STRATEGIC IRRIGATION PRACTICES FOR IMPROVING WATER USE EFFICIENCY IN TURF

The mandate of the Atlantic Turfgrass Research Foundation (ATRF) is to work as a non-profit organization for the advancement of the turf industry in Atlantic Canada. Research specific to our region is lacking. Turfgrass-specific research is the underlying factor for a successful and sustainable turfed area. It is through unbiased and sound research that maintenance problems are avoided and advanced technologies are developed for this dynamic industry.

The goal of this project involved current irrigation practices for turfgrass managers in Nova Scotia. The project was divided into two components: Evaluating Current Irrigation Practices and Field Evaluation for Estimating the Crop Factor for Turfgrass.

COMPONENT I:
EVALUATING CURRENT IRRIGATION PRACTICES

As part of the ATRF mandate research is part of the way, we support the turfgrass industry locally. A survey of Turfgrass managers was undertaken to collect information in regards to irrigation and its management as well as the irrigation infrastructure currently in place in the Atlantic region as a whole. This provided a better overview of what the irrigation needs and uses are for turfgrass managers in Eastern Canada From these results the ATRF could come up with a strategy for irrigation and any future areas of research that the ATRF should pay attention to.

The survey was mailed out in the summer of 2007 with a deadline for return of October 1st. It was set up with two main parts: Water Demand, Sources, & Use, and Irrigation System Infrastructure. A total of 159 surveys were sent out, of this number 32 were returned completed. This gives us a representative sample of 20%; this is within acceptable ranges for a representational cross section of the industry in the Atlantic region. It should be noted for all calculated values that the highest and lowest value were not included as to give a more representational value of response.

The survey was sent out to Sod Producers, Turf Managers and Golf Course Superintendents. The response rate was greatest from the golf side; the sod producer's response rate was very low. The survey was sent to 168 total participants, 9 surveys came back undeliverable, so we had a potential 159 responses. A total of 32 completed responses came back, and of these only 3 came back from sod producers and none were completed. So for these reasons we have omitted the sod producer's responses in this final report. Attached following the Survey Summary are the corresponding graphs for the key data received.

It should be noted that results of this survey were presented at the Atlantic Turfgrass Conference & Trade Show, March 18 2008 in Halifax, NS. The response to this survey was extremely positive. Prior to this survey, there had not been any of this data available within the turfgrass industry in not only Atlantic Canada but also across the country.

PART I WATER DEMAND, SOURCES, & USE

Of the responses received 78% were Class “A” Managers, with an average of 21 years service in the turfgrass industry. These professionals stated that they were responsible for maintaining an average acreage of 17.9 ha (44.3 acres) of irrigated turfgrass with a yearly consumption of 30,240,000 L (8 Million US Gallons). Most of the respondents were from 18-hole golf courses, but 9-hole golf courses were also represented in the survey.

Irrigation sources came from many different locations, collection ponds were the most popular at 37% also included were wells (22%), rivers (12%) and lakes (10%). A surprising fact that came out of the survey was that 6% of golf course reported to using effluent/reclaimed water on their golf course.

Of the respondents who replied that they were on a municipal source 10% said that they pay for their water. The average cost for this was $4400 per year. The respondents were asked if they were on a municipal source or well if their water was pumped directly into the irrigation system or into a storage pond or tank. The response was an even split at 23% into storage and 23% direct into the irrigation system.

All respondents were asked if they would be willing to try an alternative source of water if the option was available, and 72% responded yes they would be

Water conservation strategies were asked of the participants, and most responded that they use a weather station as their main strategy (23%) followed by rain shut off devices (16%) and soil moisture sensors and high wind shut off devices (3% each). Irrigation requirements were determined by the use of weather forecasts (30%), soil probe (24%), rain gauge (14%), and footprint technique (10%). At much smaller percentages, ET rates and evaporation pans and tensiometer and crop were used. Managers also stated that they used other methods that came from years of experience working with turfgrass. Examples of these methods include: feel, cup cutter visuals, and the rate of growth, ball marks, and experience at their respective properties.

A high percentage (78%) of golf courses utilize wetting agents (ionic and non-ionic surfactants) as part of their maintenance practices. Syringing practices are used by 67% of Managers in the region. This cuts down on the use of water as the process of syringing uses small amounts of water as you are just trying to cool the surface instead of getting water to the root zone.

Managers were asked if they tested their incoming water source and how commonly they did so. Most responded that their water testing was done on an annual basis. Most tested for pH (30%) as well as total salinity (22%), nutrients (17%) and bicarbonates (12%) and specific ion toxicity (11%).

PART II IRRIGATION SYSTEM INFRASTRUCTURE

Turf managers were then asked about their irrigation systems and the infrastructure that they had in place. This included the hardware (pumps, etc.) as well as the delivery system and configuration.

More than three-quarters (76%) of the respondents stated that they did not have a flow meter on their incoming irrigation system, and almost the same amount (69%) said that they have no flow meter on their outgoing irrigation system. The respondents that said they did have flow meters stated that they were calibrated yearly to ensure their accuracy.

The types of irrigation pumps in the Atlantic region are evenly split between Turbine/ Submersible (31%) and End Suction Centrifugal (36%), with only 3% of the respondents saying they had a PTO type of pump. Of the End Sectional Centrifugal type, most of the systems employ an electrical power supply (67%), the rest are made up of diesel supply (28%) and gasoline (5%). The use of variable frequency drive on pumping stations is low in the region at 31% of respondents.

The types of irrigation systems were then broken down into how it was operated, automatic, semi automatic and manual. Automatic systems were the most popular choice (62%), semi automatic systems make up 18% of the systems and manual systems account for 20%. This classification was then broken down further, if the system was classified as an automatic system with a computerized central controller does it have satellite or decoder control? Three-quarters of the courses in the region have satellite controllers versus decoders at 25%.

The next area of questions was based on the placement of heads and the particular pattern that was established for irrigating the turf. Around green sites, the most common pattern for sprinklers was a square pattern at 64%, followed by triangular at 18%. The same question was asked for tees and single was the most frequent choice at 60%. There was a good spread of answers for this same question when it was asked for fairways. Single row was the most common answer (59%), with double row the second most common (30%). These were followed up by triple row and square pattern at 6%.

Eighty-five percent of the respondents said that there sprinkler coverage was set equal head to head, and 62% said that all the sprinklers within a station matched. It was a common response (71%) that stations were configured so that areas with similar water requirements were on the same station.

