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Effect of Air Relative Humidity Harvest on Soil Moisture Content under Moroccan Climatic Conditions

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Abstract
In this work, we aim to analyse the effect of the harvest of air relative humidity on soil water content. Some experiments were conducted on hilly areas with various hypsographic and microclimatic conditions greatly affecting daily fluctuations of air relative humidity. The metrological data's were obtained by using a Campbell Scientific equipments station recorder on data loggers every half hour. Time Domain Reflectometers (TDR) is used for calculating water content at different soil layers. The effect of many parameters such as: minimal and maximal air atmospheric humidity, potential of soil water and minimal temperature of air on harvesting air relative humidity is also discussed. The experimental results indicate that soil moisture content in the upper soil layer fluctuates with the same manner to diurnal fluctuation of relative air humidity. These fluctuations due to the harvest of relative air humidity decreased with increasing soil depth and daily amplitude of relative air humidity. The water adsorbed according to this phenomenon increased with increasing maximal relative and decreasing minimal temperature. The contribution of this soil water collected is about 40% of losses due to evaporation process. The correlation between principal climatic data and soil water adsorption by harvest relative air humidity is presented in this paper in order to incorporate it in the total water balance during water infiltration.
Keywords - Harvest, relative air humidity, soil water content, water vapor adsorption, evaporation.

I. INTRODUCTION

In Mediterranean regions, the development of agriculture is strongly depending on climatic conditions and their economical and social situations are usually unstable. Controlling the consequences of the interaction between human and climatic activities in arid and semi-arid areas is very important and based on the understanding of different processes above all those that are determinant in the hydric balance. The objectives of reducing unbalances in water requirements vs water availability in most arid and semi-arid areas of the Mediterranean region, since by capturing atmospheric moisture a potential enhancement in water available to crops can be achieved without subtracting water to domestic and industrial uses, thus soothing social strains.

Finally, the major advantages of exploitation of atmospheric humidity are that it can be captured at zero cost and that a reduction in energy input can be obtained (no water lifting from deep wells, no pressurization are required) as well as the good quality of captured water. In conclusion, the study has such social, economical and environmental advantages. A review in literature indicates that two major's uses in collection of water vapour are dominated.

1. Water drink application

Most countries have been conducted some largest atmospheric humidity (i.e. fog) project in order to ensure the village water use. The principal application of fog collection was conducted by [1]. They propose as fog collector an apparatus constructed of sample and low cost materials available in all countries. The fog collector is a flat rectangular and arranged perpendicular to the direction of the prevailing wind. The surface collecting is made from nylon fine-mesh and at bottom of the panel a trough gutter collects the water droplets falling under gravity. The result indicates that 3 litres of water per day and that per square meter of collecting surface were obtained. For polypropylene mesh, the fog collector produces 3360 litters of water/day in the Sultanate of Oman over a period of two and a half years, [2].

2. Agricultural application

In this study we were interested to the atmospheric humidity harvest for agricultural uses. The existing systems for collection were the same in all Mediterranean regions. The importance of this study results on important contribution of harvest relative humidity for stopping desertification especially for our country. In last decade, an important support of works was developed by many institutions research. Generally, the soil is considered as a porous medium with capillaries of various sizes that helping the condensed water to infiltrate by capillarity, [3].

An intensive work was presented to enrich literature in this field. The authors attempt to approach and simulate the above described complicated phenomena of capillary condensation by using either fractal, [4]. Many approaches were conducted in order to simulate the transport condensable vapors in porous structures, [5] and [6].

By referring to [7], the authors have indicated that soil is considered as a porous medium with capillaries of various diameters. These capillaries condensed water to infiltrate by capillarity but in the same time in the capillaries occurs also condensation of water vapor depending on the air relative humidity. In this work, the authors tried out to qualify water vapor adsorption by soil by using weighing Lysimeters (WL) and Time Domain Reflectometers (TDR) for obtaining data under semi arid climatic conditions. The result shows that the soil moisture content in the upper soil layer fluctuates in correspondence with the diurnal fluctuations of the relative air humidity.

In more recent work, [8] have studied the parameters affecting water vapor adsorption by the soil under semi-arid climatic conditions. The authors indicate that under such climatic conditions, soil physical characteristics such as texture, surface mulching, and density of the growing plants greatly affect water vapor adsorption and soil water conservation. Also, they indicate that the process of water vapor adsorption by the sol appears to be more important for areas in which the geomorphological conditions and the proximity to the surface water, such as lakes or sea, favors high diurnal fluctuations in relative air humidity.

II. MATERIALS AND METHODS

1. Description of sites

In order to evaluate the importance of harvest relative air humidity effect on soil water content under different land characteristics, four sites (S1, S2 and S3) were chosen. All sites are characterized by intensive agricultural activities and the irrigation covered only 20% of the agricultural areas.

