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Weather monitoring setup and analysis of air, soil and leaf parameters

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Abstract. The paper presents an extended set of weather related parameters that started to be continuously monitored in order to allow the evaluation of the local potential of renewable energies and also their impact on the fruits growing process. A complex web based monitoring system, including wireless weather stations and soil & leaf stations, was designed and realised in order to create a useful database of many parameters. The paper presents some correlations that were highlighted between air soil and leaf parameters. The first results obtained, are encouraging and justify extended analysis.

Keywords: monitoring, weather station, soil station, web interface, fruits

INTRODUCTION

Different weather parameters are of highest importance in agriculture as well as in energy applications (Caprio and Quamme 1999; Gil *et all* 2002; (Menzel 2003; Roujou de Boubee *et all* 2000; Szalay *et all* 2006; Stover and Greene 2005; Warmund *et all* 2008). Growth estimation of plants, considering different weather parameters is presented in (Mandal 2007); the humidity of the soil, resulting from irrigation and its influences is presented in (Jerapat and Siriphanich 2008), some influences of the rain are approached in (Ortega *et all* 2007), different thermodynamic effects, such as evapotranspiration and evaporative cooling, are presented in (Jaber *et all* 2007; Iglesias *et all* 2007). Energy applications of the weather monitoring continues previous researches of some authors of the paper, presented in (Balan *et all* 2008; Balan *et all* 2009).

At the Technical University of Cluj-Napoca, it was designed and it was recently made available a complex monitoring system, with a double purpose. It had to provide useful data on one side to evaluate the real potential of local renewable energies resources and on other side to evaluate the weather influence on trees and fruits growing process. The system was designed in a flexible configuration, with many measuring points allowing future extensions. In each measuring point, a lot of weather and soil parameters should be monitored, thus the system was based on pairs of wireless weather stations with soil & leaf stations. Because of the large number of data that had to be acquired and because of the long term operating time planned, it was chosen a storing data system on a web server.

The data measured by the sensors located on each station are transferred to the console and stored into the data logger with a baud rate of one record at each minute. The data are transferred from the data logger into a file on the local PC, using dedicated software, once at each hour. It means that 60 records are normally copied to the PC at each transfer. From the local PC, the data are transferred through internet, on the web database, using original software, developed at the Technical University of Cluj-Napoca. The web transfer is realized once at each hour.

Each weather station is of Vantage Pro2 wireless type and is measuring the following parameters: barometric pressure; outside temperature; relative humidity; rainfall; solar radiation; ultra violet radiation index; ultra violet radiation dose; wind direction; wind speed. The station is also calculating the following set of parameters: dew point; rain rate; evapotranspiration; heat index; temperature humidity sun wind index; wind chill.

Each soil & leaf station is providing the following parameters: leaf wetness (two measurement points); soil moisture (four measurement points); soil temperature (four measurement points).

The actual monitoring system include two measuring points, one located at the University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca, and one located in a small agricultural farm in Reghin. The location of the two measuring points is indicated on Figure 1.

Figure 1. Location of the measuring points (from Google Earth)
Cluj-Napoca (N: 46° 45' 35''; E: 23° 34' 19''); Reghin (N: 46° 46' 12''; E: 24° 41' 28'')

The on-field setup and its first results on monitoring weather conditions in two locations (Cluj-Napoca and Reghin on Figure 1) are the subject of the paper.

MATERIALS AND METHODS

The Figure 2 presents the on-filed setup of the weather station in the two locations (Cluj-Napoca and Reghin). Monitoring system created a regional coverage as following:

- 31.03.2009 installation and start of monitoring for the first weather station at the University of Agricultural Sciences and Veterinary Medicine (UASVM) from Cluj-Napoca (Latitude N 46° 45' 35''; Longitude: E 23° 34' 19'');
- 30.04.2009 installation and start of monitoring for soil temperatures and moistures with the first soil & leaf station at the UASVM Cluj-Napoca;
- 2.05.2009 installation and start of monitoring for leaf wetness with the first soil & leaf station at the UASVM Cluj-Napoca;
- 16.06.2009 installation and start of monitoring for the second weather station at Reghin (Latitude N 46° 46' 12''; Longitude: E 24° 41' 28'');
- 17.06.2009 installation and start of monitoring for leaf wetness with the second soil & leaf station at Reghin.
- 6…12.05.2009 data were lost because of communication problems between data logger and local PC at UASVM Cluj-Napoca.

