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The Automated Soil Erosion Monitoring System (ASEMS)

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***Abstract*—**The advancements in technology allow the development of a new system that can continuously measure surface soil erosion. Continuous soil erosion measurements are required in order to comprehend the erosional processes and propose effective and efficient conservation measures to mitigate surface erosion. Mitigating soil erosion, especially in Mediterranean countries such as Greece, is essential in order to maintain environmental and agricultural sustainability. In this paper, we present the Automated Soil Erosion Monitoring System (ASEMS) that measures surface soil erosion along with other factors that impact erosional process. Specifically, this system measures ground level changes (surface soil erosion), rainfall, air temperature, soil temperature, and soil moisture. Another important innovation is that the data will be collected by remote communication. In addition, stakeholder's awareness is a key factor to help reduce any environmental problem. The different dissemination activities that were utilized are described. The overall outcomes were the development of a new innovative system that can measure erosion very accurately. These data from the system help study the process of erosion and find the best possible methods to reduce erosion. The dissemination activities enhance the stakeholders and public's awareness on surface soil erosion problems and will lead to the adoption of more effective soil erosion conservation practices in Greece.

***Keywords*—**Soil management, climate change, new technologies, conservation practices.

I. Introduction

SOIL erosion is one of the most serious environmental threats worldwide [17]. As a consequence soil is considered as one of the most threatened ecosystems [13]. Excessive erosion leads to soil degradation that can have major impacts on agricultural production and food cost in a world whose population is growing exponentially. Overall, many scientists consider soil erosion a threat as important as climate change.

Soil erosion is the removal and transportation of the soil particles by forces such as water and wind [10]. The reason for the excessive soil erosion worldwide is primarily unsustainable anthropogenic activities. These activities typically increase the natural erosional processes. Agriculture, urbanization, dam and road construction are examples of such anthropogenic activities. They completely transform the natural vegetation [10]. Once these land transformations occur, soil erosion levels become excessively high and exceed soil formation levels (soil forms slowly) with soil quality rapidly degrading.

The semi-arid Mediterranean region is extremely prone to erosion [18]. One of the main reasons is the Mediterranean climate that leads to sparse vegetation. In addition, this region also has frequent wildfires. Another major reason is human inhabitation for thousands of years [12], [15], [16]. Human inhabitation impacts are very evident in the unsustainable agricultural lands of the region and the few remaining patches of natural ecosystems.

Climate change will also impact soil erosion. The new climatic regimes that are being established will have different rainfall amounts and intensities, number of days of precipitation, ratio of rain to snow and evapotranspiration rates [2]. These many and complex changes make it difficult to predict the exact impacts of climate change on soil erosion. Still the expected increase in rainfall intensity will lead to increased erosion and runoff [11].

In Greece, 26.5% of the country's total land area (~3.5 million ha) experiences severe soil erosion problems [9]. Despite this fact minimal systematic and holistic efforts have been done to reduce erosion. An extensive literature review on soil erosion in Greece showed that although the number of publications and the research conducted increased over the years, a strategic management plan for the country is needed due to climate change impacts [5].

The first objective of this study was the development of a system that measures erosion very accurately at a specific location. The technologic evolutions allow the development of new and innovative system to assess soil erosion [3]. This new system will utilize ultrasound technology while at the same will measure other important factors correlated to soil erosion. The second objective is enhancing the awareness of soil erosion, climate change implications and the best conservation measures for Greece. Awareness of the public is the key for any environmental problem. This will be done through various dissemination activities.

II. Study Area

The study area is the island of Thasos in northern Greece (Fig. 1). The island occupies approximately 378 km² while the shape of the island is almost rounded and the perimeter is approximately 102 km [8]. The terrain is mountainous; with

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the highest peak being Ypsarion with an elevation of 1203 m. The climate is characterized as Mediterranean. The average annual temperature is approximately 15.8 ^{o}C and the average annual precipitation is approximately 770 mm [4]. Because Thasos Island has a wide range of precipitation, slopes, vegetation types and land-uses, despite occupying a small area, it is an idea natural laboratory to study surface soil erosion.

Fig. 1 A close up of Thasos Island and its location in Greece

The island has 18 major torrents. Torrents have typically ephemeral or intermittent flow [1]. Compared to streams they have more irregular stream flow (periods of no flow to periods of flash floods), steeper channel slope and higher sediment transport capacity. The torrent selected for this study was Kallirahis (Fig. 2), that experienced a severe wildfire in August 2013. Watersheds after wildfires tend to have high surface soil erosion.

Fig. 2 The red lines indicate the boundaries of the Kallirahi torrent watershed that was the selected study watershed and the red circle is the location where the system was placed

III. Automated Soil Erosion Monitoring System (ASEMS)

A. Need for New System

Soil erosion is typically an episodic event and does not occur gradually [7]. Most common erosion techniques cannot measure continuously although some new techniques that measure semi-continuously or continuously have been developed [6], [7]. In addition, many different variables such as precipitation and soil moisture influence soil erosion substantially. It is essential to measure these variables to study and comprehend surface soil erosion processes. By comprehending the erosional processes more effective mitigation of soil erosion problems can be achieved.

B. Design of the Automated Soil Erosion Monitoring System (ASEMS)

The idea was to develop a fully automated system that is able to monitor and store important environmental quantities, useful for the study of soil erosion. The system was named as the "Automated Soil Erosion Monitoring System" (ASEMS). The experimental setup of the system is presented in Fig. 3 and is divided into three major blocks: i) power supply, ii) measurement and logging units and iii) communication unit.

1. Power Supply

To ensure the energy independency of the system, solar panels were preferred. Solar energy is a 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).

