The Niagara Agricultural Weather Network

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ABBREVIATIONS

IPM : Integrated Pest Management
NAWN : Niagara Agricultural Weather Network
OGGMB : Ontario Grape Growers’ Marketing Board
OTFPMB : Ontario Tender Fruit Producers’ Marketing Board
OMAFRA : Ontario Ministry of Agriculture, Food, and Rural Affairs
VQA  : Vintner’s Quality Alliance

ABSTRACT

The Niagara Agricultural Weather Network is a small, regional, automated, agriculture-focused, weather-monitoring network and information delivery system located on and below the Niagara escarpment in the northern Niagara Peninsula, Ontario, Canada. The NAWN provides the agriculture and scientific community with weather data for monitoring weather conditions, calculating pest development, and performing research. The system began operating in 1994 and, since that time, information delivery has evolved to match advances in technology. The NAWN operates in near real-time throughout the year 24-hours-per-day 7-days-per-week. The data processing system is flexible and extensible and is characterized by generic algorithms customized by parameters, which are stored in external files. This has allowed the NAWN to respond quickly and efficiently to novel requests and needs for information.

INTRODUCTION

The Niagara Agricultural Weather Network is a small, regional, automated, weather-monitoring network located in the northern Niagara Peninsula, Ontario, Canada.
The entire Niagara Region is a diverse municipality (Regional Municipality of Niagara. 2002a.), which hosts urban and rural areas, manufacturing, tourism, and agriculture. The region has major transportation routes including the Welland Canal of the St. Lawrence Seaway. The agriculture sector comprises livestock and poultry, vegetables, greenhouse (primarily floriculture), tree fruit, tender fruit, and grapes. The tree fruit, tender fruit and vineyards of Niagara cover approximately 14500 ha. Vineyards alone cover approximately 5200 ha representing more than 85% of the entire Province of Ontario area planted to grapes (Regional Municipality of Niagara. 2002b.; Ontario Ministry of Agriculture, Food, and Rural Affairs. 2002.)

The Niagara Escarpment and Lake Ontario, one of the Great Lakes, have a large influence on the weather pattern and climate of the lowland of Niagara’s north shore. The steep escarpment, the circulation of air constrained by the slope of the escarpment, and the moderating influence of the lake interact to produce a large variety of meso-climate zones in a small, narrow geographic area (less than 20km north-south by 60km east-west) bounded on the north by the lake, the south by the escarpment, the east by the Niagara River (actually a strait connecting Lakes Erie and Ontario), and the west by the continuation of the lowlands beyond Niagara proper. It is in this small, narrow strip of land that most of the tender fruit orchards and vineyards of Niagara reside.

A long history of field experience shows many meso-climate areas with direct impact on the ability to grow successfully different varieties of grape. In 1993 the Ontario Grape Growers’ Marketing Board decided to create a network of automated weather- recording stations in vineyards representative of the meso-climate areas of the northern Niagara region to gather precise data with the goal to produce a scientifically based meso-climate map of northern Niagara. The map would assist the determination of the best sites for planting selected grape varieties. The OGGMB quickly realized the importance of the NAWN to help develop and implement scientifically founded IPM practices. Now the NAWN serves a broad audience including growers, wineries, the marketing boards, OMAFRA extension specialists, students, and researchers.
The stations became operational in the summer of 1994 and have been gathering data since that time.

**MATERIALS AND METHODS**

**Overall Design**

Commercially available software is used wherever possible whereas custom developed software is used to manipulate the data and produce reports.

The NAWN data processing system is designed to be flexible and extensible to allow easy addition of weather-recording sites, monitored weather variables, pest species, and new reports. To this end, as much as possible, generic algorithms are written and are customized by parameters stored in external files. The heart of the NAWN’s data processing software consists of a small core of common code and system data files.

Data are organized loosely into logical layers. Programs process data from a lower layer to obtain data for a higher layer. The layers are: (1) in field at the datalogger level, (2) input data for the central processing computer, (3) derived data and information, and (4) end-user.

**Data Collection**

The NAWN system now comprises 13 weather-recording sites connected to a central microcomputer by telephone and modem. The microcomputer retrieves data from 11 stations every 30 minutes and the remaining two stations once per day.

Weather stations consist of Campbell Scientific CR10 Measurement and Control Modules (Campbell Scientific. 1992.) and various sensors. The CR10s are programmed to sample the sensors at one-minute intervals; these samples are combined into a 15-minute “point-in-time” observation. A solar-rechargeable battery powers the entire weather station.

Table 1 shows the variables that are directly collected and those that are calculated from the directly collected data. Some variables, such as daily maximum temperature and daily accumulation
of degree-days, only have meaning in the context of a one-day observation. Only five weather sites collect radiation data. Only three weather sites collect wind data.

