THE ONLINE SUPPORTING SYSTEM FLOOD WARNING FOR VU GIA WATERSHED, QUANG NAM PROVINCE, VIETNAM: CONCEPTUAL FRAMEWORK AND PROPOSED RESEARCH TECHNIQUES

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ABSTRACT

Vu Gia watershed is located in the Central Vietnam where hurricanes represent a constant natural threat to human lives and physical infrastructure. Hydrological monitoring is considered as an effective tool to respond to high flood events by preventing and mitigating damages. The purpose of this study was to conduct and perform hydrological modeling to determine areas prone to be flooded during high rainfall events in the upstream Vu Gia watershed. The methodology involved: hydro-climatic data base building, a detailed Digital Elevation Model (DEM), a land use cover, and a soil map of the basin. With all this data, the SWAT model (Soil and Water Assessment Tool) was used to predict discharge values. These discharge values were used, along with the DEM, to predict flood hazard areas in the downstream of Vu Gia watershed floodplains. This procedure was made using the HECRAS model (Hydrological Engineering Center-River Analysis System). Finals results show the exact location of areas with high, moderate and low risk to be flooded at specific high flood events. The results also provided the location of critical areas, so that an early warning system can be located. Additionally, as a part of this study, valuable information was provided to at-risk residents about how to prevent and mitigate the effect of flood-related damages in low land areas of the Vu Gia watershed.

1. INTRODUCTION

The Vu Gia watershed, with an area about 466,128 ha, locates in mid-central region of Vietnam, key economic zone of the Central region. The geographical location is of the advantageous conditions for socio-economic development of the province. However, this is also the area seriously affected by natural disasters, thus impacts on economical growth rate of this province compared to adjacent regions. In recent years, under changes in global climate and socio-economic development; natural disasters in general, storm-flood in particular are increasing abnormally and more and more damaging. Considering different types of natural catastrophes, the disasters related to flood is on top in incidence, severity and frequency of occurrence, and they are also the type with most damages on economic, social and environment. According to recent five years statistics from 2003 to 2007, natural disaster losses in Quang Nam province are estimated averagely up to 6.26% GDP. In years with excessive rain & flood, losses can sum up to 18-20% of GDP and severely crash both human live and property. This great natural disaster's losses need systematic study to find out the cause and preventive measure to mitigate the damage.

Although there have been many studies on the hazards of flood, there are remaining limitations in-depth disciplinary scope and study area. Particularly, after the recorded floods in late 1999, 2007, 2009, and the severe drought in 2005, the calculation and evaluation on the factors of flood and drought need to be reconsidered. In line with global climate change, the variation of flow becomes more and more extreme. The disasters related to flood, occur more frequent and cause more severe damages. The purpose to build flood warning system for Vu Gia watershed is especially important.

Hence, this research attempts to solve the selected Vu Gia watershed in context of flood warning system through the GIS-IT and integrating SWAT and HEC-RAS models approach.

This study aims to support farmers who live in downstream Vu Gia watershed for preventing flooding, the main aim in this investigation is how to apply Geographic Information System (GIS) and Information Technology (IT) and Soil and Water Assessment Tool (SWAT) model and HEC-RAS model to build flood warning system for Vu Gia watershed, Vietnam. The specific objectives of this study are as follows: (1) to determine vulnerability flood area and peak flooding in Vu Gia watershed; (2) to build the online website support information about hydrometeorology at real time; (3) to support farmer in vulnerability flood area by SMS message.

2. STUDY AREA DESCRIPTION

The Vu Gia watershed locates in the East of Truong Son Mountain Range, latitude 16°55'-14°55‟ North, longitude 107°15'-108°24' East, Vu Gia watershed is one of the largest river basins in the central coastal region as shown in Figure 1. The main slope direction of the basin is north west-east south with average slope of 25.5%. Upstream of the basin is high mountain area with height of 1,700-2,045m. Mountain chains create arc which bars north, west and south parts of the basin. Downstream of the basin is plain next to sea.

