RESEARCH ON REMOTE SENSING MONITORING APPLICATION SYSTEM OF WATER RESOURCE BASED ON SWAT MODEL IN TIBET

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ABSTRACT: As Tibet's water resources are extremely rich, dynamic monitoring of water resources also become one of important research subjects. SWAT(Soil and Water Assessment Tool) model is a distributed watershed hydrological modeling tool for medium or large-size and long time-scale basin. This paper describes the basic principles of SWAT model. On the basis of SWAT model, using c# with ArcEngine method to establish a GIS and SWAT model based system. In this paper, takes the "One River and Two Streams"(Lhasa River, Nyang Qu, Brahmaputra basin) in the central Tibet as researched area. By using of this system, carried on dynamic remote sensing monitoring of river basin drought, river basin water resources, river basin water and soil conservation, water conservation ecological evaluation, river basin land use and many other monitoring tests, then gives some of simulation results.

1. INTRODUCTION

Tibet is known as "Asian reservoirs", it has abundant water resources, a total of about 448.2 billion cubic meters, ranking the first in China. The central valley of Brahmaputra, Nyang Qu, Lhasa River(hereinafter referred to as "One River and Two Streams") are located in the hinterland of Tibet, these areas are important farming region in Tibet. The "One River and Two Streams" as the central of Tibetan economic development strategy center, has launched a number of comprehensive utilization of development. But the ecological environment conditions of "One River and Two Streams" is very week and highlights the phenomenon of drought and water shortage, we need to carry out remote monitoring system of water resources in Tibet, and continued to monitor the drought, land use and etc..

SWAT model is a distributed hydrological physical model which was developed in recent years. SWAT model can simulate continuous long-time watershed hydrological processes, soil erosion, chemical processes, agricultural management practices and changes in biomass. In addition, SWAT model can also predict human activities influences to the progress stated above in different soil conditions, land use and management actions(Sun Rui, 2010), especially the runoff simulation was widely used.

This text was carried out on the basis of the project of Tibet Development and Reform Commission — The River Basin Resources Environment Remote Sensing Monitoring Demonstration System. According to the principle of SWAT Model, establish the distributed hydrological model of "One River and Two Streams" and simulate watershed runoff. This project aims to monitor water resources ecological environment, and provide technology services for region ecological environment protection, ecological construction, farming industry, forestry industry and other industries, also provide ideas and methods for the comprehensive analysis and evaluation of environment of water resources.

2. PRINCIPLE OF SWAT MODEL

SWAT(Soil and Water Assessment Tool) was developed by U.S. Department of Agriculture(USDA) Agricultural Research Services(ARS), Dr. Jeff Arnold in 1994(Yu Feng, 2008). SWAT model is a distributed watershed hydrological model for medium-sized and long time-scale basin. It can use spatial information provided by GIS and RS to simulate variety of different hydrological physical processes of complex major watershed. SWAT model simulation can be used to predict different agrotype, vegetation cover and land-use for large basins of long period and management of cultivation conditions influence on production of water, production of sediment, soil erosion, nutrients migration and non-point source pollution. Even in areas where lack of information can also use internal weather generator of SWAT model to automatically fill missing information(Arnold, 2005).

The process of SWAT model simulating hydrological water cycle is divided into land phase of the hydrologic cycle(that is convergence part of runoff and slope) and routing phase of the hydrologic cycle(that is convergence part of channel). The former controls the input quantity of water, sediment, nutrients, chemicals and others in main channels of each sub-basin. The latter decided the transportation of water, sediment and other substances from river network to basin export(Wang Zhong-gen, 2003).

