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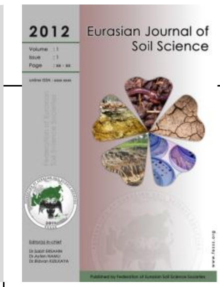

Estimation of evaporation and drainage losses from two bare soils in Sri Lanka

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Abstract

In this study, evaporation, drainage rates and water storage of two bare soils in the east (Batticaloa) and west (Puttalam) regions of Sri Lanka, were simulated using the E-DiGOR model. Daily simulations were carried out for each of the years during the periods of 1978 to 1987 in Batticaloa and 1998 to 2007 in Puttalam using standard climate data. The soils in the locations were predominantly sandy loam and/or sandy clay loam. Grass reference evapotranspiration and potential soil evaporation were higher, whereas actual soil evaporation was lower during the dry seasons. The 10-year average annual reference evapotranspiration and potential soil evaporation were 2069.3 mm and 1814.1 mm in Batticaloa, and 1908.8 mm and 1714.5 mm in Puttalam, respectively. Aridity index (precipitation/reference evapotranspiration) was 0.685 for Batticaloa and 0.606 for Puttalam. The actual evaporation from bare soil varied between 463.1—725.0 mm in Batticaloa and 543.6—646.3 mm in Puttalam. Annual drainage rates below 150 cm soil depth ranged from 321.7 to 1581.2 mm in Batticaloa and from 346.7 to 957.0 mm in Puttalam. Soil water storage changed daily depending on the intensity and frequency of rainfall events and on evaporation rates.

Keywords: Soil-water balance, E-DiGOR model, Aridity Index, Sri Lanka.

Introduction

The world population reached 7 billion in late 2011. Despite this growth, food supply is a major problem in the worldwide. In particular, crop and livestock production is often limited in developing countries. Sri Lanka is also experiencing a population boom. Unfortunately, natural resources management in developing countries among them Sri Lanka is worse compared with developed countries. Losses of water from the soils through evaporation and drainage are major components in the soil water balance of agricultural systems. Crop transpiration is regarded as beneficial process, but evaporation from bare soils or fields with a partial canopy cover is considered detrimental (Aydin et al., 2008). The soil surface remains bare under field crops for many weeks during the periods of seed germination, seedling establishment, and subsequent growth of the young crops when the moisture content of the upper soil layer can be of critical importance. In orchards, the soil surface between the trees is kept bare by frequent tillage and is continuously subjected to evaporation (Mellouli et al., 2000; Aydin et al., 2008). In many regions of the world, evaporation from the soil surface constitutes a large fraction of the total water loss not only from bare soils but also from cropped

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fields. Some earlier studies have estimated that the soil evaporation in semi-arid environments ranged from 30 to more than 60% of the seasonal rainfall (Jackson and Wallace, 1999). Similarly, other results have demonstrated that in regions where summer fallow is practiced, direct evaporation from the soil surface accounted for about 50% or more of total precipitation (Hillel, 1980; Hanks, 1992). Onder et al. (2009) reported that the actual soil evaporation in different parts of Turkey accounted for 34 to 83% of the incoming precipitation.

Major consumer of water is agriculture sector compared to other users, domestic and industrial sectors. With increase in the demand for domestic water, the agriculture sector has to be adjusted its requirement. The only option is to improve the water use efficiency. Rainfall is the source for surface, soil and ground water, among which soil water is the cheapest and most reliable one for crop production when immediate access to surface and ground water is lacking (Aydin et al., 2008). On the other hand, rainfall and irrigation are the major processes that contribute the groundwater recharge that has to be quantified to contingent use of groundwater and surface water. Similarly, quantification of water-loss through evaporation and drainage from bare soils in rainfed agriculture is very important to develop an effective soil-water management for sustainable productivity. Therefore, the loss of soil-water due to these two processes should be assessed in order to apply the feasible management practices for storing and conserving water within the soil profile. In order to estimate soil evaporation and drainage rates successfully, the applicability of E-DiGOR model to a wide range of environments has been tested by different researchers using field-based measurements (Aydin, 2008; Aydin et al., 2008; Kurt, 2011). This model is relatively simple and requires readily available input-parameters. Another advantage is that actual soil evaporation, drainage and soil water storage are quantified in an interactive way since these components are strongly interdependent (Aydin, 2008; Onder et al., 2009; Aydin and Polat, 2010; Aydin et al., 2012). In this study, soil-water balance components mentioned above were simulated using the E-DiGOR model in East and Western Sri Lanka.

