A Novel Fully Automated Soil Erosion Monitoring System

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Abstract. Soil erosion is one of the biggest global environmental problems. Finding new innovative systems to measure soil erosion more accurately is a priority. An effort is being carried out in this study to use automated electronics in order to systematically and accurately measure soil erosion. In addition, the frequent measurements taken will help collect a large amount of data on soil erosion. The design of an autonomous, fully automated and remotely controlled soil erosion monitoring system is presented in this work. A novel approach that uses ultrasounds to detect ground level changes with very good accuracy (less than 1mm), is proposed. The presented setup is capable of monitoring other import parameters related to soil erosion, such as soil moisture, soil temperature and rainfall. The collected data will be used to further understand soil erosion processes that will help land managers mitigate this problem effectively and efficiently.

Keywords: Soil erosion monitoring, Ultrasound signals, Soil erosion processes, Remote sensing.

1 Introduction

Today soil erosion is considered one the most serious environmental problems in the world despite being a natural geomorphologic phenomenon (Yang et al, 2003). Soil erosion has accelerated because of the unsustainable anthropogenic activities, especially since the beginning of the 19th century (Bakker et al, 2008). The anthropogenic activities have resulted in substantial changes of the natural vegetation cover, primarily in agricultural and urban land covers. Typically, these land-uses have excessive soil erosion levels that exceed soil formation levels (soil forms slowly).

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The Mediterranean is a region extremely prone to erosion. The main reason being that humans have inhabited it for thousands of years (Kosmas et al, 2002). In addition, the semi-arid and arid environments limit vegetation growth and cover, leaving large tracts of land that have long dry periods vulnerable to intensive erosive rainfall that lead to considerable erosion rates (Zaimes et al, 2012a; Zaimes et al, 2012b). In Greece, it has been reported that 26.5% of the country's total land area have serious problems of soil erosion (Mallios et al, 2009).

The Mediterranean region is also susceptible to climate change impacts. The IPCC forecasts, predict precipitation intensification and drought periods prolongation. These conditions will lead to higher and more surface runoff that will also increase sediment transport capacity. As a result one of the major threats that will continue and will increase in the Mediterranean region is soil erosion (Giupponi and Shechter, 2003).

The objective of this study was the developement of a sensor that measures erosion very accurately at a specific location. This new tool will use ultrasound signals while also measuring other important factors that are correlated to soil erosion. These measurements by the sensor will allow in the better understanding and comprehension of soil erosion processes, while providing scientifically sound data to the decision makers and the general public on the potential soil erosion problems of the region.

2 Erosion System Overview

The main focus of this work is the design and composition of a fully automated and autonomous system that is able to monitor and store important environmental quantities, useful for study of soil erosion study. The block diagram of the proposed experimental setup is presented in Fig. 1. It can be divided into three major blocks: i) power supply, ii) measurement and logging units and iii) communication unit.

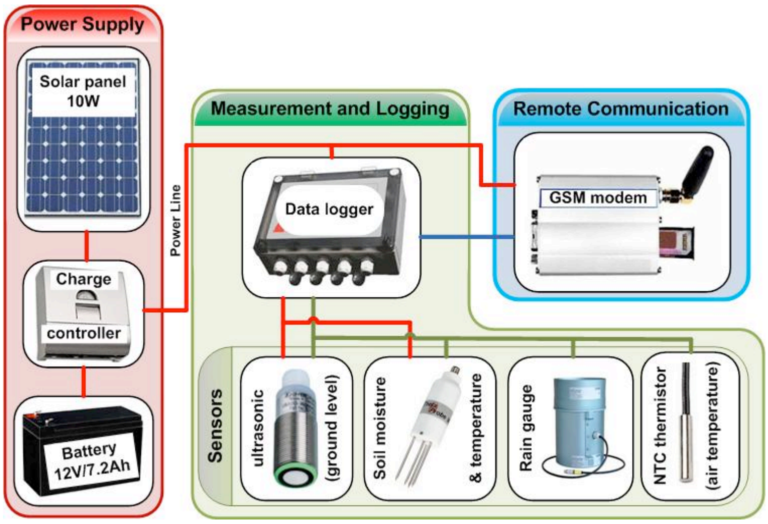

Fig. 1. Block diagram of the proposed Automated Soil Erosion Monitoring System.

