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# Development of an Online Supporting System Flood Warning for Vu Gia Watershed, Quảng 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 pose a constant natural threat to human lives and physical infrastructure. Hydrological monitoring is considered as an effective tool to respond to high floods by preventing and mitigating the losses. The purpose of this study was to conduct and perform hydrological modeling to determine the flood-prone areas during the high rainfall season in the upstream Vu Gia Watershed. The methodology involved: hydro-climatic database building, a detailed Digital Elevation Model (DEM), a land use cover, and a soil map of the basin. With all these 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 HEC-RAS model (Hydrological Engineering Center-River Analysis System). The results show the exact location of areas with high, moderate and low risk, which are to be flooded at specific high floods. The results also provide the location in critical situation, so that an early warning system can be located. Additionally, as a part of this study, valuable information about how to prevent and mitigate the affects of flood-related damage was provided to residents at risk in the low land areas of the Vu Gia Watershed.

*Keywords:* Flood warning, SWAT, HEC-RAS, Vu Gia Watershed, Quảng Nam Province.

## 1. Introduction

The Vu Gia Watershed, with an area of about 466,128 ha, is located 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 that is seriously affected by natural disasters, and therefore has

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negative impacts on economic growth rate of Quang Nam Province. In recent years, under changes of global climate and socio-economic development; natural disasters in general, and storm-flood in particular are increasing abnormally and become more and more damaging. Considering different types of natural disasters, the ones related to flood are on top in incidence, severity and frequency of occurrence, and they are also the types causing most economic, social and environmental damages. According to recent five-year statistics from 2003 to 2007, the losses due to natural disaster in Quảng Nam Province are estimated up to 6.26% of GDP. In those years with excessive rains and floods, 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, at latitude of 16°55'-14°55'' North, longitude 107°15'-108°24' East. The 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 a 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 a plain next to the sea.

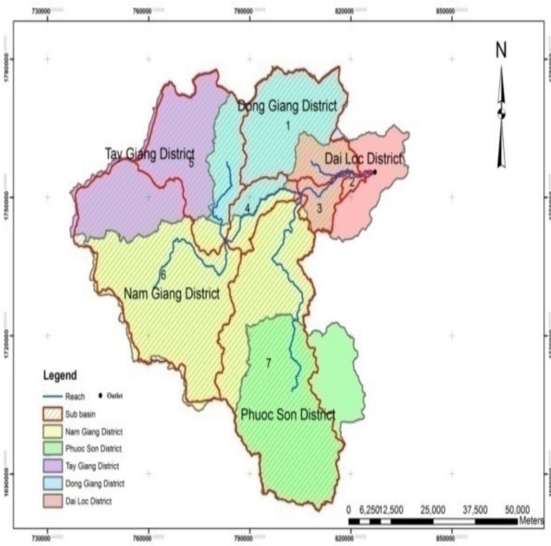



Fig. 1. Vu Gia watershed map.

The Vu Gia watershed in Quảng Nam Province with an area of 10,350km$^2$ is the most vulnerable place to storm, flood. Annually, those disasters have caused losses estimated up to thousands of billions VND and losses of people's life. Due to this reason, there have been a lot of programs and projects implemented recently and they could bring valuable results not only in term of science but also in term of practicality for mitigating the effects of flow-related disasters like flood and drought in Quảng 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 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 and does not vary much between moths 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 value 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 in 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.

## 3. Data and methology

### *3.1. Data*

The necessary data for this investigation were collected within and outside the study area as follows: topographic map at scale 1:50,000, land use map, soil map, climate data. The data were processed using GIS software, ArcSWAT software, and HEC-RAS model.

