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STUDY ON INTEGRATING SENSOR SYSTEM AND GEOGRAPHIC INFORMATION SYSTEMS FOR RESOURCE AND ENVIRONMENTAL MANAGEMENT

SUMMARY OF DOCTORAL THESIS IN NATURAL RESOURCES AND ENVIRONMENTAL GEOGRAPHY

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The thesis is defended at the Graduate University of Science and Technology, Vietnam Academy of Science and Technology.

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Introduction

1. The necessity of the research

In Vietnam as well as in the world, the issue of resource and environmental management is always the main issue topic of interest to managers, training facilities, and research institutes. In which the research

Research and application of high technology in the field of environmental resource management and protection and construction Build remote automatic monitoring systems to detect natural disaster phenomena, Monitor extreme weather phenomena affecting the environment, especially on rivers

The river area is lacking and has not been invested in research. This thesis conducts construction research Build a system that integrates spatial, temporal and response attribute data elements from automatically collecting input data through sensor systems to processes Applying GIS and modeling technology to perform simulations and display results in real time.

Because the field of natural resources and environmental management is a broad field of research, so the thesis This project limits the scope of research on solutions to integrate wireless sensor networks and systems Geographic information system (GIS) to manage and monitor water resources and the environment on the river river basin. Specifically, monitoring and observing flow factors in the Nhue - Day river basin and research design the structure of an optical sensor to measure the salinity of water with the ability to accumulate integrated into the wireless sensor network.

2. Research objectives

Proposing to build an automatic water resources monitoring and management technology solution in real time in the Nhue - Day river basin using WEBGIS technology on the basis integrating geographic background data, hydrological models and wireless sensor systems.

3. Research content

- Overview of research and application of wireless sensor networks combined with tissues GIS visualization and geographic data in water resources management in Vietnam and around the world gender.

- Applying GIS technology and hydrological models to simulate flow factors water resources management in river basins

- Research, design and manufacture an integrated sensor system to collect several meteorological and hydrological parameters text as input to the model.

- Research and design the structure of an optical sensor to measure water salinity for monitoring purposes salinity intrusion in the river basin in real time.

- Research and build a WEBGIS information system that automatically integrates data from sensors into the model to perform flow simulations and visualize water resources data and real-time river basin environment to support decision-making.

4. Research object and scope

Research object: Possible method of building a WEBGIS information system ability to integrate data from sensor systems into models for water and environmental resource management school in the river basin.

Territorial scope: Nhue - Day river basin belongs to the territorial space of 05 provinces and cities Hoa Binh street, Hanoi, Ha Nam, Nam Dinh, Ninh Binh.

Scientific scope: The thesis focuses on research on wireless sensor networks Optical sensor design theory and solutions to build a WEBGIS system that integrates models and data

in space and time to serve the management of water resources and the environment on the river basins.

5. New points of the thesis

- Built a WEBGIS system integrating wireless sensor data and data Geographic background data into hydrological models to serve water resource management in river basins in real time;

- Research and design a sensor system that can integrate various types of wireless sensors various services for monitoring and monitoring meteorological, hydrological and environmental parameters;

- Research and design an optical sensor structure capable of measuring water salinity Integrate into wireless sensor network.

6. Defense arguments

- Argument 1: The information system fully integrates space and time data and morphological attributes of a river basin are possible scientific and technological solutions effective support for water resources and environmental management in river basins.

- Argument 2: Solution for designing optical sensor structure to measure water salinity and system integrates wireless sensors capable of monitoring meteorological, hydrological and environmental data real-time field contributes effectively and practically to monitoring, supervision and resource and environmental management.

7. Scientific and practical significance of the thesis

Scientific significance:

Interdisciplinary research field, contributing scientific basis and research methods to big problems in the field of management, protection and sustainable development of resources and the environment in river basins, specifically water resources.

Practical significance:

The research results of the thesis are a scientific basis and useful means to help families management, planning reference policies to develop practical applications for management effective management of water resources and environment in river basins in Vietnam.

8. Structure of the thesis

The structure of the thesis includes Introduction, Conclusion and 4 chapters: Chapter 1. Scientific basis and research methods. Chapter 2. Application of geographic information system physics and modeling to simulate the flow regime in the Nhue - Day river basin. Chapter 3. Research on system design integrating wireless sensor networks and modeling on the platform WebGIS platform for resource and environmental management Chapter 4. Results and testing

Chapter 1

Scientific basis and research methods integrating sensor systems and geographic information systems to serve the management of water resources and environment in river basins

Chapter 1 of the thesis synthesizes documents presenting an overview of resource concepts water and basins, geographic information systems, modeling, wireless sensor networks, results Some typical research results in Vietnam, in the world and in the Nhue – Day river basin to serves as a basis, a scientific basis that provides a research process to build a system complete as the diagram in Figure 1.1 and 06 methods to conduct research.

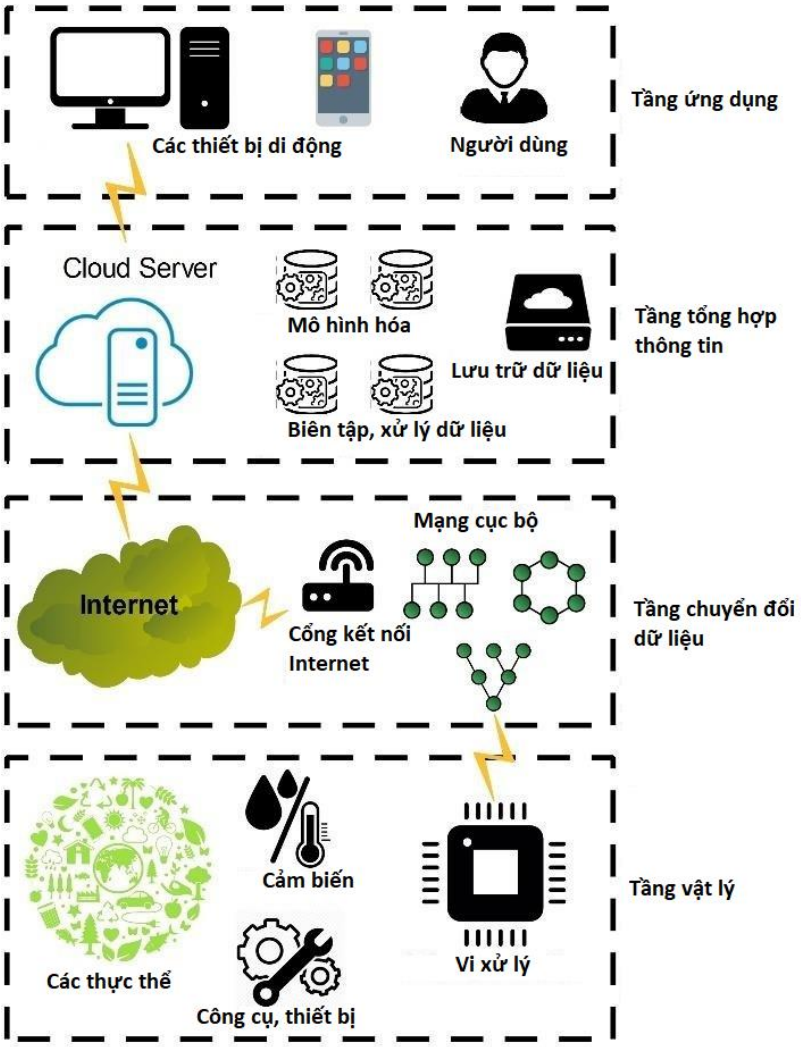


Figure 1.1: Data layers in the interdisciplinary information integration system

1.1 Overview of some concepts

1.1.1 Water resources and river basins

According to the 2012 Law on Water Resources, water resources include surface water, underground water, and water rain and sea water are within Vietnamese territory, the river basin is the land within that scope surface water and underground water flow naturally into the river and drain into a common outlet or into the sea. Save Inter-provincial river basin is a river basin located in the area of two more provinces and centrally run cities.

