

## The Conception of the Net Weather Station for Measuring the Microclimate of the Forest

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**Abstract.** The project of meteorological station is designed to monitor the state of the weather on the selected (forest areas) as well as the collecting the data to analyze the dynamic of the changes weather parameters. The main idea presented in this paper, base on assumption that single weather station can be used as a part of net. The simultaneous and continuous measurement of many parameters such as temperature, pressure, humidity and sunlight located at grid points could work out finally the weather map combined with the digital terrain model. The modern electronic make possible flexible connecting individual stations in subsystems and exchange of huge amount of information leading to build base knowledge. In the first part of the article it is presented the conception of the information system. In the next part there are outlined the results of works with the prototype of the measure mode. Dedicated to applications in forestry prototype of device, can be used to measure temperature, pressure, humidity and sunlight. The additional features of the device are the possibility of writing data on micro SD card, supplemented with current time, day, and year. The design and research is a pilot, before the creation of a regular grid of sample plots with the use of many such devices. The objective is to gather accurate meteorological data from the interior of the forest-based geostatistical analysis, necessary for breeding purposes. Because of their design frames weather, it can be installed on most trees. Presented prototype of basic station used in the concept of measuring net, generates data from the sensors, which are strongly correlated with the compared professional station.

**Keywords:** measuring net / grid, Arduino™, Stevenson Screen, sensors meteorological parameters, forest.

**Conference topic:** Environmental protection.

### Introduction

Changes in ecosystems translates into global climate. In many situations the information about weather defined as the state of the atmosphere at a particular place and time (Rożek 2011) is not enough adequate to the real situation in the specific terrain and biological conditions. The data field from traditional meteorological stations are precise in fact only in the exact place of measurement. Long strings of meteorological data are very useful because it allows to analyse and model of climate change (Grotjahn *et al.* 2016). The short sequences may be used in specific microclimatic studies (Wirz *et al.* 2016). The effectiveness of the forest management to a large extent depends on the knowledge of current meteorological parameters and their dynamics in a specific area. Interference in the functioning of a complex organism such as a forest, based not only on the global weather data provided by traditional rarely localized stations as well as to a large extent on the knowledge of local weather but environmental conditions as well. Proper analysis of the weather on the forest area, takes account of the fact that the forest itself is an active element contributing to changes in the weather. An example of a specific approach to the meteorological data in the context of forest issues is fire protection. The rate of fire spread is primarily shaped by weather conditions (Wiler 2007). In the woods there is more humidity than in not forested areas and there are different thermal conditions, especially the vertical stratification of temperature. Temperature measurements in forested areas show a slower heat loss and slower heating of the terms comparing to open areas (Szymański 2001). It is advisable to conduct twenty-four hour measurements directly inside the forest in order to more precisely determine the risk of fire.

Another example would be a search the conditions under the trees which created the forest crops and the growth of planting depend on such factors as fluctuations in temperature or humidity of the forest litter. Determining the proper time and place of permanent monitoring plays a key role (Walendzik 1992). About the influence of temperature variations on such forest crops describes Schnaider (1992), sudden drops in temperature (frost early and late). Quick start irrigation under adverse conditions can protect young seedlings from damage this year's gains (Babiński, Białkiewicz

1992). Similarly proceed in case of too high temperatures (soil 45°C–60°C) and sunlight thus avoiding the solar blights (Małuja 1992). Accurate information about the forest soil are important for silviculture plan, the forest creates a unique microclimate, called forest phytoclimate (Szymański 2001). Very important for biodiversity in search of a better size forests needed to maintain proper conditions for forest interior (Murat 2005).

In general cases, knowledge of publicly available weather data is insufficient for forest research. The solution could be a dense network of environmental sensors located inside the forest. Environmental monitoring using external servers can provide data to the control panel, which, thanks to reporting and appropriate management strategies, can help plan activities in a large environmental companies. In addition, environmental monitoring allows you to schedule the recommended temperature and humidity likely to be required by the indicators in the central database (Nkenyereye, Jang 2016). Another aspect would be to monitor the impact of large urban agglomerations or factories on the state of health of forests. The observation could be made by means of wireless sensors air quality with a system of alerting the proper services (based on the platform Arduino and XBee module), which would enable faster decision and action (Al-Dahoud, A., Al-Dahoud, A. 2015). Rahaman Laskar *et al.* (2016) created projects of small weather stations based on the Arduino platform, which measured temperature, pressure, altitude stations – the main goal was to send such a platform in the atmosphere using a balloon. Creating a meteorological measuring net is used for example in the observation area of reclaimed areas study of an open-cut surface mine in rural Australia. They show that microclimate data can provide insights into the efficiency of specific rehabilitation and provide early indicators into potential problems (Kusy *et al.* 2014). Detailed examination of the forest interior with the use of this device, can significantly enhance the scope of information useful from the point of view of biodiversity as well as basic research.

