Telecommunications networking of weather data for use in agricultural systems

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Abstract

No irrigation scheduling services using near-real time weather data are currently in operation in Southern Africa. The majority of the large irrigation schemes are in the drier areas of the country where the water supply, although controlled, is often limiting. A network which collects, collates and transforms near-real time weather data has been successfully established. This network includes an automatic weather station, a remote and on-farm personal computer, error detecting telephone modems and short-haul modems. Operational software has been developed and is used together with commercial software to access and transform the data for use in locally developed irrigation models and the crop growth simulation model PUTU.

Introduction

Recent technological developments in electronics have found application in agricultural systems (Mottram and De Jager, 1990). With respect to estimating irrigation at both the research and field levels, electronic data logging has enabled researchers and agricultural consultants to compute accurate and reliable estimates of real time reference values of crop evaporation from hourly weather data accessed by computers from automatic weather stations.

All surface weather networks require that the data collected at a particular site be transmitted to some centre for collation and possible transformation for user access. These surface weather networks require manpower and this in turn incurs high costs, the possibility of errors during transmission and loss of time.

A near-real time automated weather data network (AWDN) was developed for support of agriculture in Nebraska (Hubbard et al., 1983). The automatic weather stations comprised Campbell Scientific (Logan, Utah) CR21 data loggers (now obsolete) and associated sensors and were connected via telephone modems to a centrally located computer (Mention of trade names does not constitute an endorsement by the authors or their Universities). After retrieval, the data were visually checked, sorted for the most recent 24-h period and then merged into the data archive. Thereafter the data were transmitted to a mainframe computer connected to the agricultural management network known as AGNET.

AGNET was established in 1975 and designed "to provide information to those individuals, firms, and organisations that are involved in the complex production, marketing and coordinating activities that are part of modern agriculture" (Meyer et al., 1988). Six of the software programs available on AGNET can access weather data for use directly in the program.

The California irrigation management information system (CIMIS, 1985) is the major irrigation management program of the California Department of Water Resources (Snyder et al., 1985). CIMIS is a computerised weather network that was developed to provide crop evaporation information to Californian farmers for irrigation scheduling purposes. In 1985, CIMIS estimated crop evaporation at 43 locations in California using data from automatic weather stations. These automatic weather stations comprise Campbell Scientific data loggers for use with the associated sensors for microclimate measurement. Daily data are transferred to the data acquisition centre in Davis, California where they are quality checked and thereafter used in the estimation of crop evaporation using a modified Penman equation.

To date, in Southern Africa, no irrigation scheduling services, using near-real time weather data, are available to the irrigator. In CIMIS (Snyder et al., 1985), automatic weather stations are used as they speed up the data collection process and eliminate loss of data due to human error. Pruitt and Doorenbos (1977) suggested that automatic weather stations and computers be used to calculate crop evaporation using hourly weather data.

Irrigation provides a degree of stability to the food producing areas in Southern Africa. In 1988, government irrigation schemes covered some 456 000 ha in Southern Africa (Anon, 1989). The 75th Annual Report of the Department of Water Affairs contained the following mission statement: "To ensure the availability and the making available of water at a national level". In 1988, 2 685 x 10^6 m^3 of water was supplied to the above 456 000 ha, which is equivalent to 589 mm for this area. In the wetter areas (rainfall greater than 750 mm) of South Africa where irrigation is supplementary, this supply should be adequate. However, in the drier areas (rainfall less than 500 mm), where the majority of these government schemes are situated, this amount of irrigation water would not be sufficient to attain potential crop yields. Thus it is imperative that efficient water distribution and irrigation scheduling are practised.

Many on-farm operational decisions depend upon dynamic and constantly changing factors. One such variable is weather. A weather data network provides the necessary data which can assist farmers in their decision matrix by facilitating the scheduling of irrigation, on-farm and within irrigation project water distribution.

The aim of this paper is to present details of a network for collecting, collating and transferring on-farm weather data to a personal computer, in order that it may be used for agricultural management decision making.

Materials and methods

Figure 1 illustrates the present network for collecting, collating and transferring weather data in the irrigation project efficiency (IPE) project.

An on-farm network and the flow of weather data within a telecommunication network in order to facilitate user access to the data generated by the IPE project (De Jager et al., 1988) is shown in Fig. 2.