1.1.2 Geographic information system

Geographic Information System (GIS), according to FAO, the history of GIS began in the 1960s with with the development of Canadian geographic information systems. This first GIS application was designed designed to serve the management of natural resources scattered in a region large space. This is a fundamental tool for conducting research in the field of management resources and environment, tools capable of visualizing spatial data, integrating with the hydrological model to simulate water resources in basins.

1.1.3 Modeling

According to author Nirmala Khandan of the book ”Modeling Tools for Engineers and Scientists “Modeling Tools for Environmental Engineers and Scientists”: model Modeling is the process of applying basic understanding and experience to conduct simulation or describes a process that takes place in a natural system according to a certain goal. Model at that time can become a very powerful and effective tool when it has the ability to help people understand a natural system, often very complex. Today, scientists often use tissues models in professional activities serving the analysis and use of field and simulation data phenomena that occur in nature to be able to understand their nature and evaluate their impacts natural process.

1.1.4 Wireless sensor network

Most sensors today are embedded in everyday and commonly used devices It happens that people are not aware of their existence, nor how they exist used increasingly. While the former is the case where sensors are used as a direct interface between the physical world and human perception, today's sensory data variables are combined and processed more frequently, wireless sensor networks are used by scientists, application managers in many fields, such as monitoring environmental parameters at sources waste, water quality in river basins, etc.

1.2 Overview of research projects in the world, in Vietnam and locally research

Scientists around the world have conducted many studies related to financial management issues water resources, methods and tools for river basin management, such as applying GIS technologies, modeling, wireless sensor networks or integration between GIS and IoT systems. Research all point out that river basin management is considered very important in the sustainable development of resources water. Usually the scale of the area of a river basin is very large, the application of methods

Methods and tools need to ensure requirements for the ability to calculate, simulate, and predict natural developments occurs in the basin.

In 2018 Michelle and colleagues [55] published a comprehensive study proposing solutions Typical applications of new technologies in monitoring surface water quality in areas belongs to the Philippines (Figure 1.2). The study covers the technologies of GIS, RS, WSN and on-line systems WEBGIS route.

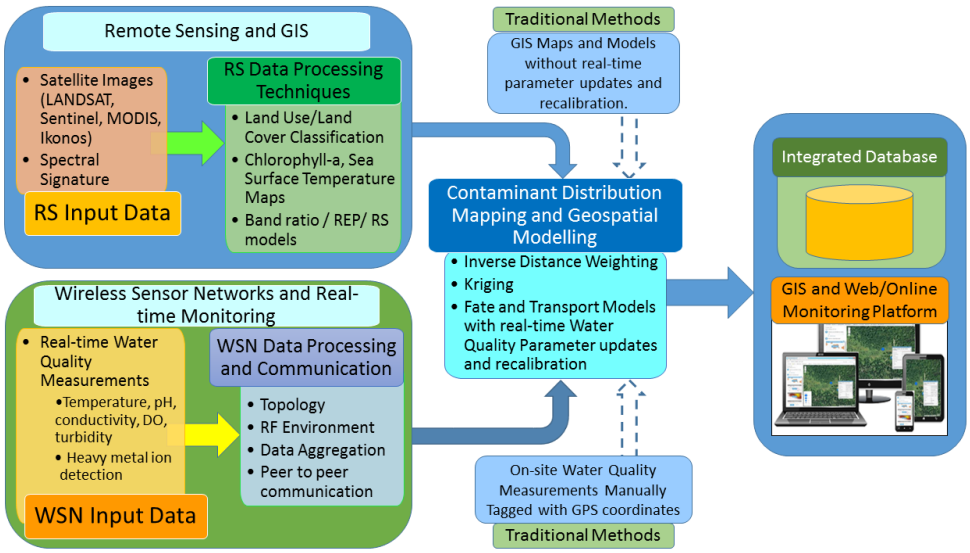


Figure 1.2: Integrated system framework for environmental monitoring using RS, GIS, WSN and RE

In 2016 Mohammad Adnan Rajib and his colleagues developed an application called SWATShare includes the network infrastructure, architecture, and environment to help scientists re-implement tissues SWAT image has been previously set up for use on the Internet environment. However, the data The visualization data simulated from the model is all past data, used for simulation, Resource assessment in river basins. Figure 1.3 is the overall architecture of the SWATShare system.

In 2019 McDonald's research team along with Srinivasan [52], one of the Open source software developer SWAT has announced a solution that enables real-time data integration details into the Web-based SWAT model from NASA data (https://earthdata.nasa.gov/). This is a scientific solution that can be applied on a global scale, after tissue SWAT modeling Simulations in specific basins can be integrated into the Web system to update data weather to continue the simulation. However, this study does not address the problem of solution solve problems that meet real-time simulation requirements.

In 2017, the research team led by Associate Professor, PhD. Le Trung Thanh was the leader of the team that conducted the research save the life of wireless sensors, integrated optical sensors applied in environmental monitoring Initially manufacturing integrated sensor circuits and testing a number of multi-hop monitoring systems remotely, giving very positive results.

The Nhue - Day River basin is one of the most densely populated areas in Vietnam. More than ten million people currently live in this area that is only partially drained.

Many studies on the application of water quality models have been researched and applied on water sources Nhue River - Day River area since the 1990s.

Through an overview of research in the world, in Vietnam and in research areas in the field Water resources management in river basins can see the main research directions using these Past spatial and temporal data for analysis, evaluation, and decision support. Most of Those studies have not proposed a comprehensive solution that combines the strengths of sensor technologies Wireless variables, WebGIS and modeling to solve practical problems in real time on a basin-wide scale. Therefore, it is necessary to carry out many interdisciplinary studies, especially for Research and application of new technologies with high integration capabilities.

