

Simulation of torrent discharge using SWAT and evaluation by field survey in Thasos Island

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Abstract

In recent years, a vital part of water resources management plans is the implementation of hydrologic models. A well-known example is the Soil and Water Assessment Tool most recognized as SWAT model. SWAT was applied in Thasos Island to simulate the water yield and highlight the most significant of the local torrents. The produced map identify four significant torrents: "Prinos" torrent, "Genna-Maries" torrent, "Limenaria-Kastrou Lakos" torrent and Theologos-Dipotamos" torrent. In addition, a field survey was conducted at the specific torrents to evaluate the results of the model and select the proper ones for further study and management plans in order to store surface water for other purposes and needs of the residents.

Keywords: SWAT, field survey, torrent discharge, management plans, Thasos

1. Introduction

Hydrology is a science that requires spatial data in order to compose water resources management plans. The hydrological models are very important for this purpose and they are used worldwide and frequently in such applications [1]. The processing speed while using complex calculations to estimate the various hydrological phases is a major advantage of hydrologic models [2]. Various hydrological models have developed in recent years with the ability to directly incorporate geographic data through its integration with Geographic Information Systems (GIS) [3]. The GIS technology has the potential of the collection, storage, processing, analysis and visualization of different data sets with geographical reference. Furthermore, using GIS allows visualization of the spatial distribution of the components of the hydrological cycle and the simulation elements of geographic space as they are arranged in nature [4]. A well-known model of this category is the Soil and Water Assessment Tool [5] through its interface with GIS (ArcSWAT). SWAT was developed for modeling hydrologic basins by taking into account the meteorological, geographical, geological and soil characteristics, land use and management practices. This study describes the application of SWAT in Thasos Island in order to simulate the torrent discharges of the local torrents.

2. Materials and Methods

SWAT is a hydrologic model developed to predict the water

yield and torrent discharge of a basin [6]. It is very useful software because it is manageable through a GIS interface named ArcSWAT [7]. The hydrologic cycle is given as the following (Eq. 1)

$$SW_t = SW_0 + \sum_{t=1}^t (R_{day} - Q_{surf} - ET_{day} - w_{day} - Q_{gw}) \quad (1)$$

where t is the simulation period, SW_t is the soil water content after the simulation period, SW_0 is the soil water content at the beginning of the simulation period, and R_{day} , Q_{surf} , ET_{day} , w_{day} and Q_{gw} are daily values (in millimeters) for precipitation, runoff, evapotranspiration, infiltration and return flow, respectively.

SWAT requires the Digital Elevation Model (DEM) (Fig. 1) for the creation and the delineation of watersheds. According to the properties of the DEM, SWAT proposes a minimum threshold value which represents the area (in hectares) for the establishment of the drainage area. In this study, the value of 100 hectares was selected and the island of Thasos (entire basin) was divided in 145 smaller sub-basins (Fig. 2).

Each sub-basin (or watershed) includes a torrent (reach), an outlet and the simulated extension of the torrent based on the DEM (longest path).

Most watersheds are typically not homogenous as they consist of different soils and land-uses. SWAT can divide the watershed into smaller hydrologic response units (HRU) that are unique combinations of soil type, land cover and slope category [8]. SWAT created 2415 HRU considered all soils, land cover types and slope classes.

The slope map (Fig. 3) was produced based on the statistics of the DEM and it was divided into five slope

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classes: i) 0-10 %, ii) 10-20 %, iii) 20-30 %, iv) 30-50 % and v) >50 %.

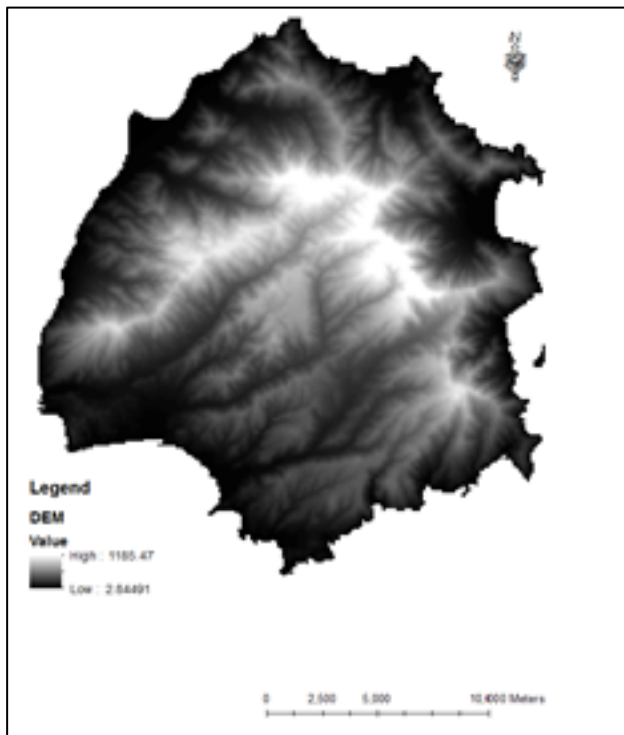


Fig. 1. The DEM of Thasos Island.