### *3.2. Methodology*

3.2.1 Brief description of SWAT model

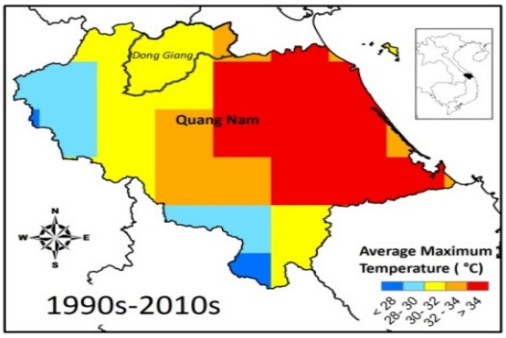
The Soil and Water Assessment Tool (SWAT) has been widely applied for modeling watershed hydrology and simulating the movement of non-point source pollution. The SWAT is a physically - based continuous time hydrologic model with Arcview GIS interface developed by the Blackland Research and Extension Center and the USDA-ARS (Arnold *et al.,* 1998) [1] 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) [2]. 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].

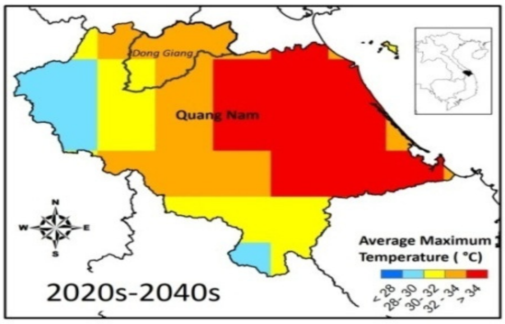
3.2.2 Hydrologic Engineering Center River Analysis System (HEC-RAS) Model

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 a wide acceptance by many others since its public release in 1995 year.

3.2.3 The Flood Warning System

The research started with the data collection process. This consists of obtaining a current land use cover from a land use map provided by Quảng Nam Department of Natural Resources and Environment. The soil and climate data bases were built using data from local government agencies and previous studies. Both were transformed and edited to be used as input files for the SWAT model. Rain gauges data were collected from all of four automatic weather stations distributed over the studied watershed. The most time consuming work was to build the four 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.

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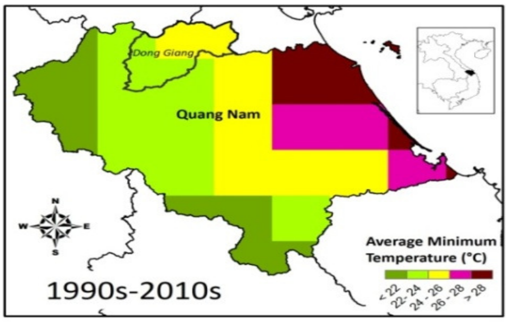


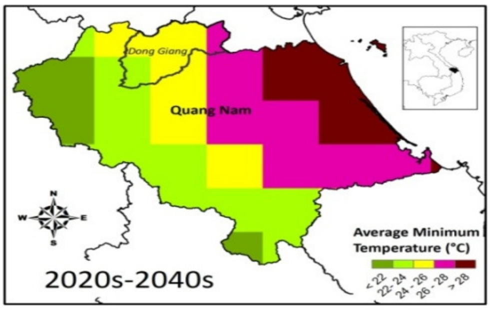


c) d)

Fig. 2. Average maximum (a, b) - minimum (c, d) temperature at present and predicted values for the future in Quảng Nam Province (Source: SEA-START, 2010).

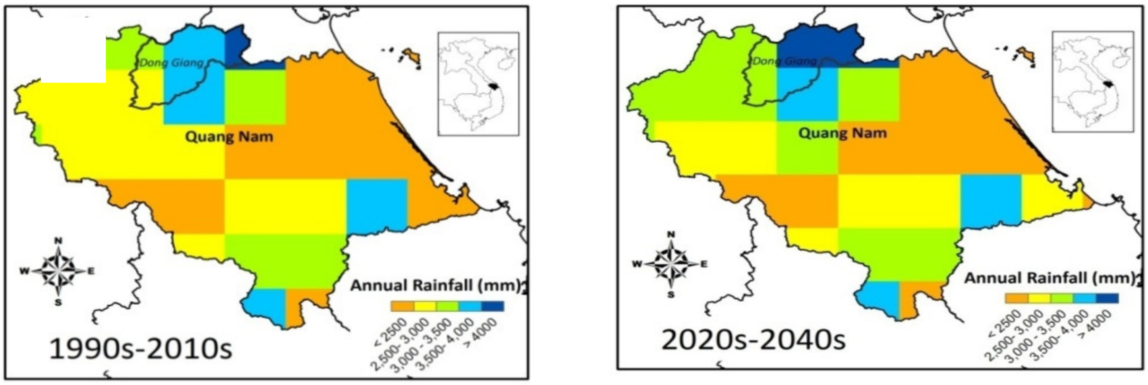


Fig. 3. Average annual rainfall during present time and future in Quảng Nam province.
(Source: SEA-START, 2010)

Further, 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 dataset.