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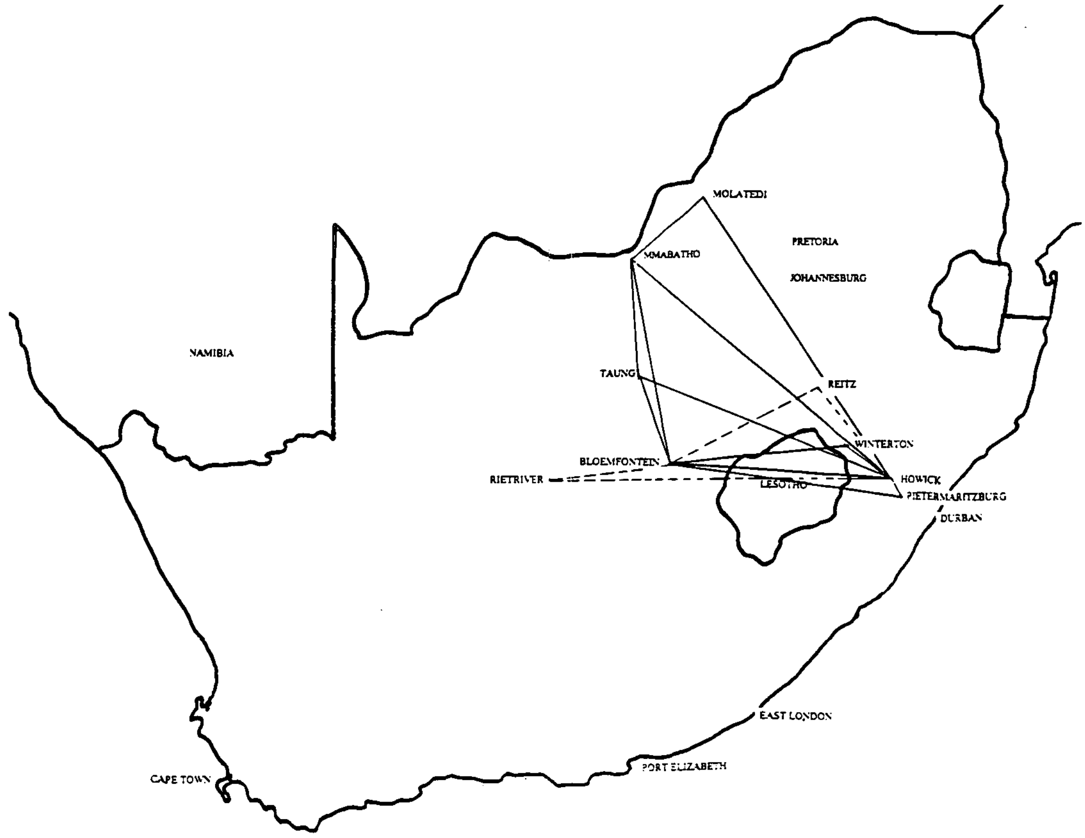

Figure 1
Network for collecting, collating and transferring on-farm weather data (Dotted line indicates those currently being set up)