Daily regular maintenance of the irrigation system for leaks and malfunctions is was done by 73% of the respondents.

The final questions on the survey pertained to the performance of the system. The question was asked if their system had under gone any audits. Ten (10%) percent responded that they had the performance checked. A resounding 83% said that they would be willing to have their systems undergo an irrigation audit, but only 44% said that they knew a certified irrigation auditor. When asked if they had taken a certified golf course irrigation audit class only 13% of the respondents said they had.

CONCLUSIONS

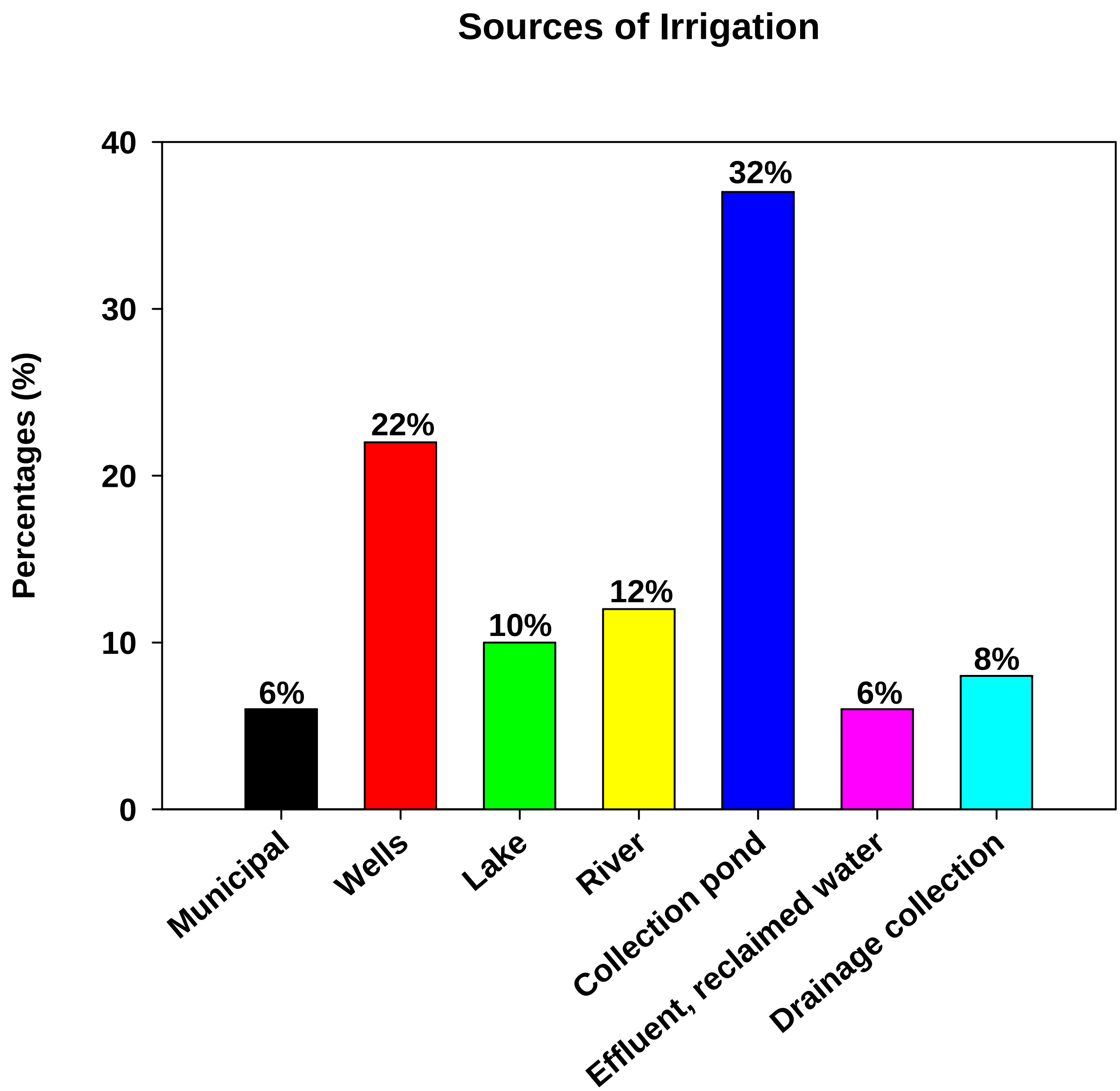
This survey helped to shed some light on where the industry is and where it would like to go in the future. The average Manager in the Atlantic region belongs to the local professional development association (AGSA) and has enjoyed working in the turf industry for an average of 21 years. Most seem open to trying new technologies and have their mind on the impact that they are making on the environment. Over three quarters of the respondents would be willing to try an alternative source of irrigation water. This could allow for future research in using reclaimed water on turf and how this might impact the environment. By using reclaimed water, we can reduce the use of fresh water supplies on golf courses. The data also shows that most Managers do not irrigate indiscriminately, almost all of the respondents based their irrigation requirements on certain measurable factors like soil probes, weather forecasts, and the footprint technique. They do not just program their irrigation system regardless of the contributing factors. Many Managers also stated they incorporate water saving techniques into their daily maintenance practices, such as syringing greens, which use a small amount of water. When this water evaporates it cools the surface of the plant. Managers also use wetting agents to help the soil retain water and help aid in its uptake.

The average turf area that was irrigated in the Atlantic region was 17.9 ha (44.3 acres) with an average consumption of 30,240,000 L. Collection ponds, lakes, and rivers were the most common irrigation sources for water. Municipal water sources made up a small component of the total irrigation sources; they are used in only 6% of the cases. Most managers tested their water sources annually allowing them to ensure that the irrigation water will not adversely affect the turf.