With the complete DEM, flood plains and channel geometry features were mapped using ArcGIS software and its 3D Analyst extension. 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):

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

where:

$WS_1$, $WS_2$: elevation of water surface at each cross section;

$V_1$, $V_2$: mean velocity;

$\alpha_1$, $\alpha_2$: velocity coefficient;

$g$: gravitational constant;

$h_e$: energy head loss.

All data were analyzed and processed using the above mentioned software and procedures. Water surface elevations predicted with HEC-RAS model 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 residents expressed their opinions on what they though it represented a risk for their life. Around 50 families were interviewed in the workshop using Participatory Rural Appraisal (PRA) method. Specifically, the PRA method in combination with field visit was conducted in Dai Loc District to collect information for an general picture of the district regarding concerns in livelihood in relation with natural disasters; and adaptation capacity of local people to the new context.

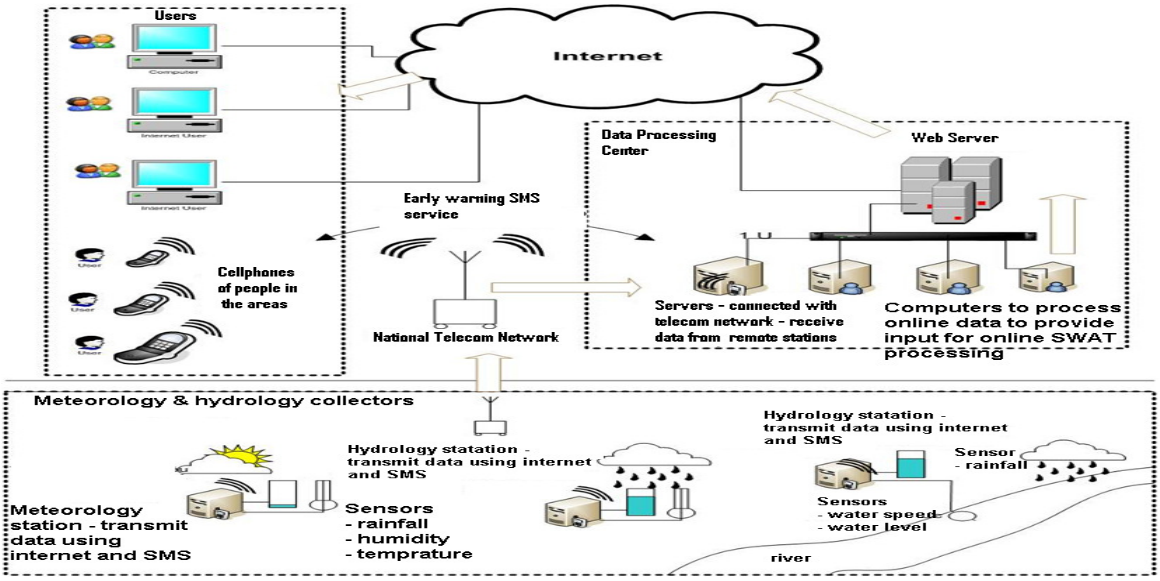


Fig. 4. Structure of online supporting system for flood warning in Vu Gia watershed.

## 4. Main results

### *4.1. Model calibration and validation*

The SWAT simulations were conducted for a ten year period (2000-2009). Calibration of SWAT was performed for years 2000 - 2003 using data from Vu Gia River basin, while the data from the years 2004 - 2009 were used for model validation. Both graphical and statistical approaches were used to evaluate the SWAT model's performance. The statistical results of the model performance for both calibration and validation periods are summarized in Table 1. Figures 5 represents comparison of simulated and observed water discharge during the calibration and validation years at Thanh My station, the figure clearly indicates that simulated water discharge reasonably match the observed water discharge most of the time except for November 2000 and December 2007, the model underestimated the water discharge. And in September 2002 and September 2008 the model overestimated the flow for Thanh My monitoring station.