### The conception of net measuring

The use of a compact network, low-cost weather station can become a tool to study the dependence of many natural occurring inside the stand. Based on data from the network devices in a specific location, eg. in Białowieża forest, we can use the geostatistical analysis methods to create a map of the changing microclimate conditions. The resulting information can help in solving the problems of natural forest renewal or fire hazard. An important step in the research will be to have a target of about 500–1000 basic meteorological stations (depending on the size of forest complex), which will send the measurement data to the middle station. Basic station will be equipped with sensors for gathering information from the target space in the forest. For example, in in Białowieża forest (Fig. 1), one basic station will be located in the middle of the forest compartment – one compartment is 25 hectares of forest. Basic stations will be placed in the middle of the compartment not to have interference measurement, eg. from passing cars or different conditions of the microclimate of the open space on the road. Each basic station will be equipped with a radio transmitter and receiver (XBee Module – Al-Dahoud, A., Al-Dahoud, A. 2015), through which will send their data to the middle station. Assuming a safe range of radio waves in the forest, middle station collecting data from base stations should not be more than the radius of 500 meters from the farthest base station (Fig. 1).

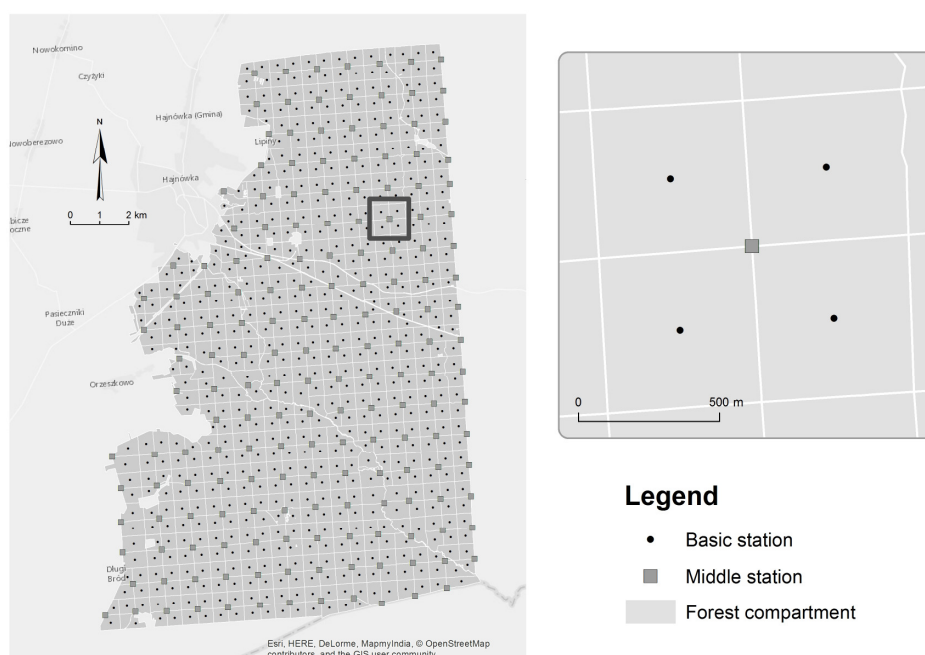


Fig. 1. The concept of measuring net in Białowieża forest – The State Forests – Forest District Hajnówka

One middle station will be responsible for collecting data from one zone – in one zone we have 4 basic stations in 4 forest compartment (may be more while maintaining the distance needed for communication). The location of this station will be at the intersection of road crossing (equal coverage for basic station). This station has no environmental sensors, for it will be equipped with a SIM card module and LTE modem, through which will send and receive data from the central station (Fig. 2). The middle station will be seated on the platform Arduino™ Leonardo and power module on Arduino™Pro Mini (Table 1; URL 1).

