Plant Growth Monitoring System

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Abstract

This project is to build a monitoring system for plant growth. Various factors such as temperature, soil humidity, atmospheric gas concentration, airflow and light intensity is monitored and analyzed to determine whether the environmental conditions are favorable for plant growth. As an extension to this we aim to control all these parameters as required for the crop variety. This project enables us to demonstrate our knowledge in embedded systems by interacting using sensors. We are interfacing soil humidity hygrometer moisture detection sensor, waterproof digital thermal sensor and photo light sensitive resistor with Arduino for measuring the humidity, temperature and light intensity respectively. This gives an opportunity to interact with ESP8266 to send the data to the cloud, which enables us to learn about Wi-Fi communication and various communication protocols.

I. Introduction

Lack of fresh produce in northern Canada due to harsh climate conditions force them to spend half of their earning for food. The food production in these areas will be possible if there is a controlled environment. To establish an ideal environment for plant growth, an effective monitoring Embedded system is required.

Plant growth and yield depends on various environmental factors. The three main factors are light intensity, soil humidity and temperature. Light is an essential factor in photosynthesis which is essential for plant growth. Temperature is another climatic factor that influence all the plant growth processes such as respiration, transpiration, photosynthesis, seed germination and trans-location in plants. Humidity is also an important factor because it an effect the functioning of stomata in plants which can regulate the water loss.

II. Proposed solution

To establish an ideal environment for plant growth, an accurate and efficient Embedded monitoring system is required. There is a need to monitor the changes in the temperature, soil humidity and light intensity. The measured reading should be logged for future analysis. To measure the temperature a digital temperature sensor(DS18b20) is used. GL12528 photo resister is used to measure the light intensity. A reliable and cost effective soil humidity sensor is used to monitor the soil humidity.

All the three sensors are interfaced to Arduino uno microcontroller. For remote data logging and monitoring ESP8266 Wi-fi module is used. ThingSpeak server is used for data logging. The server provides data analysis tools like MATLAB analysis for easy representation of data into widgets and graphs. The stored data can be used using mobile apps or online website.HC-06 Bluetooth module is interfaced for locate data monitoring using bluetooth devices like smartphones.

III. Key components

i. Arduino Uno

Figure 1: *Arduino uno*

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter

ii. Temperature Sensor

Figure 2: *Temperature Sensor*

Digital temperature sensor DS18b20 from DALLAS SEMICONDUCTOR provides 9 or 12 bit resolution which is programmable. The sensor uses 1 wire interface which requires only 1 wire for connect multiple temperature sensors. It has zero power consumption in standby mode. The temperature range is from -55 to 125 degree Celsius.

iii. Photo Resister

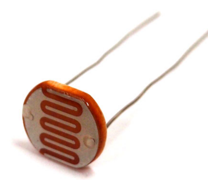

Figure 3: *GL12528 photo resister*

The GL12528 is a cost effective and reliable photo-resister which can be used to measure the light intensity after calibration. GL125 series offer good reliability and good spectral characteristics.It is widely used in industrial and photoelectric applications.

iv. Soil Humidity Sensor

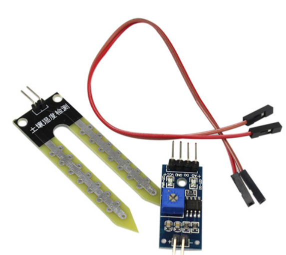

Figure 4: *Soil Humidity Sensor*

The soil humidity sensor is low cost and reliable sensor which comes with LM393 comparator. The sensor has a capacitive probe which is inserted in the soil to measure the soil humidity. When the soil is dry the sensor output a high voltage and voltage reduces with increase in the humidity. The sensitivity of can be adjusted using the potentiometer in the LM393 comparator.

v. ESP8266 Wi-Fi Module

Figure 5: *ESP8266 Wi-Fi Module*

The ESP8266 is used to send the measured reading to the cloud storage by connecting the system to the local Wi-Fi network.ESP8266 is cost effective as well as low power device. The AT commands in the inbuilt firmware is used to communicate with module by interfacing with the Arduino uno.

vi. HC-06 Bluetooth Module

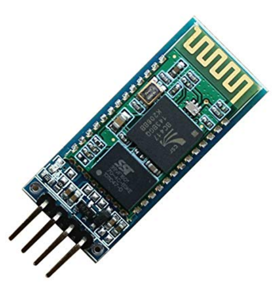

Figure 6: *HC-06 Bluetooth Module*

HC-06 Bluetooth Module is used to send the data to Bluetooth devices like smart phones which enables us local data monitoring. The module is interfaced with the Arduino uno using serial communication.

