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Understanding evapotranspiration is key to lessening the climate change angst

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Opinion

First year undergraduate students in agricultural engineering are normally introduced into the discipline through a core unit which deals with fundamental concepts in agriculture and agro-meteorology. One important concept that they have to understand before proceeding to higher levels is about how much water plants need to survive in varying climatic and soil conditions. Accordingly, two terms relating to water movement and loss in the growing environment are commonly discussed. These are infiltration and evapotranspiration, respectively.

Infiltration is a term used to describe the movement of water into the soil. Different types of soils have different rates of infiltration. For instance sandy soils have faster infiltration rate than clay soils into which water movement is very slow. Infiltration on its own is less important if not connected to the water holding capacity of a particular soil. The water holding capacity is the maximum amount of moisture that the soil can hold without causing runoff. Knowledge of infiltration and water holding capacity gives an idea on how much and how long to irrigate in Figure 1.

Figure 1 Weather station, a key facility in Agricultural Engineering.

The water held in the soil is lost through evaporation, seepage, deep percolation and absorption by plant roots. The absorption by plant roots is made possible by the combination of osmotic pressure and capillarity caused by the evapotranspiration stream. Evapotranspiration in this case is the term applied to the loss of water by evaporation from the soil surface around the plant as well as the moisture movement from the leaves of the plants. The plants leaves have some free water on the surfaces as well as water which comes out through the stomatal openings. Evapotranspiration causes a suction force which enables the translocation of water and nutrients through the plant into the leaves.

Only a small fraction of the water absorbed by the plants is used in photosynthesis and biomass formation. A larger fraction of the water is lost through the process of transpiration from the leaves. Transpiration has a cooling effect on the plant and helps modify the microclimate around the plant (Figure 2). This is possible because during the transpiration process sensible heat energy is converted in latent heat of evaporation enabling the conversion of moisture from the leaves into water vapour (gas). The latent heat of vaporization of water is relatively high, making transpiration and evaporation (Figure 3) very effective in cooling the plants and their surroundings.

Figure 2 Fruit tree and vegetable irrigation based in evapotranspiration requirements.

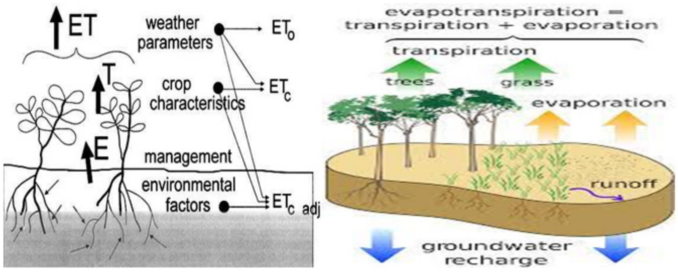

Figure 3 Evapotranspiration and translocation in plants.

Evaporation from a water or soil surface is driven by six main factors; wind speed, solar radiation, air humidity temperature, surface area and the salinity (to some extent). There are many empirical equations that have been developed to help determine the evaporation of water from an open surface, such as a dam or lake. Such equations are relatively straightforward compared to the equations used to estimate evapotranspiration from vegetated surfaces since the specific characteristics of a given vegetation will affect the transpiration rate in this case.

Different plants or crops have inherent different rates of evapotranspiration (Figure 4) because of difference in leaf size and geometry, size of the stomata, roughness of the leaves hence the aerodynamic resistance, as well as height above the ground. Additionally the rate of evapotranspiration will vary over time depending on the environmental and growth factors (wind speed, air humidity, temperature, leaf area and solar radiation intensity).

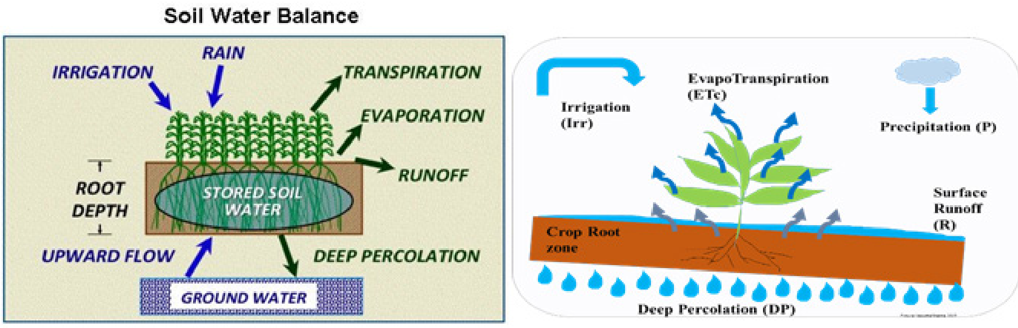

Figure 4 Evapotranspiration in the crop water budget.