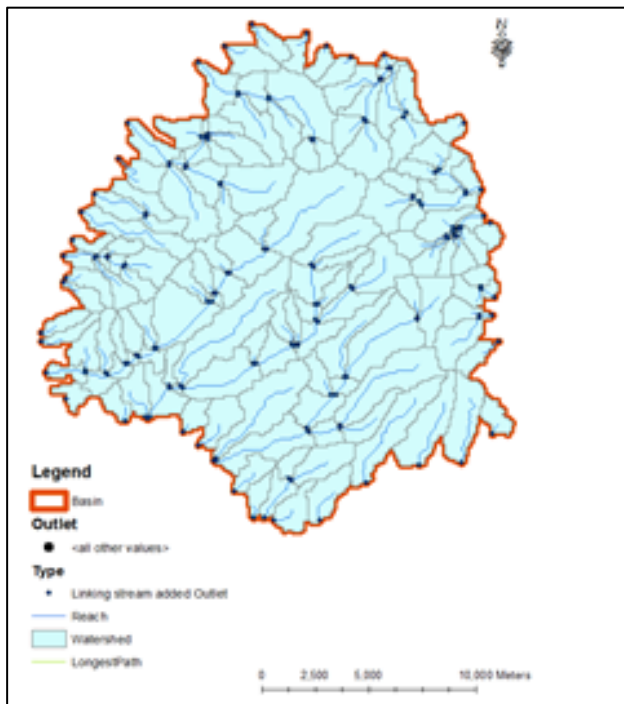


Fig. 2. The delineated watersheds of Thasos Island.

The soil map (Fig. 4) was downloaded from the European Soil Portal and the Harmonized World Soil Database Viewer 2012 that had a scale of 1:1,000,000 [9]. In addition, the geological map (Fig. 5) [10] was digitized and the geological parent material was considered and combined in order to create the final soil map.

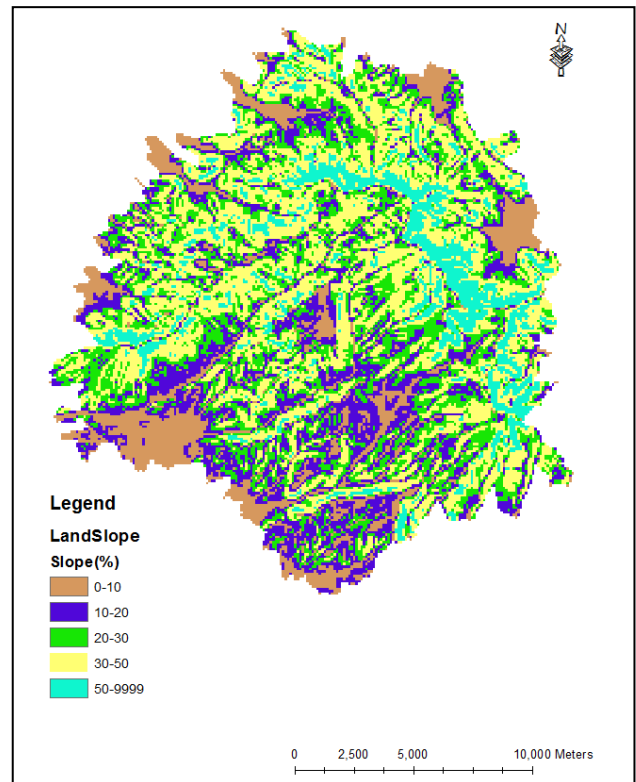


Fig. 3. The slope classes of Thasos Island.

