CACTUSNET
International Technical Co-operation Network on Cactus Pear

VIIth International Congress on Cactus Pear and Cochineal

Determination of Evapotranspiration and Crop Coefficient of Cactus Pear with an Energy Balance Technique

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Agadir, Morocco – October 17-22, 2010

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INTRODUCTION

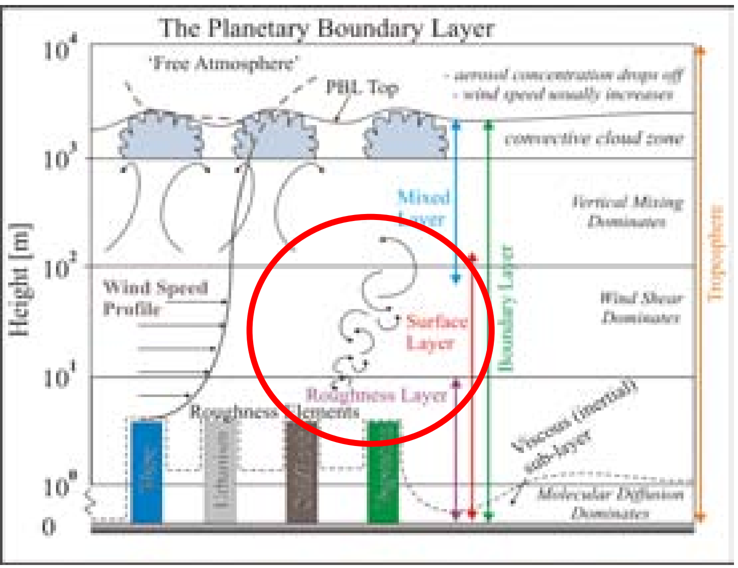
In the Mediterranean areas, cactus pear fruit development period coincides with long and dry summer

Because of the particular morphology and physiology of the species, there is little or no information, based on experimental data, concerning its water requirement and the irrigation scheduling, as related to fruit growth and quality.

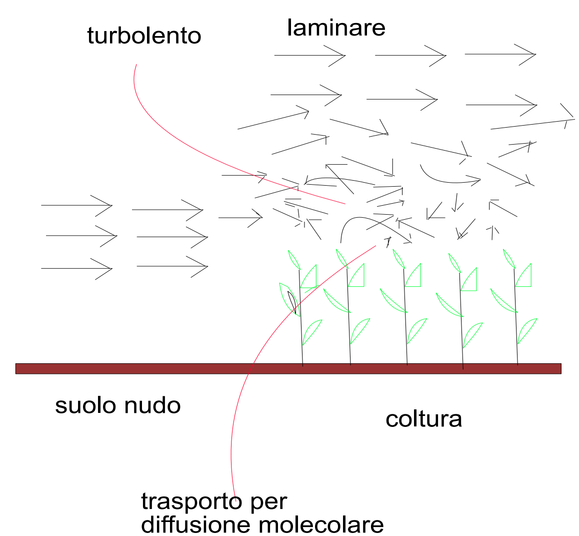
Objective: to evaluate the suitability of a micrometeorological technique to estimate the evapotranspirative fluxes of cactus pear orchard and determine its water use efficiency

INTRODUCTION

Micrometeorological techniques allow to detect the mass and energy exchanges within the soil-plant-atmosphere continuum



- The transport of H_2O, CO_2, CH_4, etc… from the vegetation to the atmosphere
- The dynamic of these processes is based on the **fluid mechanic principles**, allowing to determine for each temporal step, the position and temperature of all those molecules
- Permitting to model the **Evapotranspiration processes**



Above vegetation the fluxes are turbulent.

This condition is represented by "eddies", that driven mass and energy exchanges processes

STUDY CASE

The experiment was carried out over a a3.5 ha cactus pear, located in Western Sicily during 2009 irrigation season.

The cactus pear architecture consisted of mature plants, 4.0 m tall, with a mean estimated LAI orchard of 3 m^2 m^{-2} and PAR interception of 70%.

Trees were spaced 5 x 3 m apart.