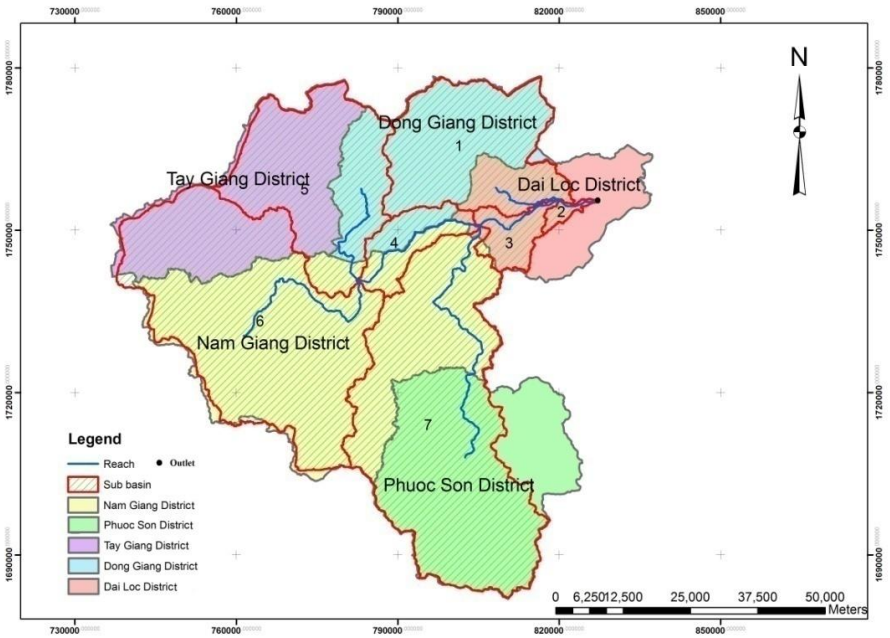

Figure 1. Vu Gia watershed map

The Vu Gia watershed in Quang Nam province with the volume of 10,350km^2 storage is the place most vulnerable to storm, flood. Annually, those disasters have caused losses estimated up to thousands of billion VND and losses of people's life. Therefore, there have been a lot of programs and projects implemented recently and they could bring results valuable in terms of not only science but also of practicality in order to mitigate the effects of the flow-related disasters like flood and drought in Quang Nam.

The climate in the area is tropical monsoon and characterized by a wet and a dry season. The wet season starts from July and ended in of December but it may extents to January in the eastern part of the province in some area, during the east west monsoon. The dry season covers the remaining months of the year. Average temperature of year is 20-21^{0}C, is not big different between the months of year. Relative humidity is generally high in the rainy season (April to October) and low during the dry season (November to March). The mean annual average humidity is recorded as 86.5% with the highest of 97% in September and lowest of 10% in March. Therefore, in agriculture and aquaculture are facing critical conditions that can cause diseases or illness for plant and animal. The annual rainfall is about 3,600mm. More than 80% of the rainfall is concentrated in the wet season. Heavy rains usually come in July and October making the water level in the rice fields near the stream rise quickly causing short-term floods.

The rainy season of Quang Nam province is similar and can be divided into three distinct parts, i.e., early rainy season (June to August); mid rainy season (September to November); and late rainy season (December to January). Future climate scenario was analyzed for the Quang Nam province, based on data from future climate projection from SEA-START Research Center, which shows trend of warming temperature and increasing annual precipitation in the area (Figure 2 and 3), which may cause higher flood risk and landslide in the area.

