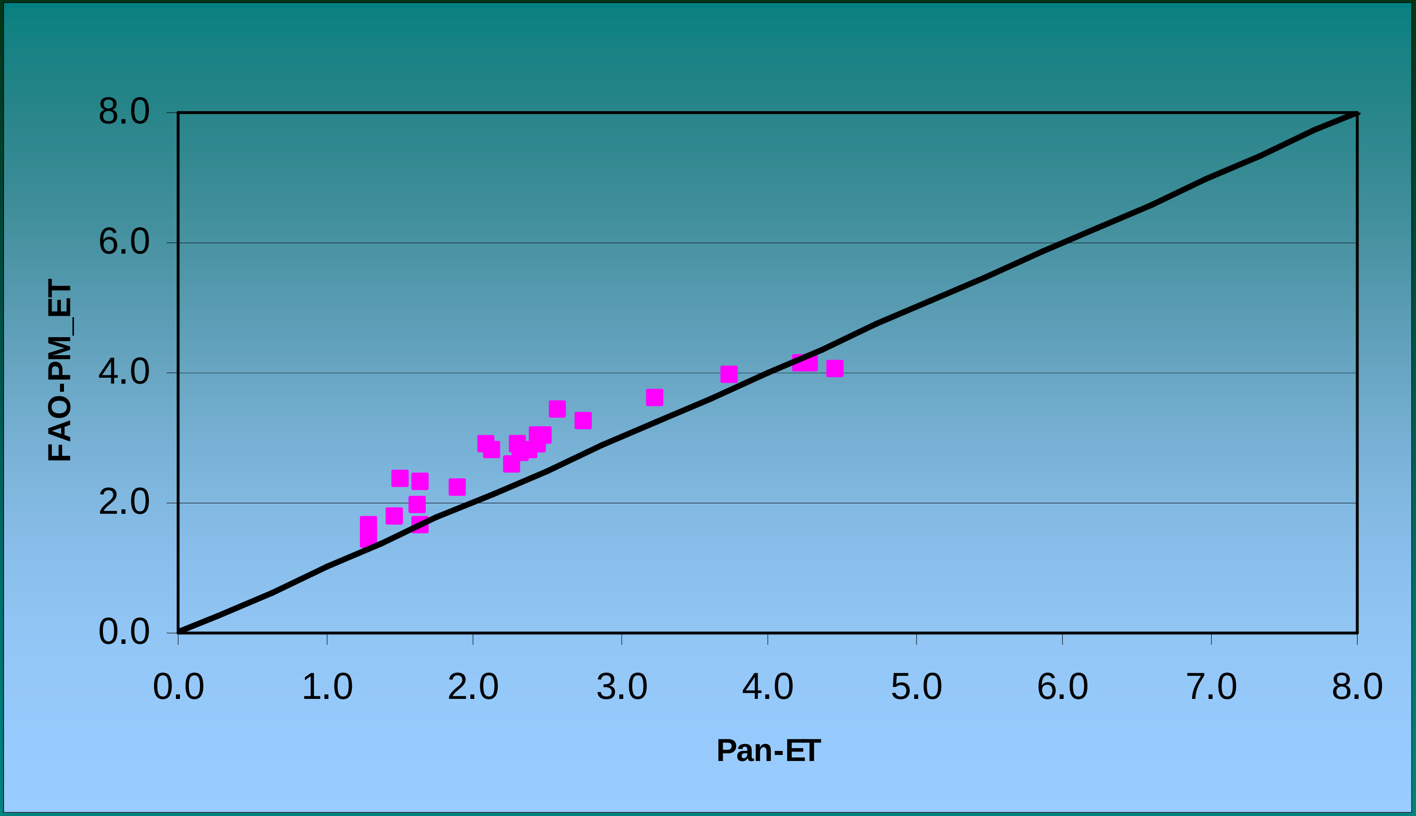


Fig:2 FAO-PM_ET vs Pan derived ET

- **Very small deviation from lower to middle range**
- **Slight underestimation at the higher range**

Salient findings

Model name	r	slope	intercept	RMSE	MBE	CV(RMSE)	NRMSE
Hrg_Tmp	0.892	0.985	2.020	2.878	3.966	0.650	0.877
Hrg_Rad	0.940	0.369	0.355	1.261	-1.143	1.024	1.100
Turc	0.915	0.640	1.469	1.021	1.176	0.337	0.433
Prst_Tayl	0.934	1.196	1.335	2.643	3.625	0.621	0.666
Mk_ET	0.921	0.578	0.976	0.637	-0.113	0.267	0.304
FAO-PM	0.946	0.817	0.819	0.682	0.744	0.242	0.250

- Makkink and FAO-PM approaches are suitable in our region
- Hargreaves-Radiation and Makkink approach made slight under estimation while all others made over estimation
- Priestly-Taylor and Hargreaves-Radiation showed high ‘r’ value implies that they can be effectively used after suitable calibration of the empirical coefficients

Thank You…..