IV. Methodology

i. High Level Architectural Block Diagram

The figure 7 shows the high level architectural block diagram

Data Acquisition The data from the sensors are send to microcontroller. The temperature sensor is a digital sensor which sends the actual temperature in degree Celsius. This sensor is connected to the digital pin of the Arduino. The LDR and Soil humidity sensor reading are analog. These two sensors are connected to the analog pin of the Arduino.Raw analog data needs to be converted to meaning full representation of data.

Data Logging The Measurement are send to ESP8266 Wi-Fi module and HC-06 Bluetooth module using the serial communication. This requires more than one serial communication which is established using software serial in Arduino.The ESP8266 will be connected to Internet using the local Wi-Fi network and the data will be sending to the cloud storage

Data Representation Thingspeak servers are used for data logging. Visualization tools like widgets and graphs are used. MATLAB functions offered in this site can be used for detailed data analysis. The data send using the bluetooth module can be viewed using mobile application.

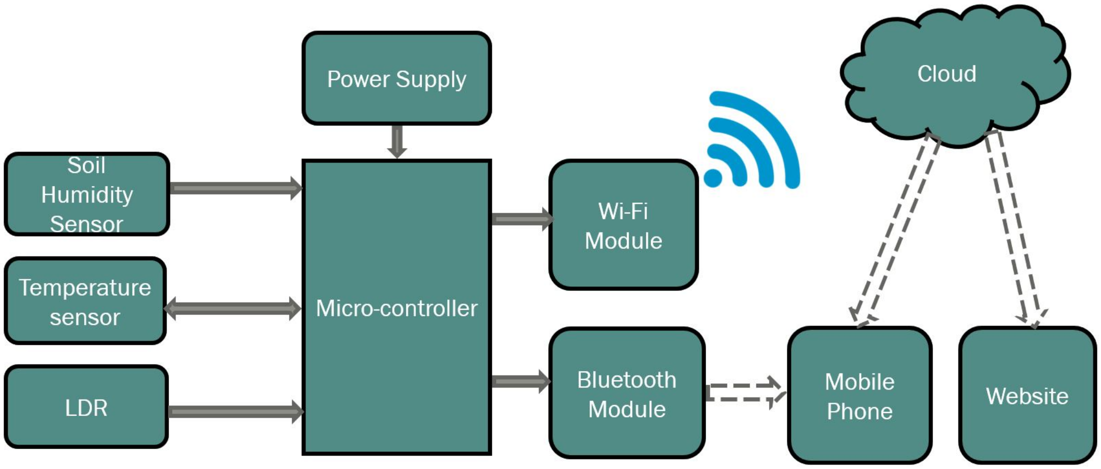

Figure 7: *High level architectural block diagram*

ii. Testing of Sensor

Soil Humidity Testing

The soil humidity sensor testing is done using dry samples and wet samples.The humidity in the soil is varied to get different humidity setting.

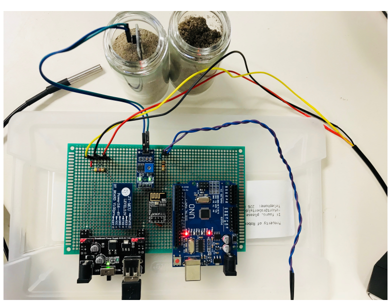

Figure 8: *Setting used to test the soil humidity*

Dry Soil Sample Results

The sample used for testing is dry soil. The figure 9 shows the variation of humidity in percentage verses time. Each reading is taken after 2 minutes time interval.

