



Società Idrologica Italiana
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agenzia regionale strategica per lo
sviluppo ecosostenibile del territorio



Politecnico
di Bari

LE GIORNATE DELL'IDROLOGIA

2025

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SCENARI, RISCHI E STRATEGIE DI ADATTAMENTO

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8-10 SETTEMBRE 2025

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Le Giornate dell'Idrologia 2025
Bari, 8-10 settembre
Book of Abstract

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Le Giornate dell'Idrologia 2025

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Sensitivity analysis of Evapotranspiration - A comparison of Northern and Southern climate of Italy

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Abstract

Understanding the sensitivity of reference evapotranspiration (ET_0) to meteorological variables is critical for improving urban water management and climate adaptation strategies. This study analyses the one-way and two-way sensitivity of ET_0 to maximum temperature (T_{max}), wind speed (u_2), net solar radiation (R_n), and maximum relative humidity (RH_{max}) using the FAO-56 Penman-Monteith equation for multiple meteorological stations in Northern (Liguria and Lombardy) and Southern (Sicilia) regions of Italy. Liguria is a coastal strip with moderate climatic conditions while Lombardy is an inland region with humid subtropical climate and almost no dry season. Sicily is a southern island region with a Mediterranean climate, featuring long, hot summers and mild, wet winters.

ET_0 , at daily scale was estimated by Penman Monteith equation with respect to the guidelines given in FAO irrigation and drainage paper 56 (Allen et al., 1998). Sensitivity analysis of ET_0 was made throughout the year by producing relative variations in the dependent variable (ET_0 in mm/day) with respect to the relative variation of a single independent variable among maximum temperature (T_{max} in °C), solar radiation (R_s in MJ/m²/day), wind velocity (U in m/s), and maximum relative humidity (RH_{max} in %), while maintaining all other independent variables constant (Irmak et al. 2006; Emeka et al. 2021). 2-way sensitivity analysis was made for maximum temperature and maximum relative humidity to understand their joint role in modifying vapour pressure deficit.

Hourly datasets for climatic variables were obtained from Agenzia Regionale per la Protezione Ambientale (ARPA: Regional environmental protection agency) of Liguria, Lombardy and Sicilia. The sensitivity analysis of ET_0 using the FAO-56 Penman-Monteith equation examined the effects of maximum temperature (T_{max}), wind speed (u_2), net radiation (R_n), and maximum relative humidity (RH_{max}) across multiple meteorological stations covering urban and suburban environments (Allen et al., 1998). One-way sensitivity analysis involved varying each independent variable (T_{max} , u_2 , R_n , RH_{max}) individually by applying percentage perturbations from -25% to +25% in steps of 5%, building 10 scenarios in the observed value, while keeping all other variables constant. For each perturbed scenario, ET_0 was recalculated, and the sensitivity coefficient (SC_x) was derived for the perturbed variable X using the following equation:

$$SC_x = \frac{\frac{ET_{0x} - ET_{0Base}}{ET_{0Base}}}{\frac{X_p - X_{base}}{X_{Base}}} = \frac{\Delta ET_0 / ET_{0Base}}{\Delta X / X_{Base}}$$

Here, ET_{0Base} represents the baseline ET_0 computed using observed data, while ET_{0x} is the recalculated ET_0 using the perturbed value X_p of the selected variables. A sensitivity coefficient (SC) was calculated for each variable by dividing the relative change in ET_0 by the relative change in the variable. The mean daily and annual sensitivity coefficient across all scenarios was computed providing a scalar value representing the sensitivity of ET_0 to respective variable. This approach has been widely used as a simple and reliable method for sensitivity analysis (Irmak et al. 2006; Emeka et al. 2021). The output of analysis was obtained in the form of dimensionless sensitivity coefficient, SC_x .