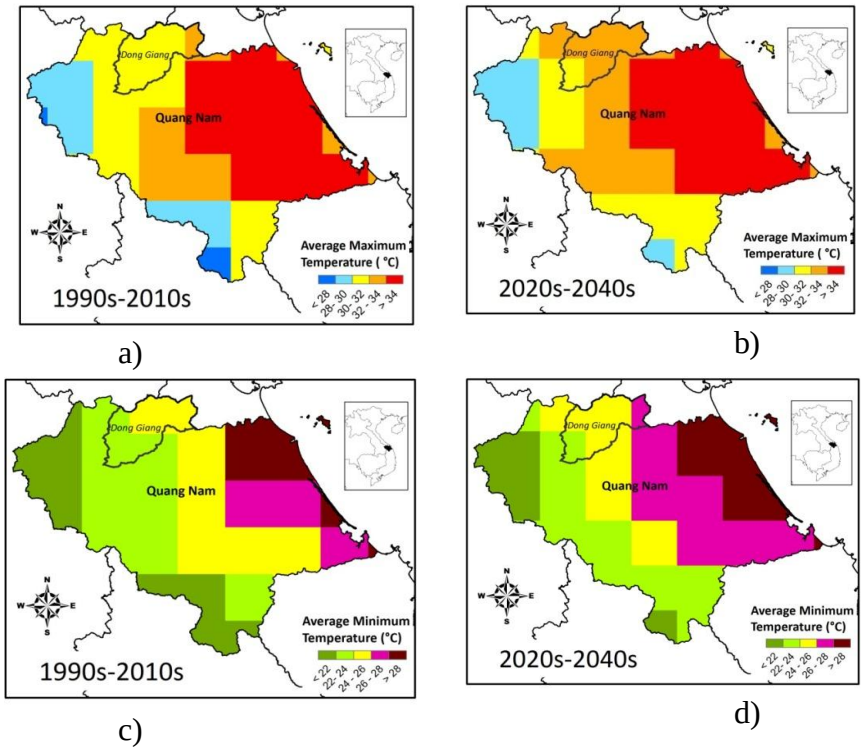

Figure 2. Average maximum (a, b) - minimum (c, d) temperature during present time and future in Quang Nam province (Source: SEA-START, 2010)

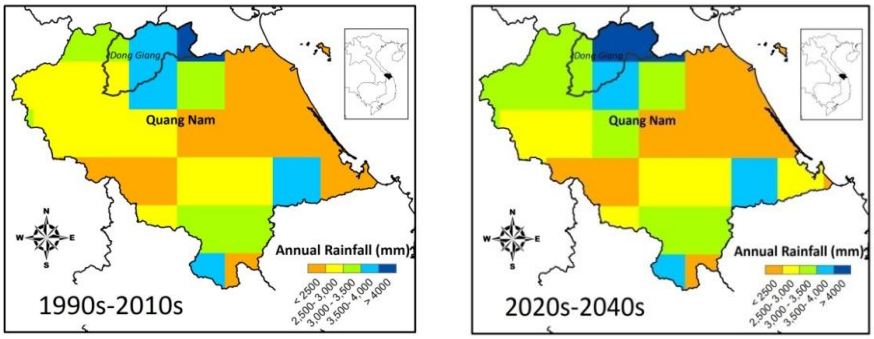

Figure 3. Average annual rainfall during present time and future in Quang Nam province (Source: SEA-START, 2010)

3. MATERIALS AND METHODS

3.1 Materials

The necessary materials for this investigation were set up for the purpose of secondary data of socio-economic within and outside of the study area were also taken into account. The materials are as follows: Topographic map scale 1:50,000, Land use map, Soil map, Climate data; Server, Personal computer; GIS software, ArcSWAT software, HEC-RAS.

3.2 Methods

3.2.1 Brief description of SWAT model

The Soil and Water Assessment Tool (SWAT) has been widely applied for modeling watershed hydrology and simulating the movement of non-point source pollution. The SWAT is a physically – based continuous time hydrologic model with Arcview GIS interface developed by the Blackland Research and Extension Center and the USDA-ARS (Arnold *et al.,* 1998) to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex basins with varying soil type, land use and management conditions over long periods of time. The main driving force behind the SWAT is the hydrological component. The hydrological processes are divided into two phases, the land phase, which control amount of water, sediment and nutrient loading in receiving waters, and the water routing phase which simulates movement through the channel network. The SWAT considers both nature sources (e.g. mineralization of organic matter and N-fixation) and anthropogenic contributions (fertilizers, manures and point sources) as nutrient inputs (Somura, H. *et al.,* 2009). The SWAT is expected to provide useful information across a range of timescales, i.e. hourly, daily, monthly, and yearly time-steps (Neitsch *et al.*, 2002).