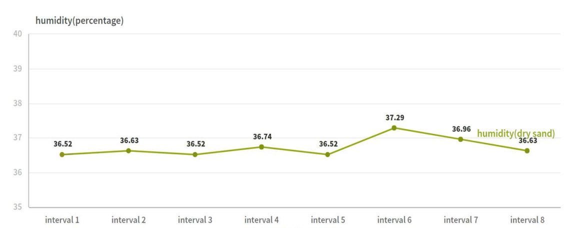

Figure 9: *Graph showing the variation in Humidity in dry soil*

The graph shows that the humidity reading obtained form the dry sample was around 37 percentage.

Soil Water Mixture Sample Results

The sample used for testing is obtained by changing the sand to water ratio in the mixture. Testing was conducted using 3 different sand to water ratios 14:1,14:2 and 14:4. The figure 10 shows the variation of humidity in percentage verses time. Each reading is taken after 2 minutes time interval.

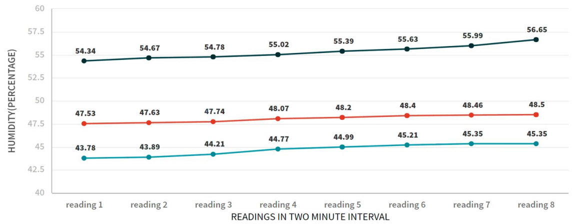

Figure 10: *Graph showing the variation in humidity when wet sample is used*

The Blue line graph corresponds to the results obtained when the sand to water ratio in the mixture was 14:1.The reading obtained was around 44 percentage.The Red line graph corresponds to the results obtained when the sand to water ratio in the mixture was 14:2.The reading obtained was around 48 percentage. The Black line graph corresponds to the results obtained when the sand to water ratio in the mixture was 14:4.The reading obtained was around 55 percentage

Temperature Sensor Testing

The sensor used is a digital sensor (DS18b20) which does not require much calibration.To test the sensor we have used ice and hot water. The figure 11 shows the setting used for testing the sensor.

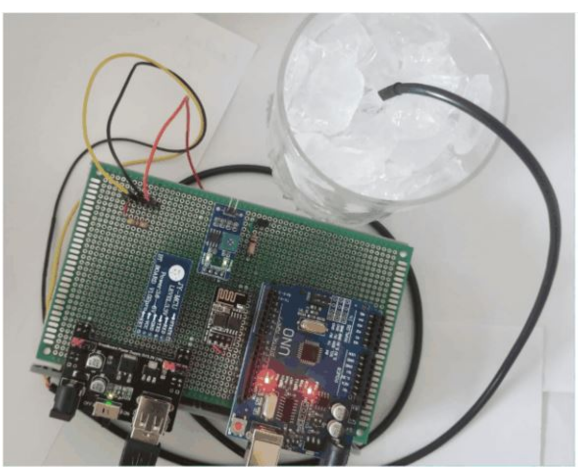

Figure 11: *Setting used to test the temperature sensor*

Result of Temperature Sensor on Ice

The graph shows the variation in the temperature when the testing was done on the ice. The reading was taken with a time interval of 2 minutes.

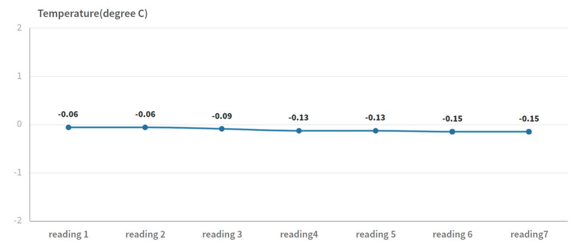

Figure 12: *Setting used to test the temperature sensor*

The blue line graph shows that the reading where consistent around -0.15 degree Celsius.

Result of Temperature Sensor on Hot water

The graph shows the variation in the temperature when the testing was done on the hot water. The reading was taken with a time interval of 2 minutes.

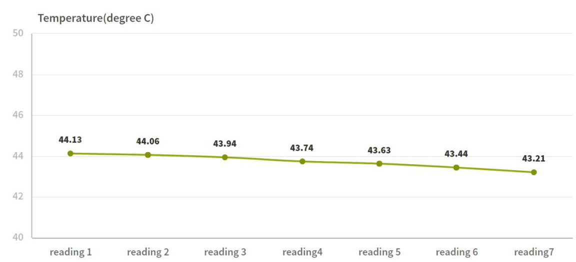

Figure 13: *Setting used to test the temperature sensor*

The blue line graph shows that the reading where consistent around 43 degree Celsius.