Material and Method

Study locations

Batticaloa (7°72´N, 81°70´E) and Puttalam (8°03´N, 79°83´E), which were the sites evaluated, are located in the East and West of Sri Lanka, respectively. Daily climate data for the study areas were obtained from the Department of Meteorology, Sri Lanka (Table 1). Puttalam is located in the Kalpitiya Peninsula on the West coast of Sri Lanka. The area is flat, with a maximum elevation of 10 m. The long-term average annual rainfall is 1100 mm, with the majority of rain occurring from October to May (Jayasekera et al., 2011). The tropical climate is governed by two main seasons, *yala* (dry season) and *maha* (wet season). Therefore, irregular rainfall distribution and acute water shortage during the dry period from June to September have been the major constraint of agricultural development in this region. The climate of the region is hot and humid throughout the year. The mean annual temperature at the site is between 28 and 29 ^{0}C. The mean relative humidity was 78-79% based on the meteorological data for the period of 1998-2007. Batticaloa receives an annual rainfall ranging from 900 to 2000 mm. However, 75-80% of the total rainfall falls intensively from October to February, as also reported by Panabokke et al. (2002). Flooding is recorded in the area approximately every year. The average annual temperature and relative humidity were about 27-28 ^{0}C and 77-78%, respectively, based on meteorological data from 1978 to 1987.

The agricultural lands are mainly used for growing paddy, vegetables and fruits. These areas are underlain by clay and located mostly in the sandy stretch. In some parts, flood irrigation takes place for paddy cultivation. In addition, onion, eggplant, ground nut and chillies are grown in home gardens and small fields. Soils with different proportions of sand, silt, and clay fractions in these locations are predominantly sandy loam in Batticaloa and sandy loam/sandy clay loam in Puttalam.

Description of the model

In the assessment of soil water management under bare-field conditions, approaches to quantify the components of water balance are of major importance. In this regard, the E-DiGOR [**E**vaporation and **D**rainage **i**nvestigations at **G**round of **O**rdinary **R**ainfed-areas] model was recently developed by Aydin (2008) as a helpful tool to quantify drainage rates, soil evaporation and water storage. The E-DiGOR model takes into account the physical processes important to quantifying these components (Onder et al., 2009; Aydin and Kececioglu, 2010). The model part for actual evaporation had been previously validated by Aydin et al. (2005 and 2008) using measured data from different environments in Japan and Turkey and predicted data from the Regional Climate Model of Japanese Meteorological Research Institute during a 10-year period (2070-2079) for Adana-Turkey. The model has been adapted to assess drainage losses from soil profiles using field capacity concept. The theory of the processes simulated by E-DiGOR program has been extensively described by Aydin (2008). The model required the input of daily climate data and information on soil properties (Aydin and Polat, 2010). In principle, the E-DiGOR model can simulate the components of soil-water balance on the scale of a plot. Kurt (2011) tested the model in olive plantations in a Mediterranean environment and concluded that the model could successfully quantify the components of soil water balance in orchards. In this section, the basic equations included in the E-DiGOR are defined except the equation proposed by Aydin (2010) to estimate runoff from bare plots.

Table 1. Monthly mean climatic data for the study locations

Month	Mean Temperature (°C)	Mean relative Humidity (%)	Mean duration of sunshine (h day^{-1})	Mean wind Speed (m s^{-1})	Rainfall (mm)
Batticaloa: 1978-1987					
January	25.2	93.3	7.0	3.6	188.7
February	25.6	92.0	8.3	3.4	128.8
March	27.0	80.1	8.7	3.0	73.6
April	28.6	73.2	8.7	3.1	61.6
May	29.4	69.1	9.1	3.1	33.1
June	30.1	66.3	7.8	3.2	35.4
July	29.1	71.7	7.9	3.1	39.2
August	29.4	70.1	8.2	3.3	15.5
September	28.4	73.1	7.5	4.4	78.7
October	27.2	75.1	7.3	4.9	168.6
November	26.2	80.4	6.1	4.3	315.7
December	26.0	88.4	6.2	4.0	271.1
Puttalam: 1998-2007					
January	26.3	77.8	6.5	2.0	72.9
February	27.2	76.0	8.9	1.8	38.3
March	28.5	74.1	8.7	1.6	71.1
April	29.0	78.7	8.1	1.6	186.1
May	29.5	80.1	7.9	2.9	90.4
June	29.1	79.5	6.9	3.4	28.1
July	28.7	78.5	7.1	3.4	30.6
August	28.8	77.4	7.7	3.4	15.4
September	28.9	77.1	7.8	3.1	49.7
October	28.0	80.5	6.5	2.1	202.8
November	27.1	82.6	5.3	1.5	226.2
December	26.3	81.0	5.2	1.8	144.1