The sites of (S1 and S2) are located in Marrakech Tensift Alhaouz region. The sites (S1) and (S2) are respectively located about 60 and 20km from Marrakech city at an average elevation of 600m above see level. The relief of this region is characterized by a great diversity: the interior flats and plates that contain good arable lands; the old solid masses, the littoral plates and high mountains of the Atlas. The climates are warm and dry with relativity cold period during the winter. Precipitations are weak and irregular (in Marrakech 240 mm/year). The summery temperatures are very high (37.7°C at maximum) and the winter ones are low (4.9°C at minimum). The evaporation is important (2300mm/ year) and the rainfall is variable: 50% of the territory has an averaged-300 mm-rainfall per year and almost 30% has a rainfall ranging from 300 to 400mm per year (Toufliht station). We noticed that the averaged rainfalls increase from the North to the South. It's completely normal because the south is characterized by heights (High Mountains). Agriculture constitutes the principal activity for 60% of regional population. The principal productions are annual cultures (cereals, alfalfa, tobacco, etc…) and plantations of olive –trees, citrus fruits and fruit trees.

The site of (S3) is located in Doukkala region and about 40Km from ELJadida city. The soil is essentially dominated by Sand, Tirs and Hamri. The climate is of a Mediterranean type, semi-arid in winter with a soft temperature, and was generally hot and dry. It was characterised by an index irregularity and intra-annual. The annual average pluvial is about 317 to 592mm, registered in 40 and 60 days between October and April. The relative air humidity data indicate a dramatically variation between each month and between maximum and minimum values. The air temperature is moderate and its value varies between 10°C and 36°C. The existing vegetation in these areas is exclusively growing by occurring available rain and the water adsorbed by the soil from the atmosphere.

2. Man characteristics of the study soils

Table 1 show the principal characteristics of the soils considered in this study are presented as : the constitution of (S1 and S2) soils is dominated clay constitution (47% and 39%) and lemon (34% and 40%). However the constitution of (S3) is principally dominated by sand (52%) and lemon (34.5%). For This study, the relation-ships between soil water content and soil water potential, and between hydraulic conductivity and water content are given respectively by [9] and [10] formulas :

$$\frac{\theta}{\theta_s} = \left[1 + \left(\frac{\psi}{h_g}\right)^n\right]^{1-(2/n)} \quad \text{and} \quad K = K_s\left(\frac{\theta}{\theta_s}\right)^\eta \qquad (1)$$

Where: θs: maximal soil water content (%) ;
Ks : Hydraulic conductivity at saturation (m/s) ;
h_g : Hygrometric pressure (m) ;
n and η : Regression parameters of Equation (1).

Table 1. Main characteristics of the study soils.

Site	Clay (%)	Sand (%)	Lemon (%)	Ks (m/s)	hg (m)	n	η
(S1)	46	17.2	34.3	0.8×10^{-6}	-0.14	2.3	11
(S2)	39	19	40	0.9×10^{-6}	-0.13	2.2	10.7
(S3)	10	52.4	34.5	1.2×10^{-6}	-0.08	2.1	9.5

3. Climate data

The climatic forcing needed was averaged over a 30 min time step. Global radiation, atmospheric humidity, speed of wind, temperature (max and min) and rainfall were measured at the follow sites described above. In table 2, we present the results given by many meteorological stations placed at the studied sites for ten years in term of average annual relative air humidity, air temperature, evaporation and wind speed. The result indicates that the average annual relative air humidity varies from 58 to 85%. The average annual air temperature (T) varies from 11°C for coastal site (S3) to 21°C to mountainous site (S2). The wind speeds indicate that all locations are favourable to harvest of relative air humidity because the average values of WS were situated from 1.8 to 3.4m/s. The average total evaporation is very important for all study sites especially for interior region.

Table 2. Main climatic data calculated for ten years.

Study site	Average humidity %	Temperature °C	Total evaporation mm	Wind speed m/s
S1	64	19.2	2383	2.2
S2	58	21	1804	2.0
S3	85	11	1410	3.4

The results presented in Figure 1 shows a very important daily variation of relative air humidity for (S1) during the period of end December 2003 to May 2004. These high undulations were favourable to harvesting of relative air humidity by the soil especially in dry period.

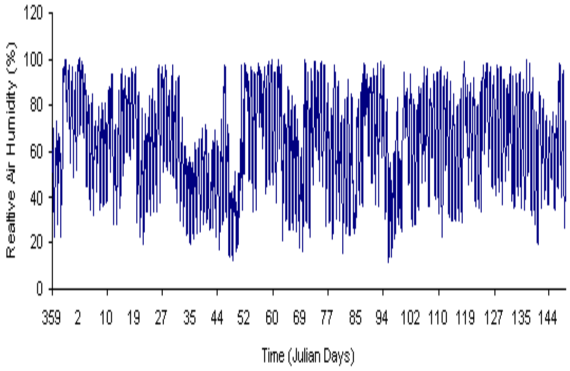


Figure 1. Variation of relative air humidity for the site of S1 during end December 2003 to May 2004.