Photo-resister testing

The photo-resister is tested using a calibrated LUX meter. To obtain a controlled environment the testing is done on the room with brightness control.
The figure 14 shows the arrangement used to calibrate the photo-resister.

Figure 14: *Setting used to test Photo resister*

Photo-resister vs LUX meter comparison

The graph shows the LUX measured using the LUX meter and photo resister for different brightness settings.

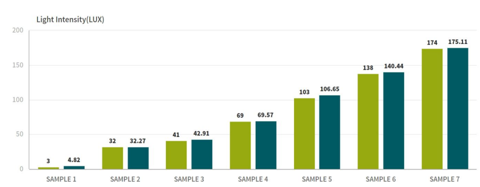

Figure 15: *Results of Photo resister Calibration*

The green bar graph shows the reading taken using LUX meter and the blue bar graph shows the reading taken using the LDR.

From the graph its is clear that the LDR readings closely matches the LUX meter reading. The percentage error is less than 4 percentage.We could able to get usefulness of a costly LUX meter using an photo-resister.

V. Results

We were able to implement an accurate and efficient embedded monitoring system that can not only interface to various sensors to measure vital information but also send the data to the cloud storage that can be displayed on (both mobile and web) dashboard.

i. Results obtained using Wi-Fi

The remotely logged data using ESP8266 Wi-Fi module.

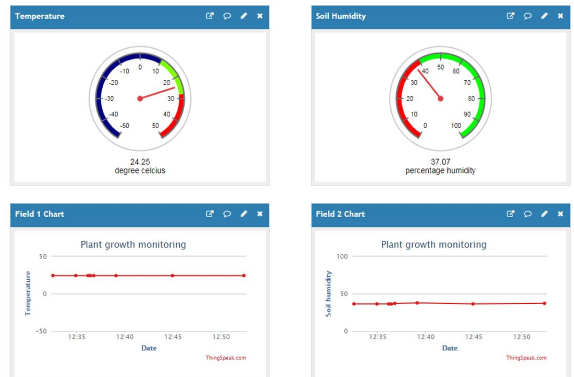

Figure 16: *Data representation in thingSpeak*

The data is represented using widgets and analyzed using line graphs. The results can be viewed using the link below.

https://thingspeak.com/channels/518310

ii. Results obtained using Bluetooth

Local data monitoring using HC-06 Bluetooth module.

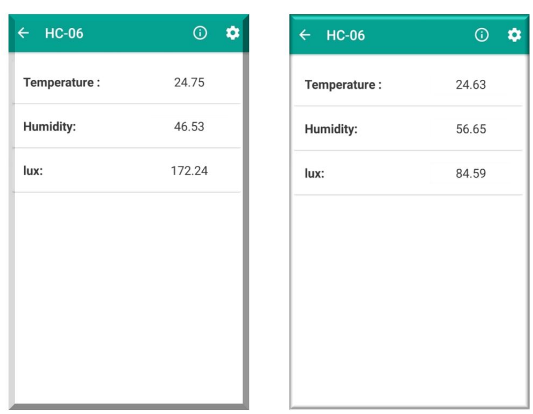

Figure 17: *Data representation in Mobile App*

The figure 17 shows the data monitoring using the smart phone via bluetooth.

VI. Recommendations

As future enhancement several systems will be deployed to the actual environment for field test to collect the data to be able to design a feedback control system towards autonomous growing of fresh produce.

More sensors will be added to measure atmospheric gas concentration, Ph value of the soil for detailed plant growth monitoring. The corroding effect of the soil humidity sensor probe will be analyzed to learn the effectiveness of readings.

VII. Acknowledgment

The authors wish to thank Professor So-Ra Chung, Professor Rudy Hofer and our sponsor Robert Elder for their assistance and support in successfully completing the project.