Evaporation from a bare soil surface is a complex process. The most important transport processes are characterized by a simultaneous change in the amount of energy or material with time and place (Aydin and Huwe, 1993; Aydin, 1994). In general, soil evaporation is modelled by limiting potential evaporation with soil and or aerodynamic resistances. Daily potential evaporation from bare soils can be calculated using the Penman-Monteith equation (Allen et al., 1994) with a surface resistance of zero (Wallace et al., 1999; Aydin et al., 2005):

$$E_p = \frac{\Delta(R_n - G_s) + 86.4 c_p \rho \delta / r_a}{\lambda(\Delta + \gamma)} \tag{1}$$

where E_p is potential soil evaporation (E_p =kg m^{-2} day^{-1}≈mm day^{-1}), Δ is the slope of vapour pressure-temperature curve (kPa ^{o}C^{-1}), R_n is the net radiation (MJ m^{-2} day^{-1}), G_s is the soil heat flux (MJ m^{-2} day^{-1}), ρ is the air density (kg m^{-3}), c_p is the specific heat of air (kJ kg^{-1} ^{o}C^{-1}=1.013), δ is the vapour pressure deficit of the air (kPa), r_a is the aerodynamic resistance (s m^{-1}), λ is the latent heat of vaporization (MJ kg^{-1}), γ is the psychrometric constant (kPa ^{o}C^{-1}), and 86.4 is the factor for conversion from kJ s^{-1} to MJ day^{-1}.

Evaporation from soils, as a physical process, takes place in the aeration zone on the upper surface of the soil (Denisov et al., 2002). Initially evaporation from wet soil proceeds at the potential rate. With time, the soil surface becomes progressively drier, and the drying front moves into the soil. Thus, the soil water potential at the top surface layer decreases. The following equation can be used to estimate the soil water potential at the top surface layer (Aydin et al., 2008):

$$\psi = -\left[(1/\alpha)(10\sum E_p)^3 / 2(\theta_{fc} - \theta_{ad})(D_{av}t/\pi)^{1/2}\right] \tag{2}$$

where ψ is soil water potential (cm of water) at the top surface layer, α is a soil specific parameter (cm) related to flow path tortuosity in the soil, ΣE_p is cumulative potential soil evaporation (cm), θ_{fc} and θ_{ad} are volumetric water content (cm^3 cm^{-3}) at field capacity and air-dryness, respectively, D_{av} is average hydraulic diffusivity (cm^2 day^{-1}) determined experimentally, t is time (day), and π is 3.1416.

During a drying period, the top surface layer of the soil may dry out eventually to air-dry wetness and the soil surface approaches equilibrium with the overlying atmosphere. The soil then no longer evaporates at a considerable rate, except water transport by the slow process of moisture diffusion. Assuming that the water potential at the dry soil surface is at equilibrium with the atmosphere, the minimum water potential can be derived from the Kelvin equation (Brown and Oosterhuis, 1992; Aydin et al., 2005; Aydin, 2008):

$$\psi_{ad} = \frac{R_g T}{mg} \ln H_r \tag{3}$$

where ψ_{ad} is the water potential for air-dry conditions (cm of water), T is the absolute temperature (K), g is the acceleration due to gravity (981 cm s^{-2}), m is the molecular weight of water (0.01802 kg mol^{-1}), H_r is the relative humidity of the air (fraction), and R_g is the universal gas constant (8.3143x10^4 kg cm^2 s^{-2} mol^{-1} K^{-1}).

Many studies assess evaporation through two different stages, which are related to the soil water content: (1) when the actual water content is high, evaporation is controlled by the atmospheric evaporative demand, (2) when the amount of water is low, evaporation is limited by the actual soil water content and, as a consequence, driven by the hydrodynamic characteristics of the soil. The Aydin equation can be used to successfully describe soil evaporation from the soil water potential (Aydin et al., 2005; Falge et al., 2005). The Aydin equation is based on energy fluxes and soil properties, and experimental data are used to define a threshold separating of the two stages of evaporation (Quevedo and Frances, 2007; Romano and Giudici, 2007). Consequently, it is possible to incorporate Eqns (1) to (3) into the Aydin equation to compute the actual evaporation from bare soil (Aydin et al., 2005):

$$E_a = \frac{Log|\psi| - Log|\psi_{ad}|}{Log|\psi_{tp}| - Log|\psi_{ad}|} E_p \tag{4}$$

If $|\psi| \leq |\psi_{tp}|$ then $E_a = E_p$ or $E_a/E_p = 1$

For $|\psi| \geq |\psi_{ad}|$, $E_a = 0$. Remember that $E_p \geq 0$.

where E_a and E_p are actual and potential evaporation rates (mm day^{-1}), respectively, $|\psi_{tp}|$ is the absolute values of soil water potential (matric potential) at which actual evaporation starts to drop below potential one (cm of water), $|\psi_{ad}|$ is the absolute values of soil water potential at air-dryness (cm), and $|\psi|$ is the absolute value of soil water potential at the surface layer (cm) determined by Eqn (2).