Solar radiation was chosen to ensure the energy independency of the system, since it is the most well known, reliable and virtually maintenance-free renewable source. All the electronics included in the station are powered by a small Pb battery (12V/7.2Ah).

The automation of measurement procedure and data storage is performed by the data logging module. It is a low power/high accuracy, special purpose data logger, equipped with a secure non-volatile flash memory. Its memory capacity (>500000 readings) is sufficient enough to store data for over 10 years of continuous recording, for the selected measurement time interval (1 hour).

Another important feature of the proposed system, regarding the logging frequency, is that it provides dual rate recording (aka accelerated logging). The data logger is able to change (shorten) the measurement time interval for specific quantities (e.g. soil moisture, soil erosion), when triggered by a predefined parameter (e.g. rainfall).

The quantities that can be monitored, as shown in Fig. 1, are: i) soil erosion/deposition (ground level changes), ii) soil moisture, iii) soil temperature, iv) rainfall and v) air temperature. More information about the sensors used is given in the section that follows.

Remote communication with the station is achieved through GSM network. It is a simple, secure and consistent solution that sets no limits to the positioning of the station, since it can be placed wherever there is mobile network coverage.

3 Measured Quantities

As mentioned above, some of the quantities that need to be measured to study soil erosion are: a) ground level changes, b) soil moisture, c) soil temperature and d) rainfall.

A novel approach is proposed to measure ground level changes using ultrasounds. Soil erosion/deposition is detected using a diffuse mode ultrasonic sensor. The sensor emits ultrasonic pulses and receives the reflected ones. The distance from the sensor to the reflector (ground) is determined by measuring the propagation time. Using this approach, an accuracy of less than 1mm can be achieved.

Soil moisture is measured using electromagnetic waves. When the sensor is powered, it creates an electromagnetic wave (similar to FM radio), that is applied into the soil. The sensor is able to detect the influence of soil permittivity to the applied field, resulting in a sufficient measure of soil moisture content (1% vol accuracy).

A modern double tipping bucket rain gauge (aka udometer) with an orifice of $200cm^2$, is used to record rainfall. A pulse is generated at each tipping action that equals to 0.2mm rainfall. The output of this sensor is used as a trigger signal to enable the previously described accelerated logging.

Finally soil and air temperatures are measured by two different 10KOhm NTC thermistors.

Conclusions

A novel fully automated soil erosion monitoring system is introduced. The proposed system is energy independent, has very low (almost none) maintenance needs and uses an innovative approach to detect soil erosion through ultrasounds. A demo station has already been assembled in the laboratory and is ready to be placed in the field. Measurement results will be available in the very near future.

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References

1. Bakker, M.M., Govers, G., van Doorn, A., Quetier, F., Chouvardas, D. and Rounsevell M. (2008) The response of soil erosion and sediment export to land-use change in four areas of Europe: The importance of landscape pattern. Geomorphology, 98, p. 213-226.
2. Giupponi C. and Shechter M. (eds.) (2003) Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar Publications: Glos, UK.

3. Kosmas, C., Danalatos, N.G., Lopez-Bermudez, F. and Romero-Diaz M.A. (2002) The effect of land-use on soil erosion and land degradation under Mediterranean conditions. In Mediterranean desertification. A mosaic of processes and responses eds. Geeson, N.A., Brandt, C.J. and Thornes J.B., pp. 57-70. John Wiley and sons: Chichester, England.
4. Mallios Z., Arapaki, S., Frantzis, A. and Katsifarakis K.L. (2009) Management of water resources of Thassos island in the frame of sustainable development. In Proceeding of the conferences of the 11th of EYE and 7th of EEDYP, Patra, Greece (In Greek with English abstract).
5. Yang, D., Kanae, S., Oki, T., Koike, T. and Musiake, K. (2003) Global potential soil erosion with reference to land use and climate changes. Hydrological Processes, 20, p. 2913–2928.
6. Zaimes, G.N., Emmanouloudis D. and Iakovoglou, V. (2012) Estimating soil erosion in Natura 2000 areas located on three semi-arid Mediterranean islands. Journal of Environmental Biology, 33, p. 277-282.
7. Zaimes, G.N., Gounaridis, D., Iakovoglou, V. and Emmanouloudis D. (2012) Assessing soil erosion risk for Rhodes Island, Greece with a GIS-based multi-criteria decision analysis. In Proceedings of the IASTED International Conference, Water Resources Management (AfricaWRM 2012): Gaborone, Botswana.