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Appendix A

Schematic Diagram

The figure 18 show the wiring diagram of Plant growth Monitoring System.

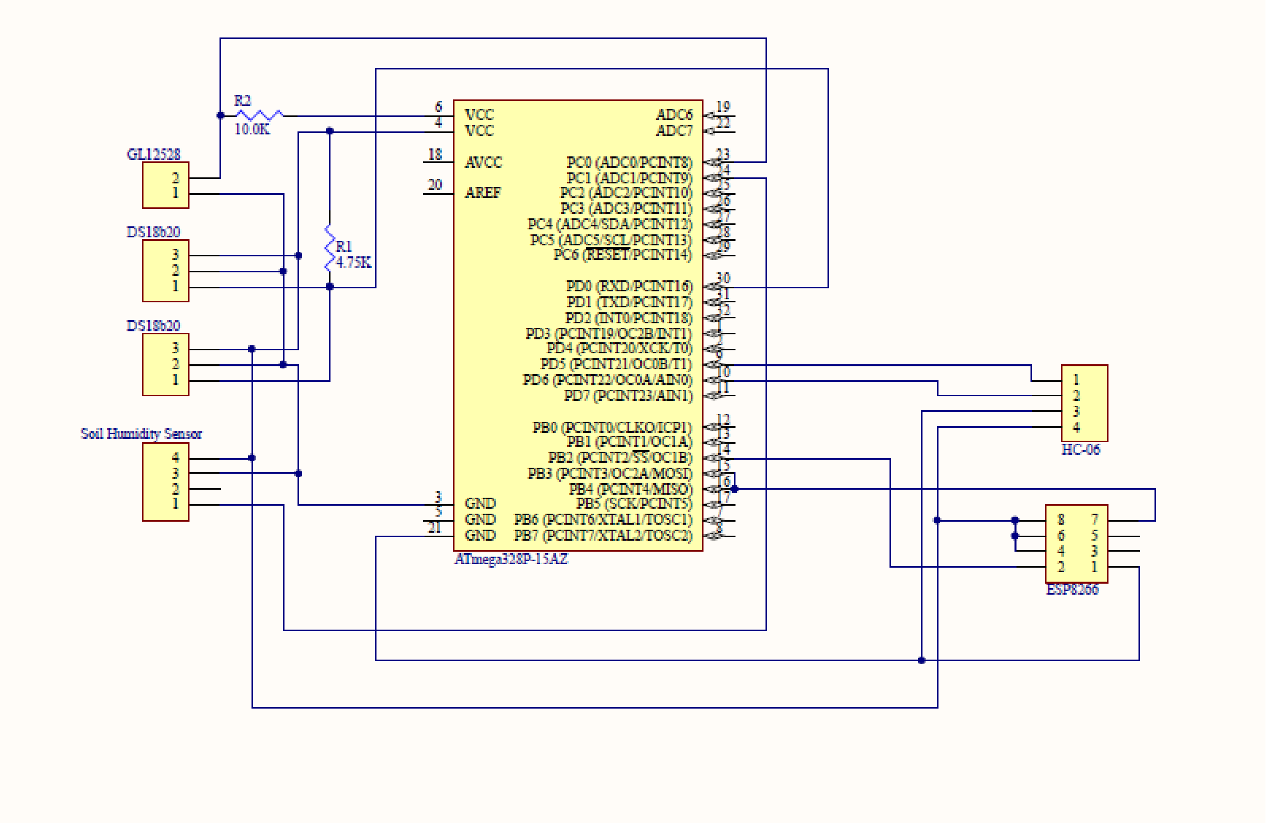

Fig. 18 Plant growth monitoring system wiring diagram

Appendix B

Map Showing Plant Hardiness Zones in Canada

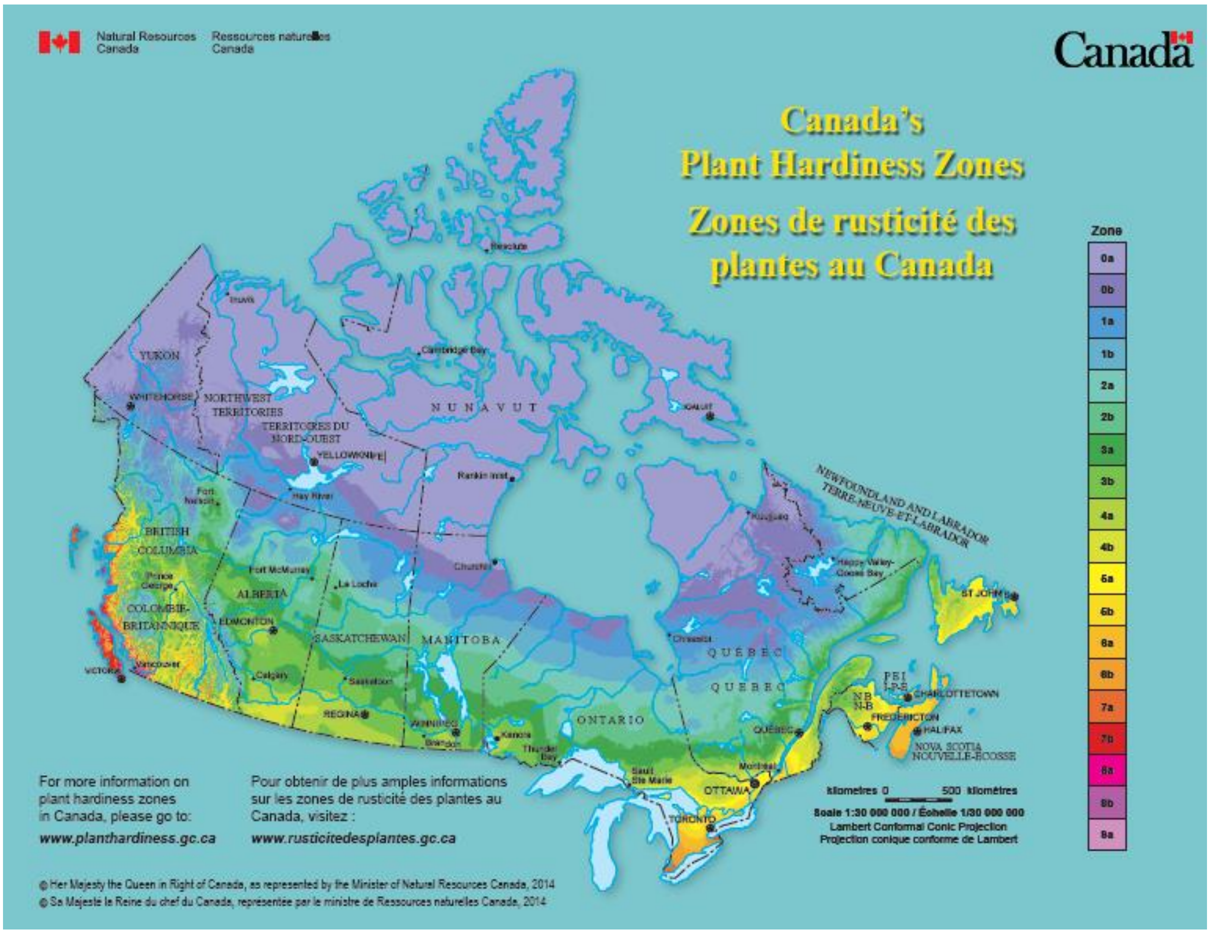

Fig. 19 Map showing plant hardiness zones in Canada

Equation and definition of suitability Index.

$$Y = -67.62 + 1.734X_1 + 0.1868X_2 + 69.77X_3 + 1.256X_4 + 0.006119X_5 + 22.37X_6 - 0.01832X_7$$

where:

- Y = estimated index of suitability
- X_1 = monthly mean of the daily minimum temperatures (°C) of the coldest month
- X_2 = mean frost free period above 0°C in days
- X_3 = amount of rainfall (R) from June to November, inclusive, in terms of R/(R+a) where a=25.4 if R is in millimeters and a=1 if R is in inches
- X_4 = monthly mean of the daily maximum temperatures (°C) of the warmest month
- X_5 = winter factor expressed in terms of $(0°C - X_1)R_{jan}$ where R_{jan} represents the rainfall in January expressed in mm
- X_6 = mean maximum snow depth in terms of S/(S+a) where a=25.4 if S is in millimeters and a=1 if S is in inches
- X_7 = maximum wind gust in (km/hr) in 30 years