The soil water storage (S) on any day can be imposed on the difference between rainfall (P, in case) and actual evaporation on the consecutive day. Symbolizing this produced variable as W, and assuming a negligible runoff from nearly level soils, the following expression can be derived (Aydin, 2008):

$$W^{(j)} = S^{(j-1)} + P^{(j)} - E_a^{(j)} \tag{5}$$

If $W^{(j)} < \theta_{fc}Z$, then $S^{(j)} = W^{(j)}$

If $W^{(j)} \geq \theta_{fc}Z$, then $S^{(j)} = \theta_{fc}Z$.

In practice, soil water storage between the soil surface (0) and a given depth (Z) is calculated by integrating the water content of individual soil layers ($\int_0^z \theta_i dz$).

Drainage is simply calculated by the mass balance. The cumulative drainage until day j can be expressed as follows (Aydin, 2008):

$$\left[\sum D\right]^{(j)} = \int_0^z \theta_i dz + \left[\sum P\right]^{(j)} - \left[\sum E_a\right]^{(j)} - S^{(j)} \tag{6}$$

where ΣD is cumulative drainage (mm) out of storage depth since the first day of simulation period, ΣP is total rainfall (mm), and ΣE_a is cumulative actual soil evaporation (mm). Thus, from the differences between the consecutive days, drainage rates (D = mm day^{-1}) can be easily calculated, if any: $D^{(j)} = \left[\sum D\right]^{(j)} - \left[\sum D\right]^{(j-1)}$.

The upward flux from deeper layers into the profile zone is considered negligible. For comparison, all quantities are expressed in terms of volume per unit area (equivalent depth units).

With standardized height for wind speed, temperature and humidity measurements at 2 m and an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1}, and an albedo of 0.23, the reference evapotranspiration can be calculated using the FAO Penman-Monteith equation as follows:

$$ET_r = \frac{0.408\Delta(R_n - G_s) + \gamma \dfrac{900}{T_a + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{7}$$

where ET_r is grass reference evapotranspiration (mm day^{-1}), T_a is mean daily air temperature (°C), u_2 is wind speed at 2 m height (m s^{-1}), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa).

In the simulations, the volumetric water content at field capacity was taken as 0.18 cm^3 cm^{-3} for Batticaloa soils and 0.20 cm^3 cm^{-3} for Puttalam soils. Albedo of bare soils was assumed to be 0.15 (van Dam et al., 1997; Ács, 2003). The tortuosity parameter, which can be defined as the actual round about flow path for the soils, was taken as 1.1 cm (Onder et al., 2009). The volumetric water content under air-dry conditions and hydraulic diffusivity of soils were assumed to be 0.005 cm^3 cm^{-3} and 20 cm^2 day^{-1} for Batticaloa, 0.01 cm^3 cm^{-3} and 25 cm^2 day^{-1} for Puttalam, respectively. The threshold potential is always greater than 15 cm (for sand) and may exceed 60 cm (for clay soil) as reported by Aydin et al. (2005). We used 20 cm of water as a threshold for Batticaloa and 25 cm for Puttalam.

Results and Discussion

Simulations of daily ET_r, E_p, E_a, D and S were conducted for each of the years during the periods from 1978 to 1987 in Batticaloa and 1998 to 2007 in Puttalam. Graphical illustration of daily P, ET_r, E_p, E_a, D and S values for the entire period would have required a lot of space. For this reason, daily changes in the variables for Batticaloa in 1987 were given as representative examples in Figures 1 and 2. Monthly variations of ET_r, E_p, E_a, and D along with rainfall in Batticaloa for a period of 10 years are depicted in Figure 3. In order to demonstrate the relationships among the variables, the comparisons for Puttalam in 2007 are shown in Figures 4 and 5. Monthly mean values of the soil-water balance in Puttalam for a 10-year period are presented in Figure 6.