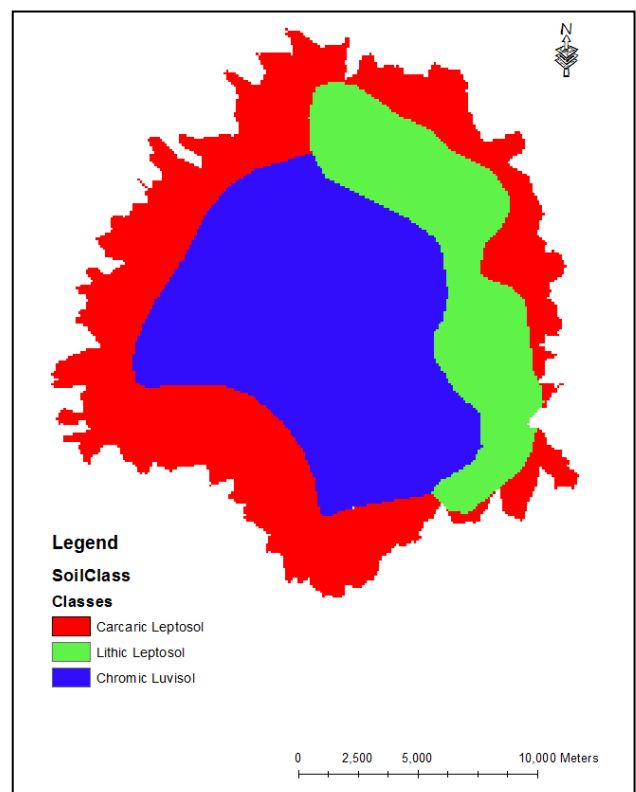


Fig. 4. The soil map of Thasos Island.

The CORINE 2000 vector files by European Environment Agency were acquired in order to display the land-cover of the island and had a scale of 1:100,000 [11]. The land cover of CORINE was reclassified to the categories of land cover that already exist in the SWAT database (Fig. 6). Finally, the weather data were obtained by a meteorological station located in the city of Limenas. The

data concerned monthly precipitation and temperature that covered the period from 1975-1997 [12].

3. Results

A map was produced (Fig. 7) that identifies the average simulated torrent discharges based on the outputs of SWAT. The depiction is in the view of the sub-basins/watersheds and shows which watersheds discharge had the highest amount of water. Five categories were selected based on the statistics of the flows and specifically they were divided in: i) 0-0.05, ii) 0.05-0.10, iii) 0.10-0.25, iv) 0.25-0.50 and v) 0.50-1.0 (the discharge values are in m^3/sec). Based on the produced map the torrents that discharge significant amount of water are four (red and orange color): a) “Prinos” torrent located at northwest of island, b) the torrent named “Genna-Maries” that is the larger torrent and situated at the southwest part of Thasos, c) “Limenaria-Kastrou Lakos” that is located southern than the previous one and d) “Theologos-Dipotamos” torrent at the south part of the island.

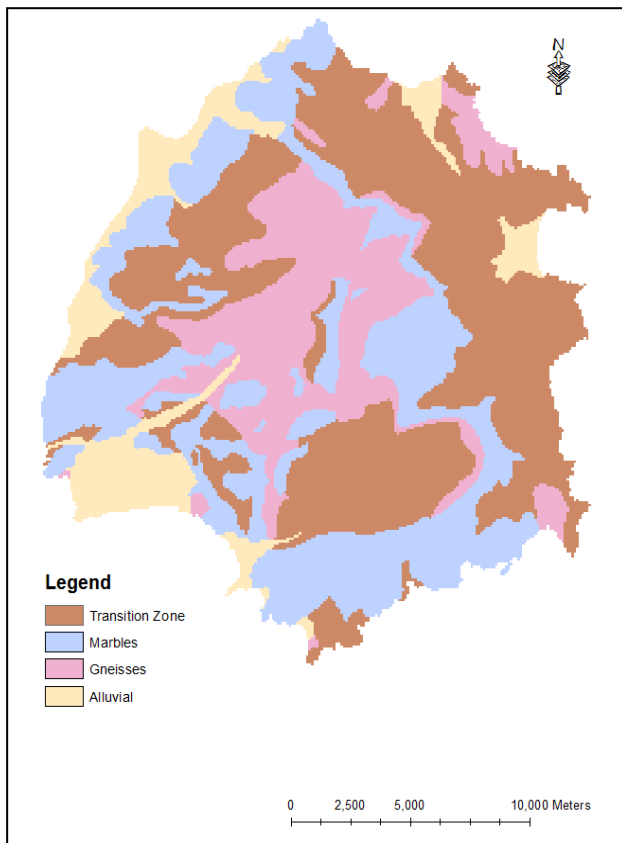


Fig. 5. The geological map of Thasos Island.