The traditional method of determining evapotranspiration is the water balance in Figure 5 method on a lysimeter platform. However, models for estimating crop evapotranspiration have also been developed. The famous FAO Penman-Monteith equation has been developed to help estimate evapotranspiration for different crops growing in different climatic zones and at different growth stages. But note that there are hardly any models for predicting the water use for uncultivated plants. And there are hundreds of thousands of plant species in the world, apart from crops. Another approach, the eddy covariance method that has recently been used in predicting evapotranspiration in micro-meteorology still exhibits large deviations from the well-established measurement approaches.

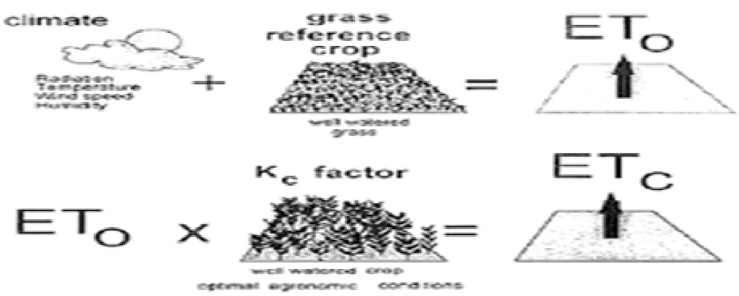

Figure 5 Determination of Reference Evapotranspiration and Crop Evapotranspiration (ETcrop).

The most accurate approach for scientific prediction of climate is based on the energy and mass balance method which is derived from the First Law of Thermodynamics. It is a process-based (mechanistic) approach that has evapotranspiration as one of the core inputs. This has severally been implemented in MATLAB/SIMULINK by many authors, in addition to other software platforms. When applied over a large control volume, the energy and mass balance approach suffers from inaccuracy due the prevalence of microclimatic (Figure 6) nodes within the volume. It has a scale and complexity limitation. Secondly, the evapotranspiration equations can hardly be applied to predict the atmospheric water budget because of the inherent differences between plants making the models prone to wide generalizations. Hence the contribution of evapotranspiration to climate, though very important, cannot be accurately predicted.