Figure 2 indicate that soil temperature calculated at different depth varies between 3 (hiver) to 30°C (spring) for all section. The soil temperature varies with the agreement of relative air humidity variation depending on soil characteristics, climatic conditions, soil surface conditions and rainfall. The result shows that the values of soil temperature for Z=5cm are higher than Z=10cm and 20cm values because the climatic conditions were an important effect on the upper layers of soil. In the period situated between 20th to 30th Julian days, we assist to a decreasing soil temperature due to rainfall.

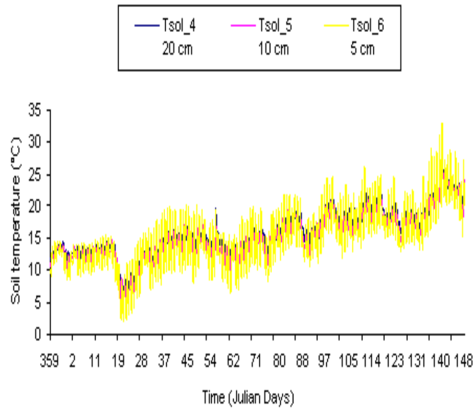


Figure 2. Variation of soil temperature at different depth for the site of S1 during end December 2003 to May 2004.

4. Determination of soil water potential

In order to calculate the water potential (ψ) corresponding to a given air relative humidity, we use the equation given by [11]:

$$\psi = \frac{RT}{M} \ln\left(\frac{RH}{100}\right) \quad (2)$$

Where: R is the gas constant ($8.31 J\ mol^{-1} K^{-1}$) ; T is the temperature (K) and M is the partial molar mass of water ($0.018 kg\ mol^{-1}$). By referring to [12] work, when soil suction varies between 0 and 100 bars, the vapour pressure changes only by 1.6 mbar. This variation induces automatically some variation in temperature profiles in soil especially at 5cm depth that fluctuating between 8 and 25°C, [7].

In Table 3, we present the monthly variation of soil water potential maximum ψ_{max} and minimum ψ_{min} with reel data for the (S1) site. The results indicate that the amplitude of the difference of RH_{max}- RH_{min} is very important and varies during January to December from 75 to 88%. This amplitude is very important that when air and soil temperatures are weak, the harvesting water by soil becomes very important. These variations are also an important effect on soil water potential. This potential varies between diurnal and nocturne period for July from 21.3kPa to 331.3kPa. In diurnal period, the evaporation increases and the stress become important, so, the vegetation grows only by using irrigation or rainfall. However, in nocturne period, the phenomenon of soil water adsorption becomes important that can assure the part of water need for vegetation. The result indicates that both air temperature and relative air humidity have an important effect on soil water potential and root extraction, and illustrates that the function ψmin (RH_{max}) has the same variation of annual temperature T_{max} because the maximum is shown during June to August month and the minimum values of ψ_{min} are detected from November to February. The variation of ψ_{min} passes from 1.3kPa observed in January to 21.3kPa observed in July. For ψmax (RH_{min}) function, the maximum is shown in July and the minimum is detected in January. The value of soil water potential passes from 228 to 331.3kPa. These variations between maximum and minimum value of soil water potential are responsible on soil water adsorption phenomenon. This behaviour is shown in the soil water content variation especially for the first depth of soil. The showing undulations observed in the experimental data for soil water content between night and diurnal period explain this comportment because in diurnal time the evaporation and transpiration rate are equal zero. So, the soil water adsorption is considered as an important parameter that must be considered in the balance of soil water and in control of water storage process.

Table 3. Calculation of ψmin and ψmax of (S1).

Month	RH_{max}- RH_{min} *(%)*	ψ_{min} (bars)	ψ_{max} (bars)
January	82.4	1.3	228
February	88.2	1.4	250
March	85.7	2.1	292.5
April	85.2	2.7	223.9
May	80.4	4.8	296.4
June	81	12.2	312.1
July	75.5	21.3	331.3
August	74.7	15.2	297.3
September	78.7	9.9	260.8
October	78.3	3.5	215.4
November	79.5	1.6	207.7
December	78.7	1.8	200.6

III. MEASUREMENT OF SOIL MOISTURE CONTENT

In each site, five Time Domain Reflectometers (TDR) (Campbell Scientific, type CS615), were installed in order to measure the volumetric soil moisture content at different soil depths. The probe of each reflectometer was installed horizontally into the soil to detect the passing of wetting fronts. The reflectometers were calibrated by taking measurement at several knows water content by using theta probe equipment and gravimetric methods. The soil moisture was registered on a data logger at half hourly intervals. The volumetric soil water content was measured using a third degree polynomial equation, [13]. In this paper we present only the data relative to volumetric soil water content for (S1) and (S3).