Drainage occurred on some rainy days (and/or on the consecutive days). Drainage rates below a soil depth of 150 cm were high during rainy months with a maximum value of 157.1 mm day^{-1} in Batticaloa and 53.8 mm day^{-1} in Puttalam (Figures 1 and 4). Drainage was affected by rainfall and increased with a higher amount of rainfall and soil water content. In general, ET_r rates were higher than E_p values. Aydin et al. (2008)

also found a similar relationship between ET_r and E_p. Kroes et al. (1999) reported that ET_r rates could be multiplied by a coefficient value of 0.5 to 1.5 to obtain E_p. The evaporation from bare soils depends not only on the atmospheric conditions but also on soil properties.

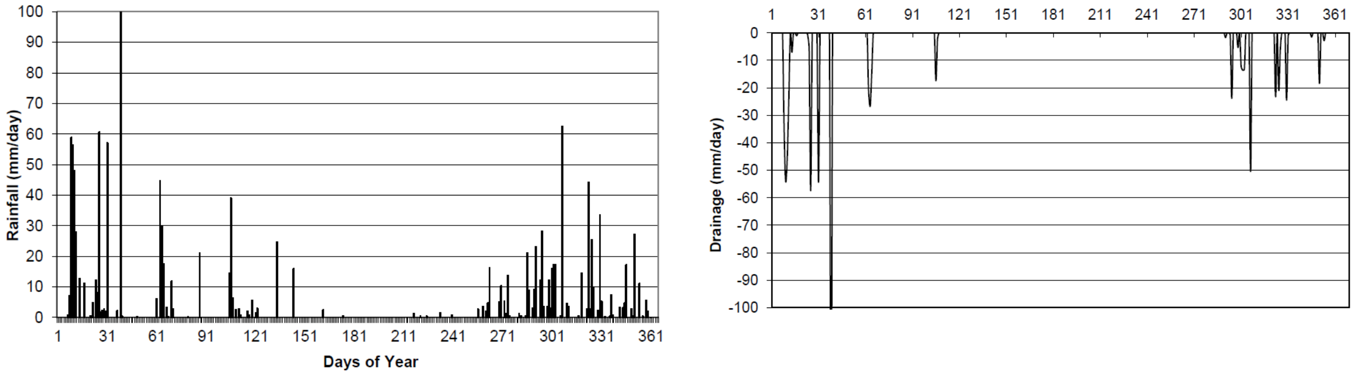

Figure 1– Drainage rates below a soil depth of 150 cm along with rainfall in Batticaloa in 1987.

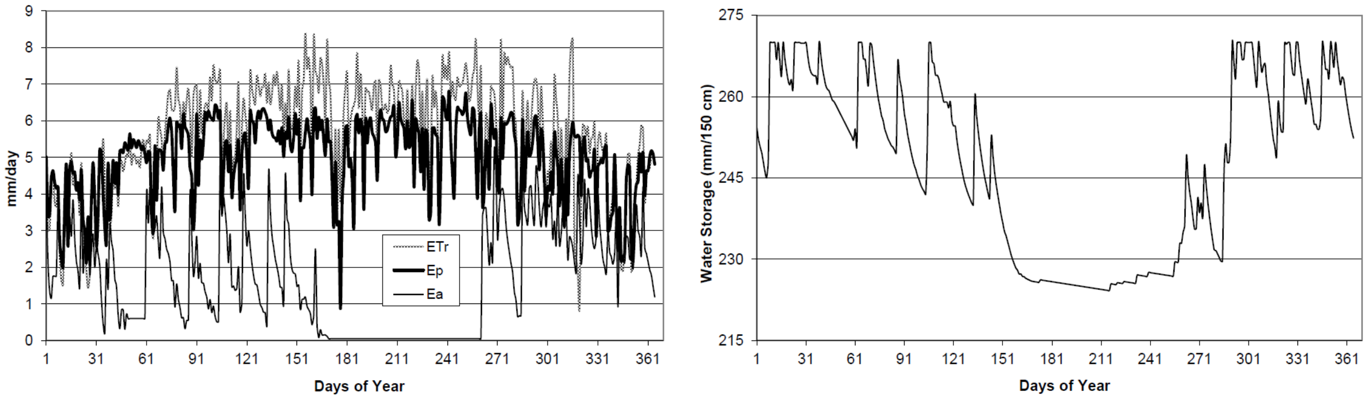

Figure 2– Comparison of reference evapotranspiration (ET_r), potential (E_p) and actual (E_a) soil evaporation, and water storage in the soil profile of 150 cm for Batticaloa in 1987.