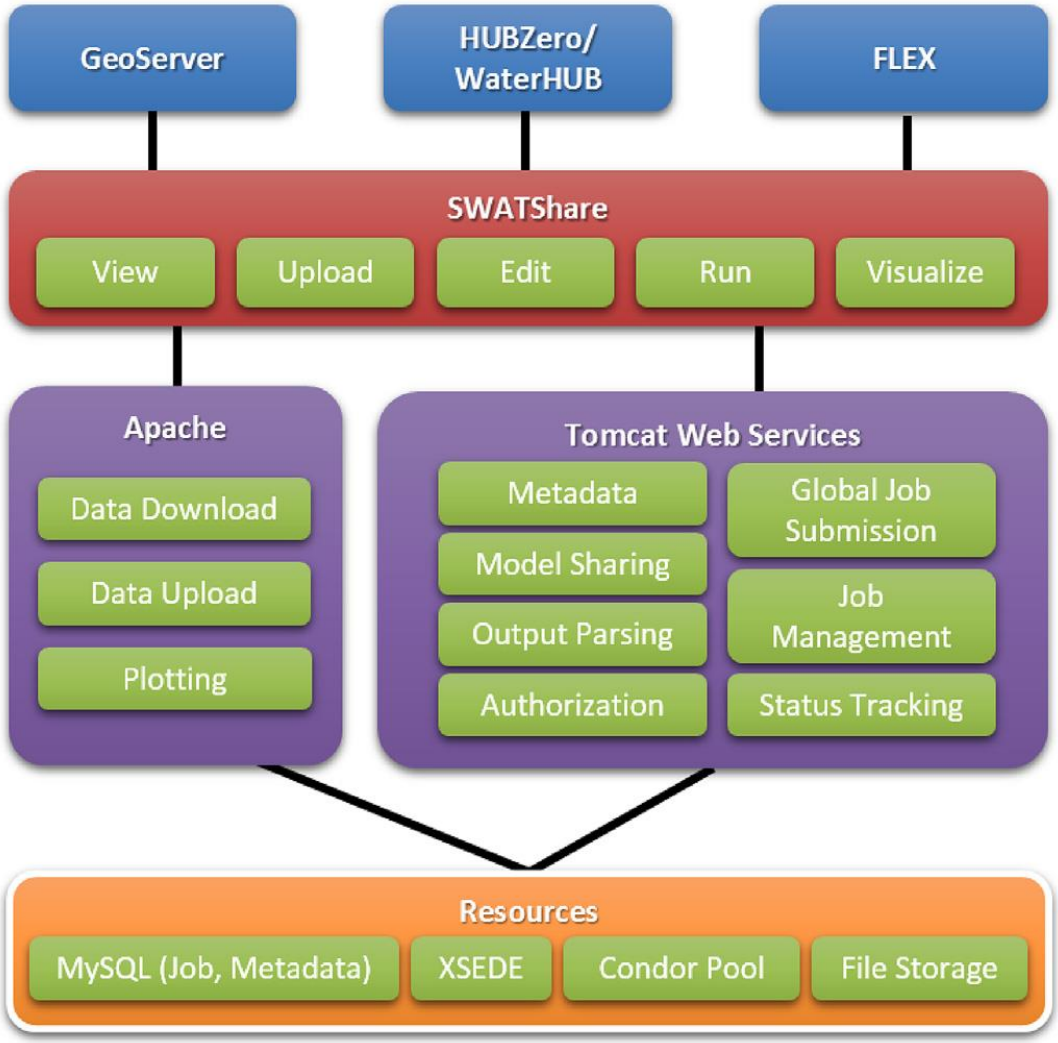


Figure 1.3: Architecture of the SWATShare system

1.3 Research methods

The thesis uses several main methods as follows:

- Field survey methods;

- Methods of applying GIS technology to process spatial data and supporting attribute data resource and environmental management;

- Application of the SWAT model to simulate flow factors and water resources in the Nhue - Day river basin.

- Method for designing wireless sensor systems (electric sensors and optical sensors) to support monitoring remote, automatic meteorological, hydrological and environmental factors;

- Method for building an information system that integrates results collected from sensors as input data input for model;

- Method for visualizing spatial data and attribute data on cumulative information systems suitable for monitoring, supervision and decision support.

Chapter 2

Application of geographical and tissue information systems modeling and simulating the flow regime at the reservoir Nhue - Day river basin

2.1 Characteristics of the Nhue - Day river basin

Nhue - Day river basin, located in Hanoi city and the provinces of Hoa Binh, Ha Nam, Nam Dinh and Ninh Binh. This basin is divided into sub-basins on the basis of the DEM map and main river and tributary networks. The Nhue Day river basin has a humid tropical monsoon climate hot with cold dry winters and hot rainy summers. The average annual temperature ranges from 24-270C.

Average annual rainfall ranges from 1500-2200 mm, with peak rainfall occurring at Ba Vi Mountain in the upper reaches of the Tich River.

River and stream network: Main rivers in the basin: Nhue, Thanh Ha, Tich, Hoang Long, Chau Giang, Dao, Ninh Co. To Lich River is the main branch of Nhue River receiving water from Lu and Kim Ngu, Set river. River network density: varies from 0.7-1.2km/km2. - The entire Nhue-Day river basin has it natural area of 7665 km2, accounting for about 2% of the country's area

2.2 Classification of modeling

Most modeling studies in the environment can be placed into one of three categories basic: experimental physical models, estimation models and mathematical models (physical modeling, empirical modeling, and mathematical modeling). While the above three models have complete characteristics are different but they complement each other and all have an important role, including the real physical model experiments and estimated models provide extremely important information for the modeling process by mathematical methods. These include models such as the MIKE-NAM model, MIKE-SHE, HEC- HMS, WEAP, SWAT.

2.3 Select and set up SWAT model

In this chapter, the author of the thesis will focus on analyzing applications of GIS and modeling in simulating flow factors and water resources in the Nhue - Day river basin.

Based on the analysis in Chapter 1 on model selection criteria and on the characteristics of the Nhue - Day river basin is a basin with an average area, the basin has an imperfect topography is a plain, nor is it a steep mountainous area and is based on the capabilities of research models lifesavers choose the SWAT model, which is a semi-distributed model.

The input data of the SWAT model includes attribute data and boundary spatial data Filed and processed through ArcGIS software and some other programming tools. Advanced SWAT model simulating the Nhue - Day river basin includes the process of dividing the basin into sub-basins

Based on DEM data, overlaying topographic data, land use data, and soil data and spatial data as well as attributes of monitoring stations to form hydrological units literature.

2.3.1 Terrain data (digital elevation model, DEM)

Digital elevation maps with a resolution of 30m x 30m per pixel were used to build the model.

For the study area, the DEM map is integrated into the Nhue - Day River Basin Administrative map.

2.3.2 Soil data

Soil soil data collected for each profile sample, at the Soil Evaluation Center, General Department of Land, Ministry of Natural Resources and Environment includes data on: soil thickness, pHKCl,OM, total phosphorus, Catrion exchange, mechanical components.

2.3.3 Land use data

Land use data are compiled into raster format according to the requirements of the SWAT model includes types of land use, in which symbols of land use types are converted to fixed codes form of the SWAT model.

2.3.4 Hydrometeorological data

Meteorological and hydrological data including rainfall data from 2011 to 2020 were collected at Ha Dong, Ba Tha, Phu Ly and Nhu Tan stations; temperature data from 2011 to 2020 collected collected at Ha Dong station; data on flow rate collected at Ba Tha station from 1978 to In 1980, hydrological stations in the Nhue - Day river basin have stopped monitoring water flow factors.

amount of flow. Rainfall and flow data at Ba Tha station from 1978 to 1980 will be used to calibrate and validate the model.

2.3.5 Requirements for data standardization

- DEM, soil, and land use data are standardized into Raster (grid) format with the system WGS 1984 coordinates, UTM projection, zone 48N.

- Soil and land use data describe pixel values corresponding to soil type and land use type from the original map information. These files (look-up tables) are in ASCII or DB IV format.

- Daily rainfall data series were collected in two periods from 1978 to 1980 at Ba Tha station, period 2011-2020 collected at Ha Dong, Ba Tha, Nhu Tan stations, data is organized in excel format into text files and standardized according to the model format SWAT.

- Daily flow data series compiled for the period from 1978 - 1980 for calibrating and verifying the model and data collected at Ba Tha station. Reason for use the data series at this stage is because meteorological and hydrological stations in the basin have stopped monitoring traffic factor and only have data for 3 years from 1978 to 1980.

2.4 Set up and calibrate the model

2.4.1 Model establishment process

The first step is that the model uses DEM data to divide the Nhue - Day river basin.

The basin is simulated based on the upstream and downstream points of the river. In research in this thesis, the Nhue - Day river basin is divided into 23 subbasins based on the region receiving water from main tributaries in the basin. This process is performed by function "Watershed delineator" by ArcSWAT software, the model automatically calculates elevation based on degrees topographic elevation of the DEM map to form flows and divide them into sub-basins such as the figure.

The next step is to build an HRU (hydrological uniform unit) map, with data updates Data on soil, land use, slope classification (5 classes according to the convention of the Ministry of Agriculture and Development Rural Development, MARD). After reclassifying land use type and soil type and slope, assign The ArcSWAT interface allows overlaying these 3 map layers together for construction HRU (hydrological uniformity unit) map layer.

In this thesis, the author sets up a model using input data as rainfall data at Ha Dong, Ba Tha, Nhu Tan meteorological stations.

2.4.2 Calibrate and verify the model

The calibration and validation process usually includes the following steps:

- Determine the range of monitoring data collected;

- Run the model with different values for unknown parameters, until the conclusion model results match reality;

- Apply the calibrated model to the remaining monitoring data series to see its capabilities to what extent the model is accurate, this process is called model validation.