The irrigation system included on-line labyrinth sprayers, in a number of 4 per plant, with discharge rate of 40 l/h at a pressure of 150 kPa.

$$R_N = G + H + LE$$

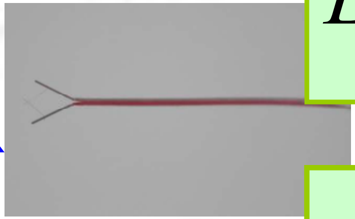
Net radiometer (6 meter)

Sonic anemometer (4.5 meter) : three wind components measurements; used for SR calibration

$$ET_a = \frac{LE}{\lambda}$$

Soil heat flux plates (buried at 5 cm)

Soil temperature thermocouples (buried at a depth of 4-1 cm)



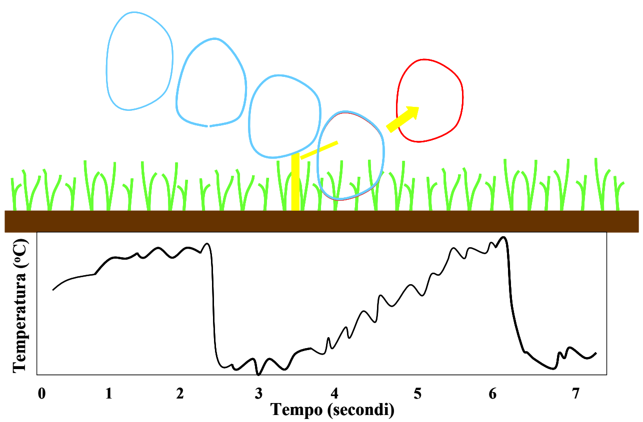
High frequency thermocouples (4 Hz, 4.5 m)

$$K_c = \frac{ET_a}{ET_o}$$

$$ET_0 = \frac{0.408\,\Delta\,(R_n - G) + \gamma \frac{C_n}{T + 273} u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + C_d\,u_2)}$$

SURFACE RENEWAL

High frequency air temperature measurements were collected at a fixed height (0.5 m) above the canopy top. Temperature traces show ramp-like pattern, characterized by an amplitude (a, °C) and a period (l+s, sec)



$$H = \alpha \cdot \rho \cdot C_p \left(\frac{a}{l+s} \right) \cdot z$$

SR equation for sensible heat flux

α: calibration factor embodying temperature variation below the sensor; z: measurement height; ρ: air density (g/m^3) e C_p: specific heat of dry air at constant pressure (J/g·K)

SURFACE RENEWAL

High frequency temperature data were processed in the datalogger to output **half-hourly means of the 2°, 3° and 5° order moment of the temperature differences**

$$S^{n}(r)=\frac{1}{m}\sum_{i=1}^{i=m-j}[T(i+j)-T(i)]^{n}$$

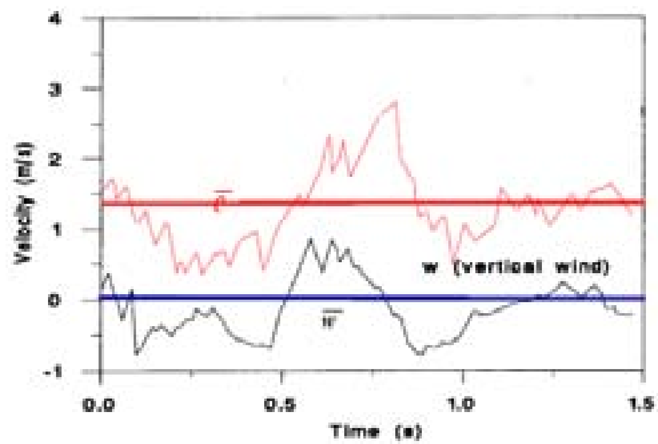
Moments were uploaded and analyzed to determine (a) and (l+s), using the Van Atta (1977) methodology