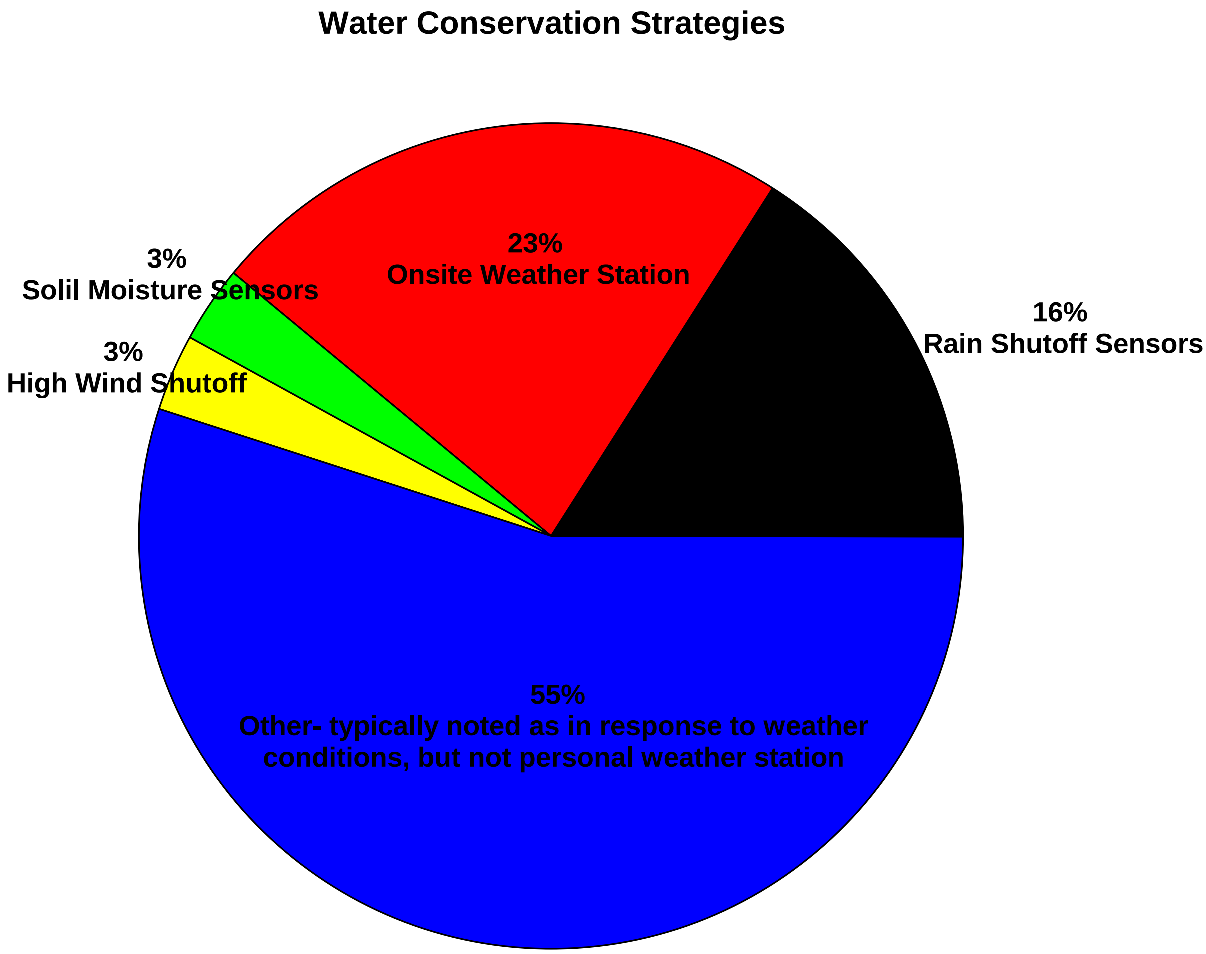
The survey showed that most managers in the area are using an automatic irrigation system. This gives the manager the best opportunity to manage their resources as well as save water, because they only irrigate the areas they need. The study also revealed that most of the irrigation systems were set up with areas that had similar irrigation requirements were found on the same stations. This also helped to prevent water from being wasted by not over watering areas that did not require it.

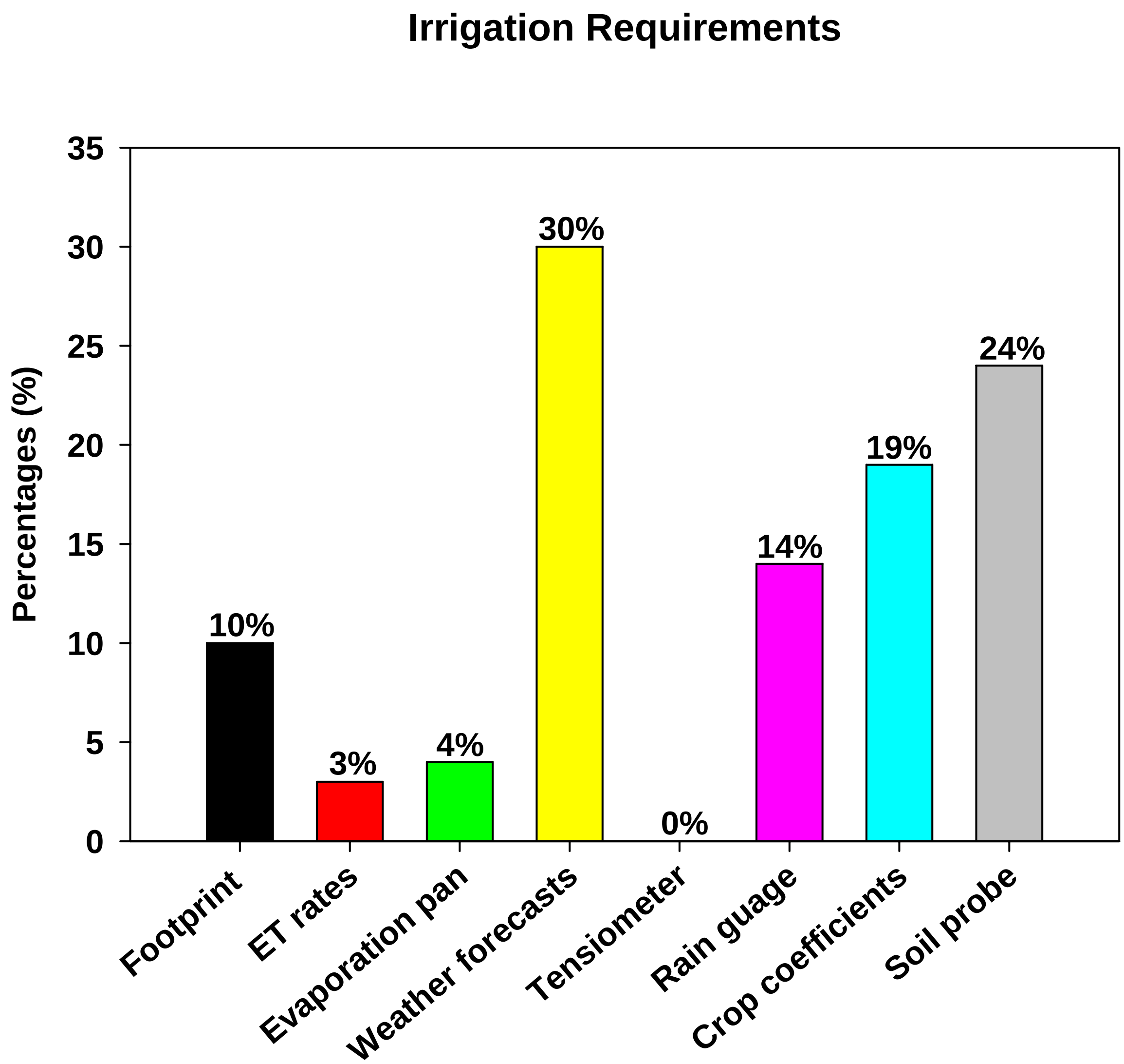
Other infrastructure questions asked pertained to the maintenance of the system. Most managers responded that they checked their systems daily for leaks and malfunctions as a way to prevent any major issues coming up in the future.