Table 1. Model performance for water discharge simulation

| *Period* | *Time step* | *Value* | |
|---|---|---|---|
| | | $R^2$ | *NSI* |
| Calibration (2000-2003) | Monthly | 0.61 | 0.68 |
| Validation (2004-2009) | Monthly | 0.68 | 0.73 |

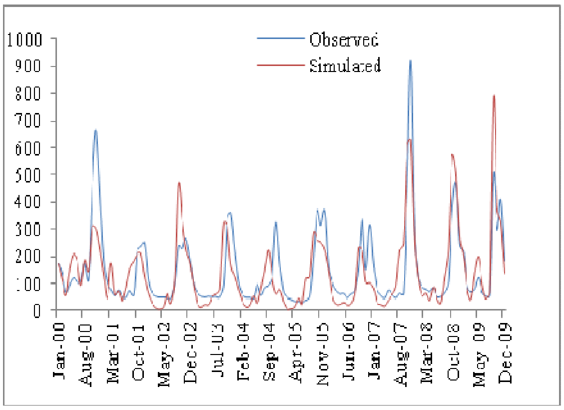


Fig. 5. Comparison of simulated and observed water discharge during 2000 - 2009 period at Thanh My monitoring station.

### *4.2. Online decision support system (DSS) for flood warning*

The online flood warning system has been started in Vu Gia watershed since 2012. The SWAT simulated and observed water level in 2012 year at Thanh My station is shown in Figure 6 and website http://gislab.hcmuaf.edu.vn/add_data/. The output water level from SWAT model was automatically transfered to HEC-RAS model (http://gislab.hcmuaf.edu.vn/output/Tmp1.Tmp). The map of flood risk areas on October 24, 2012 is shown in Figure 7 and the residents who live in flood areas were received a SMS message from the system. Based on the real time information from flood warning system, the local government (Quảng Nam Province) will make decision to farmer who lives in risk area to response to flooding. The WebGIS online DSS for warning was shown at http://gislab.hcmuaf.edu.vn/vugia/.

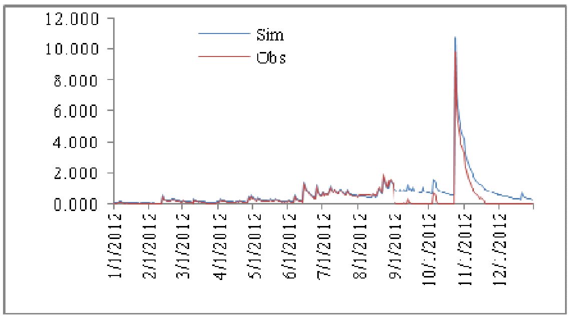


Fig. 6. The simulated and observed water level in 2012 at Thanh My monitoring station.

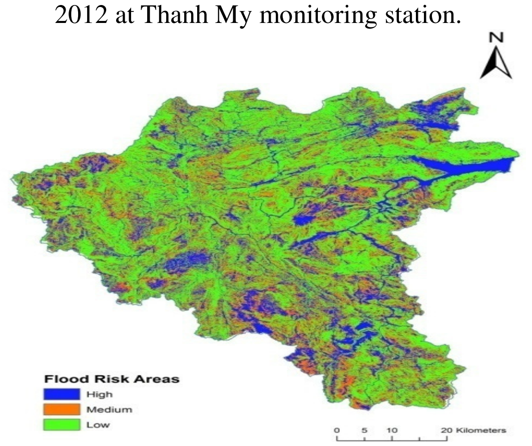


Fig. 7. Map of flood risk areas in Vu Gia watershed on October 24, 2012.

## 5. Conclusions

This research is just the first step to apply SWAT and HEC-RAS models in Vu Gia watershed. The SWAT model performed well in simulating the general trend of water level 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, Quảng Nam Province, Vietnam.

## 6. Acknowledgements

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