EDDY COVARIANCE

The **parameter** α of SR equation for H was determined by comparison of SR results with independently measured exchange rates by Eddy Covariance:

$$H = \alpha \cdot \rho \cdot C_p \left(\frac{a}{l+s} \right) \cdot z$$

$$H = \rho C_p \overline{\left(w'T' \right)}$$

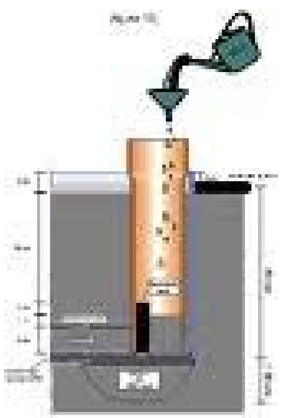


One sonic anemometer was installed at 4.5 meter (same height of the high frequency thermocouples) and then used to calibrate SR

Latent heat flux λE (o ET) was then determined as residual of the energy balance equation:

$$\lambda E = R_n - G - H$$

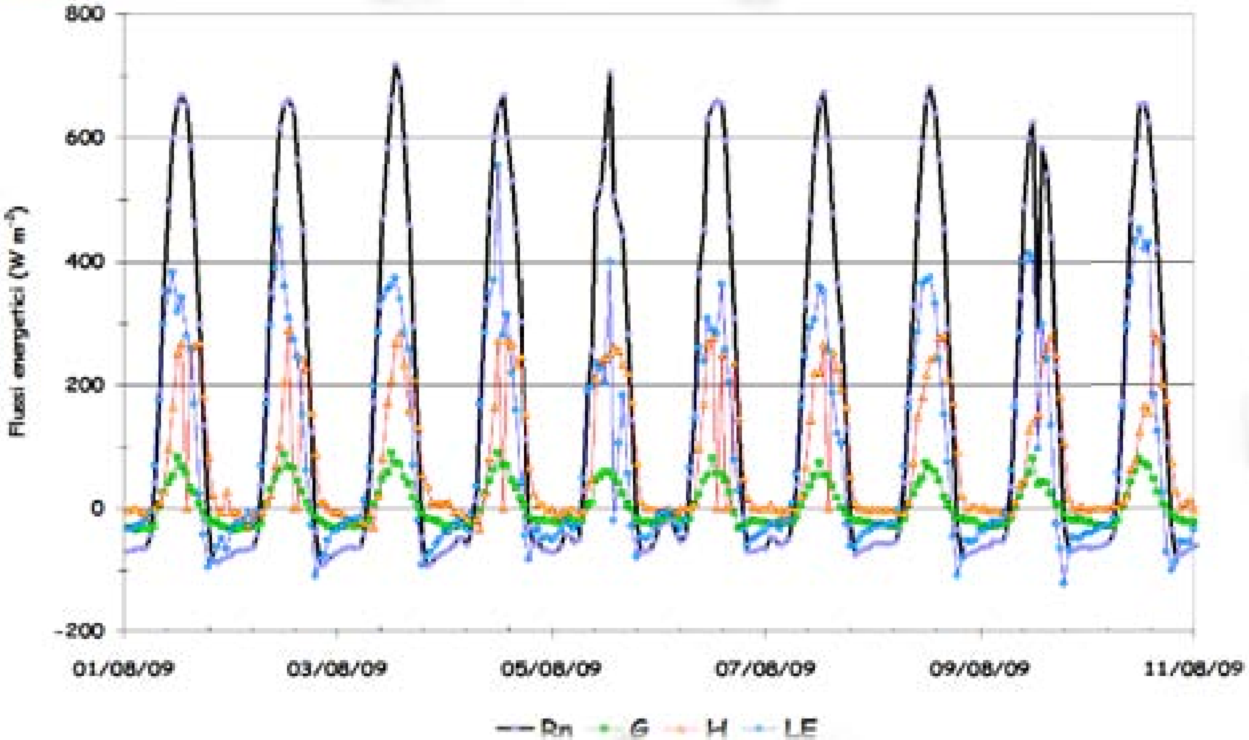
H from Surface Renewal



Microlysimeters have been built to determine soil evaporation (E_s) in the field under study. Small undisturbed soil samples were located in rings of limited height, which are closed at the bottom, weighted and reinstalled in the field