In Figure 3a, we present the change in volumetric soil moisture content at the depths of 5, 10 and 70cm for (S1) soils. In the same figure we present the rainfall and water irrigation rates applied during the experimental period in order to evaluate their effect on soil moisture content distribution. The result indicates that soil moisture content measured by the TDR electrodes showed an important diurnal fluctuation, analogue to the air relative humidity fluctuations. For all data, the amplitude of diurnal fluctuations of the volumetric soil moisture content becomes very important for first soil depths situated between 5 cm to 20 cm. This is confirmed by the result obtained in term of the measured soil moisture content at TDR 70cm. The result shows weak amplitude variations in term of soil water content when depth is more than 25 cm. These undulations observed in the first depths were disappeared for TDR 70cm because the climate conditions have a negligible effect on variations of soil moisture content at this depth.

As shown in Figure 3a, the soil moisture content increase quickly for all depths and we assist on very important amplitude of the observed undulations especially for the first depths when the water irrigation is applied. The diurnal change in soil moisture content phenomenon is a result from the water adsorbed by harvesting relative air humidity. These fluctuations depend on many factors as soil constitutions, crops occupation, climate conditions (temperature and air relative humidity and initial soil humidity).

In Figure 3b, we present the variation of soil water content during end December 2003 to May 2004 for TDR 5, 10 and 20cm. The result shows increasing undulations of soil water content for the first depth especially when irrigation or rainfall is applied. These undulations become weak when the depth of soil is higher than Z=20 cm. By comparing the results presented in Figures 3a and 3b, the effect of climatic conditions is evident. The amount water by rainfall or irrigation has a very important effect on the undulations amplitude.

For this period, the harvest water is observed only on the upper layers Z≤25cm. While in (S3), this phenomenon is more pronounced and it is observed for the profound layers Z≤40cm. This is due to the soil characteristics and the climatic conditions, (Fig. 3c). It is also mentioned that in this year (2005) the amount water by rainfall is very weak and the harvest water is only observed in the humid period but in dry period the phenomenon is totally absent.

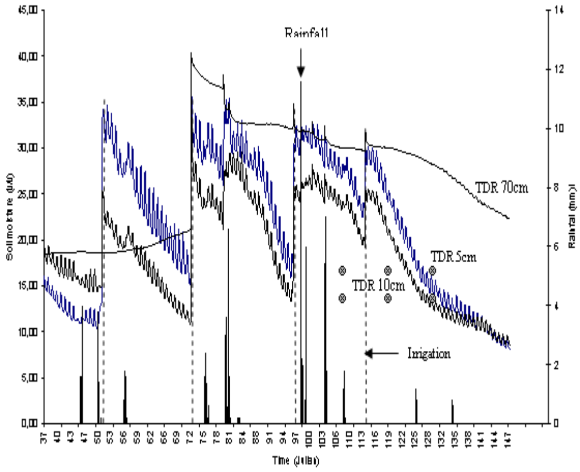


Figure 3a. Changes in soil water moisture content with time due to Irrigation, Rainfall and Harvest of Relative air Humidity at TDR 5cm, TDR 10cm and TDR 70cm depths under various climatic conditions (February 2003 to May 2003) for (S1) site.

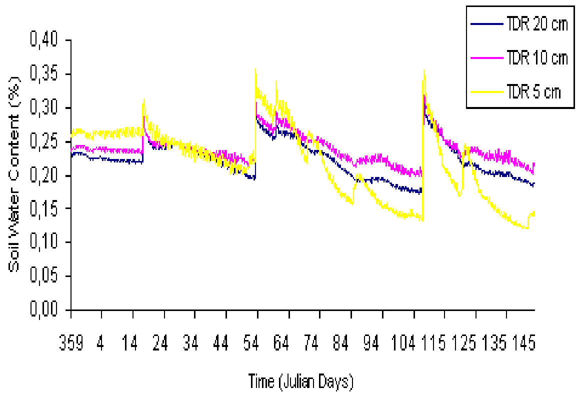


Figure 3b. Changes in soil water moisture content with time due to Irrigation, Rainfall and Harvest of Relative Air Humidity at TDR 5cm, TDR 10cm and TDR 20cm depths under various climatic conditions (end December 2003 to May 2004) for (S1) site.