The Nhue - Day river basin only has three years from 1978 to 1980. Therefore, the thesis will proceed

Calibrate and validate the model with this data series, if flow data is available monitoring at an upstream station and a downstream station, the calibration and verification process model will be better.

The process of sensitivity analysis in the model (sensitivity analysis) is the process of investigating the impact of parameter values to know which parameters have a large or small impact on the results of the model.

a) Evaluation coefficients during the model calibration process

The Nash - Sutcliffe coefficients (NSE), coefficient of determination R2 and percentage bias (PBIAS) were used to evaluate the model's calculation results.

The results of the model calibration process achieved the values NSE $\geqslant$ 0.5, R2 $\geqslant$ 0.6, PBIAS ± 15% of the flow rate is considered a successful correction.

b) Results of adjusting model parameters

The model calibration process was conducted at Ba Tha hydrological station in 1978 and 1979.

Based on the values of the evaluation indexes R2, NSE, PBIAS which are 0.53, 0.61, 6.89% respectively, it can be concluded the combination of correction values as shown in the table below meets the requirements.

c) Model verification results

The process of model validation is the process of using the results of the model calibration process, observed flow data in 1980 at Ba Tha station will be used in the model validation process. Simulation results compared with monitoring data as shown in Figure ??. Values of evaluation indexes R2, NSE, PBIAS times equal to 0.91, 0.9, 6%.

2.4.3 Calculate flow rate and create a water resource map for the Nhue-Day river basin

Calculate the amount of water resources in the basin Water resources in the basin are simulated and calculated by the SWAT model according to the equation 2.4.3:

$$WY\ LD = Qsurf + QLAT + Qgw - QTLOSS - Wpond$$

The process of establishing a SWAT model for the Nhue-Day river basin has been carried out, the results of The model includes spatial and attribute results. Attribute results are obtained in the set news output.hru. The total amount of water leaving the HRU to form river flow will be the result calculated by each HRU unit and aggregated in the WYLD data field in the file "output.hru". In the next step, the author uses FORTRAN and GIS programming tools to create a resource map water resources as shown in Figure 2.1.

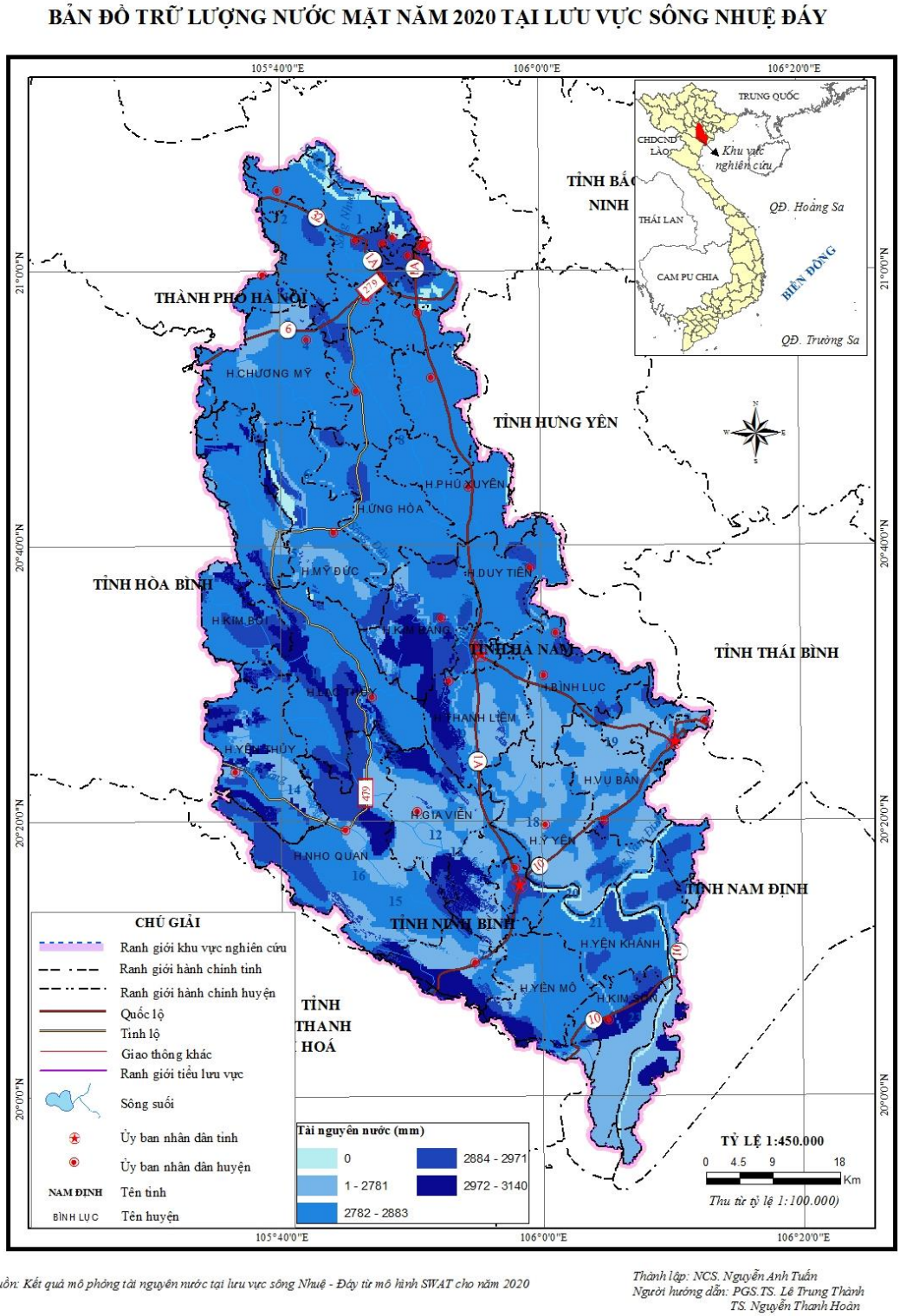


Figure 2.1: Water resources map of the Nhue-Day river basin in 2020

2.5 Summary of chapter 2

- This chapter of the thesis has successfully established a SWAT model for the Nhue - Day river basin. The calibration process was carried out in 2 years 1978 - 1979, the model validation period was carried out in 1980.

- Simulation results help divide the basin into sub-basins for easy calculation Calculate and evaluate the flow rate in each sub-basin, a map of surface water resources is created established based on simulation results. The results from this study demonstrate applicability Effectiveness of GIS technology and modeling in assessing water resources in the basin.

- Based on the results of successfully establishing the model, follow up research directions on monitoring solutions monitor flow rates at any point in the river basin using modeling technology Wireless sensor networks will be implemented in the next chapter.

Chapter 3

Research and design network integration systems Wireless sensing and modeling on WebGIS platform for asset management resources and environment

This chapter proposes a WebGIS system architecture that integrates data from the sensor network wireless as input to the model. Specifically, rain, temperature, and humidity data are monitored and collected from the wireless sensor system and transmitted to the center through terminal devices. Host system The center is set up on the Internet "cloud", data from sensors is transmitted to the system server system through the dispatcher node (Gateway) and processed according to the input data format of the SWAT model to conduct real-time simulations.

3.1 Design the WebGIS system architecture to integrate data from the sensor network wireless and modeling

3.1.1 Design the physical architecture of the system

Interdisciplinary information system architecture based on integration of sensor systems, hydrological models and Geographic background data (GIS) includes components as shown in Figure 3.1.