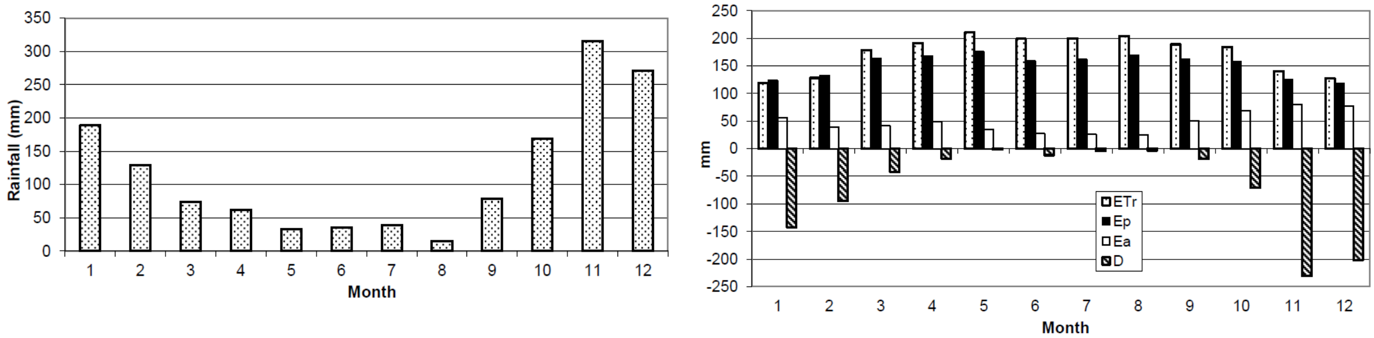

Figure 3– Monthly mean rainfall, reference evapotranspiration (ET_r), potential (E_p) and actual (E_a) evaporation from bare soil along with drainage below a soil depth of 150 cm over a period of 10 years starting from 1978 in Batticaloa.

In Batticaloa, the ET_r and E_p rates were higher during dry months from June to September because of the higher atmospheric evaporative demand. However, the E_a rates were mainly found to be a function of the amount and timing of rainfall, and presumably soil wetness in addition to atmospheric demand. In Puttalam, the daily ET_r, E_p, E_a, S and D pattern determined from simulations were different than those in Batticaloa (Figures 1, 2, 4 and 5).

During much of the rainy months, evaporation from bare soil was at or close to the potential rate. During a drying period, E_a began to decrease continuously. Similarly, during the dry months, with a dry layer at the soil surface, E_a rates were very low or zero (Figures 2 and 5). E_a outputs of the model were consistent with the results of Aydin (2008), Aydin et al. (2008) and Aydin and Kececioglu (2010). Soil water storage varied daily depending on the intensity and frequency of rainfall events and on evaporation rates. The water stored in the soil reached field capacity during the wet periods with lesser evaporative demand of the atmosphere. However, the water storage decreased continuously during the dry periods (Figures 2 and 5). When the soil became drier, water could not be supplied to the soil surface fast enough to meet the evaporative demand.

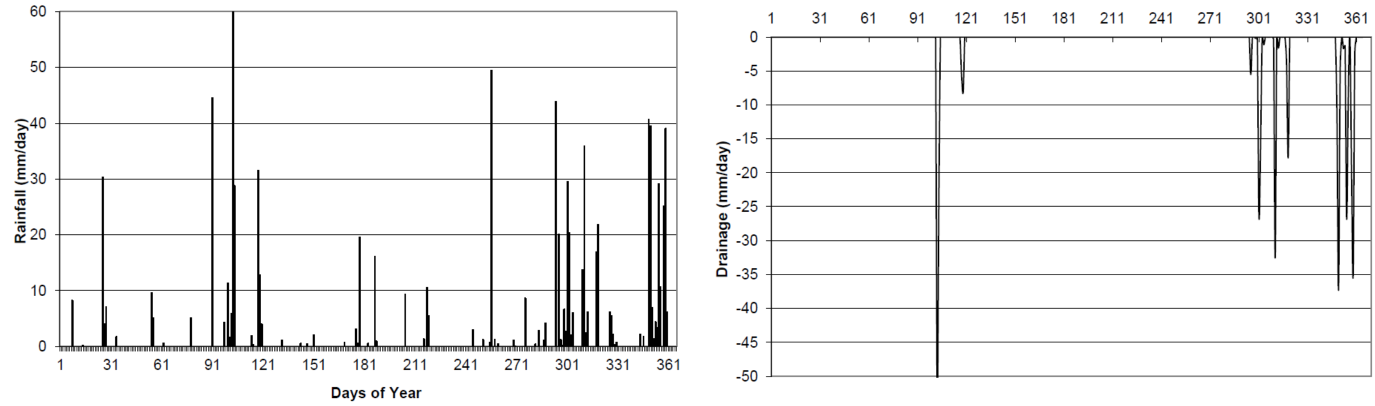

Figure 4– Drainage rates below a soil depth of 150 cm along with rainfall in Puttalam in 2007.