**Data Processing**

The NAWN does not interpolate data at sites lacking a weather station. Spatial interpolation is very desirable (Magarey. 2001.); however, spatial interpolation is difficult along the northern Niagara coastline because of the escarpment and Lake Ontario (McFadden-Smith. 2001.).

The central processing computer calculates development of several arthropod species and also calculates downy mildew infection periods. From these calculations and from the weather data the central processing computer produces reports in “real-time”, daily, and monthly, as appropriate.

**Data Structure**

Data files contain data corresponding to only one variable. For example, data for wind speed (and only wind speed) are stored in a file separate from data for wind direction. The data files are written in a standard format unrelated to the datalogger’s internal format. This allows the use of dataloggers from various manufacturers. This design simplifies access to the data because one file format is used for all data files, and allows different sites to record different sets of weather variables. The system is flexible with respect to adding or removing variables from the recorded set of data. This design also simplifies the addition of pest models from various sources, for example “Bugwatch” (Yee and Yee. 1990.) and DMCast (Seem. 1991.). All that is needed is a translator from the NAWN format to the model’s data-input format. The simplicity and flexibility of this design is gained at the expense of disk space.

Similarly, the NAWN writes reports in only a few formats. This reduces the programming effort required to develop a report writer and also presents users with a few, familiar formats.

**Operations**

The NAWN is designed for unattended operation. This includes data collection, generation of all pre-written reports (“real-time”, daily, and monthly reports), publication on the Web, sending electronic mail, flagging the beginning and end of the growing season (April 01 to October 31) and
ice wine season (December 01 to March 02), alerting subscribers when their account will expire, and alerting the operations manager of minor errors. Unattended operation is the only practical method that can accommodate "real-time" data processing and report publishing on a year-round, daily, 24-hours-per-day basis.

Upon subscriber request, the NAWN sends reports to subscribers by electronic mail on a schedule selected by the subscriber.

The Brock University Web server hosts the NAWN Web site (www.brocku.ca/nawn) and operates the delivery portion of the NAWN automatic email service.

Most of the system manager’s “at keyboard” interaction with the system is related to administration of subscriber accounts, backup, and correction of major errors.

RESULTS AND DISCUSSION

Operational Challenge

The major operational challenge for the NAWN is serving multiple audiences with different needs. For instance the NAWN must be able to provide:

( a ) acceptably frequent recording rate e.g. at least once per 60 minutes

( b ) acceptably frequent processing of the data into new variables (e.g. degree-days)

( c ) acceptably frequent writing and publication of reports, the frequency depends on the report

( d ) a variety of interfaces to the same dataset e.g. simple, pre-written reports; regular electronic mailings; a data archive; "pick-your-own" reports from the Web

This challenge means the system must be resilient to errors in the data and hardware, operate continuously with very little human interaction, and provide suitable user access and access control.

Technology available to the audiences

The NAWN must be sensitive to the technology possessed by the audience. This is most important with respect to the delivery of data and information. For instance, in 1996, when the NAWN first started delivering reports to subscribers, some growers owned only a fax machine.
Thus, the NAWN implemented a fax service. Subscribers who had computers and modems could access the NAWN through a bulletin board service. Now the NAWN publishes data and information on a Web site.

Growers, for the most part, need standardized information; they do not need to customize their reports. Also, most growers do not process weather data on their own computers to monitor pest development. The NAWN writes standard reports to serve these growers.

**Information and Reports Produced by the NAWN**

The NAWN’s pre-written reports present basic weather data, calculated variables such as degree-days, pest development for several pests of apple (Yee and Yee. 1990.), probability of downy mildew infection (Seem. 1991.), hours the temperature remained below –8 deg. C (for ice wine harvest), among others.

"Real-time" observations are published on the Web site every 30-minutes; daily summaries for degree-days, ice wine hours, etc. are published only once per day.

Some reports are published only during certain times of the year. For example, ice wine reports are published from December 01 to March 02.

Historical, long-term observations are available on CD and not by online archives or pre-written reports. These observations are directed to research work.

**Uses and Research Work**

The marketing boards and the VQA use the information to monitor annual degree-day and rain accumulations. The VQA also uses the data to monitor conditions during the ice wine harvest season.

A major winery collects and uses information about climatic conditions to help with the site selection process. It also checks on temperatures for the nights when growers have gone out to harvest ice wine.

A major processor keeps daily and weekly weather summaries from across the peninsula to assist in forecasting orchard development through the course of the season. Winter records are used
to determine if fruit bud injury may have occurred due to extreme low temperatures. Weather data are used in compiling annual reports on growing conditions, fruit quality and yield of crop as it relates to the grape and wine industry in Southern Ontario.