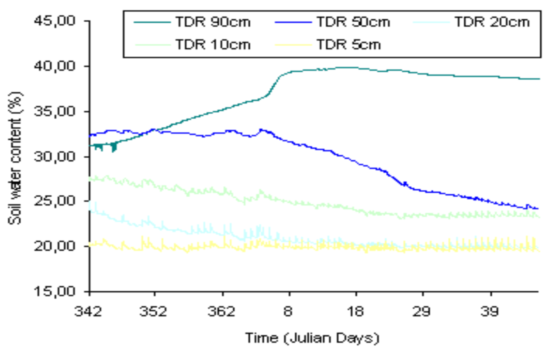


Figure 3c. Changes in soil water moisture content with time due to Rainfall and Harvest of Relative Air Humidity at TDR 5, 10, 20, 50, 90 cm depths under various climatic conditions (December 2004 to February 2005) for (S3) site.

In Figure 4, we presented the observed undulations of soil water moisture content with time due to water vapour adsorption at TDR 5cm, TDR 10cm and TDR 20cm depths under various climatic conditions (February 2003 to March 2003) for (S1). A supplied water of irrigation at 51st Julian day is also shown in order to explain the rapid increases of soil moisture content at different depths. The moisture increases about 150, 120 and 80 respectively for Z=5, 10 and 20cm of depths. Undulations variations were reached for all depths (especially for 5 and 10cm) after and toward irrigation. In this period, the applied water by rainfall has a reduced effect on the changes in soil water content because its intensity is very weak and the redistribution of water with time is realised slowly.

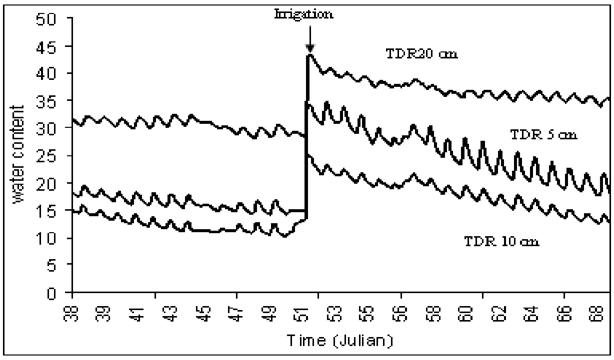


Figure 4. Observed undulations of soil water moisture content with time at TDR 5cm, TDR 10cm and TDR 20cm depths under various climatic conditions (February 2003 to March 2003) for (S1) site. The effect irrigation is also presented.

IV. CALCULATION OF SOIL WATER ADSORBED (WG) AND SOIL WATER LOSSES (WL)

The soil water captured by harvesting relative air humidity (WG) and the soil water lost by evaporation (WL) for each soil layer are calculated by using the differences between maximal and minimal volumetric water moisture content occurred at night for each section of soil and multiplied by the section of soil Z (in mm) as demonstrated in the following expressions:

$$WG = (\theta^{j}_{max} - \theta^{j}_{min}).Z \qquad (3)$$

$$WL = (\theta^{j}_{max} - \theta^{j+1}_{min}).Z \qquad (4)$$

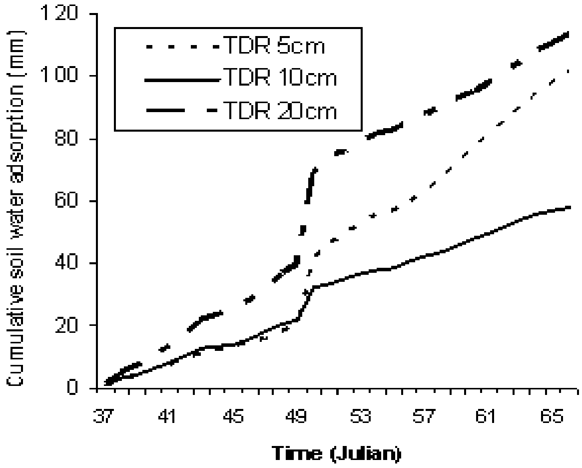
Where (j+1) is the following Julian day.