The project involves the central station located in the vicinity, eg. a town or forest district, because it will require a constant power supply. The station will be additionally secured by an alternative power source as in the case of primary and middle station (solar panels, more batteries, Arduino™ Pro Mini). The station is equipped with a Arduino™ Mega (Table 1) which will be connected to the module SIM cards along with LTE modem. All data from each middle station will be collected on a traditional HDD disc with a minimum capacity of 2 TB (Fig. 3). The central station will synchronize data with a cloud web and send to the server. The cloud is to archive the basic data received from the central station. The last part of the entire network monitoring microclimate of the forest is a computer as a server, located at the institute / university / home. The server will collect data by downloading them from the web cloud, and carried out detailed geostatistical analyses by producing maps (Fig. 4). All data will be available to the public in the form of a “Microclimate Geoportal”, which will present the current situation, eg. in Białowieza forest, as well as archival measurements with statistics.

From the server using the appropriate application it will be possible to make changes in the source code of each station in real time. The changes will be sent to the central station using LTE, which in turn pass them in the same way to each station average. The next step is will send command from middle station to the basic station via radio waves (Fig. 2, 4).

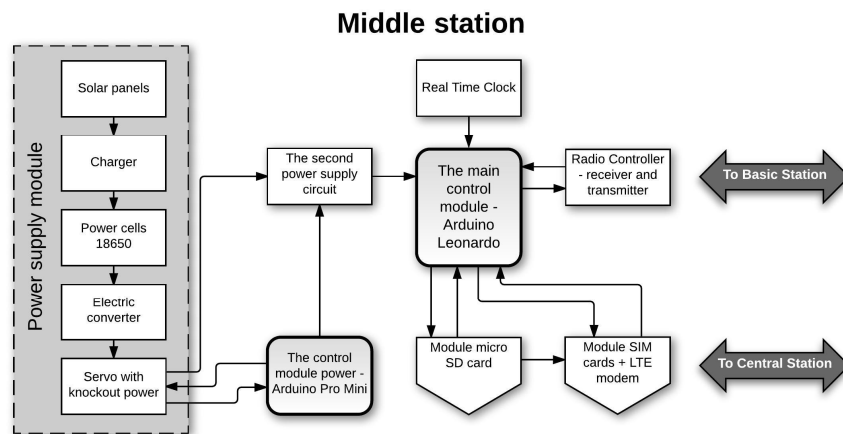


Fig. 2. Scheme prototype – Middle Station

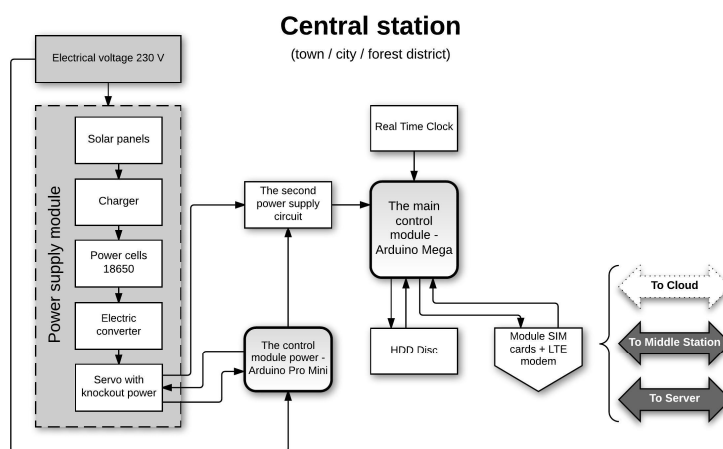


Fig. 3. Scheme prototype – Central Station

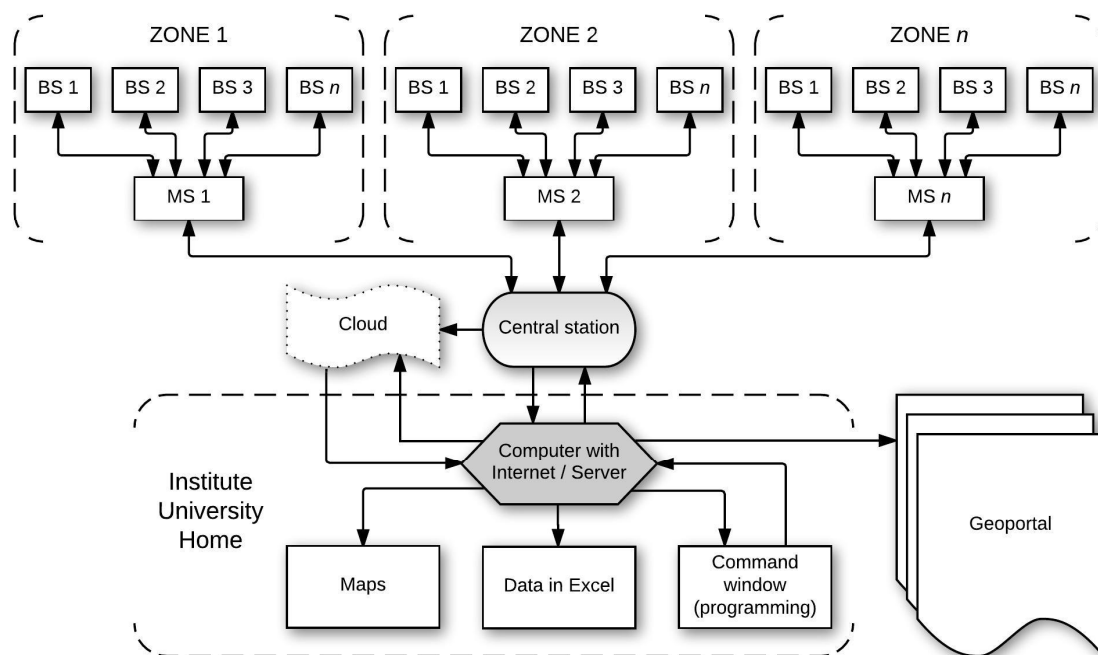


Fig. 4. Scheme prototype – All net measuring

#### The basic station – prototype of the measuring device

In preparation for the presented concept, we created and developed a prototype of a meteorological station as a fundamental element of entire network system called basic station. The criteria for determining the suitability of basic station in the network concept is: the price enabling the construction of a stations network, ease to use and maintenance of metrological parameters close to the parameters of the classical meteorological station. Designed method of mounting is not a negative effect on the tree trunk, weather resistance and modular design due to the possibility of further expansion. In prototypie provides for the possibility of recording data on the micro SD card.