3.2.2 Hydrologic Engineering Center River Analysis System (HEC-RAS) Model

HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The program was developed by the US Department of Defense, Army Corps of Engineers in order to manage the rivers, harbors, and other public

works under their jurisdiction; it has found wide acceptance by many others since its public release in 1995.

3.2.3 The Flood Warning System

The methodology started with the data collection process. This consisted of obtaining a current land use cover. A land use map, generated for the area collected from Department of Natural Resources and Environment in Quang Nam province. The soil and climate data bases were built using local data from government agencies and previous studies. Both were transformed and edited to be used as input files for the SWAT model. Rain gauges data was collected from all 4 automatic weather stations distributed all over the studied watershed. The most consuming time part was to build the 4 automatic weather stations. Digital Elevation Model (DEM) for the Vu Gia watershed was collected from government agency. Contour curves (20-meter) were digitized to complete a DEM for the entire area.

Further, the data bases containing: land use, soils, and climate data were adapted with field data and information collected from local agencies. In order to predict stream flow patterns, SWAT simulations were ran using the soil, climate, DEM and land use data.

With the complete DEM, flood plains and channel geometry features were mapped using ArcGIS software and the extension 3D Analyst. River flow direction was also determined to further use it as a model input variable.

Cross sections are perpendicular lines to the flow direction. Their width varies depending upon channel geometry and floodplain configuration. These cross sections were calculated for the valley floodplains subjected to frequent inundation events.

Information from channel geometry and SWAT-generated discharges values were used to generate HEC-RAS channel flows. HEC is a very sophisticated computer program to model water surface profiles from corresponding discharge values. The HEC-RAS model calculates water surface elevations at all locations of interest for given values. It uses Bernoulli equation as below (Equation 1) for subcritical flow at each cross section (Bedient and Huber, 2002):

$$WS_2 + \frac{\alpha_2 V_2^2}{2g} = WS_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \tag{1}$$

where:

WS_1, WS_2 = Elevation of water surface at each cross section
V_1, V_2 = Mean velocity
α_1, α_2 = Velocity coefficient
g = Gravitational constant
h_e = Energy head loss

All data were analyzed and processed using the software and procedures above mentioned. Water surface elevations predicted with HEC-RAS were used as input to generate

the flood area coverage. This information allowed us to visualize where the high hazard areas might be located. The general methodology was shown in Figure 4.

As a last step, a vulnerability analysis workshop was conducted in a set of community meetings, in which at risk resident expressed their opinions on what they though it represented a risk for their lives. Around 50 families were interviewed in the workshop using Participatory Rural Appraisal (PRA) method. Specifically, the PRA method in combination with field visit were conducted in Dai Loc district to collect information for an overall picture of the district regarding concerns in livelihoods in relation with natural disasters; and adaptation capacity of local people to the new context.