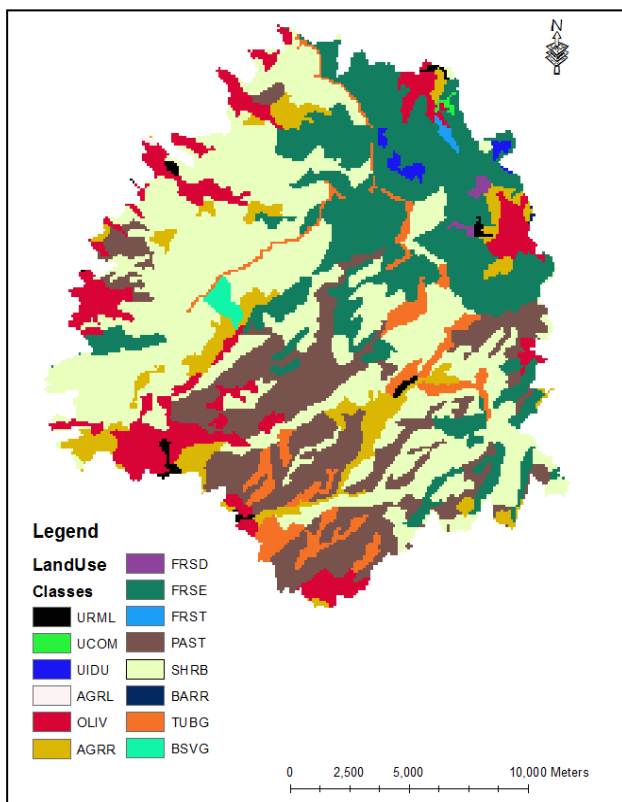


Fig. 6. The land cover map of Thasos Island.

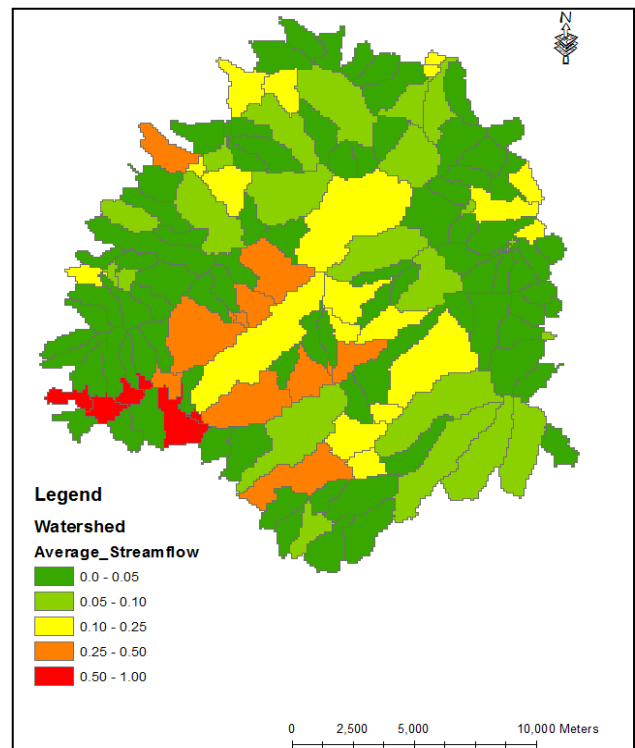


Fig. 7. The average simulated discharges of the watersheds.

Field survey was also conducted at these four significant torrents (Prinos” torrent, “Genna-Maries” torrent, “Limenaria-Kastrou Lakos” torrent and Theologos-Dipotamos” torrent) based on the produced map in order to evaluate the results of the model. The field survey took place during June, July and August of 2013 to check the existence of and its depth in the torrent channel during the drier months as flow is always observed during the wet months.

- “Prinos” torrent has irregular yearly water flow. The flow varies from no flow during summer to extreme floods after precipitation events. In addition, the field survey pointed that the specific torrent shows very high sediment transport capacity. For these mentioned reasons the torrent is not qualified to manage and utilize the surface water.
- The field survey in the watershed of “Genna-Maries” torrent resulted in the existence of water

even during the summer months. There is also a physical reservoir-lake. The depth of the water in this reservoir was approximately 1.5 meters in August 2013. The specific torrent has significant flow and as it drains a large area of Thasos it is very suitable for water management purposes.

- c) "Limenaria-Kastrou Lakos" is a torrent with no water flow during the summer months. The field survey are found barren land that consists of metalliferous layers of iron (Fe) and zinc (Zn). For these reasons the specific torrent is not considered as the best area to utilize the discharged water.
- d) Concerning "Theologos-Dipotamos" torrent, water flow with sufficient amount was observed during all months. Stakeholders in the region mentioned the existence of a lake near "St. Kiriaki" which was filled with rubble approximately in 1974. They also stated the existence of many springs with artesian water. For these reasons the specific torrent appears appropriate for the needs of the study.

Two of the mentioned torrents ("Genna-Maries" and "Theologos-Dipotamos" torrent) satisfy the demands to manage them properly in order to store surface water. These torrents have significant discharge during the wet period (Fig. 8) and the existence of water was also recorded during dry period (Fig. 9).



Fig. 8. Torrent discharge during wet period.



Fig. 9. Torrent discharge during dry period.

4. Conclusions

This study was an attempt to predict the torrent discharges of Thasos Island. For the specific scope, the hydrologic model SWAT was implemented to simulate the hydrologic conditions. The produced map combined with field surveys during the summer period highlighted the best qualified torrents to utilize surface water resource. The selected areas are: 1) "Genna-Maries" torrent located at the southwest region of Thasos and 2) "Theologos-Dipotamos" torrent located at the south of the island. These two torrents are the best preferable among others in order to utilize the torrent flow for various purposes from agriculture irrigation to suppressing wildfires.

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