The managers also replied that they would be interested in having their systems audited to check the performance of the system. This would provide a baseline to see if the system was operating within acceptable tolerances and if not the system could be changed to increase efficiency and prevent the overuse of resources.

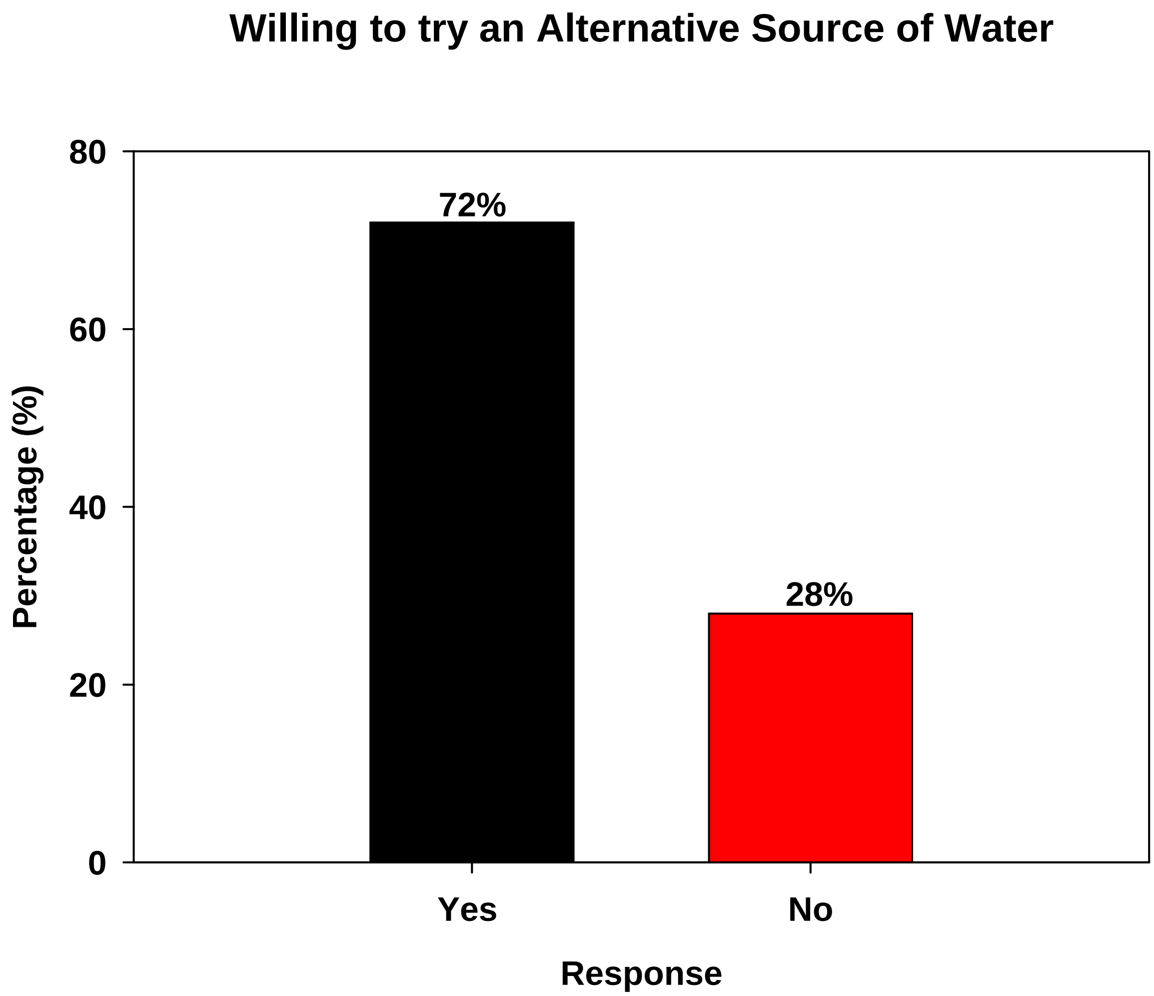


Sources of Irrigation
Percentages (%)
0
10
20
30
40
6%
22%
10%
12%
32%
6%
8%
Municipal
Wells
Lake
River
Collection pond
Effluent, reclaimed water
Drainage collection


Water Conservation Strategies
23%
Onsite Weather Station
3%
Solil Moisture Sensors
3%
High Wind Shutoff
16%
Rain Shutoff Sensors
55%
Other- typically noted as in response to weather conditions, but not personal weather station



Irrigation Requirements
Percentages (%)
35
30
25
20
15
10
5
0
10%
3%
4%
30%
0%
14%
19%
24%
Footprint
ET rates
Evaporation pan
Weather forecasts
Tensiometer
Rain guage
Crop coefficients
Soil probe


Willing to try an Alternative Source of Water
80
60
40
20
0
72%
28%
Percentage (%)
Yes
No
Response

COMPONENT II:
FIELD EVALUATION FOR ESTIMATING THE CROP FACTOR FOR TURFGRASS

INTRODUCTION

The turfgrass plant is composed of approximately 90% water, which is essential for every stage of growth (O'Brien and Brown, 1989). The industry has been progressive in identifying water management solutions in an attempt to reduce water use, improve water quality and become less reliant on conventional supplies.

Plant water use determines how much water is needed by rain or irrigation. Too little water can reduce turf quality. Too much irrigation can waste energy, water, and nutrients, and unnecessarily deplete the water supply. Smart irrigation management starts with knowing the water use. The goal is to give turf exactly what it needs, when needed.