Map Showing Temperature Zones in Canada

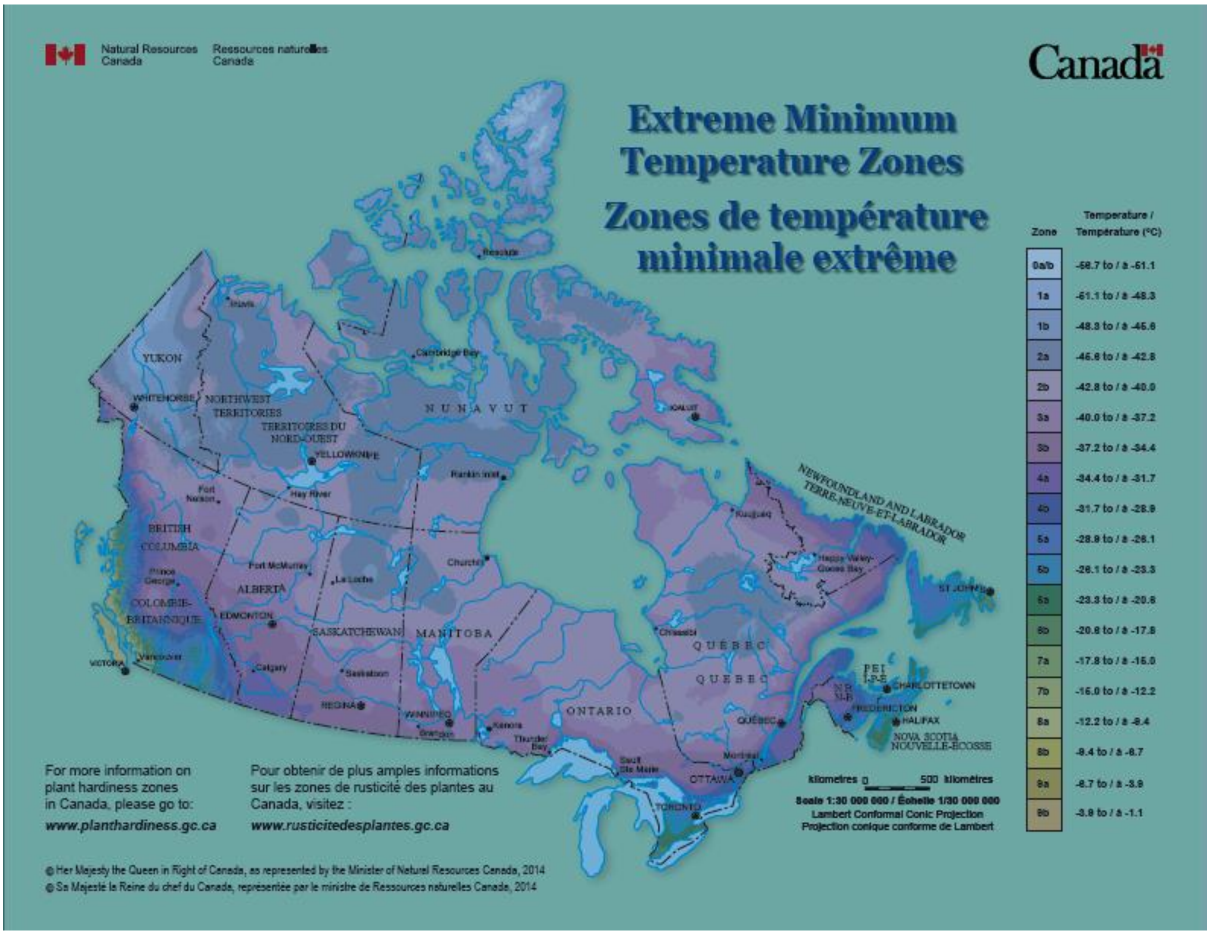

Fig. 20 Map showing temperature zones in Canada