In the two-way sensitivity analysis, the combined effect of varying maximum temperature (T_{max}) and maximum relative humidity (RH_{max}) on reference evapotranspiration (ET_0) was investigated. Perturbations ranging from -25% to +25% were applied simultaneously to T_{max} and RH_{max} , resulting in a grid of perturbation combinations (T_{max-PP} , RH_{max-PP}). For each combination of T_{max-PP} and RH_{max-PP} , corresponding changes in vapor pressure deficit (VPD) were computed, as VPD is a dependent variable influenced by both T_{max} and RH_{max} . Using the perturbed T_{max-PP} , RH_{max-PP} , and the corresponding perturbed VPD values, ET_0 was recalculated for each perturbation combination employing the Penman-Monteith equation.

Table 1. Average annual Sensitivity coefficient of selected independent variables across all stations

Sensitivity coefficient	Genova	Imperia	Bergamo	Milan	Agira	Massina
SC_T	0.4387	0.403	0.4718	0.4653	0.5214	0.5074
SC_RH _{max}	-0.432	-0.221	-0.346	-0.3648	-0.2160	-0.241
SC_Rn	0.4616	0.4654	0.6192	0.5972	0.4727	0.5379
SC_U	0.3160	0.3089	0.1817	0.2733	0.3359	0.2037
SC_VPD	0.5384	0.5427	0.4824	0.4080	0.5273	0.4621

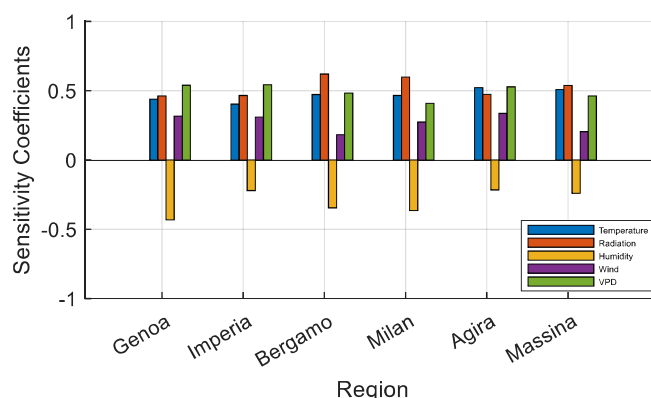


Figure 1. Annual SC for all variables across each station

Although, local weather conditions, latitude and altitude of the area, urban setting and time of year alters the course of sensitivity but the relation of investigated input variables with ET_0 remains similar as observed in these results. T_{max} , R_n and u_2 positively affect the ET_0 while RH_{max} negatively impacts the ET_0 , whereas vapour pressure deficit has a nonlinear behaviour. In Genova, a sensitivity coefficient (SC_T) of 0.4371 means that a 5% increase in maximum temperature would result in approximately a 21.81% increase in ET_0 . Solar radiation emerged as the most influential variable overall, particularly in the inland Lombardy stations (SC_{Rn} up to 0.6192), highlighting its dominant role in driving ET_0 where clearer skies are common indicating that inland ET_0 is highly responsive to solar input. It can be due to urban setting of the environment and heat trapping capacity of built environment. T_{max} sensitivity was highest in Sicily ($SC_T \approx 0.52$), emphasizing the impact of high temperatures in southern climates on evaporative demand. RH_{max} had a consistently negative effect on ET_0 , with the strongest response in the humid coastal station of Genova (-0.432). Wind speed showed the lowest overall sensitivity but demonstrated a noticeable seasonal pattern: its impact was more pronounced in winter months when solar radiation is weaker and atmospheric demand is driven more by aerodynamic factors. In contrast, during summer, radiation and temperature effects overshadowed wind influence. A two-way sensitivity analysis of T_{max} and RH_{max} showed that their interaction, captured through vapor pressure deficit (VPD), significantly affects ET_0 across all stations, with the highest SC_{VPD} values observed in Liguria and Sicily. These findings underscore the need for region- and season-specific calibration of ET_0 models to support accurate urban drainage planning and water resource management.

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