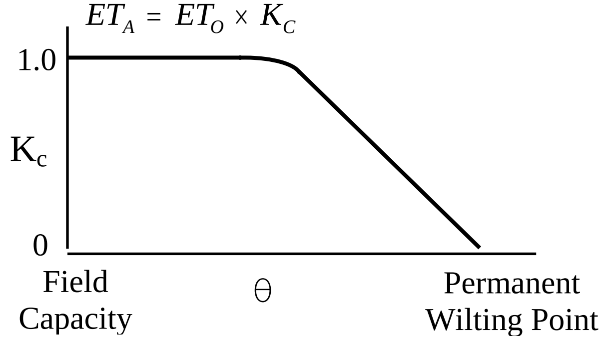
Evapotranspiration (ET) is the total water lost from the soil and plant surface (evaporation) and water used by the plants (transpiration) over a given period of time. In general, two factors affect ET: (*i*) the energy available to transform the liquid water to a vapour; and (*ii*) the vapour pressure gradient within the air near the surface which represents the driving force for the operation (Hann et al., 1982; Oke, 1987). Incoming energy into the earth-atmosphere continuum is in the form of either shortwave (solar) or longwave radiation. The vapour pressure gradient is described by the vapour pressure deficit. For ET to occur, there must be a gradual lessening in the water vapour held by the air at various temperatures as distance from the surface increases, known as the gradient. Plant species, size of plant, weather conditions, and the amount and quality of water available to the plant all affect the rate of ET.

The generic energy balance equation takes into account net radiation, soil heat flux, latent heat, and sensible heat. Several methods may be used to quantify ET, consisting of (*i*) pure measurement methods, (*ii*) statistical methods, and (*iii*) combination methods. The research utilized a pure measurement method and one of the combination methods.

Pure measurement methods include lysimeters, Class-A pans, and depth sensors in water bodies. Class-A pan measurements give a value for the ET_O corrected to the surface under study by the use of coefficients (Haan et al., 1982). One of the combination methods is the Bowen ratio energy balance approach, which is a ratio of sensible heat flux to latent heat flux (Bowen, 1926). This ratio is based upon a gradient theory, which assumes eddy diffusivities of heat and water vapour within the free air above the measurement surface are equal and that the measurements are being recorded over a homogeneous surface with extensive fetch (Perez et al., 1999). Typical upwind distance to upper measurement height should be 1:100. The value obtained for the Bowen ratio is incorporated into the energy balance equation to solve for latent heat. Dividing this value by the constant value for heat of vapourization of water provides an estimate of ET_A. The Bowen ratio technique, the most widely used for estimating sensible and latent heats, relies on being able to determine temperature and vapour pressure gradients between two heights. This method has been used to measure ET_A over dams and reservoirs, a variety of agricultural crops, wetlands, and numerous other studies.

The measurements of ET_O and ET_A will provide the necessary information to estimate K_C for turf in the Atlantic region. The K_C value ranges from 0 to1, is a function of soil moisture, and is best described by the equation and figure below:

$$ET_A = ET_O \times K_C$$



There is a need to estimate K_C for turf in the Nova Scotia region. The K_C modifies the turfgrass reference ET to more closely approximate the plant water requirement and to more accurately represent regional conditions as seasons change.

Objectives

The objective of this study was to develop a crop factor for turf managers and producers to incorporate into irrigation scheduling and better manage water resources.

Materials and Methods

Experimental Site. The study was conducted on a commercial sod farm located in Upper Stewiacke, Nova Scotia. The equipment was stationed on the East side of the field with a fetch meeting the minimum requirement of 100m. The predominant wind direction was from the Southwest direction.

Fig. 1. Set up of CSI Bowen Ratio equipment on East of field.

Fig. 2. Fetch in the Southwest direction.

Fig. 3. Fetch in the West direction.

Data Collection. Two methods were used to quantify ET from the site. The first was a Class-A evaporation pan that was used to manually estimate ET_O on a daily basis. The second was to measure the individual components of the energy balance equation to quantify ET_A. These components included temperature, vapour pressure differentials, net radiation, and soil heat flux. A Bowen Ratio System (Campbell Scientific Inc., Edmonton, AB) was used to estimate these parameters along with a CR21X datalogger (Campbell Scientific Inc., Edmonton, AB) to assist in data collection.

Bowen Ratio Energy Balance. The Bowen Ratio (Campbell Scientific Inc., Edmonton, AB) apparatus estimated ET by measuring temperature change and vapour differential at two different heights. Water vapour was measured by sampling air at two heights above the surface of the turf. Air was sampled at 0.4 L min^{-1} through differential intakes equipped with 1 μm Teflon filters. The vapour pressure was then calculated from wet bulb depression using a Dew-10 cooled mirror hygrometer. The upper intake was at 1.5 m and the lower at 0.5 m. Temperature was also measured at these two levels. It was measured with chromel-constantan thermocouples. Net radiation was measured using the CNR1 Net Radiometer (Campbell Scientific Inc., Edmonton, AB). Solar radiation was measured by two CM3 pyranometers one facing up to measure the incoming solar radiation and one facing down to measure reflected solar radiation. Two CG3 pyrgeometers measured the far infrared radiation from the sky (facing up), and the second measuring the far infrared radiation from the soil (facing down). To measure soil heat flux, two HFT3 soil heat flux plates were buried at a depth of 8cm. The average temperature of the soil layer above the plate was measured using four parallel thermocouples. The heat flux at the surface was calculated by adding the heat flux measured by the plate to the energy stored in the soil layer.

Hydro-Meteorological Measurements. Windspeed and direction were measured using an R.M. Young Wind Monitor (Traverse City, Michigan, USA). This sensor was mounted on the cross piece set on top of the weather station assembly at a height of approximately 2.5 m.

Datalogger. The CR21X (Campbell Scientific, Edmonton Alberta) was writing to final storage at 20 min intervals. Power was supplied by a battery attached to a solar panel for continuous power. Data was downloaded every second day.

RESULTS AND DISCUSSION

The experiment ran from August 1 to August 16, 2007. There were some lapses in the data due to the thermocouples being removed during periods of heavy precipitation because of their sensitivity and tendency to become damaged.

Data Filtering. The Bowen Ratio apparatus ran continuously. Negative ET values were removed. Typically, these values occurred during the night when the calculation approached a negative number and was considered unusable (Ohmuna, 1982). Data were also removed when it became apparent that the sensors were malfunctioning. Precipitation events also hindered data collection, due to the sensitivity of the temperature thermocouples. Two major rain events occurred during the collection period and in general, August was much wetter than anticipated. In fact, while the 30 year average for August (1971 – 2000) was 98.1 mm for the area, close to 196 mm were received in August 2007.