In order to analyse and extract significant data from the database tables, it was realised a web interface that allow to extract the date/time and any measured parameter for each available measurement location. Following information are related with the experimental setup of the system:

- The sensors of the weather station are placed at about 2.5m over the ground at Cluj-Napoca and at about 1.5m over the ground at Reghin.

÷ The weather station and the soil & leaf stations are placed at about 100m distance and at about 20m altitude at Cluj-Napoca and near each other at Reghin.
÷ The soil moisture and soil temperature are mounted in pairs, as can be see in figures 6 and 7, at the following depth: 0.18m, 0.4m, 0.89m and 2m. These sensors are already mounted only at Cluj-Napoca, but will be mounted following the same scheme at Reghin.
÷ The leafs sensors are placed one at about 1m and the second at about 2m over the ground at Cluj-Napoca and at both at about 0.5m over the soil at Reghin.
÷ At Cluj-Napoca the weather station is placed on a hill, into an orchard with different types of trees, at height distance of any building.
÷ At Reghin the weather station is placed in a small agricultural farm and one small familial house is in the vicinity. From this reason the station will be mounted higher, at about 2.5m.

Following relations were investigated:

÷ Between the outside temperature and the temperature of the soil at different depth;
÷ Between leafs wetness, rain, outside temperature, outside dew point and outside relative humidity.

Figure 2. Experimental setup
a: Wireless weather station, Cluj-Napoca; b: Wireless soil & leaf station, Cluj-Napoca;
c: Leaf sensor, Cluj-Napoca; d: Moisture and soil temperature sensors (Cluj-Napoca);
e: "d:" before mounting; f: Weather and soil & leaf stations, Reghin

From the outside and soil temperatures point of view, the amplitude of the temperature oscillations will be analysed together with the moment when maximums are reached.

From the leaf wetness point of view, it can be determined by two possible events, rain and dew.

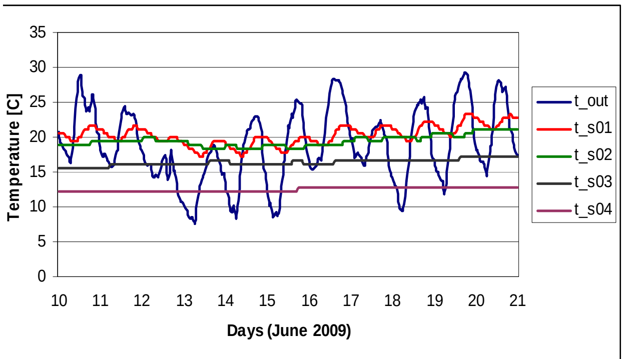
Because there are two reasons for which leafs can become wet, it will be checked that the weather station recorded a rain fall or if the outside temperature became equal with the dew point temperature. The saturation of the air determined by the raise of temperature in the vicinity of the dew point is also indicated by the value of the outside relative humidity, which become closer to 100% in this case. It means that the outside relative humidity recorded by the weather station will be also checked. In conclusion, if rain fall is recorded by the weather station, it means that the leafs become wet due to this event, but if the weather station don't indicate any rain fall and the outside temperature become closer to the dew point temperature, it means that the leafs became wet because of reaching the dew point.