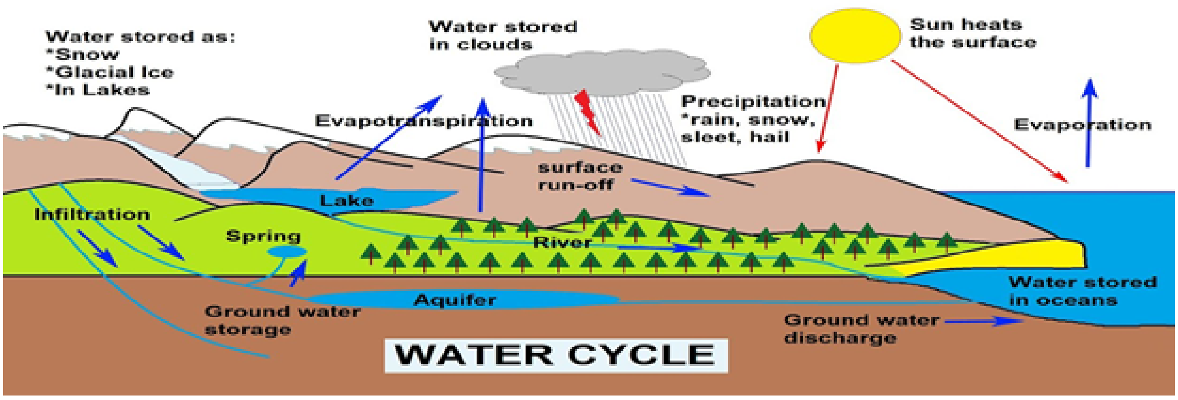

Figure 6 Conventional illustration of the water cycle

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So where does this leave the numerous scientific efforts aimed at understanding and predicting regional and global climate? Should such noble efforts be discarded? Do climate prediction scientists portend unnecessary angst? Well, I think micro-scale climate prediction such as for agricultural and human buildings is still sensible as it helps us mitigate and adapt to the consequences of natural and anthropogenic (human) effects on our habitats and ecosystems (Figure 7). Equally important are the prediction of effects of climate and land-use changes on catchment processes. However, long-term meso-scale (regional) predictions suffer a lot of inaccuracy despite consuming so much money and should be discarded.

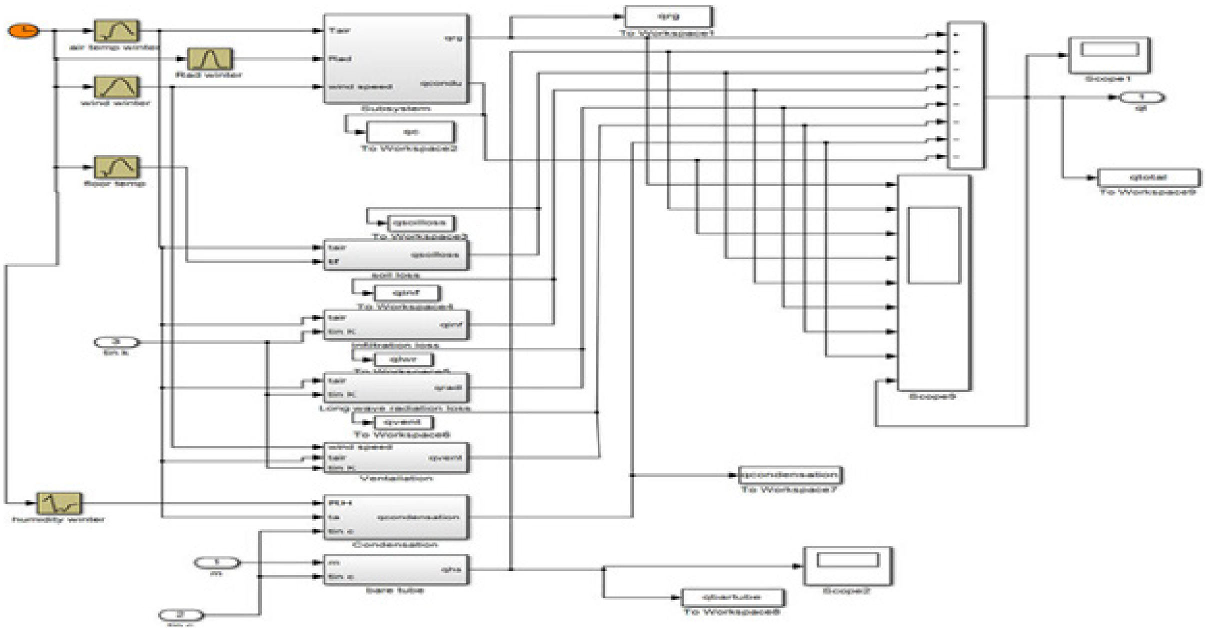

Figure 7 General schematic of mathematical modelling of a greenhouse using MATLAB/SIMULINK

Yet studying evapotranspiration and climate will always be important in national and international development. Activities aimed at improving or maintaining the micro-climate of a region such as afforestation, soil conservation, controlled stocking rates, land-use planning and erosion control are still important in mitigating risks. Equally we must also adapt to apparent changes through water-saving irrigation, greenhouse technology, flood control structures, water harvesting, minimum tillage, better plant varieties and other appropriate technologies.

There still exists a lot of unsubstantiated allegations about the effects of greenhouse gas emissions on current and future global climate. These claims are based on fairly sophisticated models for which evapotranspiration is a core input. These projections should not buffet us with too much angst because of their inability to accurately account for evapotranspiration, amongst other factors.

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Conflicts of interest

There are no conflicts of interest.

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