After data filtering the usable data time periods included:

August 1 (12:00) – August 3 (13:20)

August 5 (12:40) – August 10 (14:00)

August 11 (11:40) – August 13 (10:00)

August 15 (10:20) – August 16 (15:40)

The data used for the overall calculations during the above time periods are shown in Figs. 4 to 7. The following table shows the ETa rates, ETo rates, percentage of data removed during the day and the resulting Kc factor

Period	**ET_A (mm)**	**% of ET_A Data Removed between 9:00 – 20:00**	**ET_O (mm)**	**Kc**
Aug 1 – 3	4.62	9	9.52	0.49
Aug 5 – 10	8.02	8	11.91	0.67
Aug 11 – 13	2.99	11	4.76	0.63
Aug 15 – 16	1.95	12	4.76	0.41

Potential Sources of Error. Within the Bowen Ratio system there are some factors of the energy balance equation that are directly being measured and others that are calculated through measurements. Therefore there can be many sources of error that would lead to lower values of ET_A.

When measuring and calculating the soil heat flux and heat storage term it was integral that the heat flux plates were in full contact with the soil to ensure quality soil heat storage measurements. Also, it was very important to have the four soil thermocouples to be parallel, directly above the soil heat flux plates, and in good contact with the soil to ensure good measurements. The CS616 installation was critical as well as these probe rods should be installed as parallel as possible to maintain the design of the wave guide geometry. It was also important that there were no air pockets around the probe rods to maintain accuracy.

Installation of the CNR1 Net Radiometer was important that the sensors should have no shading so placement of the sensors south of the mounting arm was important. Also, the height of 1.5m promoted spatial averaging. The R.M. Young Wind Monitor required some key installation directions. It required the junction box to face south while the nose was rotated to true north and the base of the sensor would read zero. The wiring was originally done incorrectly and was not repaired until August 8 (Day 220). This did not directly affect ET_A measurements but acted as a filtering tool for data to ensure the wind was blowing from the right direction (Southwest).

Weather. As was mentioned earlier, the temperature thermocouples were removed during times of precipitation due to their sensitivity. While the temperature was typical of August with daytime highs reaching 30°C and nighttime lows of 5°C, the amount of precipitation hindered the sampling period.

Evaporation Pan. The pan was checked everyday between 12:00 and 13:00. The levels were checked, recorded, and the water level was filled back to 20 cm. To calculate ET_O, a pan correction of 0.75 (Sheard, 2000) was used. Due to the percentage of data removed from the ET_A calculations, a lower than expected crop factor of 0.55 was calculated. This may be attributed to the cutting height, turf quality, and type of grass.

Future Recommendations. The percentage of data removed for just daytime values ranged from 8 – 12%. While daily trips were taken to the site, constant monitoring and immediate instrumentation resolution was inhibited because of the 50 km distance from Bible Hill. The experiment might have given a better crop factor value if there was a closer location for better monitoring. This study also needs to include data from a much longer sampling period (at least two full growing seasons). This would help to incorporate sporadic weather patterns. In addition, this would allow for better data filtering in hopes to obtain a true representative crop factor for turfgrass.

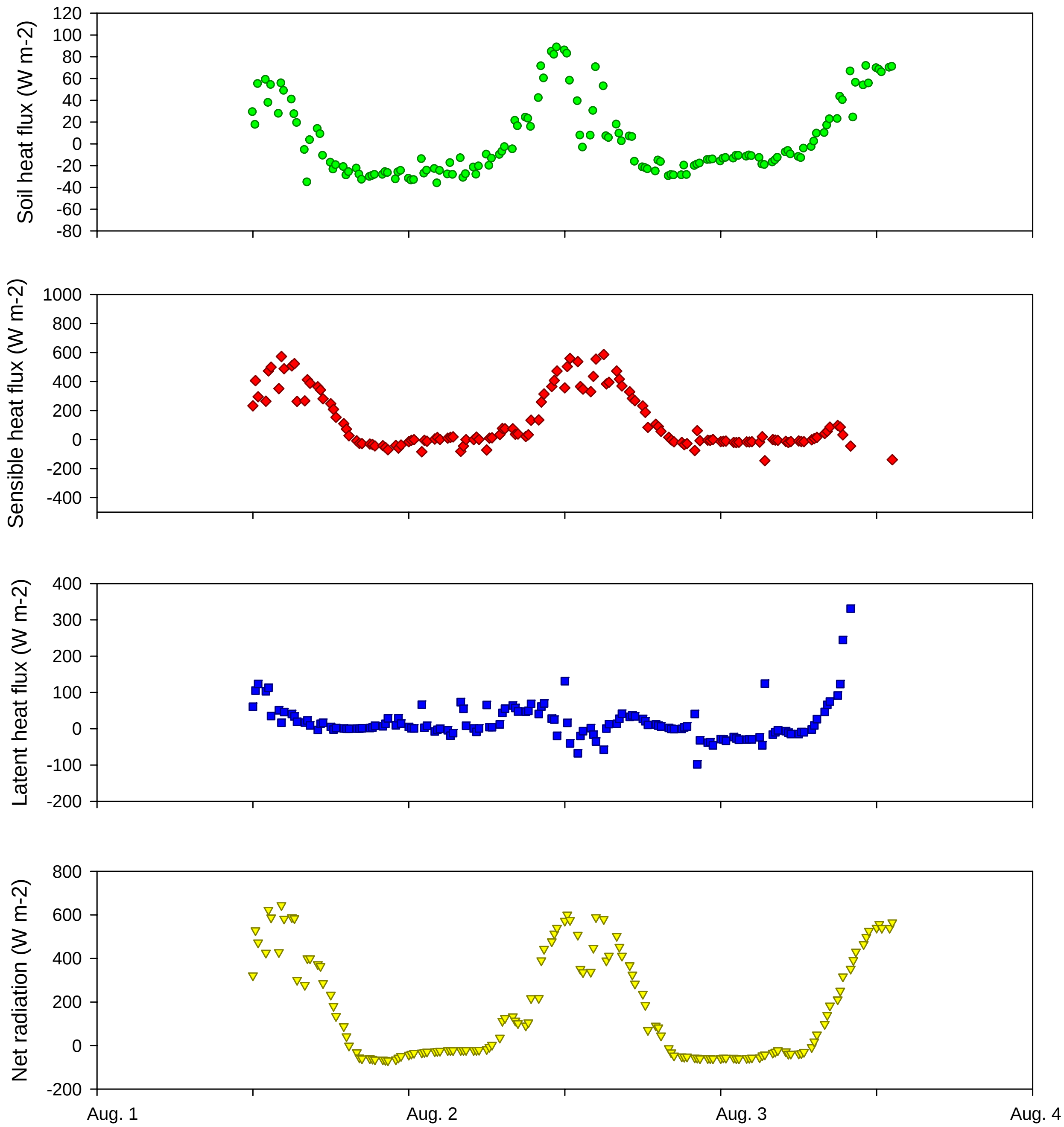


Fig. 4. Soil heat flux, sensible heat, latent heat, and net radiation data from 1 to 4 August, 2007.