This is the physical architecture of an overall system that integrates cross-disciplinary information on a coherent basis Integrating monitoring data from sensor systems, modeling and GIS geographic data. The main steps are procedures to set up the system include:

- Collect and process meteorological and hydrological data at Ha Dong meteorological stations and Nhu Tan hydrological stations adopts a wireless sensor network including temperature, humidity, and precipitation data;

- Integrate data obtained from the sensor system as input to the SWAT model and proceed with tissue processing burns;

- Design a WebGIS system that connects data to the model storage server (SWAT) through advanced API functions Real-time flow simulation;

- Edit and create water resource maps, visualize flow data at the reservoir Nhue - Day river basin.

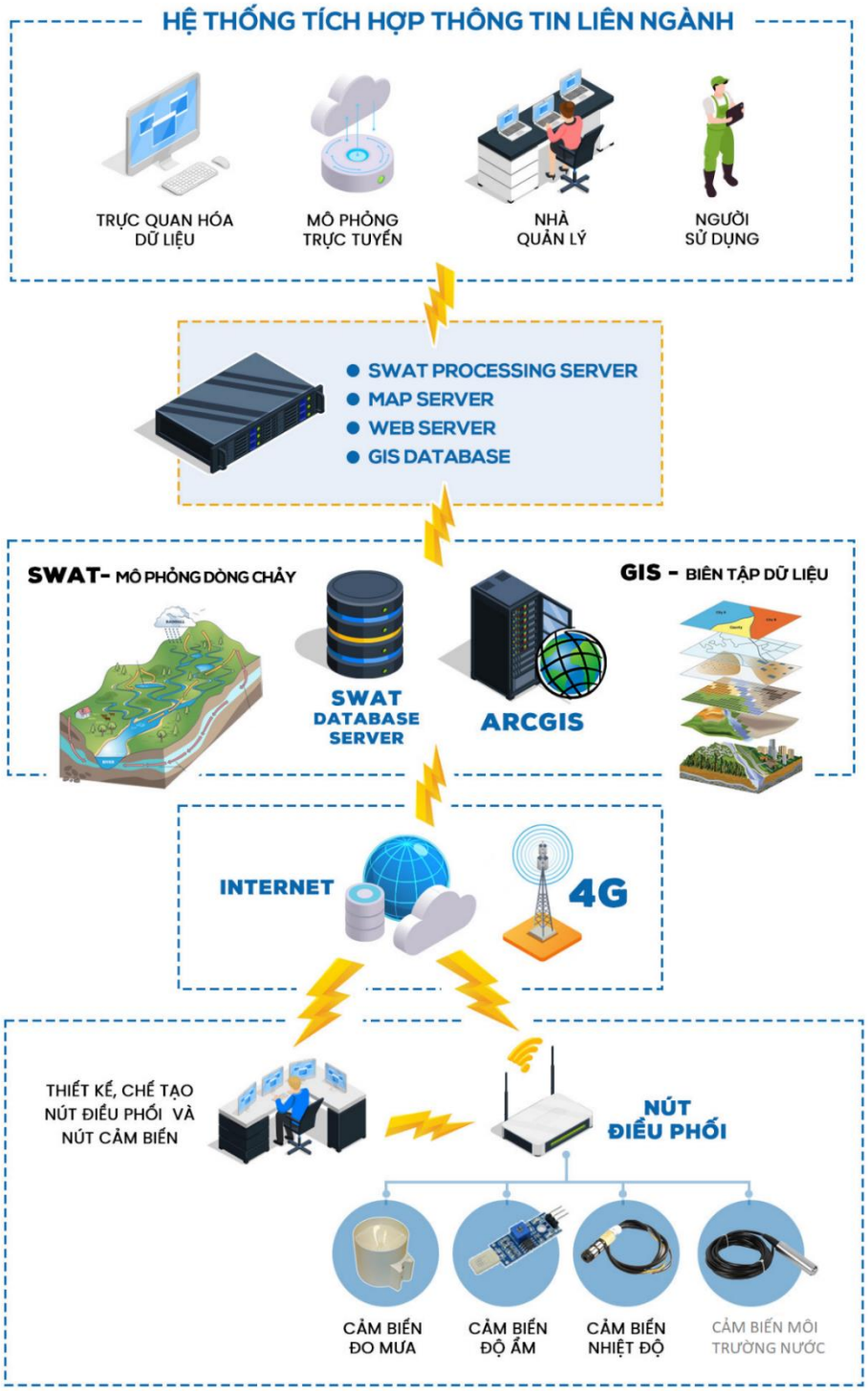


Figure 3.1: Interdisciplinary integrated information system architecture

3.1.2 Design the system's logical architecture

In this thesis, it is assumed that sensor data is collected continuously with a frequency of once every hour and stored in the IoT database. Spatial data on distribution of basins and boundaries research area, current land use status, data on land types, etc. will be stored in the database GIS data. In addition, the system also distributes a results database to store information after modeling is executed, this result will be directly integrated into the GIS database to attach information space to provide a more intuitive view for users. From there, when users access

enter the system and need to execute the online model, the system will receive the user's request user through the graphical interface, then send requests to the model server through the APIs installed on the Web server.

3.1.3 System database design

The database architecture of the WebGIS integrated system consists of a set of data tables spatial and non-spatial. In there:

- Spatial data table includes: lyr_station, lyr_basin, lyr_watershed, lyr_hru, lyr_outlet, lyr_reach, lyr_landuse.

- Non-spatial data table includes: rainfall_hourly, rainfall_daily, swat_automation-logs.

3.1.4 Standardize the database

Spatial entities representing geometric features are often connected to sets describe their relativeness in attribute data using a spatial convention.

In the geospatial data model, different attribute tables store different sets of information together. The relevant information for a particular purpose can be collected from many tables way of linking or connecting tables together to obtain specific information about a set of properties spatial ability.

3.2 Design a sensor system to monitor some meteorological and hydrological parameters suitable for the model

3.2.1 Design an integrated sensor system using Zigbee technology and Arduino board

Integrated sensor system design using Zigbee technology and Arduino board including transmitter develop software and hardware into a complete system. Figure 3.2 depicts an architecture of monitoring system for a number of hydrometeorological and environmental parameters.

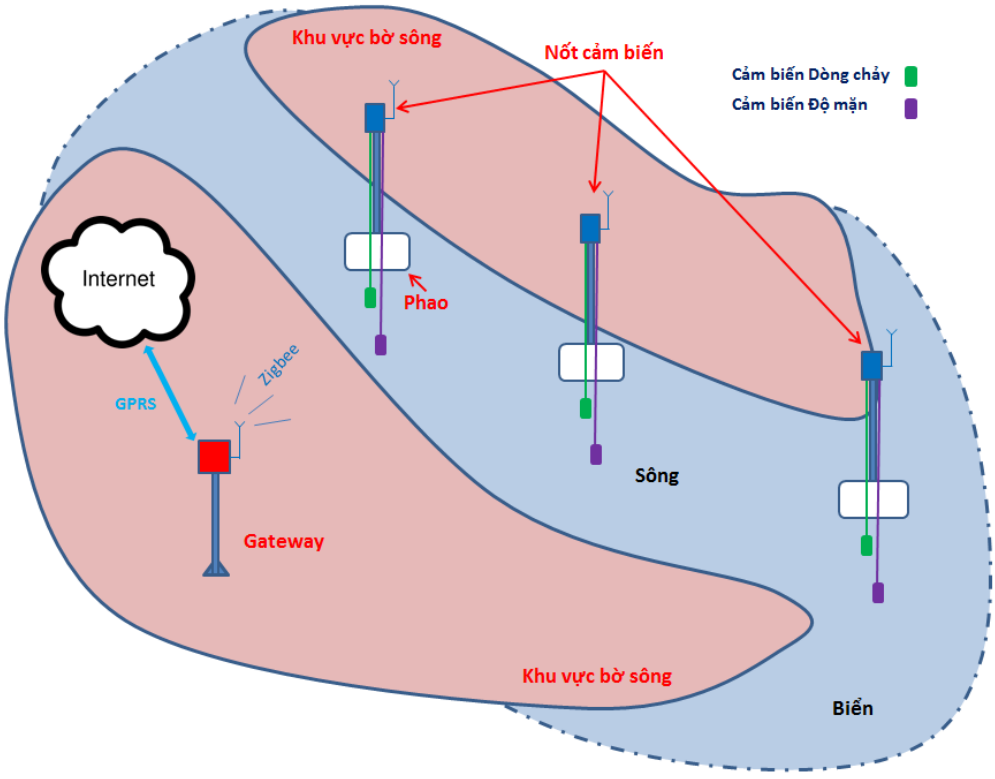


Figure 3.2: Structure of a monitoring system model

The monitoring system is designed based on Zigbee technology, which is a network standard Wireless has low operating costs and consumes little energy, the system is often chosen for installation designing and manufacturing battery-powered devices, the advantage of Zigbee technology is providing communication information low latency is often integrated with radios and microcontrollers.