As a result of reviewing the market of low-cost weather stations it was not possible to find the station with corresponded to the expected criteria. It was decided to create own design called later in this article “SZ/SZ 261” (own name). The project is based on a modular design, which enables optimization of measurement parameters. The concept of a weather station includes the use of an open platform with the possibility of programming via the USB interface and the radio waves, as well as LTE modem. Due to the low energy consumption, high availability of additional modules and ready-made scripts programming chosen Arduino™ Pro Mini based on microcontrollers AVR 8 bit (Table 1).

Table.1. Comparison of several models Arduino™ (URL 1)

	Arduino™ Pro Mini	Arduino™ Nano	Arduino™ Leonardo	Arduino™ Mega
Microcontroller	ATmega328	ATmega328	ATmega32u4	ATmega2560
Clock speed	16 Mhz	16 Mhz	16 Mhz	16 Mhz
Memory	32 kB	32 kB	32 kB	256 kB
Digital pins	14 (6 PWM)	14 (6 PWM)	20 (7PWM)	54 (15 PWM)
Analog pins	6	8	12	16
Programmer	no	built-in	built-in	built-in
EEPROM	1 kB	1 kB	1 kB	4 kB

Despite the low energy consumption of the controller to prolong the working prototype, it features a photovoltaic modules mounted beneath the acrylic transparent roof. Structures used birch wood painted in white colour reflecting the sun's rays. Total weight (approx. 1 kg). At the bottom of the frame provides space for batteries, printed circuit board and the system responsible for power control. In the upper part of the housing is a printed circuit board and

sensors on the platform Arduino™ (Fig. 5). The main control unit is based on the platform Arduino™, which is a key element of the station (Tuczyński 2015) responsible for power control and reading of the sensor, saving them on a memory card and send data by radio waves or LTE modem. The estimated cost of building a single device with sensors is about 120 € (the moment of purchase of part-dollar exchange rate.: 1\$–0.92 €, buying rate on the day 10.01.2017r.: 1\$–0.94 €).