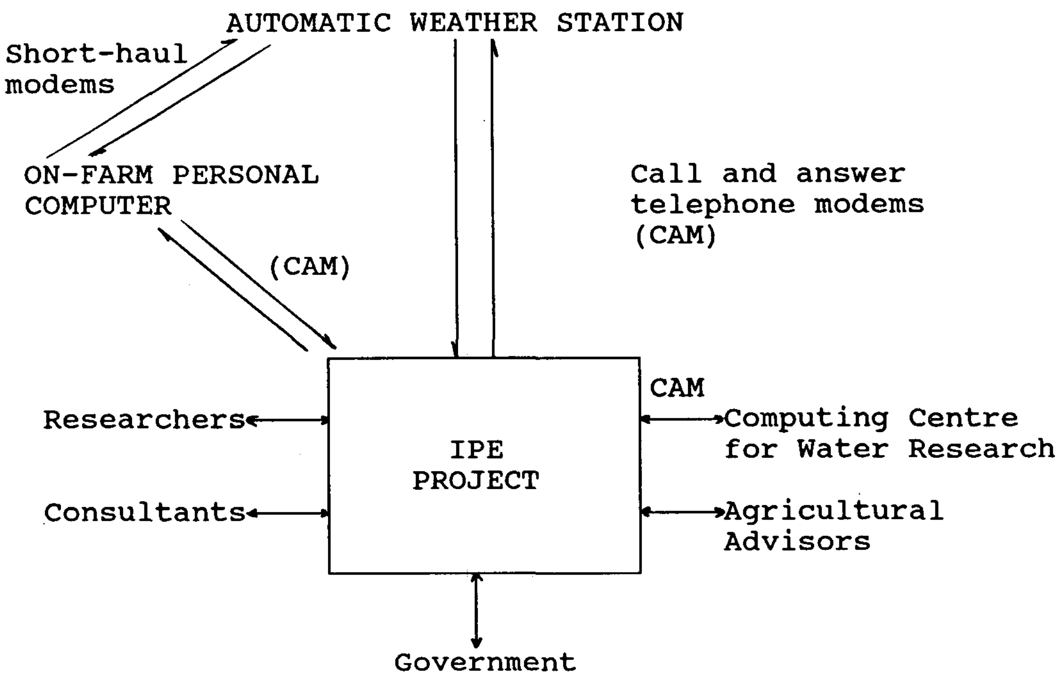

Figure 2
On-farm weather data network link-up to IPE project indicating the proposed flow of data through the IPE project