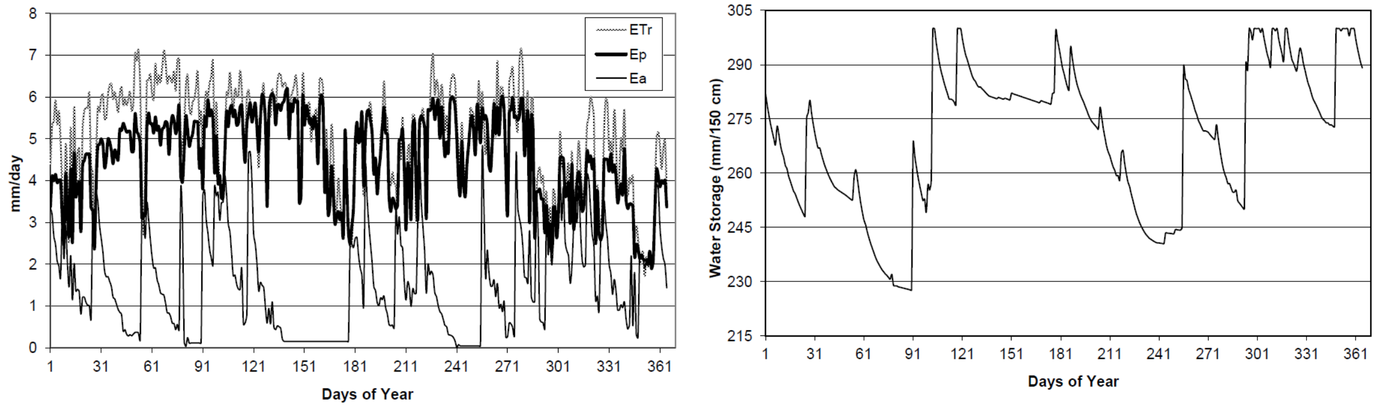

Figure 5– Comparison of reference evapotranspiration (ET_r), potential (E_p) and actual (E_a) soil evaporation, and water storage in the soil profile of 150 cm for Puttalam in 2007.

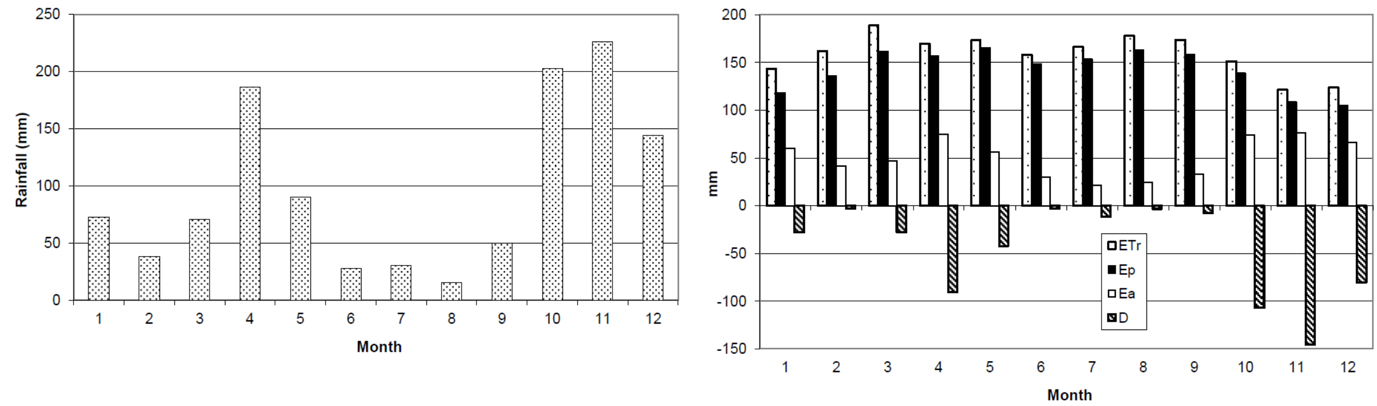

Figure 6– Monthly mean rainfall, reference evapotranspiration (ETr), potential (E_p) and actual (E_a) evaporation from bare soil along with drainage below a soil depth of 150 cm over a period of 10 years starting from 1998 in Puttalam.