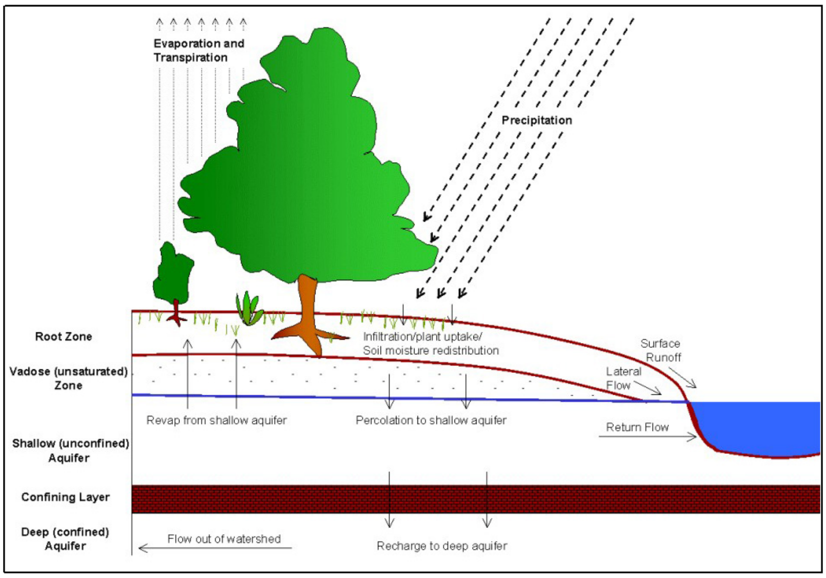

Figure 1. Schematic Representation of Hydrologic Cycle

2.1 Land Phase of the Hydrologic Cycle

In the runoff calculations, SWAT model imported the concept of hydrological response unit(HRU) to reflect the changes of vegetation coverage and agrotype influence on runoff and evaporation. Calculate runoff yield for each HRU separately, and superimposed to get sub-basin runoff, slope convergence, turn into main channel of sub-basin, and finally obtain the total basin runoff by calculating river network confluence.

The hydrologic cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_0 + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}\right) \quad (1)$$

Where SW_t is the final soil water content(mm H_2O), SW_0 is the initial soil water content on day i (mm H_2O), t is the time(days), R_{day} is the amount of precipitation on day i (mm H_2O), Q_{surf} is the amount of surface runoff on day i (mm H_2O), E_a is the amount of evapotranspiration on day i (mm H_2O), w_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), and Q_{gw} is the amount of return flow on day i (mm H_2O)(S.L Neitsch, 2000).

In the land phase of the hydrologic cycle of SWAT model mainly considered climate, hydrology and vegetation coverage and other factors. Among them, the basin climate controls the balance of water and many other sections of hydrological cycle. The climate factors that need to enter including daily precipitation, maximum and minimum temperature, solar radiation, wind speed and relative humidity. These data mainly obtained from National Climatic Data Center(NCDC).

2.2 Routing Phase of the Hydrologic Cycle

Routing phase of hydrologic cycle that is the channel confluence part, mainly considered water, sediment, nutrients(N, P) and pesticides transporting in river, including the confluence calculation of main channel and reservoir.

Once SWAT model determines the loadings of water, sediment, nutrients and pesticides to the main channel, the loadings are routed through the stream network of the watershed using a command structure similar to that of HYMO (Williams and Hann, 1972). In addition to keeping track of mass flow in the channel, SWAT models the transformation of chemicals in the stream and streambed. Figure 2 illustrates the different in-stream processes modeled by SWAT.

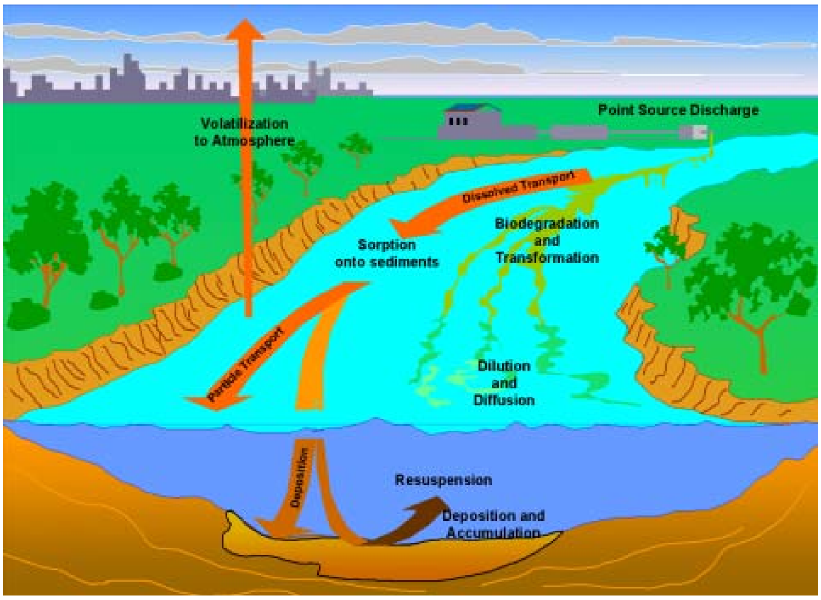

Figure 2. In-stream Processes Modeled by SWAT

2.3 Summary

SWAT model is a GIS-based distributed hydrologic model, and has been rapidly developed and applied in recent years. SWAT model has absolute advantage in application research such as runoff simulating, vegetation covering, watershed land using, water conservation and so on. Therefore SWAT model is important for the study of environment monitoring of water resources. In this paper, according to the principle of SWAT model algorithm, we compiled SWAT into an executable program, designed interfaces, and applied into my system, and then simulate monitoring water resources.