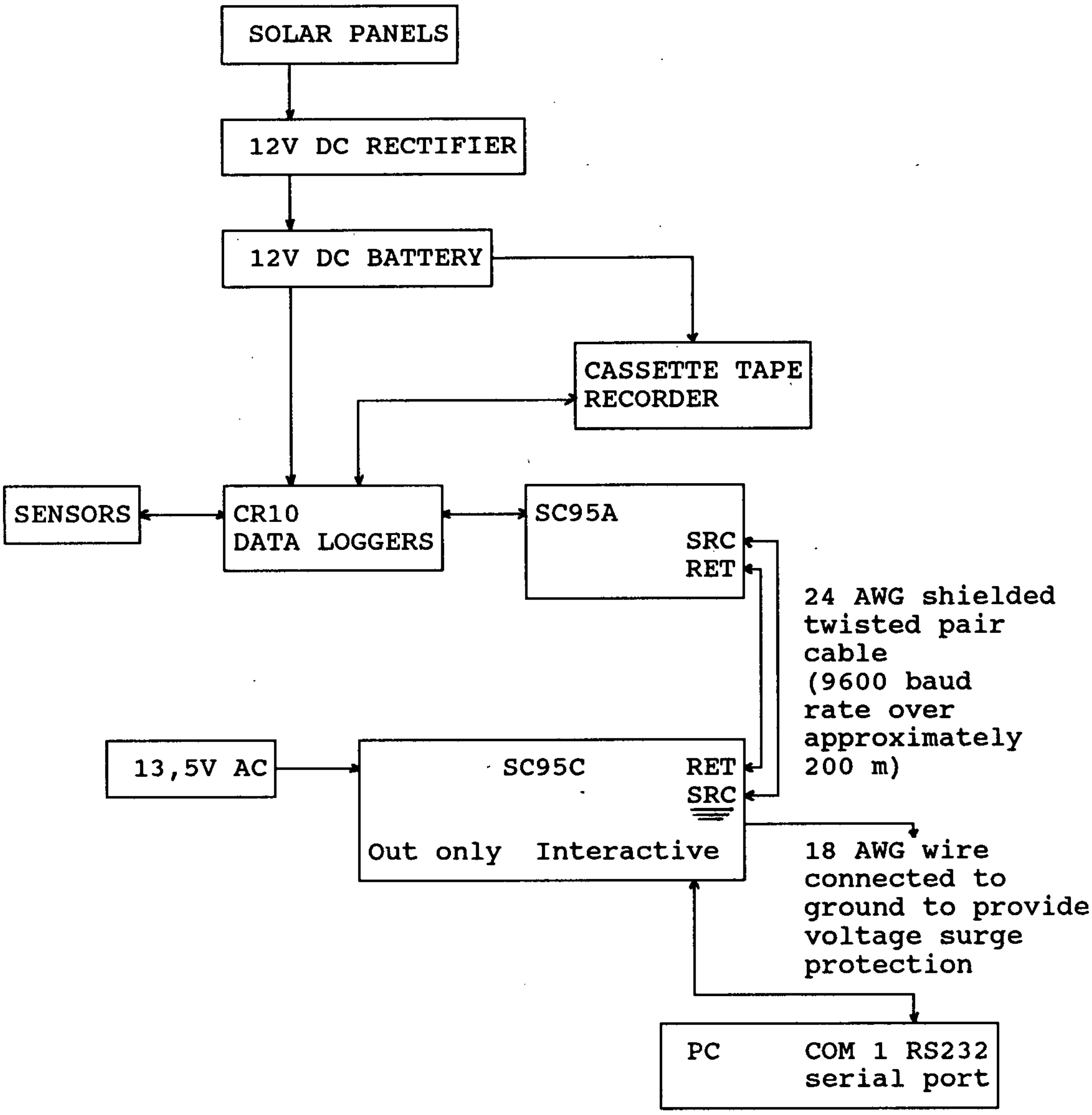

Figure 3
Connections and accessories for communicating between an automatic weather station and on-farm personal computer

The automatic weather station comprising a Campbell Scientific model CR10 data logger and associated sensors, was erected in the Karkloof, Natal at 30°14'E and 29°23'S. This weather station allows the monitoring and recording of real-time values of solar irradiance, relative humidity, air temperature, rainfall, wind speed and wind direction. The data logger, solar irradiance, wind speed and wind direction sensors, and the solar panels are mounted on a 3-m tower. Two short-haul modems connect the weather station to a personal computer.

The CR10 logger and data tape recorder are powered by a 12V DC battery whose charge is maintained by solar panels in parallel with a 12V DC rectifier.

A Campbell Scientific model SC95C short-haul call modem is connected via its interactive port to the RS232 COM1 port of the computer. This SC95C modem is powered by 13,5V AC and is connected via a shielded twisted pair cable, whose total wire resistance does not exceed 600 Ω in both directions, to a Campbell Scientific model SC9A short-haul modem at the weather station. This SC95A modem is connected to the CR10 data logger. The connections in this network are shown in Fig. 3. More recently the SC95A and SC95C short-haul modems have been superseded by the RAD haul Model SRM-6A short-haul modem.

The Campbell Scientific PC208 software package (as part of a suite of communication and telecommunication programs) enables the data logger to be computer controlled remotely with respect to programming, real-time data monitoring and data transfer.

Sensors

Wind speed is monitored by a 3-cup anemometer mounted on top of the tower. This sensor, ECO Model WS/D86 (available at ECO, PO Box 4332, Pretoria), utilises a reed switch located on the central axis of the sensor. Two separate magnets attached to the hub of the rotating assembly provide two contact closures of the reed switch for each revolution of the cup assembly. Wind speed is measured in $m \cdot s^{-1}$ and averaged over the hour.

The wind direction sensor mounted uppermost on the tower utilises a 10 Ω plastic potentiometer whose wiper is rotated by the vane assembly. The rotation angle is 358°. In order to protect the potentiometer from high current damage a 10 kΩ resistor is connected in series with the potentiometer. The CR10 logger is programmed for DC excitation and voltage measurement. The multiplier used to convert the input voltage to degrees of direction is determined by dividing 360° by full-scale input voltage.

Incoming solar irradiance is measured using a LI-200 SZ pyranometer sensor. This sensor measures the sum of direct and diffuse irradiance. Within the sensor is a silicon photodiode which has an equal spectral response from 250 to 2 800 nm. The pyranometer is mounted level, free from any obstruction to either direct or diffuse radiation. Total incoming radiation is integrated over the hour.

Air temperature is monitored by an ECO model TP87 temperature probe placed in a Stevenson screen. This is a silicon resistance thermometer having the circuit configuration shown (Fig. 4).

The sensor comprises the sensing element in series with a resistor to linearise the sensor output. The two components are mounted in a metal tube sealed with polyurethane. The sensing circuit operates as a variable potential divider, the resistance of the sensor varying with temperature.