3.2.2 Design of coordination button

The structure of a dispatcher node includes the following components: Arduino Mega motherboard, Module Zigbee communication, SIM – GPRS Module, and a power supply including storage battery and battery sun. The design diagram of a gateway node is described in Figure 3.3. Communication method between the sensor node and the coordinator node use the 802.15.4 (or Zigbee) transmission protocol, collecting data received from the sensor node will be transmitted to the coordinator node and through the communication protocol using the module GPRS, 3G, 4G to transmit to the central server (Cloud Server). Data is stored on a central server The center can be displayed and visualized through Web Server and API functions to display on mobile platform.

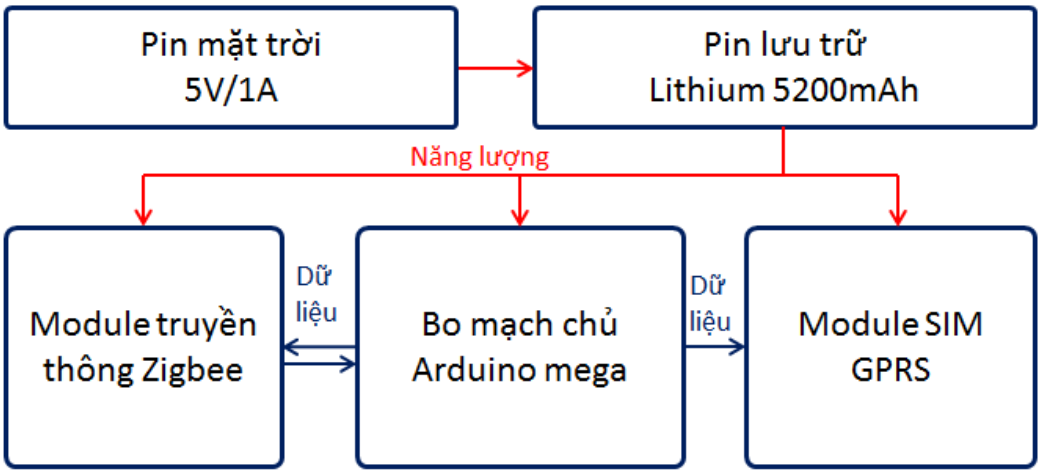


Figure 3.3: Coordination node structure

3.2.3 Sensor button design

Design of sensor button to measure temperature and humidity The sensor button is designed using an Ardunio motherboard similar to the structure of the control button coordinate. The structure of the sensor node includes: Arduino Mega motherboard, Zigbee communication module Configured as a Router, DHT11 temperature and humidity sensor, power supply includes battery solar energy storage and batteries. The Arduino Mega motherboard will read the corresponding returned digital signal temperature and humidity values from the sensor; and calculate and convert digital values to temperature and degree values corresponding moisture, then transmitted to the coordinator node through the Zigbee network.

Design of rain sensor button

The structure of the rain sensor button includes: Arduino Mega motherboard, Zigbee communication module Configured as a Router, rain flow sensor, power supply including Storage Battery and Battery Solar.

The Arduino Mega motherboard will read the electrical pulse value corresponding to the amount of rainwater when overflowing bucket at the measurement location and calculates

and converts the voltage value to the rain flow value over time corresponding time, then transmitted to the coordinator node via the Zigbee network.

3.2.4 Data processing principles of the sensor system

The connection between the sensor nodes and the coordinator node is a Zigbee wireless connection, allowing the nodes The network saves energy but still ensures a longer connection distance than standards common wireless connections such as Bluetooth, Lora, or Wifi. However, to connect the nodes the network must operate on the same frequency band and with the same transmission parameters. Such a network nodes can transmit data at any time when needed. This will result in a the problem that wireless sensor network systems often encounter is signal conflict. In a period of time, if there are more than 2 network nodes transmitting data and signals from the network nodes

These will "conflict" with each other at the receiver, which is the coordinating node device. Signal conflicts will cause harm The received data is corrupted, causing the network node to retransmit. With a smart wireless sensor network usually, data transmission at network nodes is done according to timing. So with the Sensor network nodes have the same role, then timing data playback still results in “pulses data burst during transmissions. To solve this problem, some connection standards for sensor networks are proposed the wireless switch has integrated access control mechanisms, to limit conflicts and handle incidents conflicts occur, for example, in the Wifi connection standard, which applies multiple access mechanisms to avoid conflicts at the layer physics (CSMA/CA).

3.3 Design an optical sensor to measure seawater salinity based on the addition mechanism benefit from

3.3.1 Introduction to optical sensors

First, to have an overview of optical sensor technology, Figure 3.4 shows the diagram Overview of an optical sensor system. The optical signal source is fed into the sensor via the input fiber. The output of the sensor is connected to an optical receiver. Intensity, step The wave, phase or polarization of the output signal will change depending on the environment to be measured. By measuring the changes of those parameters, the environmental parameters to be measured can be determined.

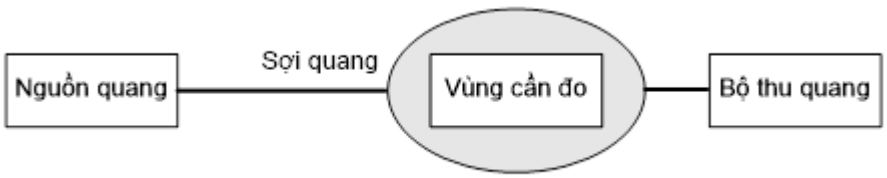


Figure 3.4: General structure of the optical sensor system

Optical sensors have many advantages compared to other sensors such as avoidance electromagnetic interference, high sensitivity, compatible with optical communication system, fast response and bandwidth huge pine.

3.3.2 Applying optical sensor technology to design a highly sensitive salinity measuring sensor

Method to design a new structure of water salinity measurement sensor with high sensitivity based on an optical microring resonator embedded in a multimode interference structure. Solution set this design also proposes an approach for optical sensors to be integrated with sensor networks wireless for online and real-time applications. Sensor structure can provide 581nm/RIU sensitivity based on optical intensity mechanism. This design method can

be used silicon waveguide for the whole sensor design, this sensor structure can operate in step 1550nm operating wave, suitable for fiber optic communication.

New optical sensor structure design

The proposed structure contains a 2x4 MMI coupler. At an output port, a microresonator only creating a special phase. In this design, the silicon waveguide has a height of 220 nm, 500 nm width is used for single-mode operation. The wavelength is 1550nm. Silica is used used to coat the shell at the reference resonator, brine is used as the coating at the site sensor contact.

Can the optical sensor to measure seawater salinity designed in this section use a sensor network? IEEE 802.15.4 Zigbee wire (frequency 2.4GHz, data rate 256kbps) as mentioned in section 3.2.1 to integrate integrated into the monitoring system to monitor the level of salinity intrusion in the upper estuary area river basin. Zigbee network configuration includes three components as shown in Figure 3.5.