Researchers and students at the Cool Climate Oenology and Viticulture Institute of Brock University have used the NAWN’s data to study the effect of weather on the sensory character of grapes, grape vine growth and development, erosion processes (under the Brock high school science mentorship program), and the Beamsville Bench terroir.

NAWN data have been used in the classroom. As an example, students taking statistics courses in the Mathematics Department, Brock University, have performed statistical analyses of the temperature data and shown the differences among the zones covered by the NAWN monitoring area.

Work In Progress

The diversity of the user community requires more reports than is possible to anticipate and pre-write. This has led to a project to develop a Web-based report writer to allow users to request custom reports.

The database now contains seven years of data. Researchers can begin to conduct studies on the medium-term, meso-climate patterns in the NAWN monitoring area. To assist these studies one of the authors (JZ) at the University of Manitoba is supervising a graduate student to develop a datamining tool to search for associations and patterns among weather variables.

Ongoing work includes (but is not limited to) studies of: irrigation requirements for optimizing winegrape yield and quality, evapotranspiration using the Penman-Monteith formula, grape plant respiration, wind resource assessment of the Niagara Region, and soil stability.

OMAFRA specialists and researchers at Brock University and the University of Guelph have discussed reworking the climate zone map of the Niagara Region.
CONCLUSIONS

The NAWN is not a static project limited to collecting data. While the core processes of collecting data have remained the same, the use and delivery of the data have evolved.

Information and data are distributed (on a subscription-fee basis) by publication on the Web, automated electronic mail, and CD for historical data. As users have adopted newer computer technology, older distribution methods, such as computer bulletin board and fax service, have been discontinued.

The NAWN operates year round, 24 hours a day, for its grower and winery audiences. In spring and summer the NAWN reports on pest development and disease infection periods. In winter the NAWN reports on temperature for ice wine harvest and daily and cumulative ice wine hours. The NAWN publishes selected weather reports every 30 minutes on the Web site.

The NAWN provides data to help support an active community of researchers, teachers, and students. Beyond its original purpose to gather data to produce a meso-climate map of northern Niagara, the NAWN provides the raw data and information for its various audiences to use, develop and implement effective and efficient agricultural practices.

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REFERENCES


Table 1. Variables Collected and Calculated

<table>
<thead>
<tr>
<th>Directly Collected Variables</th>
<th>Calculated from the Collected Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Temperature</td>
<td>Degree Days Base 10 Degrees Celsius – Daily Total</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>Degree Days Base 5 Degrees Celsius – Daily Total</td>
</tr>
<tr>
<td>Air Temperature in the Grape Vines</td>
<td>Wind Speed – Daily Maximum</td>
</tr>
<tr>
<td>Rain</td>
<td>Hours the Relative Humidity Is Greater Than 95 Percent</td>
</tr>
<tr>
<td>Leaf Wetness above the Grape Canopy</td>
<td>Air Temperature in the Grape Vines – Daily Maximum</td>
</tr>
<tr>
<td>Leaf Wetness in the Grape Canopy</td>
<td>Air Temperature in the Grape Vines – Daily Minimum</td>
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<tr>
<td>Radiation</td>
<td>Air Temperature in the Vines – Daily Mean</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>Rain – Daily Total</td>
</tr>
<tr>
<td>Wind Direction</td>
<td>Radiation – Daily Total</td>
</tr>
<tr>
<td>Air Temperature – Daily Maximum</td>
<td>Variables Calculated from the Directly Collected Data</td>
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<tr>
<td>Air Temperature – Daily Minimum</td>
<td>Degree Days Base 10 Degrees Celsius – Daily Total</td>
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<td>Air Temperature – Daily Mean</td>
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<tr>
<td>Relative Humidity – Daily Minimum</td>
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</tbody>
</table>
Wind Speed – Daily Minimum

Wind Speed – Daily Mean

Relative Humidity – Daily Mean

Radiation – Daily Maximum

Radiation – Daily Mean

Chill Hours Base -7 Degrees Celsius – Daily Total

Chill Hours Base -8 Degrees Celsius – Daily Total

Chill Hours Base -9 Degrees Celsius – Daily Total

Chill Hours Base -10 Degrees Celsius – Daily Total

Chill Hours Base -11 Degrees Celsius – Daily Total

Chill Hours Base -12 Degrees Celsius – Daily Total

Chill Hours Base -13 Degrees Celsius – Daily Total

Chill Hours Base -14 Degrees Celsius – Daily Total

Chill Hours Base -15 Degrees Celsius – Daily Total