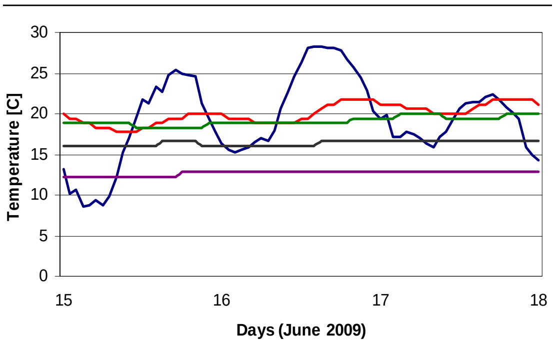
In all the analyses were used data recorded with a time step of one hour, which allow to correctly presenting the trend of the data variation.

The sensibility of rain fall measurement is of 0.2mm so rain quantities lower than 0.2kg=200g/m^2, are not registered. This fact may allow low rain to not be recorded by the weather station.

RESULTS AND DISCUSSION

Figure 3 presents the evolution of the outside temperature and the soil temperatures, recorded by the station of Cluj-Napoca, in the period of 10…20.06.2009. Expanding the period from day 15 to day 18 from Figure 3, the temperature variations are as in Figure 4. The plots from Figures 3 and 4 are represented using the temperatures values recorded with a time step of one hour.





t_out: outside; t_s01, t_s02, t_s03, t_s04: soil (at 0.18, 0.4, 0.89 and 2m depth respectively)

Figure 3. Outside and soil temperatures (Cluj-Napoca: 10-20.06.2009)

Figure 4. Outside and soil temperatures (Cluj-Napoca: 15-17.06.2009)

Results given in Figure 3 allows following remarks:

÷ In the soil, the amplitude of the temperatures variations are lower than the outside temperature variation;
÷ In soil the maximums of the temperature variations are reached later than the maximums of the outside temperatures;
÷ At the depth of 0.89m in the soil, the temperatures variations are very low;
÷ At the depth of 2m in the soil, the temperature is almost constant.

In the period of 10…20.06.2009 the following ranges of temperatures variations were recorded: For the outside temperature (7.6…29.2)°C; For soil at the depth of 0.18m (17.2…23.3)°C; For soil at the depth of 0.40m (18.3…21.1)°C; For soil at the depth of 0.89m (15.6…17.2)°C; For soil at the depth of 2.00m (12.2…12.8)°C.

In the period of 15…17.06.2009 the values of daily maximal and minimal temperatures recorded outside, at the depth of 0.18m and at the depth of 0.40m, together with the recording moments, are presented in Table 1.

Table 1. Daily maximal and minimal temperatures (Cluj-Napoca: 15-17.06.2009)

Measurement point	Day	Min. (°C)	Time (h, from 0 to 24)	Max. (°C)	Time (h, from 0 to 24)
Outside	15.06	8.6	4; 6	25.4	17
Soil at 0.18m depth		17.8	8…10	20.0	19…24
Soil at 0.40m depth		19.9	11…21	18.3	0…10; 22…23
Outside	16.06	15.3	2	28.3	14
Soil at 0.18m depth		18.9	5…11	21.7	18…24
Soil at 0.40m depth		18.9	0…19	19.4	20…24
Outside	17.06	15.9	8	22.4	17
Soil at 0.18m depth		20.0	8…13	21.7	17…22
Soil at 0.40m depth		19.4	0…2; 10…18	20.0	3…17

During 12…20.06.2007 was identified 13 periods with wetness on leafs, represented in Table 2. As supplementary data, were represented graphs of t_dif (temperature difference between outside temperature and dew point temperature) and rh (relative humidity).

