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Short Comminucation

Internet of Things-based approximation of sun radiative-evapotranspiration models

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Evapotranspiration is the vital component of hydrologic cycle (Dar *et al.,* 2017; Tahashildar *et al.,* 2017; Latief *et al.,* 2017). Its precise estimation is of key importance for studying hydrologic water balance, design of irrigation systems and crop yield simulation.Various methods and equations are already employed to measure and monitor the evapotranspiration, but owing to difficulty in getting precise evapotranspiration measurement directly, it is generally estimated from locally or globally available meteorological data with the help of multiple models. Numerous studies have been conducted to compare and evaluate the performance of different models, till date (Caprio 1974; Irmak *et al.,* 2003; Tabari *et al.,* 2013; McGuinness *et al.,* 1972). Each model has its own pros and cons that make it different from other and suitable for particular type of scenario.

Radiation based models mainly depend on parameters viz. solar radiation, extra-terrestria lradiation, average air temperature, duration of sunshine etc. In the present study a novel measurement approach is prescribed to estimate using selected radiation based models (Table 1). The reason behind such selection is that these are completely dependent on R_s and T which are easy to capture through sensors and easy to map with an automated ICT based infrastructure.

The proposed study is performed in the Department of Computer Application laboratory, situated at Gangtok (27.3389° N, 88.6065° E), the capital of the north-eastern hill state Sikkim, during the month of September 2017. This case study may be apprehended as a proof-of-concept to the fact that the Internet of Things (IoT) is well capable to uplift the process of computation of various models in more ease, efficient and cost-effective way.The objective of this study is to validate the aspects of completely autonomic computation of the sun radiative models through advanced ICT tools such as the Internet of Things (IoT).

IoT is a recently introduced domain of computation which acts like the backbone of the futuristic ICT-based systems. IoT is comprehended as the horizontal computing platform where sensors, actuators, microcontrollers, and

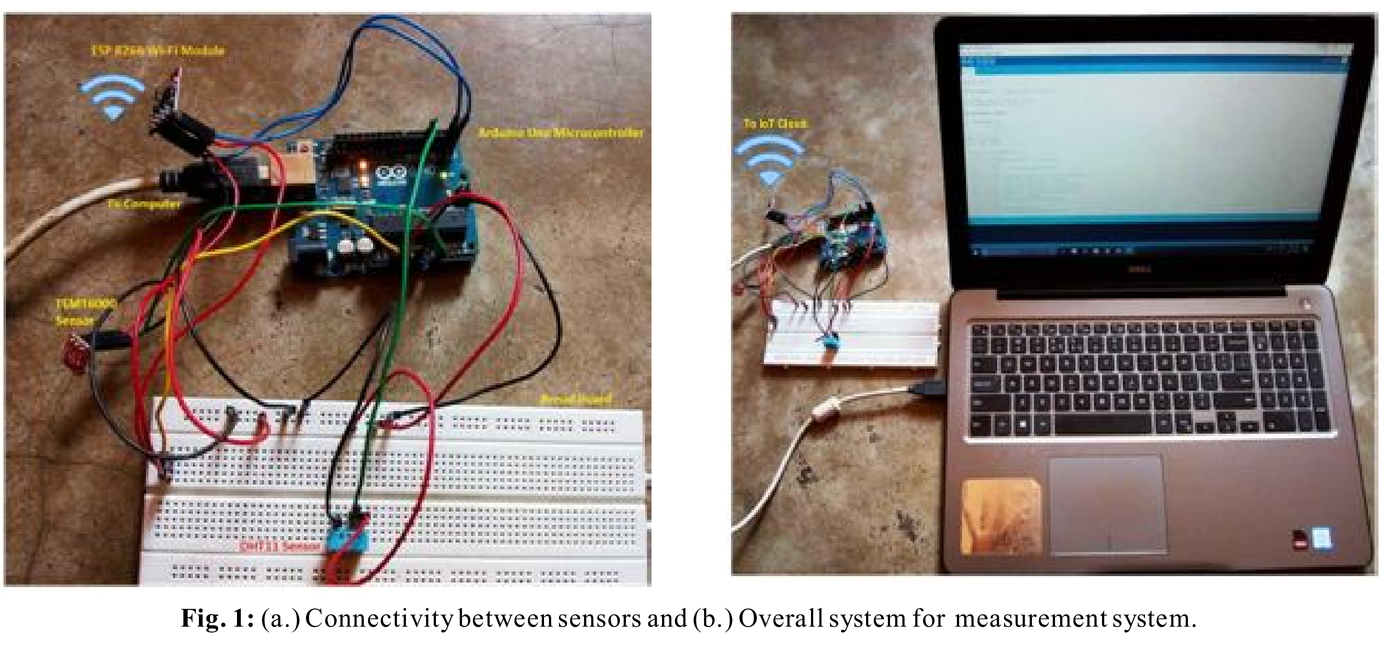

Fig. 1: (a.) Connectivity between sensors and (b.) Overall system for measurement system.

Table 1: Radiation based selective models

Equations (abbreviation)	Reference(s)	Formula
Caprio (CP)	Caprio (1974)	$ET_0 = (0.01092708*T+0.0060706)*R_S$
IRMAK1	Irmak *et al.* (2003)	$ET_0 = -0.611+0.149*R_S+0.079*T$ (IRMAK1)
IRMAK2	Tabari *et al.* (2011)	$ET_0 = -0.642+0.174*R_S+0.0353*T$ (IRMAK2)
(MGB)	McGuinness and Brodne (1972)	$ET_0 = (0.005*T - 0.0838)*R_S$

Note: R_ST are solar radiation and average temperature (°C) as defined in the FAO56PM

Table 2: Equations deployed through IoT enabled micro controller.