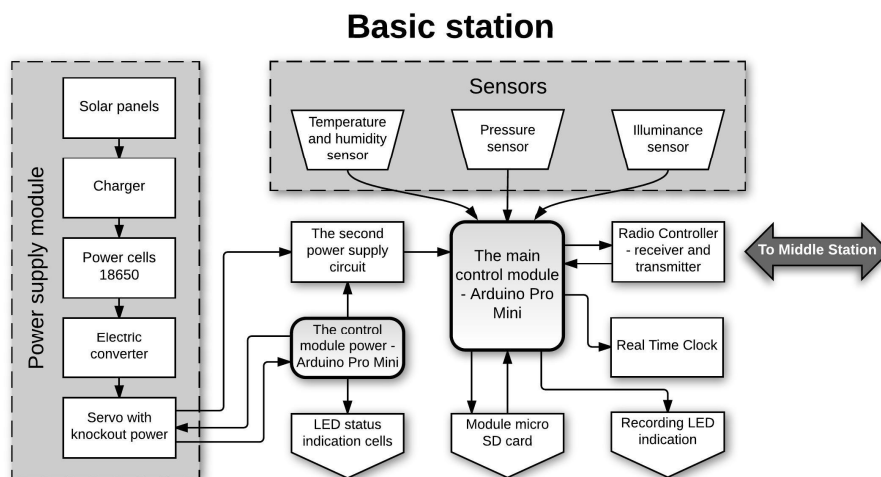


Fig. 5. Scheme prototype SZ/SZ 261 – Basic Station

The evaluation of measurement accuracy and efficiency of the meteorological station prototype SZ/SZ 261 – Basic station was tested in real conditions at a temperature below zero. All data from Rogow stations were used as reference (Fig. 6). The results obtained by prototype indicate a strong correlation with the reference data from the station in Rogow (Table 2)

The course and test conditions:

Places:

- Measurements of temperature, humidity and pressure on the device prototype and classic (standard) meteorological station dimensions 15×15 m located in Rogow (51°49'07.0''N 19°53'45.2''E – Poland).
- The analysis of the light intensity sensor was carried out in the open urban space in Ostroleka (53°04'56''N 21°33'51''E – Poland).

Used equipment reference:

- Measurement of temperature, humidity, pressure - equipment professional, certified meteorological station in Rogow (made 345 measurements – in a time resolution of 1 hour).
- Measurement of light intensity: L-50's Sonopan (made 122 measurements – in a time resolution of 1 minute).



Fig. 6. Device prototype (on the left) mounted at same height sensor (on the right) – reference station Rogow (Fig. P. Szymanski)

Table 2. Summary of differences in mean values, minimum and maximum values of the correlation coefficient for the analyzed characteristics of a prototype measuring meteorological cage in comparison with the reference data

	Average	MIN	MAX	Correlation coefficient [r <sub>xy</sub> ]
Temperature [°C]	0.2	0.0	-2.7	0.9954
Humidity [%]	-3.7	0.0	-12.8	0.9618
Pressure [hPa]	-3.4	2.1	-4.4	0.9996
Illuminance [klx]	-0.8	-0.4	-1.3	0.9995

## Discussion

The presence of a USB interface and radio with LTE modem enables fast programming and easy to read weather data stored in the cloud and displayed on the “Microclimatic Geoportal”. Low final cost of manufacture of the prototype will allow in the future to create a complete measurement net in the forest, which could monitor large areas such as Białowieża forest. Comparison of results with the devices SZ/SZ 261 and the reference devices concluded that there was a high convergence results recorded. In addition, tests have shown high reliability power supply, carried out at low temperatures lasted without interruption for more than 14 days.

The measurements are dependent on the spatial arrangement of trees that could be affected by changes in temperature and humidity phytocoenose forest. Additionally, it can be tested according to fluctuations in temperature and humidity for the renewal of the stand within the seats, and in forest areas located around socket. An example would be a study of the microclimate for European beech (*Fagus sylvatica* L.), analyzing its scope and possible modeling of the border, eg. in southern central Europe (Mellert *et al.* 2015). The collection of data and the values and distribution in the forest area of temperature, humidity, intensity of light that reaches the forest interior gives information whether the specified area will be possible to be effective, natural regeneration of trees and thanks measuring illumination will be possible to study how much light reaches the interior of the forest. With such data, eg. in Białowieża forest will be possible to link this information together with the spread dynamics of the spruce bark beetle (*Ips typographus*), which picks the lighted tree trunks.

## Conclusions

- The proposed solution of the forest microclimate net with use the presented basic station is a economically viable and valuable from the science point of view.
- Valuable asset is the ability to collect data about the forest environment continuously presenting maps of changes in the form of a “Microclimate Geoportal” shared society and scientists for basic research, as well as for archiving purposes as historical data.
- The measurement results of the prototype comparing to professional weather station are strongly correlated, which justifies the decision to use this device for measurements in the forest environment
- It is possible to further expanding basic station of the other modules: such as CO<sub>2</sub> content in the air sensor, measuring ground temperature at a depth of 5–10 cm, wind speed sensor, the camera (photo-trap, monitoring the environment in the colours RGB or IR).

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