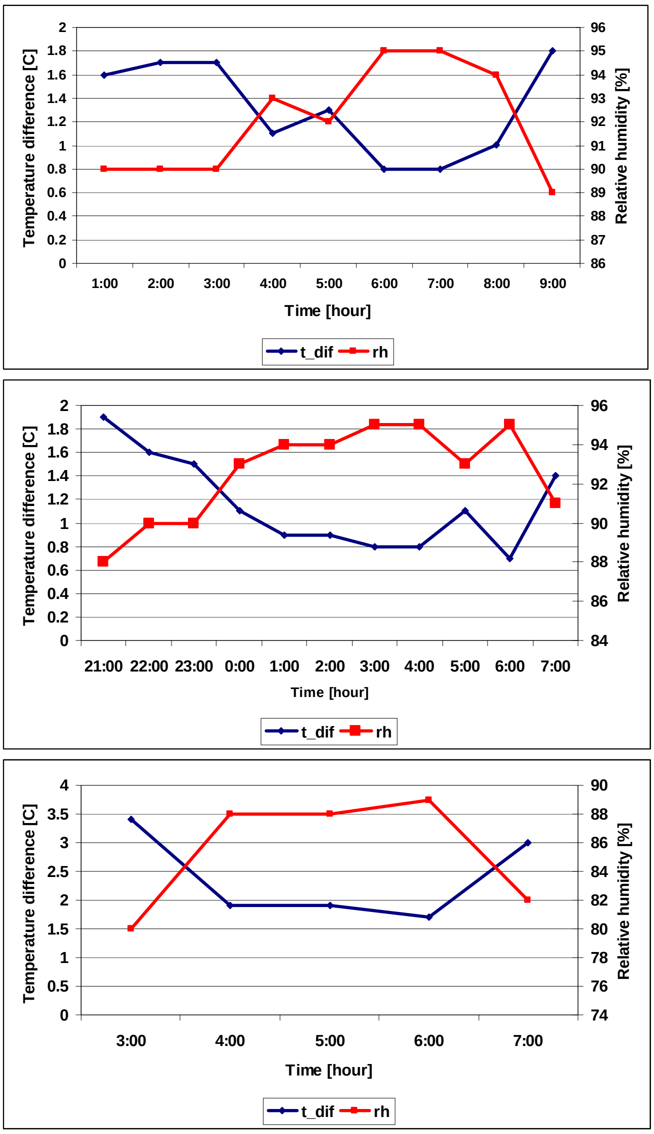
Table 2. Periods with wet leafs (Cluj-Napoca: 10-20.06.2009)

Days; Hours	lw1 lw2	Rain fall	Supplementary information
10.06.09 14	15 15	Yes	Wetness between: 13:48…14:25; Outside temperature different than the dew point
11.06.09 1… 9	1…15 1…15	No	See Figure 5a; t_dif = (0.8…1.8)°C; rh = (89…95)%; Outside temperature closed to the dew point; Very height relative humidity; Long period of time
11.06.09 16	1…9 1…9	No	Low wetness between: 16:11…16:22; *Light rain*
12.06.09 01…09	0…14 0…13	Yes	Rain fall recorded by weather station; Intermittent wetness between: 01:00…09:00
12.06.09 14…15	14…15 12…14	No	Wetness variable between: 13:45…15:20; Outside temperature different than the dew point; Relative low relative humidity; *Light rain*
12…13.06.09 21…07	15 11…15	No	See Figure 5b; t_dif = (0.7…1.9)°C; rh = (88…95)%; Outside temperature closed to the dew point; Very height relative humidity; Long period of time
16.06.09 2	0…1 0…1	No	Wetness very low between: 1:25…2:30; Outside temperature different than the dew point; Relative low relative humidity; *Light rain*
16.06.09 5	0…15	No	Wetness variable between: 4:17…5:07; Outside temperature different than the dew point; Relative low relative humidity; *Light rain*
17.06.09 1…7	0…15 0…15	Yes	*Rain fall recorded by weather station*
18.06.09 3…7	0…15 0…15	No	See Figure 5c; t_dif = (1.7…3.4)°C; rh = (80…89)%; Outside temperature closed to the dew point; Height relative humidity; Long period of time
19.06.09 2…6	1…3 1…3	No	Low wetness variable; Outside temperature different than the dew point; Relative low relative humidity; *Some drops of rain*
20.06.09 3…6	1…2 1…2	No	Low wetness variable; Outside temperature different than the dew point; Relative low relative humidity; *Some drops of rain*
20.06.09 19…24	15 15	Yes	Constant height wetness; Outside temperature different than the dew point; Relative low relative humidity; *Rain fall recorded by weather station*

Results given in Table 1 allows following remarks:

÷ Between the daily maxim temperatures for the outside and soil at 0.18m depth, it is a delay of 4…7 hours. This delay can be explained by the difference between the specific heats of air and soil. The same delay exists between the daily minim temperatures in the two measurement points.