As shown in Figures 3 and 6, the monthly rates of ET_r were overestimated when compared with those of E_p. Both potential rates represent the evaporative demand of the atmosphere and were higher during the dry months than the rainy ones. In contrast, E_a rates were very low in the dry periods and high in the wet months and depended on the rainfall pattern and soil wetness. In a warm climate with lesser precipitation, an increased evaporative demand of the atmosphere favours soil dryness. Drainage occurred during rainy months, with a peak in November in both locations (Figures 3 and 6). The results demonstrated that the D component should not be neglected when dealing with water conservation even in deep soils. Thus soil water storage should be facilitated by the management practices favouring soil moisture retention. These results may be instructive in terms of prevention of water losses through evaporation and drainage from bare soils and adoption of an effective management strategy for soil water, particularly, in rainfed-areas as reported by Aydin (2008).

During the wet periods when E_a was close to E_p, the fields should be kept cropped to increase beneficial use of soil water by crops, which would prevent water loss through evaporation from soil. Alternatively, adoption of such agronomic practices as retention of crop residues or formation of a natural layer of mulch on the soil surface by proper and timely tillage when evaporation rate is most rapid, can decrease the loss of soil water (Aydin et al., 2008).

Annual quantities of water balance components for 10 years are summarized in Table 2. Annual precipitation, reference evapotranspiration and potential soil evaporation had noticeable inter-annual variations. The Aridity index (P/ET_r) ranged from 0.371 to 1.194 with a mean value of 0.685 for Batticaloa (sub humid) and from 0.491 to 0.847 with a mean annual value of 0.606 for Puttalam (dry-sub humid). Actual evaporation from bare soil varied between 463.1 and 725.0 mm in Batticaloa and 543.6 and 646.3 mm in Puttalam. Drainage varied substantially inter-annually (321.7 to 1581.2 mm in Batticaloa and 346.7 to 957.0 mm in Puttalam) and depended on the intensity and frequency of rainfall events and especially soil water storage from the preceding dry periods. A similar trend in drainage was also reported by Eilers et al. (2007) and Aydin (2008). Puttalam showed comparatively lesser inter-annual variations in E_a and D, than Batticaloa due to mainly rainfall pattern.

Table 2. Annual quantities of water balance components in two locations of Sri Lanka over a period of 10 years

Year	Rainfall (mm)	Reference ET (mm)	Aridity Index	Potential soil evaporation (mm)	Actual soil evaporation (mm)	Drainage (mm)
Batticaloa						
1978	1242.8	1991.2	0.624	1741.1	648.9	603.4
1979	1888.9	2157.5	0.876	1927.4	589.0	1295.4
1980	789.9	2129.7	0.371	1898.0	463.1	321.7
1981	1015.9	2076.4	0.489	1841.9	501.7	525.9
1982	1299.1	2031.2	0.640	1804.3	490.2	807.4
1983	920.0	2116.2	0.435	1851.8	478.0	443.9
1984	2313.0	1937.4	1.194	1723.6	725.0	1581.2
1985	1632.3	2097.4	0.778	1749.1	630.4	1007.6
1986	1637.2	2095.7	0.781	1780.5	612.0	1026.0
1987	1358.9	2060.3	0.660	1823.1	618.3	746.6
Average	1409.8	2069.3	0.685	1814.1	575.7	835.9
Puttalam						
1998	1183.4	2018.0	0.586	1786.5	646.3	537.1
1999	965.5	1912.8	0.505	1744.9	617.2	365.4
2000	947.8	1868.8	0.507	1693.6	543.6	389.4
2001	945.3	1925.4	0.491	1757.7	598.6	353.3
2002	1584.9	1944.2	0.815	1740.2	637.6	957.0
2003	1280.0	1971.2	0.649	1744.3	620.8	663.0
2004	1219.9	1928.4	0.633	1709.7	638.5	569.7
2005	990.0	1879.1	0.527	1675.9	544.9	457.7
2006	1520.8	1796.2	0.847	1634.7	625.3	886.9
2007	918.3	1843.9	0.498	1657.4	567.7	346.7
Average	1155.6	1908.8	0.606	1714.5	604.1	552.6

Conclusions

The actual soil evaporation, as calculated by the model, accounted for 41 and 52% of the incoming precipitation in Batticaloa and Puttalam, respectively. Drainage occurred during rainy months, with a peak in November in both locations. Drainage should also not be neglected when dealing with water loss even in deep soils. In addition, the results of this study have demonstrated the need to quantify the components of soil water balance in other regions of Sri Lanka. Although the E-DiGOR model appeared to be useful, the model calibration and validation must be relied on measured events. Therefore, simulated quantities with the model should be interpreted cautiously. In further studies, the model outputs can be compared with field-based measurements, although physical credibility of the model is quite high since several earlier works have validated the model in a wide range of environments.

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