Relative humidity is monitored using a XNAM10205 sensor. This transducer is a composite of organic and inorganic crystals which sense water vapour by the hygromechanical stress of small but powerful inert cellulose crystallite structures acting on a kovar beam, to which a pair of thermally matched, electrically isolated, silicon strain gauges are bonded in a half a Wheatstone bridge configuration. This instrument provides a full range response to relative humidity from 0 to 100%. The CR10 logger averages the humidity over the hour. Many problems, particularly sensor drift, have arisen with the use of these probes (Van Zyl, 1990). Frequent calibration is necessary.

Rainfall is monitored by a tipping bucket rain gauge. Each bucket tip is equivalent to 0,2 mm rainfall and the CR10 logger totalises the number of tips over the hour.

Power supply

Two solar panels, connected in parallel, supply regulated power to the 12V DC battery during daylight hours. The rectifier circuit is such that these panels do not drain the battery during the night.

Costs

An automatic weather station and sensors as described above costs approximately R18 000 (excluding the cost of the computer). The labour costs incurred in general maintenance of such a station are minimal when compared to those of a SA Weather Bureau first order weather station monitoring similar variables. The capital costs of a first order weather station are also approximately R18 000 (Botha, 1990). Data obtained using a first order station are daily maximum and minimum values and instantaneous recordings of the variables at specific times viz. 08:00, 13:00 and 18:00. The labour costs of a first order weather station include maintenance costs for the grass surrounds and maintenance of the sensors and recorders, as well as recording certain variables three times per day. There is also a significant saving on the costs associated with the use of wind speed and wind direction wax chart paper as well as chart paper required by other clock-type recorders. For some stations, Campbell-Stokes sunshine recorder data are used to calculate daily total radiant density from an Angström-type relationship. The cost of this process involves the cost of the recorder, the sunshine cards and the labour costs associated with changing the cards each day and the time-consuming task of determining the hours of sunshine for each day and then calculating the daily total radiant density. In the case of the automatic weather station, the solar irradiance is measured and the daily total radiant density routinely calculated.

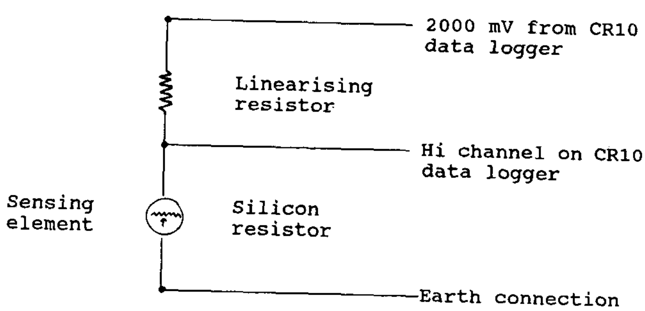

Figure 4
Circuit configuration of the ECO model TP87 temperature probe

Data acquisition

Remote programming of data logger

Use of the program TERM (part of the PC208 software from Campbell Scientific) allows one to remotely program the data logger. The station name is specified, followed by /E to edit the parameters used to indicate data logger type, communication adaptor, baud rate as well as the interface device viz. SHORT HAUL. "T" is specified to emulate the terminal and either 7H or 2718H to place the CR10 logger in the remote keyboard state. The CR10 responds by sending a carriage return, line feed and the > prompt. The CR10 logger is now ready to receive the standard keyboard instructions.

Once remote communications are complete, the CR10 logger must be returned to the telecommunication command state by entering *0.

Data logger to tape recorder to computer communication

The logger may be programmed manually or, via the short-haul modems by the computer, to store all data from its memory on an audio-cassette tape at either predetermined time periods via the logger or manually using the portable key pad. The data on the tape, the latter removed and replaced manually, are downloaded by the computer using the PC201 tape recorder card.

Data logger to short-haul modem to PC communication

It is assumed that the modems have been coupled correctly to each other, the data logger and the mains supply via the 13,5 V AC transformer (Fig. 3). It is also assumed that in the case of the CR10, instruction 96 has been included at the end of the output instructions in the program table. This instruction is used to activate the tape, storage module or serial data (printer) output.

- To monitor data logger input locations - use the TERM program to select the CR10 data logger and communications port (COM1 or COM2). TERM will prompt for this information whenever a new station name is entered or /P option is entered following an existing station name.