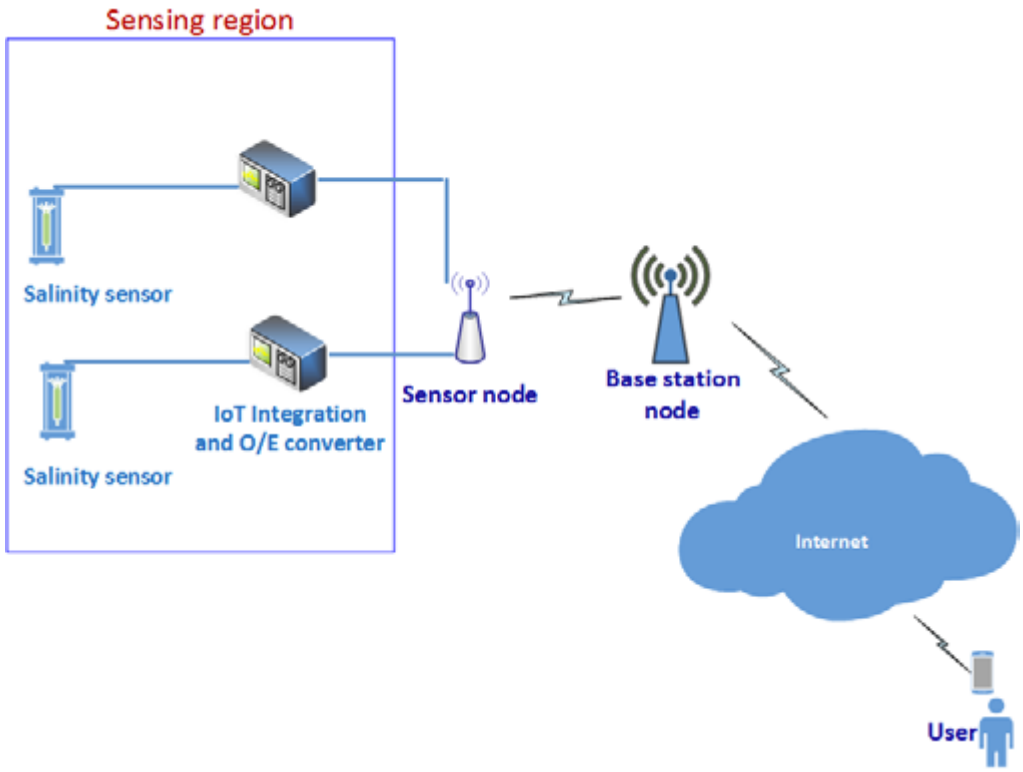


Figure 3.5: Integration structure with IoT system

3.4 Summary of chapter 3

Chapter 3 of the thesis solved the following three problems:

- Design and manufacture a sensor system to monitor hydrometeorological factors remotely, in real time includes factors such as temperature, humidity, and precipitation. This result was published with work no 1: ”Research on solutions to monitor (salt erosion in coastal areas) the environment through the network Wireless sensor using Arduino board” in the November issue of Hydrometeorological Magazine 2019;

- Successfully designed a new optical sensor structure based on a 2x4 MMI coupler integrated with a microresonator (MRR) to measure water salinity (NaCl concentration) as a premise to manufacturing optical sensors capable of monitoring the level of salinity intrusion in sea areas. Sensory structure this sensor has high sensitivity, and has the ability to integrate with wireless sensor networks for applications real-time online and remote monitoring. The results were announced at the ICSSE 2021 Conference selected into the IEEE Xplore database:

”High Sensitity Optical Sensor Based on Resonance Wavelength Shift for Seawater Salinity Integrated with Wireless Sensor Networks” and more magazine ”International Academy of Microwave and Optical Technology” in category Scopus: Ultra-Low Power PAM-4 Generation Based on a Cascaded 2x2 MMI Coupler for Optical Interconnect and Computing Systems

Chapter 4
Results and testing

Results of stream flow simulation and water resource mapping have been performed in chapter 2 of the thesis. In chapter 3, the author of the thesis designed the WebGIS integrated system architecture Includes an integrated wireless sensor system to monitor climate factors (rainfall, temperature, humidity).

SWAT model serves to simulate river flow in real time. This is important results, solving practical problems in water resource management and operations Monitor and warn of natural disasters in river basins. In this chapter, the thesis presents the results of building a capable WEBGIS information system Integrate data from the sensor system into the above model for water resource and environmental management river basin.

4.1 Data used in the thesis

4.1.1 Spatial data

- DEM: 30x30 (m) collected at Nasa's Electronic Information Portal.

- Land data (soil) and current land use data in 2010 were collected at the Department of Finance. Resources and Environment of provinces and cities with annual administrative boundaries in the basin

4.1.2 Data over time

- Daily rainfall at Ha Dong, Ba Tha, Nhu Tan stations was collected from 2011 to 2020. Ba Tha station alone collected additional data from 1978 to 1980 to serve correction and control model evidence.

- Daily average temperature data at Ha Dong, Ba Tha, Nhu Tan stations were collected from 2011 to 2020.

- Daily humidity data at Ha Dong, Ba Tha, Nhu Tan stations has been collected since 2011 until 2020.

- Data source: National Hydrometeorological Center and sensors

Figure 4.1: Experimental installation of the sensor system at Ha Dong meteorological station and Nhu Tan hydrological station

4.2 Conduct testing in the research area

4.2.1 Description of the study site

After being designed and manufactured, the sensor system was tested for a number of criteria such as temperature, humidity at the Hydrometeorological Monitoring Center under the National Hydrometeorological Department, Testing results meet industry standards. The sensor system includes rain sensors, temperature sensors, and humidity were tested and installed at two stations including Ha Dong Meteorological Station (Hanoi) in upstream and Nhu Tan hydrological station (Ninh Binh) downstream of Nhue - Day river basin.

4.2.2 Test scenario

- Select the location to install the sensor at Ha Dong and Nhu Tan stations. Each sensor covers includes a dispatcher node and sensor nodes that measure precipitation, temperature, and humidity.

- Load the embedded programming code to set up the system to collect measurement data from the sensor with a measurement frequency of 15 minutes/time. Measurement data will be transmitted directly to an online IoT database stored on the machine cloud master. At the same time, after each measurement, the average daily data is also recalculated and stored in the above database.

- Configure input parameters for the SWAT model. API programming allows model execution SWAT on cloud server. In which, the data is collected from the sensors that serve SWAT model operations will be retrieved from the IoT database and then automatically determined reformatted to match the model's input parameters.

- Set up a CronJob mechanism that allows executing the SWAT model through the API programmed with frequency 4 hours/time per day. The output results of the SWAT model will be continuously updated each time executable, extracted and stored directly into the SWAT database on the cloud server.

- The WebGIS system allows visualization of spatial data about the location of internal sensors basin, study area boundaries, current land use status, data on soil types, etc. Simultaneously, Develop tools that allow retrieval of data collected from sensors including data

Rainfall, temperature, and humidity data are presented in near real-time graphs. Result The simulation of the SWAT model will also be visualized by a separate tool to display the information numbers on water flow in the basin, etc.

4.3 Results of integration on the WebGIS system

4.3.1 Integrating sensor data

WebGIS information system integrates wireless sensor data and geographic background data into Hydrological models for real-time water resource management in river basins include three segments system as follows:

- Online data collection subsystem applies wireless sensor network as input to the tissue the image includes rain data and air temperature data. Sensor node after collecting data at the scene will be packaged and sent to the coordination node (gateway node) and transmitted to the central server via 4G network to store and process every 1 hour. This solution helps save energy quality and prolong the device's operating time.

- Data processing subsystem as input to the model: Data collected from sensors will be calculated calculated into daily average data in the format required by the SWAT model.