2. Measurement and Logging Units

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

The logging frequency provides dual rate recording (a.k.a. accelerated logging). This is a very important feature because it allows the data logger to change (shorten or lengthen) the measurement time interval for specific variables (e.g. soil moisture, soil erosion), when triggered by a predefined variables (e.g. rainfall).

The variables measured by the sensors are: i) soil erosion/deposition (ground level changes), ii) soil moisture, iii) soil temperature, iv) rainfall and v) air temperature. More specific information about the sensors that measure the used is given in the following section.

3. Communication Unit

Since many sites that experience erosion cannot be visited frequently, remote communication was a necessity. In our case remote communication is achieved through a 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.

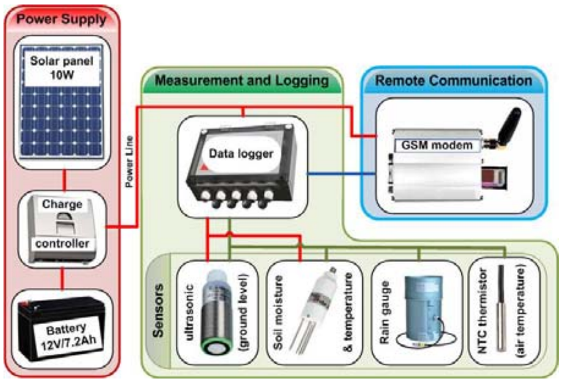

Fig. 3 The experimental setup of the Automated Soil Erosion Monitoring System (ASEMS)

C. The Measured Variables and Sensors

The measured variables of the Automated Soil Erosion Monitoring System are: a) ground level changes, b) soil moisture, c) rainfall, d) soil temperature, and e) air temperature.

To measure ground level changes, a new novel approach is used with ultrasounds. Ultrasonic signals have been used successfully to scan the surface of objects [14]. 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 (a.k.a. udometer) with an orifice of 200 cm^2, is used to record rainfall. A pulse is generated at each tipping action that equals to 0.2 mm rainfall. The output of this sensor is used as a trigger signal to enable the previously described accelerated logging.

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

D. Placement of the Automated Soil Erosion Monitoring System (ASEMS) in the Field

Two Automated Soil Erosion Monitoring System (ASEMS) were developed and placed in the field (Fig. 4). The two sites selected in Kallirahi watershed were expected to have different erosion rates. Specifically, one of the sites has limited overstory vegetation cover (higher erosion rates) while the other has good overstory vegetation cover (lower erosion rates). Calibration is required to check the quality of the measurements recorded by the system. This is accomplished by placing 10 erosion pins around each Automated Soil Erosion Monitoring System (ASEMS); a common surface erosion technique [6]. During the study period the system measurements will be compared with the measurements provided by the erosion pins.

Fig. 4 The field setup of the Automated Soil Erosion Monitoring System (ASEMS)

IV. Dissemination Activities

Awareness of any environmental problem is important in order to manage it effectively. In Greece, despite having more than a quarter of the country severely eroding, only few systematic soil erosion conservation measures have been implemented [9]. To enhance awareness on the serious problems that soil erosion can cause, a number of different groups are being targeted (government and agency employees, local people, general public and scientific community). Reaching all the target groups is essential because a project is truly successful when it is recognized by its peers (scientific community), the system developed is adopted by appropriate professionals (government and agency employees) and the outcomes are accepted by the general public.

A variety of dissemination methods and approaches are utilized in order to reach the different target groups. Firstly, typical dissemination printed material are used to inform the general public, including press releases, leaflets and booklets. In addition, electronic dissemination materials are used such as a multi-media CD and the project website. The project website is hosted at the following link http://map-erossion.eu and is frequently updated. Accounts in Social Interactive Networks were opened to attract younger people, a target group that in many cases is difficult to reach. Specifically, a Facebook and a Twitter account were opened. In addition, one workshop was held in May 2015 at the Department of Forestry and Natural Environment Management, EMaTTECH in Drama (Greece) to inform government employees on soil erosion and the project's outcomes. A second workshop will be held in October 2015 in the Forest Service in Kavala, Greece. Finally, for the scientific community a conference was organized in March 2015 in Kavala, Greece. The International Conference was titled "Frontiers in Environmental and Water Management" and results from the project were presented. In addition, in the conference more than 350 people participated with 80 presentations from 11 different countries and 3 continents (Fig. 5).

Fig. 5 Participants of the International Conference "Frontiers in Environmental and Water Management" that took place on 19-21 March 2015, in Kavala, Greece

V. CONCLUSION

The Automated Soil Erosion Monitoring System (ASEMS) measures surface soil erosion continuously and very accurately (1 mm). In addition, it measures other very important variables that influence soil erosion; rainfall, soil temperature, soil moisture and air temperature. This system can take continuous measurements that are necessary since erosion is typically an episodic event. In addition, by transferring the data through remote communication the erosion events can be seen at real time. Cost is also reduced since you do not need to be visit the site withe system frequently. Overall, these measurements will help study and comprehend erosional processes e.g. the precipitation and soil moisture conditions under which soil erosion occurs. The Automated Soil Erosion Monitoring System (ASEMS) can be used and adopted by the appropriate soil managing authorities in Greece and potentially utilized in the greater Mediterranean Basin. The accuracy of its measurements will help the appropriate professionals make more educated decisions on reducing soil erosion problems in Greece. Specifically, it will allow targeted approaches in the placement of soil conservation practices or alterations of agricultural practices to more sustainable ones. The dissemination activities have substantially enhanced the awareness of the problems soil erosion can cause to natural ecosystems but also to agricultural systems. By understanding the extent and consequences of an environmental problem, people will try to reduce them. When stakeholders know and understand what the appropriate measures to mitigate e.g. soil erosion, they are more likely to implement these measures.

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