÷ For the soil temperature at 0.40m depth, the temperature variation doesn't present anymore a daily variation, and the temperature differences becomes low (1.6°C in 15.06; 0.5°C in 16.06 and 0.6°C in 17.06).



Cluj-Napoca: 11.06.2009

Cluj-Napoca: 12-13.06.2009

Cluj-Napoca: 18.06.2009

Figure 5. Difference between outside and dew temperatures and relative humidity

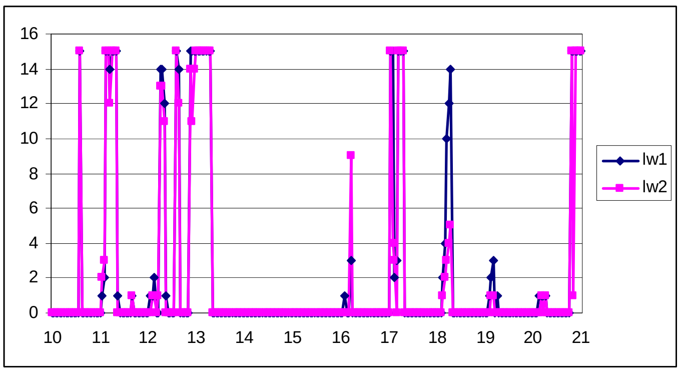


Figure 6. Wetness variation at leafs (Cluj-Napoca: 10-20.06.2009)

The second main analysis was dedicated to the identification of the leaf wetness source (rain or dew point). The wetness variation on the two leafs sensors mounted in Cluj-Napoca (lw1 at 1m and lw2 at 2m over the ground), is presented in Figure 6. The two curves on Figure 6 are drawn using the values recorded with a time step of one hour. The values of the leaf wetness are recorded into the range of 0 (completely dry) to 15 (completely wet).

CONCLUSIONS

Using a complex regional web based data acquisition system, it was possible to establish some correlations between the weather related parameters, recorded by wireless weather station and wireless soil & leaf station. The data acquisition system consists of two pairs of stations placed in two different Romanian cities. One measurement point in completely equipped with sensors and the other one is in testing, some sensors (soil moisture and soil temperature) steel needed to be added.

The results presented in the paper are provided by the completely equipped measuring point located at the University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca.

By comparing and correlating the recorded values and moments for the outside temperature and for the soil at different depth, the following conclusion was extracted:

÷ In the soil, the amplitude of the temperatures variations are lower than the outside temperature variation;
÷ In soil the maximums of the temperature variations are reached later than the maximums of the outside temperatures;
÷ At the depth of 0.89m in the soil, the temperatures variations are very low;
÷ At the depth of 2m in the soil, the temperature is almost constant.
÷ Between the daily maxim temperatures for the outside and soil at 0.18m depth, it is a delay of 4…7 hours. The same delay exists between the daily minim temperatures in the two measurement points.
÷ For the soil temperature at 0.40m depth, the temperature variation doesn't present anymore a daily variation, and the temperature differences becomes very low (0.5…1.6) °C.

By analysing the leaf wetness, rain fall records, outside temperature, dew point temperature and relative humidity, it was possible to establish the nature of the wetness from the leafs: rain or dew.

The obtained results are encouraging and justify the extension of the monitoring system and also the approach of different types of analysis.

The authors are planning to cooperate with the University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca, in order to establish also correlations between the weather related parameters and the trees and fruits growing process.

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