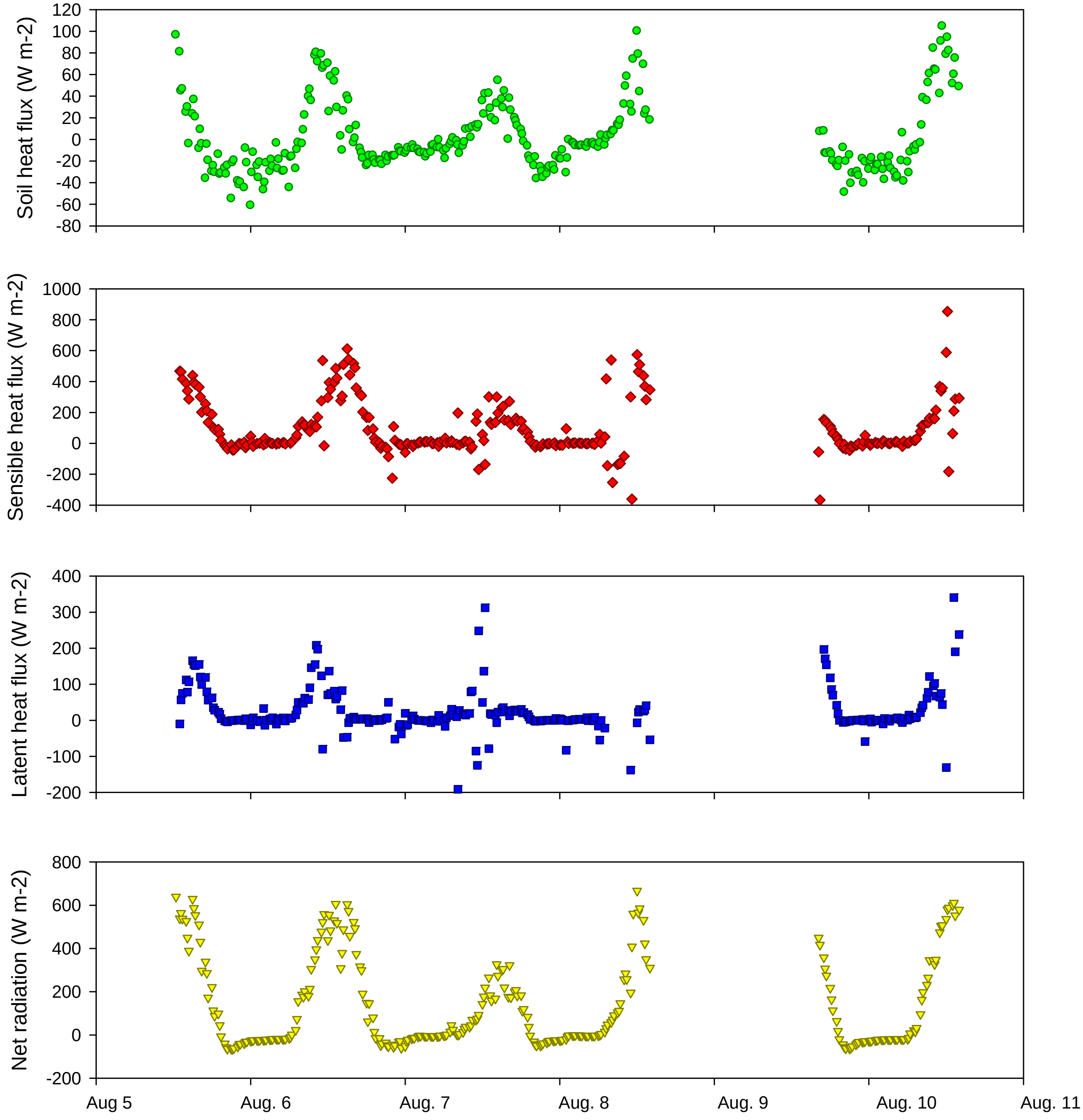


Fig. 5. Soil heat flux, sensible heat, latent heat, and net radiation data from 5 to 11 August, 2007.