  Once the necessary parameters have been entered, a file is

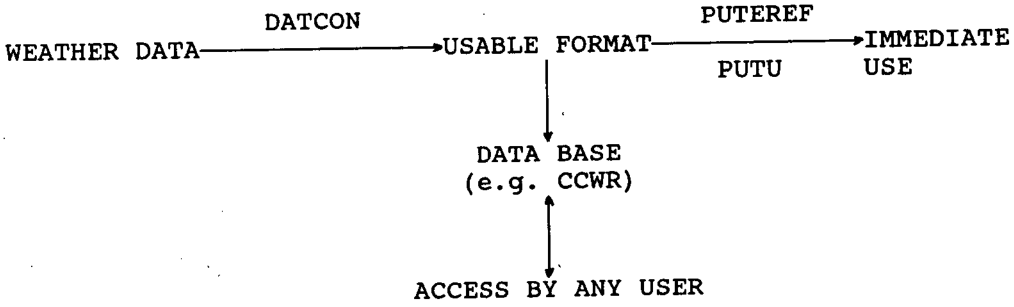

Figure 5
Processes involved in data transformation and handling by immediate users and data bases

saved with the relevant station name plus the extension .STN. To monitor the input locations, call the station by pressing the key M. The locations monitored are updated at the rate defined by the CR10 logger's program execution interval of Table 1. To exit monitoring locations press CTRL. and then Q to quit the TERM program.

- To retrieve and store data — the program TELCOM allows PCs to retrieve and store data from the CR10 logger. TELCOM will prompt for the station name.

To edit parameters, the station name must be followed by /e. The edit parameters sub-menu requires the data logger type, data collection method (select "since last call or most recent"), append file, data file format (select "comma delineated ASCII"), fix clock time and other options to be specified.

In order to transfer the data in the data logger's final storage, change the "next time to call" to a time a few minutes after current computer time.

To transfer the data from data logger to PC, for example, 9/G is entered. This will cause background transfer of all the finally stored data logger data into the file "9.dat" unless another file name has been specified. Thereafter select 9/C to call the logger and thus append the most recent data to the 9.dat file.

Results and discussion

Once data have been transferred to the host computer they must be transformed and collated into a usable format for use in the field or for storage in an accessible data base. The pathways involved in this process are illustrated in Fig. 5.

After retrieval, the data are checked and sorted for the most recent 24-h period and then into a data archive using a word-processor package (Word Perfect). Thereafter, the data are converted using the program DATCON. DATCON converts, lists and saves the hourly weather data in a standard format for use in the program PUTEREF.

PUTEREF transforms the hourly data to daily data and, using a parameter and crop factor file, calculates daily reference crop evaporation for use in the crop growth simulation model PUTU.

The irrigator can immediately use the reference crop evaporation ratio with the relevant crop factor for scheduling irrigation. Should the PUTU program be available, irrigation dates can be forecasted and the sensitivity of the crop to water stress can be determined.

These transformed data are also sent via modems to the Computing Centre for Water Research, University of Natal, Pietermaritzburg where they become available for registered users.

This network system has been operating successfully for more than a year and the weather station has been accessed from various remote computer stations around South Africa with no technical problems.

The on-farm scheduling programme in operation is set on a 5-d cycle. During the winter of 1989 the water supply decreased to such a level that the irrigation system could only run for 1 h every 6 h. Having access to near-real time data enabled the irrigator to apply this limited water effectively, preventing any significant crop water stress.

Summary

According to the literature, no irrigation scheduling services using near-real time weather data are in operation in Southern Africa at present. As most of the major government irrigation schemes are in the drier areas of the country, water supply is limiting and it is essential that this supply is scheduled effectively.

A network which collects near-real time weather data from an automatic weather station, collates and transforms the same, has been established in the IPE project and has been operating successfully. This network includes a remote and on-farm PC, error detecting telephone modems and short-haul modems.

Operational software has been developed and is used together with the commercial software to access the data and transform it for use in locally developed irrigation models and the crop growth simulation model PUTU.

Automatic weather stations which are affordable when compared to current first order surface weather stations have proved to be reliable even under extreme conditions and are commercially available. Such weather stations are used in this network which is invaluable for on-farm water distribution and management, as well as between farms.

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