- Data display subsystem: Flow data and spatial data after being simulated by the tissue Images will be calculated, collected and displayed in the online environment, data includes data belonging to spatial data and computing (GIS).

4.3.2 Integrate simulation results of the model

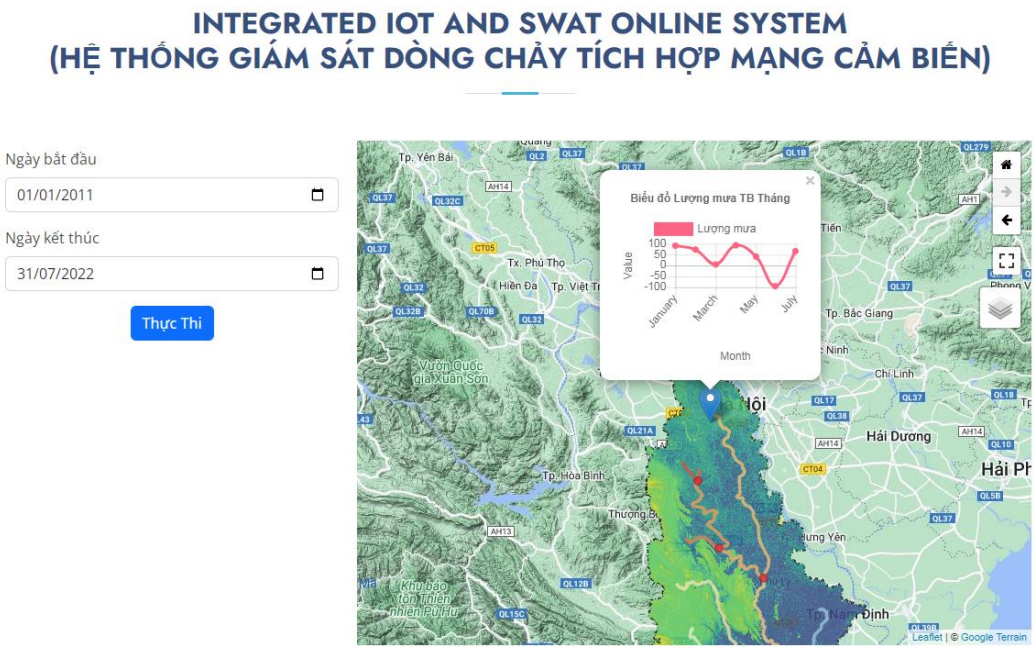
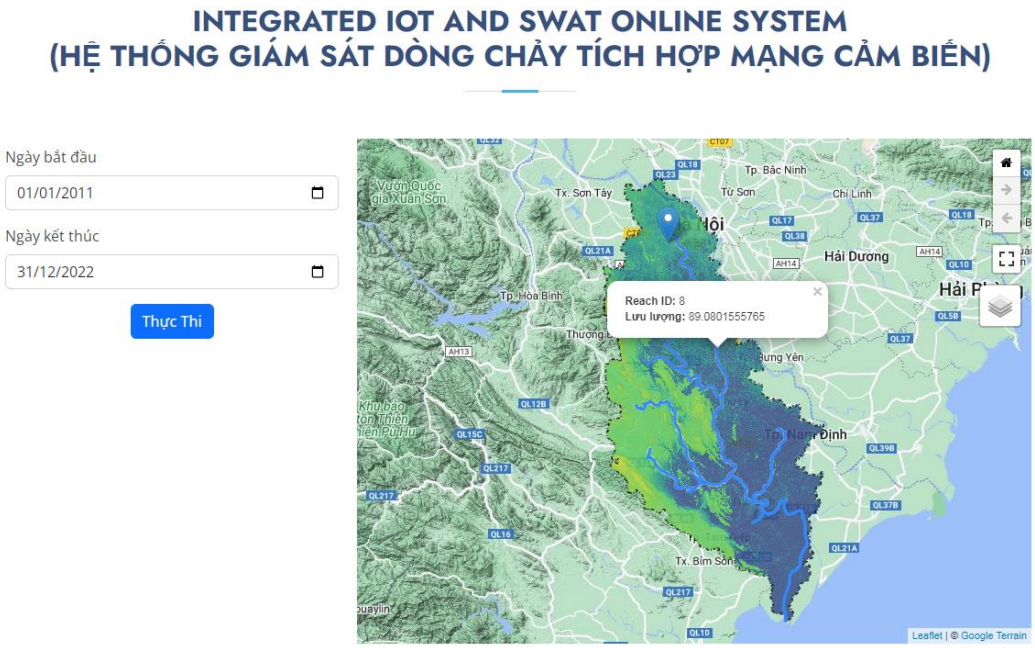


Figure 4.2: Function to monitor average rainfall by month

After rain data is collected as input to the SWAT model, the system will process the data collected and conducted simulation in real time or near real time to calculate flow rate flow and build a water resource allocation map. Next, the system will visualize the data flow from the model's calculation results, the flow rate factor is updated daily or average by month as Figure 4.2.

The system can also directly access daily flow data at river sections has divided the regions in 23 sub-basins as shown in Figure 4.3 and established a water resources map based on them model calculation results.



4.3.3 Evaluate test results

The solution for monitoring water resources and the environment in the river basin has been completely designed Tuning components include hardware devices, wireless transmission technologies, and technology Store and process spatial and temporal data on the Internet environment. The system has tissue capabilities Simulate and monitor data in real time, meeting practical service requirements prevention and control of natural disasters and floods, support for decision-making in matters of management and reasonable use water resources in the river basin.

The system has advantages over current systems in simulation and data extraction features according to waking time during certain periods of time. However, the monitoring sensor system is weak New meteorological and hydrological elements are testing equipment. So that the system can operate stably and long term and have the ability to operate in outdoor weather and climate conditions that require consideration in design and construction created according to industry standards.

4.4 Summary of chapter 4

Chapter 4 presented the results of integrating monitoring results of the wireless sensor system and the model SWAT into the WebGIS system supports monitoring and supervision of water resources in the Nhue - Day river basin. Part of these results were published in the Journal of Transportation Science, volume 71, number 06, August 2020: ”Design of IoTs system based on Zigbee wireless sensor network serving hydro-meteorological and environmental monitoring”.

Conclusions and recommendations

1. Contribution of the thesis

The thesis has proposed and solved 3 problems, which are new contributions to research directions research in the field of natural resources and environmental management, especially upstream water resources management river basin:

- First, build a WEBGIS system integrating wireless sensor data and data geographical background into hydrological models to serve water resource management in river basins over time real;

- Second, research and design a sensor system that can integrate various types of wireless sensors various services for monitoring and monitoring meteorological, hydrological and environmental parameters;

- Third, research and design an optical sensor structure capable of measuring water salinity Integrate into wireless sensor network.

2. Propose solutions to be applied in practice

The results of the thesis have proposed a comprehensive solution from data monitoring at key points monitoring on the basin, to processing data from the wireless sensor network as input for the model for implementation

Currently simulating and calculating flow rates in river sections in sub-basins and nationwide basin, visualize simulation results, and monitor water resource data remotely, over time real. In the immediate future, if the system is applied, it can help reduce human resources, as well as materials to carry out monitoring of meteorological, hydrological, and environmental factors in the basin. Simulation results are reported to managers' mobile devices to grasp the situation visualization and decision support.

3. Recommendations

- Nhue - Day river basin is a large basin, so to ensure input data is rain, temperature, and humidity data distributed evenly across the basin, showing the characteristics of the climate from the upstream and downstream areas, it is necessary to add a number of rain monitoring stations.

- The manufacturing equipment of the sensor system needs to be designed according to industrial standards to be capable usability in different conditions and environments, ensuring data continuity.

LIST OF THE AUTHOR'S RESEARCH PAPERS RELATED TO THE THESIS

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