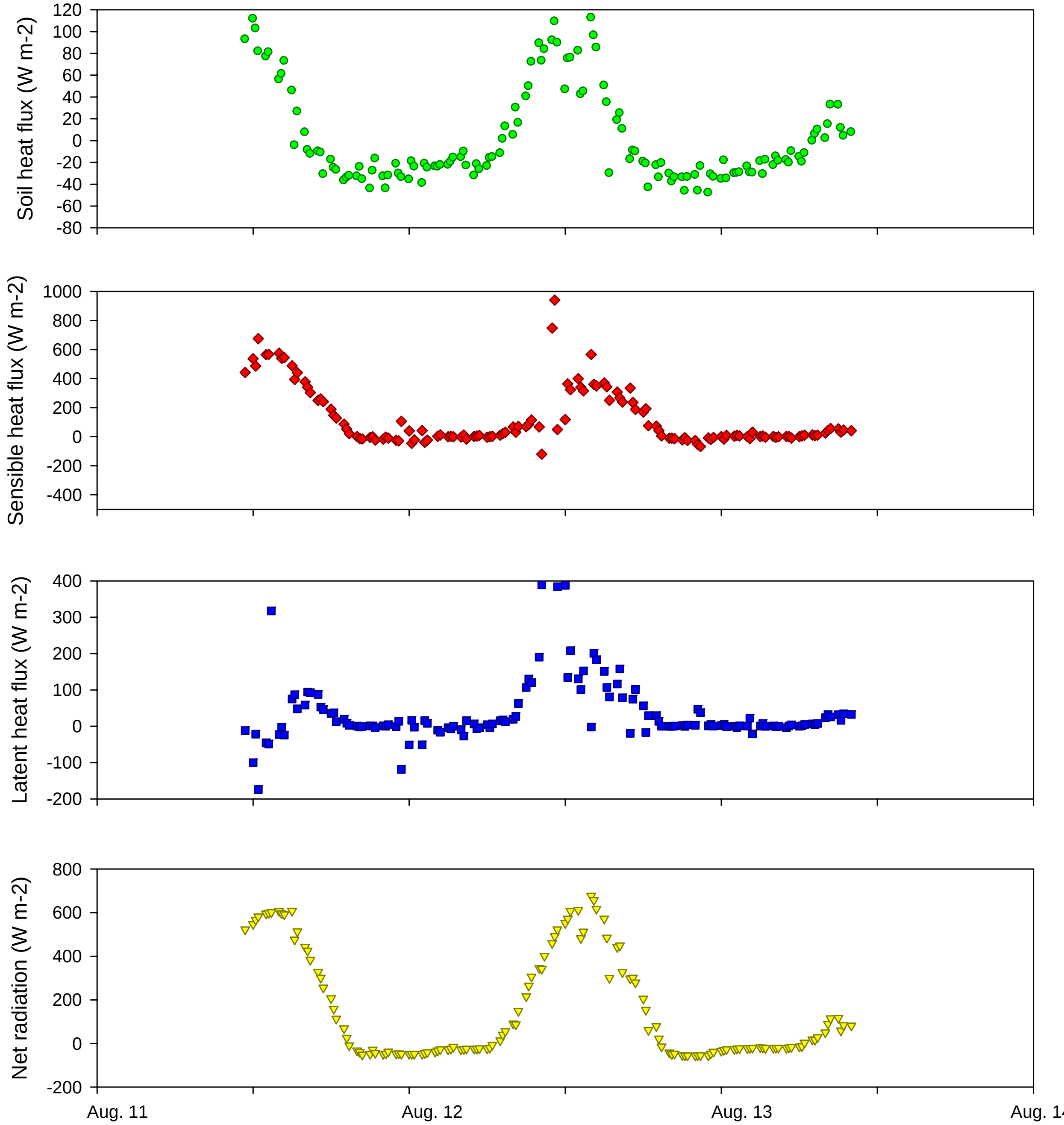


Fig. 6. Soil heat flux, sensible heat, latent heat, and net radiation data from 11 to 14 August, 2007.

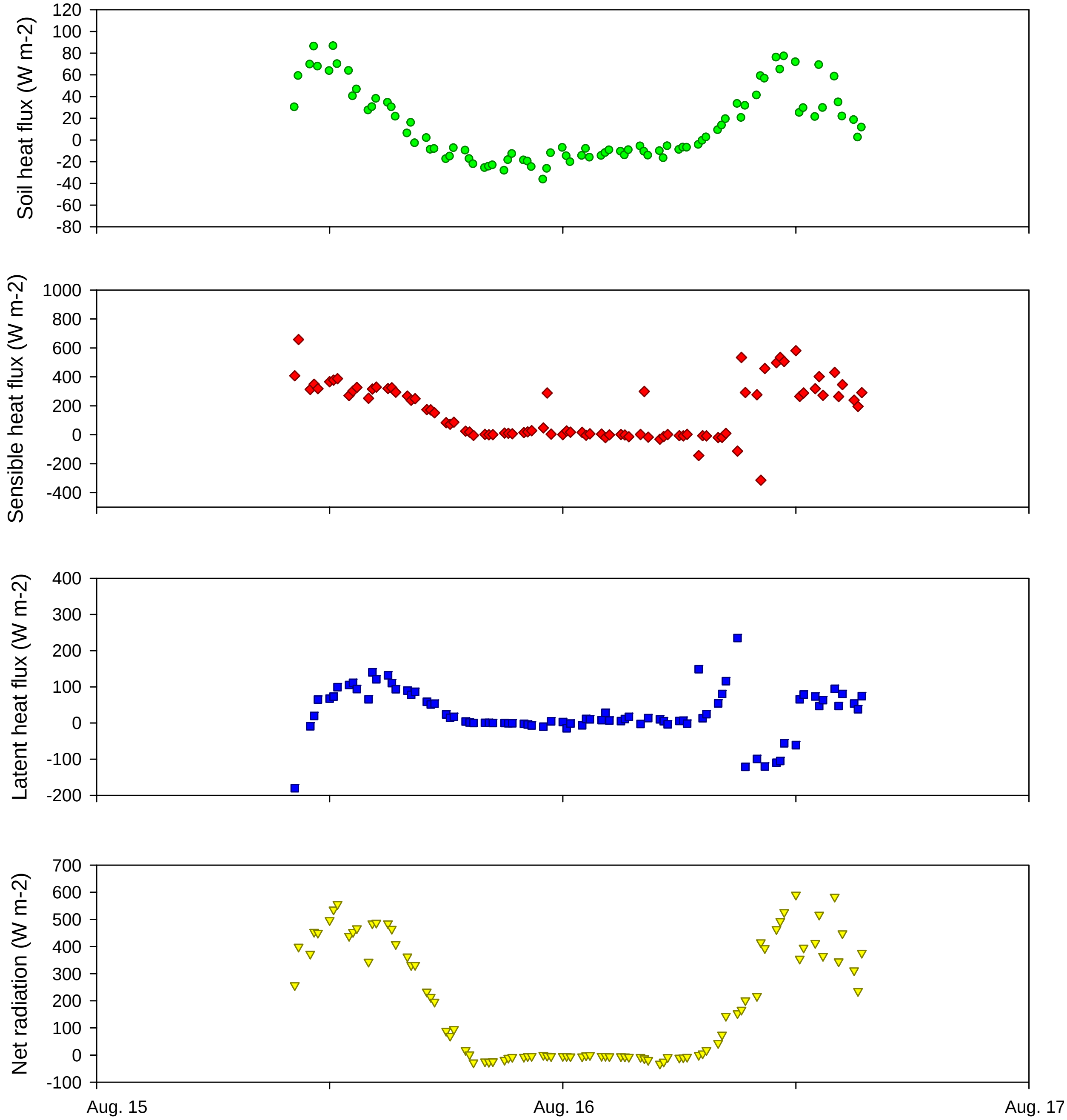


Fig. 7. Soil heat flux, sensible heat, latent heat, and net radiation data from 15 to 17 August, 2007.