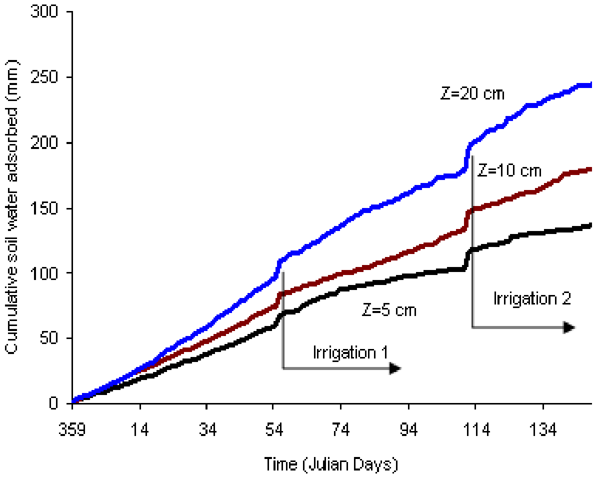
The result shows that WL is greater than WG for all days and all layers excepted when irrigation are rainfall is applied. WG increases when irrigation or rainfall is applied and fluctuated as the same variation of air relative humidity. However, WL is a decreasing function with humid period. For the 121th day, the harvest atmosphere humidity contribution in water movement decreases with depth. This contribution is about 56.5, 10.8 and 6.4% respectively for Z=5, 10 and 20cm. The total water adsorbed by soil is 8.27, 10.3 and 5.06mm respectively for Z=5, 10 and 20cm. The total water losses in this period are 13.8, 19.3 and 26.5mm respectively for Z=5, 10 and 20cm. The contribution of harvest of relative air humidity in water balance is about 60, 53 and 19% respectively for Z=5, 10 and 20cm. These results indicate that in each time, the contribution of soil water adsorbed by harvesting relative air humidity can replace the losses quantities by evaporation and root extraction. These results were observed at 130th Julian day when RHmax (92%) was very important and Tmin was very weak (about 8°C). This phenomenon can explain the growing of agriculture in arid climate without irrigation.

1. Irrigation effect on cumulative soil water adsorption (CWG)

In order to explain the contribution of soil water adsorption in total soil water movement, we present the variation of cumulative soil water adsorption, CWA, with time for all soil depth. The result indicates that CWA is an increasing function of time for the studied depths. The maximum of cumulative soil water adsorption is observed when Z varies from Z=0 to 10cm. When Z≥20cm the soil water adsorption is a decreasing function of depth. These decreases are due to the reduced of amplitude of undulation of soil moisture content. The effect of water irrigation on cumulative soil water adsorption is clearly shown by the following curves presented in Figure 5a and 5b respectively for (S1) and (S3). The results indicated that when water irrigation is applied, the curves corresponding to cumulative water content increase rapidly especially for the first soil layers (Fig. 5a). This increases is very important for Z=20cm because the majority of water applied by irrigation affect considerably the global distribution of moisture content profiles especially for the profound section of soil. The result shows two tendencies of cumulative soil water adsorption. The first behaviour indicates the same tendency of increases in CWG and weak differences between the corresponding values of CWG for all depth when water irrigation isn't applied. The second behaviour indicates the visible effect of irrigation on tendency and values of CWG. The differences become very important between the studied depths. When water irrigation is applied, the increases observed in term of CWG at 49^{th} day are 25, 15 and 30mm respectively for Z=5, 10 and 20cm that indicated an inverse sense of variation that is shown in Fig. 5. The same phenomenon increased after a rainfall event and become significantly high especially during 3 or 4 day after a rainfall. The amount water by rainfall has a weak effect on cumulative soil water adsorption (Figure 5b).

a)





b)

Figure 5. Effect of water irrigation on variation with time of cumulative soil water adsorption by harvest or relative air humidity, a) site (1) and b) site (S3).

2. Effect of climate on harvest of relative air humidity

In order to evaluate the effect of climate conditions on harvest of relative air humidity, we present in Table 3 the amount of water adsorbed by the upper 10cm soil layer in (S1, S2 and S3) sites for the period of May. The result indicates that this amount was important ranging from 24.8 to 31.7 mm. In this period, the average maximum relative air humidity is ranged from 87.6 to 95.5%, while the average minimum humidity is ranged from 38.5 to 65.4%. These high daily fluctuations favour the formation of a high vapour pressure gradient from the atmosphere to the soil that responsible of soil water adsorption, [8]. Air at a relative air humidity (RH) of 98.2% which is a maximum measured value in the study areas during the night and air temperature T=293K will be in equilibrium with soil at a water potential of about 2.5 bars (Equation (2)). Air at a RH of 37.1% which is an average minimum value for the study areas during day time and air temperature T=308K, the water potential will be 140.5 bars. As stated a change in matric suction between 0 to 100 bars is accompanied by vapour pressure change of only 1.6mbar, [12]. Under such conditions soil air is nearly vapour saturated at almost all times and water vapour adsorption is limited. The diurnal amplitude of soil temperature measured at 5cm soil depth fluctuated between 6.5 to 27°C depending on time of the year, soil characteristics and soil surface conditions. Under such climatic conditions, the soil surface layers become very dry allowing the water to be adsorbed by the soil during night time.

Table 3. Effect of climate conditions on relative air humidity harvest.