3. SYSTEM OVERALL DESIGNMENT

This project takes the “One River and Two Streams” as representative area, and establishes basin water resources database of this area. Contraposed the problems of fragile ecological conditions, unstable ecological systems, highlight the phenomenon of drought and water shortage and any other problems, we conducted a dynamic remote sensing monitoring of basin drought, basin water and soil conservation, ecological evaluation of water conservation and basin land use, and provide decision-making services for region development, ecological construction and water resources management.

3.1 System Structural Organization

The overall structural organization of this system is shown as below:

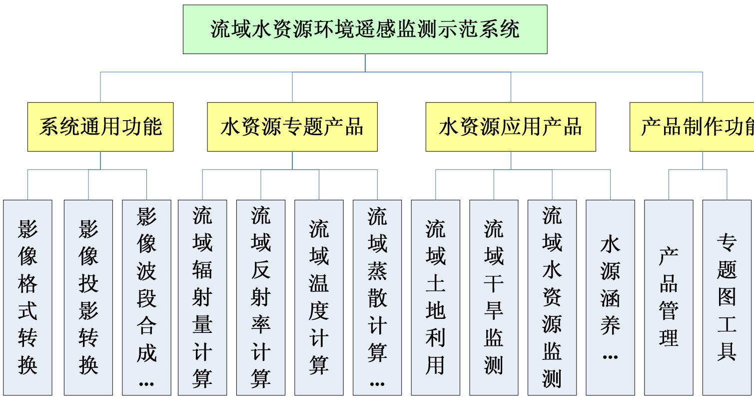

Figure 3. Overall System Structure Diagram

We adopted the C/S(Client/Server) structure to build the system, and used the mode of C#+ArcEngine secondary development to develop this system. ArcObjects is a GIS technical framework provided by U.S. ESRI (Environmental Systems Research Institute, Inc). It is a set of COM components developed based on Microsost COM technology. ArcObjects provides more than 3000 objects for developers to invoke, and can achieve the following functions: image processing operations, thematic maps production, interaction of spatial database and so on. ArcEngine contains most of the functions of ArcObjects, and is a embedded component library formed by encapsulated most of interfaces, classes and libraries. ArcEngine takes common software development tool c# as development platform, and carried on secondary integrated development for system general functions.

Contraposed the functions of basin water resource subject products and application products, we wrote script driver program of compiled SWAT model, and invoked the script via C# program. This way, we can carry out water resource products by using compiled SWAT model.

3.2 Data Management

The system integrated SWAT model with GIS, resulting a large amount of data. We managed data in a way of Oracle combined with ArcSDE. Oracle is spatial database management software, and ArcSDE is spatial database engine. Spatial data and attribute data are stored separately, and interaction between them is achieved by relevant characteristics or corresponding relationships, then we can access data dynamically.

1) Remote Sensing Image Database

Image data including MODIS reflectance data product from 2000 to now of Tibet, resolution of 250 meters; CBERS-02B images and also TM(Thematic Mapper) images. Spatial data are stored on the server, and the image metadata tables are stored in an Oracle database.

2) Attribute Database

Attribute database includes the vector data of “One River and Two Streams”, meteorological statistical report data and other soil parameter data. Vector data are stored in an Oracle database via ArcSDE. Meteorological statistical report data and soil parameter data are stored in the database to the form of a form.

4. SYSTEM APPLICATIONS

4.1 Application of Soil Erosion

Soil erosion is a highly complex process, affected by many factors. Including meteorological factors(precipitation, wind, temperature, humidity, etc.), terrain factors(elevation, slope, etc.), vegetation factors(vegetation type, coverage, etc.), soil factors(soil texture, structure, etc.) and some human factors(Zhang Jin-Ying, 2007). We build basic database of SWAT model by using hydrological data and meteorological data of Tibet. According to the simulation results, dividing several soil erosion intensity levels, and then generate the spatial distribution of soil erosion intensity.