TDR probes were used to monitor the volumetric soil water content along a vertical profile 30 cm deep

RESULTS



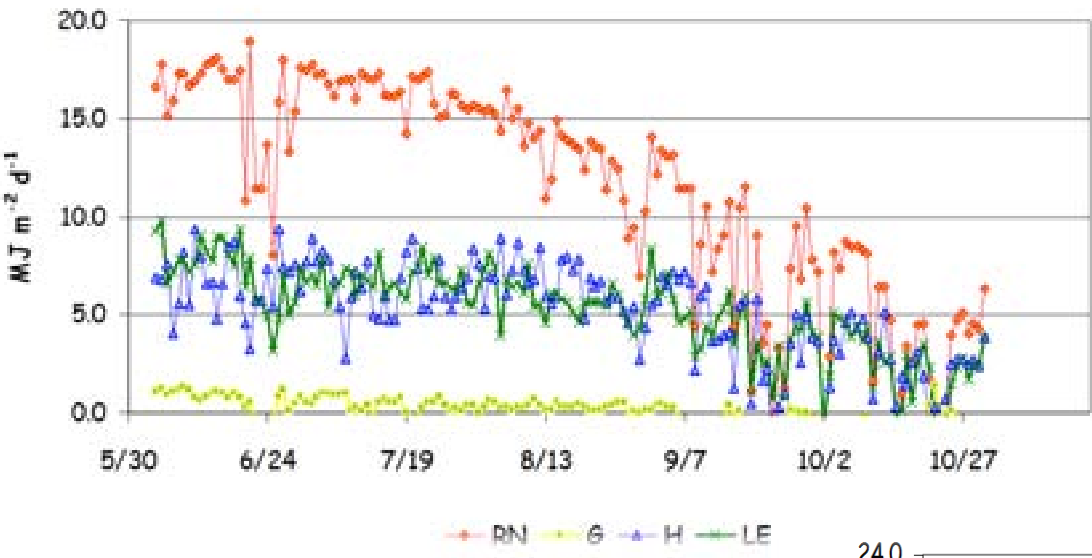
Hourly energy fluxes within the studied soil-plant-atmosphere continuum

$$EF = \frac{LE}{R_N - G} = 0.45$$

Daily mean energy fluxes and standard deviation

	RN (net radiation) ($MJ\ m^{-2}\ g^{-1}$)	G Heat soil flux) ($MJ\ m^{-2}\ g^{-1}$)	H Sesible heat= ($MJ\ m^{-2}\ g^{-1}$)	LE Latent heat) ($MJ\ m^{-2}\ g^{-1}$)
Mean	10.9	0.11	4.9	4.9
σ	5.7	0.58	2.5	2.4

RESULTS



Clay-loam soil, with 40% of water at field capacity

and mean hydraulic **permeability at saturation of 10^{-5} m s^{-1}**

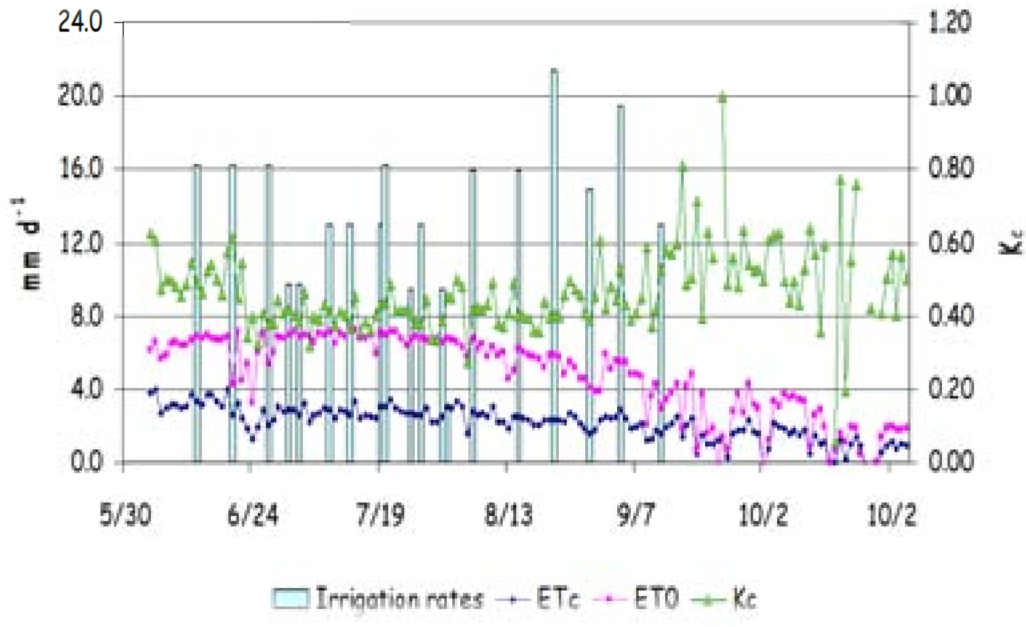
Mean values:

ET_0=4.7 mm/d

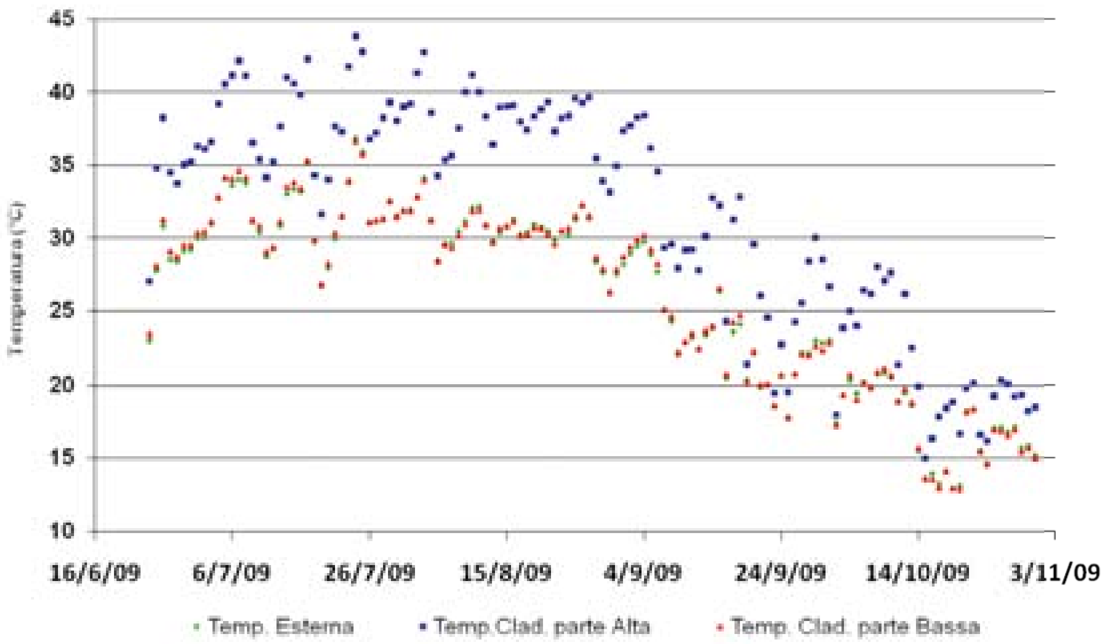
ET_c=2.1 mm/d

K_c=0.47

Irrigation rate corresponding to 2.3 mm/d



RESULTS



The monitored cladodes internal temperature follows the mean course of the estimated energy fluxes

Maximum temperature values reach about 40 °C

Soil evaporation, monitored during July-September period through microlysimeter technique, represents 25% of the total evapotranspired water

RESULTS

- During June-October 2009, the monitored cactus pear evapotranspited (ET_c) a total of 320 mm of water (variation of 40%);

- Reference ET (ET_0) by Penman-Monteith method reached 700 mm;