Site	R (mm)	RH_{max} (%)	RH_{min} (%)	CWL (mm)	CWG (mm)
S1	56.8	90.1	37.1	163	25.2
S2	50.8	87.6	38.5	185	24.8
S3	86.5	98.2	63.4	135	31.7

In this period, the amount of rainfall in this period is ranged from 50.8 to 86.5mm, while the total evaporation is ranged from 135 to 185mm. According to this result, the amount of water adsorbed by soil might be of the great importance for the soil water balance under the existing climatic conditions of the study areas. As Table 3 shows, the amount of cumulative soil water absorbed during May by harvesting relative air humidity satisfies a great portion of cumulative soil water losses by total evaporation root extraction. Soil water 13 to 23% of the total evaporated water was recovered by CWG under the existing climatic conditions of the study site. In total soil water balance, the amount of both rainfall and CWG measured during the study period varies between 40% for the dry site to 87% for the humid site.

V.EFFECT OF RELATIVE AIR HUMIDITY AND SOIL WATER POTENTIAL

Figure 6 shows the effect of relative air humidity on the absorbed soil water which is calculated for Site (S3) during January and February 2004. The results shown in this figure indicate that water adsorbed by soil according to harvest air relative humidity increased as the daily fluctuation in relative air humidity (measured at the difference between maximum and minimum daily values) increased for the soil potential lower than 320KPa. The soil water adsorption WG was inversely and proportionally related to the minimum value of relative humidity. This is because when humidity is decreased, the potential of soil is higher and the soil becomes dry and the adsorption phenomenon is also important. The following linear relations were found to predict the water harvested by the study soil of (S3) as a function of the minimum daily relative humidity (RH_{min}, %) and the daily amplitude of relative humidity (RH_{max}-RH_{min}, %) of the upper 5cm soil layer :

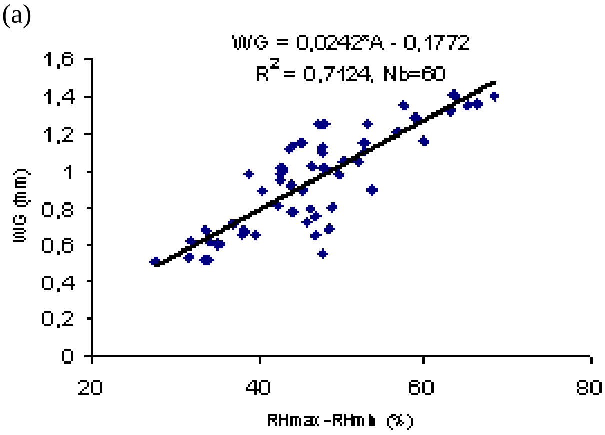
$$WG = a \times (RH_{max} - RH_{min}) + b \quad (5)$$

$$WG = a \times RH_{min} + b \quad (6)$$

$$WG = a \times (h)^b \quad (7)$$

As shown in figure 6, the above empirical equations adopted are satisfactorily for describing the soil water adsorption by harvest of relative air humidity soil for all depths considered in this study. The correlation coefficient varies between R=0.78 to 0.92 under the existing climatic conditions.

(a)



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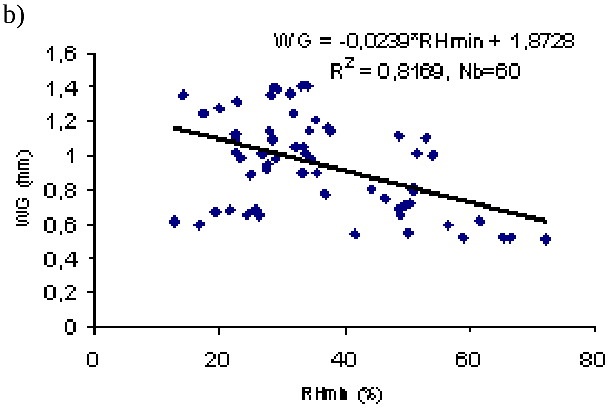

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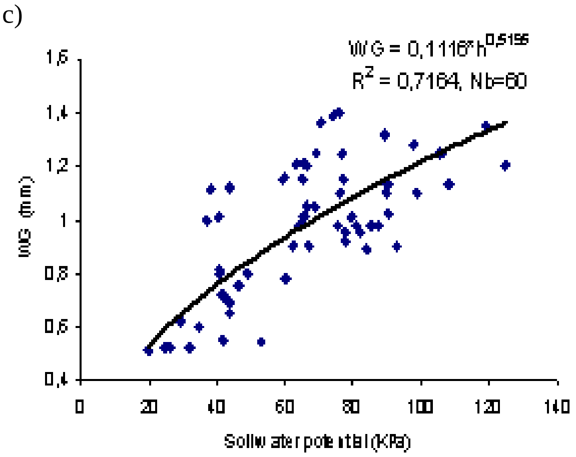

Figure 6. Relation between soil water adsorbed by harvest relative air humidity and a) daily amplitude of relative air humidity (RHmax-RHmin, %), b) minimum air humidity (RHmin, %) and soil water potential (h, KPa). Z=5cm.