Equation Number	Equation
Volts = analogRead (A0) * 5.0 / 1024.0; // Receive luminance data from Analog A0 port of Microcontroller and convert into 10-bit Voltage resolution	(Eq. 1)
Amps = Volts / 10000.0; // Apply Ohm's Law across 10K Ohms	(Eq. 2)
Microamps = Amps * 1000000; // Convert into Ampere	(Eq. 3)
Lux = Microamps * 2.0; // Convert into Lux	(Eq. 4)
Irradiance = Lux * 0.0079; // Convert into W/m2	(Eq. 5)
Irradiance_MJ = Irradiance * 0.0864; // Convert into MJ/m2	(Eq. 6)
ETo_mm-_d-1 = Irradiance_MJ * 2.45; // ETo equivalent value conversion	(Eq. 7)

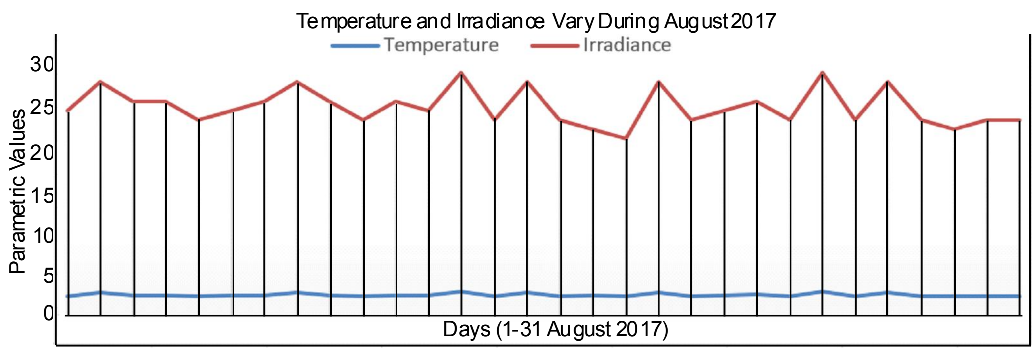

Fig. 2: Data transmission between deployed system and IoT cloud server.

cloud services are organized together to perform highly distributed tasks by means of heterogeneity and super flexibility. Due to the super adaptability, inherent smartness, and high-interoperability, IoT has been emerged as the most promising technology in the field of several sectors of applications that includes smart meteorology, precision agriculture, smart city, intelligent industrial production, e-healthcare etc. (Partha 2017).Most of the cases, internet plays the vital role in realizing the actual development and orientation of applications using IoT. This study also utilizes the craftsmanship of IoT to efficiently measure various radiative ETo.

The experiment was conducted during 1-30th September, 2017 while gathering daily average of temperature in °C and solar illuminance (lux) data by means of DHT11 and TEMT6000 Sensors, respectively. Solar luminance value was later converted into equivalent solar irradiation for further processing by the microcontroller. The same can be equally calibrated with the system model's activity states correspondingly. Equation 1-7 present the equations which were deployed through IoT-enabled microcontroller (Table 2). Equation 4 and 5 were used to convert sensor input data into irradiance, per following the sensor datasheet.

Fig.1(a and b) present the physical level connectivity between various components and complete system structure used in this study.Fig.2 represents collected temperature and solar irradiance values during 1-31st August, 2017. Highest average daily value was recorded as 26 °C, whereas the average daily lowest was 19 °C. Similarly, highest average

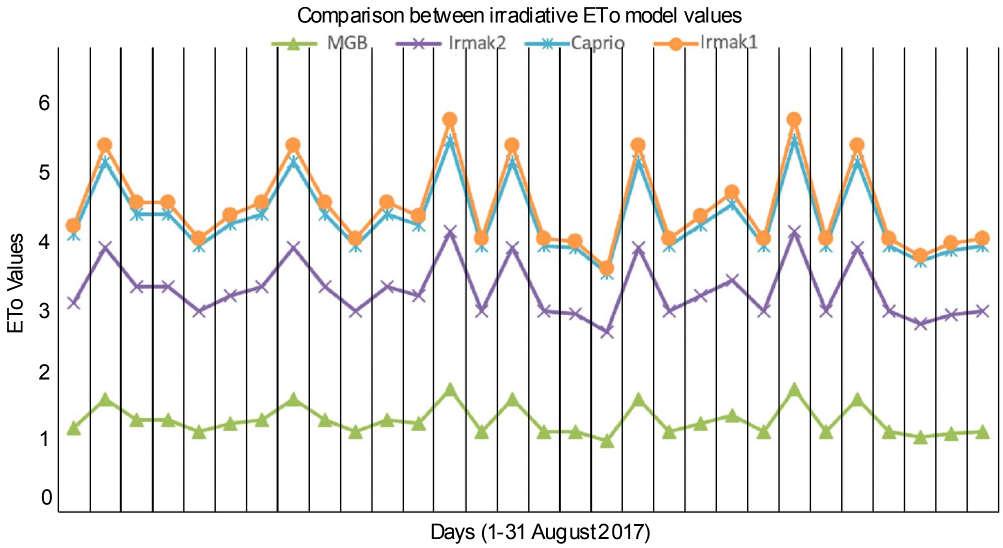

Fig. 3: Data transmission between deployed system and IoT cloud server.

solar irradiance was measured as 4.85 MJm^{-2} and lowest average was 1.21 MJm^{-2}. These data set was stored in IoT cloud server for further processing and analytics whenever required. Fig.3 shows the comparative values of estimated by different methods during the same test duration. Irmak1 value performed best of all i.e. 4.73 mm day^{-1}. Caprio, Irmak2, and MGB followed the pattern toward lower down the activity having average value of 4.4 mm day^{-1}, 3.28 mm day^{-1}, and 1.09 mm day^{-1}.

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