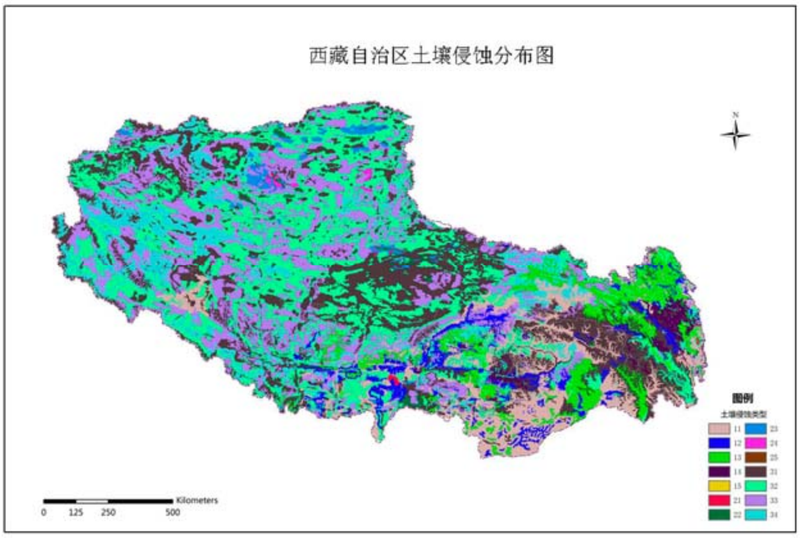

Figure 4. Spatial Distribution of Soil Erosion Intensity

4.2 Application of Land Use

Land use and land cover change(LUCC) is one of Global research hotspots. Using a combination of RS and GIS technology to produce land use map. Combined with DEM data and slope data, we used SWAT model to generate spatial distribution of land use changes.

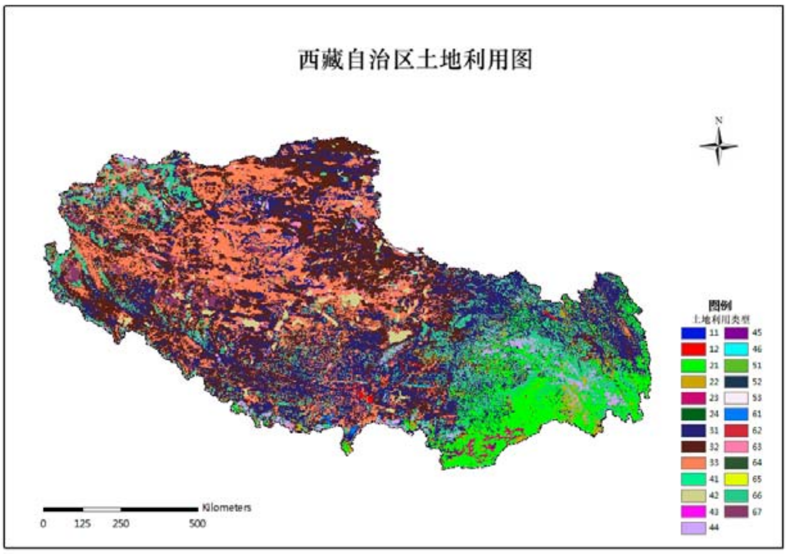

Figure 5. Spatial distribution of land Use Changes

5. PROBLEMS IN CURRENT APPLICATION

5.1 Problem of Accuracy of SWAT Model

As SWAT model was developed by the U.S. Department of Agriculture, the database comes with the model is mainly designed for the structure of soil, land use, vegetation, hydrological of North America, and the model parameters are also set for the hydrological characteristics of North America. Therefore these data are not suitable for China’s water resource research. The uncertain of parameter values will affect the accuracy of simulation. So we need to adjust the model parameters database, especially to establish our own natural geographic database.

5.2 Problem of Data Source

In the system, we used the Global Summary of the Day data products provided by NCDC(National Climatic Data Center) as meteorological data required by SWAT model. The data is relatively sparse distributed in Tibet, and the accuracy of meteorological raster data generated by interpolation is also low, therefore the simulation accuracy of water resource monitoring has also been affected.

5.3 Problem of System Speed

In the system, we called complied SWAT model program to simulate water runoff and calculate watershed parameters. As the complexity of SWAT model, resulting in slower operation speed.

6. CONCLUSION

China is a water-shorted country, while Tibet has abundant water resources. The study of water resource of Tibet, has fundamental significances to strengthen the comprehensive planning of “One River and Two Streams”, ameliorating the status of water-shortage, and protected the water resources of “One River and Two Streams” effectively.

The applications of SWAT model have been expanding. The flexibility and expandability of SWAT model has become powerful, and is easy to enhance SWAT model algorithm, upgrade and secondary development. This paper successfully complied SWAT model to an executable program, designed interface calling and used SWAT model on the base of GIS. With the development of information technology, SWAT as one of support model for water resource integrated management has a very important application foreground(Chunlei Wu, 2010).

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