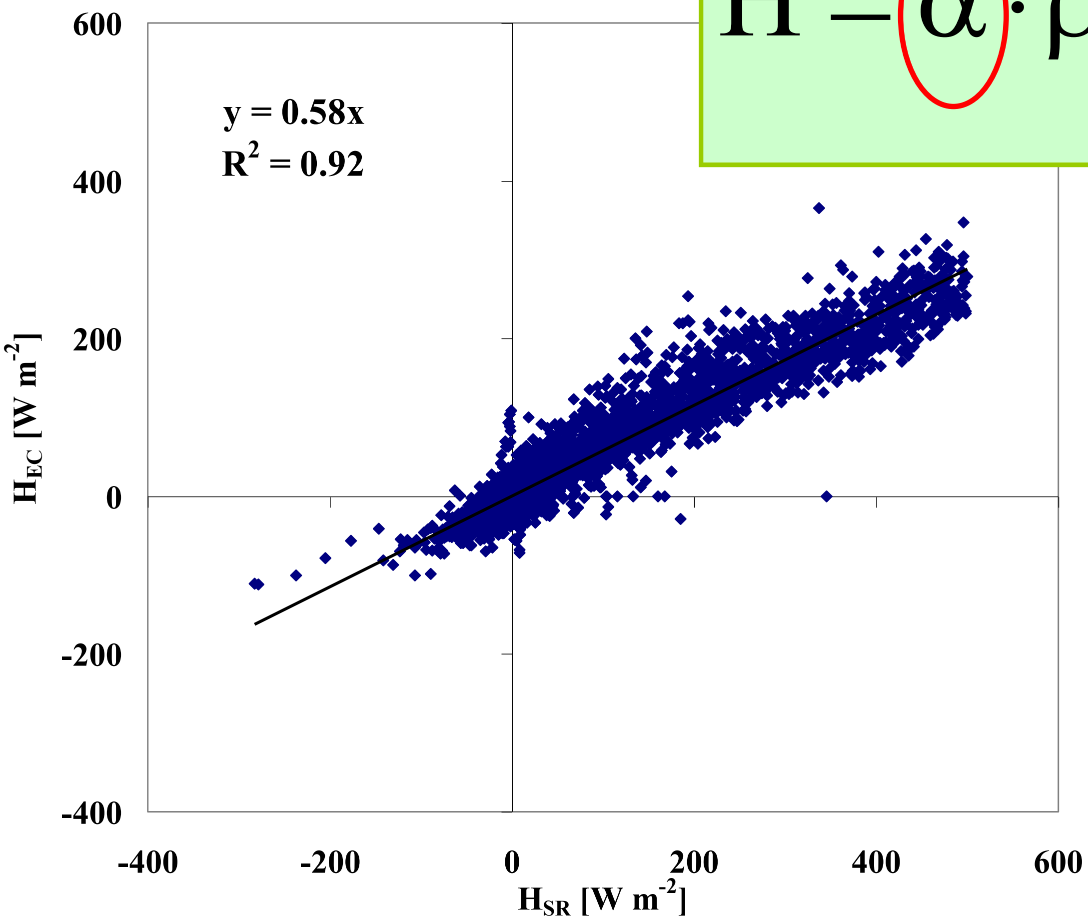
- Mean crop coefficient ($K_c=ET_c/ET_0$) values during the period was of 0.47 (variation of 10%);

- The analysis of LE values evidenced a night condensation process (negative LE values), due to the high relative humidity (RH, %) (dew point temperature);

- The **produced dry matter** was of 16,210 Kg ha^{-1}, with a corresponding **Water Use Efficiency** (WUE) of about 198.0 kg H_2O kg^{-1} of dry matter; results match well those obtained by Han e Felker, 1997 in *O. ellisiana*

RESULTS

$$H = \alpha \cdot \rho \cdot C_p \left(\frac{a}{1+s} \right) \cdot z$$



Eddy covariance H versus Surface Renewal H to determine the calibration coefficient α

$$\alpha = 0.58$$

FINAL REMARKS

- First results of the study evidenced the reliability of the **Surface Renewal – Energy Balance technique** to achieve fairly good estimates of Cactus Pear ET rates;

- Further developments of the study will be addressed to the **direct measurements of LE patters** (by using closed path gas analyzer) and to the analysis of dry matter storage processes accomplished with the definition of irrigation schedule parameters.