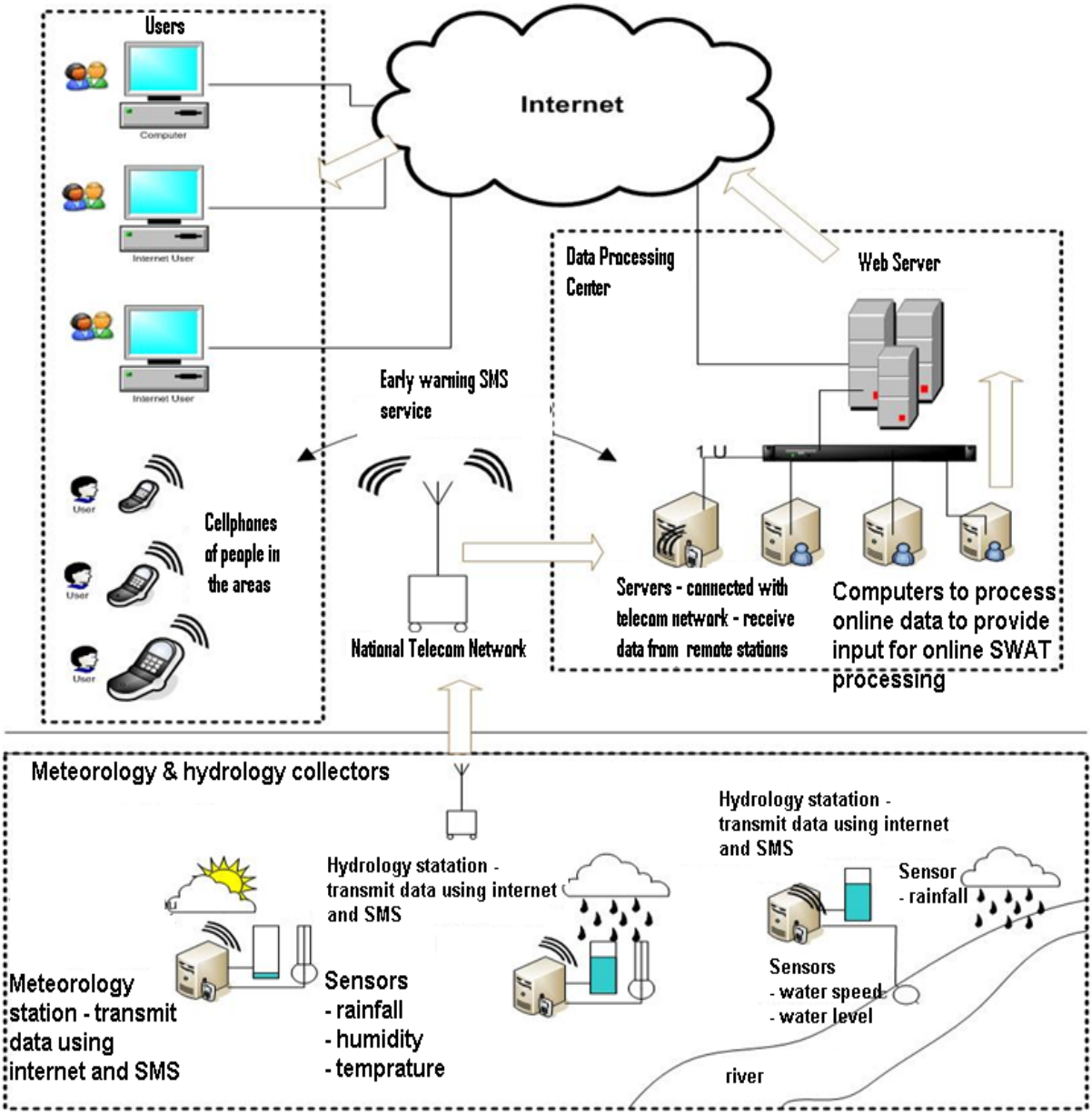

Figure 4. The general methodology for the online supporting system flood warning in Vu Gia watershed, Quang Nam province, Vietnam

4. CONCLUSIONS

This research is just the first step apply SWAT and HEC-RAS model in Vu Gia watershed. The SWAT model performed well in simulating the general trend of surface runoff at watershed over time for secondly, hourly, daily, monthly time intervals. This paper provides an insight of how the HEC-RAS model can be a useful tool for providing important information about river flow fluctuations affected by extreme rainfall events. Future studies are needed to evaluate with more detail each land management practice. Work is still in progress to improve SWAT and HEC-RAS data bases to Vu Gia watershed, Quang Nam province, Vietnam - tropical conditions.

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