VI. CORRELATION OF WATER ADSORPTION WITH CLIMATIC DATA

The finding result shows that water adsorption by soil increased as the daily function of the daily fluctuations in relative air humidity (RH_{max}-RH_{min}) and increased with increased of soil water potential (h_{soil}). The daily fluctuations in minimum air humidity have an inverse effect on soil water adsorption by harvest of air relative humidity. The amount of water vapor adsorbed by the soil could replace about 20-25% of water lost by evaporation during dry periods under arid or semi arid climatic conditions. This contribution is about 30-45% in coastal region when the phenomenon is important and covers a large period of year, [8]. This contribution of water adsorption is very important to take it in the total balance of moving water in soil- vegetation - atmosphere system. In order to take it, we propose a correlation of soil water adsorption WG as a multiple linear relation with minimal air relative humidity RH_{min}, daily amplitude of air relative humidity (RH_{max}-RH_{min}) and soil water potential h_{soil} (KPa). The proposed correlation equation is given by the following equation and in Table 4, we present the correlation coefficient.

$$WG = a + b \times RH_{min} + c \times (RH_{ma} - RH_{min}) + d \times h_{soil} \qquad (8)$$

Table 4. Parameter for the proposed correlation.

depth	a	b	c	d	R
Z=5cm	1.36	-0.003	0.0014	0.211	0.78
Z=10cm	0.316	-0.016	0.0019	-0.27	0.74
Z=15cm	0.137	-0.019	0.0003	-0.33	0.76

VII. VII. CONCLUSION

In this paper we have study the effect of many important parameters on humidity harvesting such: maximal and minimal air relative humidity, the soil potential of water, the average temperature of air and we have present some correlation laws. Also, we have noted that the state of soil has an important effect on humidity harvesting, because when the soil is humid, the soil temperature decreases and the condensation becomes more important than a dry soil.

We have presented some new results in order to estimate the real contribution of harvesting humidity in the total water balance. These results concern the period of April 2005 to February 2006. Evapotranspiration ET has been estimated and it is demonstrated that for such climatic We have presented some new results in order to estimate the real contribution of harvesting humidity in the total water balance. These results concern the period of April 2005 to February 2006. Evapotranspiration ET has been estimated and it is demonstrated that for such climatic conditions and soil characteristics, water captured from air relative humidity contribute about 30% of the total water balance.

The results obtained by meteorological station, time domain reflectometers and theta Probe indicate that soil water content is greatly affected by the harvest of relative air humidity. Four sites were selected with different climatic data and various soil characteristics. The Experimental data obtained by time domain reflectometers indicate that soil moisture content in the upper soil layer fluctuates with the same manner to diurnal fluctuation of relative air humidity. These fluctuations due to water vapour adsorption decreased with increasing soil depth and daily amplitude of air relative humidity. The contribution of water adsorption is considered important that must be introduced in the soil water balance. Its contribution is about 50% of losses due to evaporation (and root extraction) process. The applied water irrigation has a strongly effect of cumulative soil water adsorption because the values of CWG becomes important for Z=20cm and disappear completely when Z≥30 cm. The water adsorbed by harvest of relative air humidity contributes to the soil a significant amount of water which may positively affect the water needed of vegetation. It is demonstrated that:

1. RH_{min} has an inversely effect on harvesting of relative humidity by the soils. When RHmin increases, the soil water adsorbed by harvest relative air humidity is scientifically reduced ;
2. The variation of amplitude between maximal and minimal daily of relative air humidity, A=(RH_{max}-RH_{min}), has an important effect on soil water adsorption. WG is an increasing function with A ;

3. When soil water potential increases, the capitation of water by soil according to the relative air humidity harvesting increases. This increase becomes very important when the soil is dry and the soil potential is higher ;
4. When the proportion of sandy and lemon increase, the soil water adsorption phenomenon becomes important especially for the first layers and its also observed for the profound layers.

The present study includes some environmental considerations such as:

1. Developing the non-irrigated crops in arid regions contributes to stop the progress of desertification especially for the south countries of Mediterranean basin. In these regions the water resources are very weak and growing crops is done only by rainfall (about 100-150mm/year) and the humidity capture can contribute positively to regulate a fraction of the water balance ;
2. The use of water captured from air relative humidity in other regions (example, Agadir, Elwalidia, Lâarach, Chaouia and Doukkala) contributes to preserve water resources and the quality of soil ;
3. The collection of fog water and the harvest of air relative humidity by forests constitute an important support of research in order to preserve the ecology system especially in the arid regions.

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