REMOTE SENSING INTERPRETATION AND GIS MODELING FOR THE STUDY OF WATER RESOURCES IN THE HIGHLANDS OF DONG VAN- MEO VAC, VIETNAM

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ABSTRACT

This paper provides the use of image interpretation techniques of Spot and Landsat ETM+ images and Geographical Information System (GIS) modeling in a investigation of potential water resources in the highlands of Dong Van- Meo Vac, Hagiang province, Vietnam. The study area is characterized by high elevation and complicated karst landform of limestone surrounded by early Devonian and Triassic formations. The SPOT and Landsat images were interpreted to extract information regarding potential water resources based on image patterns and relief features. GIS hydrology modeling was used to delineate watershed boundaries and mapping the water table with a Digital Elevation Model (DEM) of the area as primary input. Data used to create the DEM came from contour lines digitized from 1:50 000 scale topographic maps and the Shuttle Radar Topographic Mission (SRTM-3). Merging the two datasets enhanced the resolution of the SRTM-3 product DEM at 90-m resolution to 20 m. Relationship of land cover and geological formation to ground water resources was investigated.

Keywords: Spot data, rock type, image pattern, digital elevation model, water table, hydrology, and ground water.

1. INTRODUCTION

People in the Dong Van -Meo Vac Highlands, in North Vietnam are faced with many challenges with obtaining sufficient water for drinking and for irrigation purposes during the dry season (October – April). Evaluation of geo-hydrological characteristics and potential traps of underground-bearing water structures in mountainous regions is greatly needed, but such evaluations are often difficult to carry out over a large karst terrain surface with ground investigation.

The main objective of this study is to investigate the possibilities of using remote sensing (RS) and GIS methodologies for analyzing watershed and surface-stream characteristics in relation to groundwater structures defined by geo-hydrological complexes. The data used for this analysis included data from SPOT false color composite (FCC) 321 image (Figure 1) and Landsat 7 ETM+ images, SRTM-3 (2000) digital elevation model (DEM), topographical contour lines, a geological map, and results from a groundwater drilling experiment.

2 METHODOLOGY

2.1. The study area

The study area is located in the highlands of NE Vietnam, bounded with China in the north, within longitude E104 ^{o} 48'-105^{o}36' and latitude of 22^{o} 52'-23^{o}30' (Figure 1).

2.2. Data input

The SPOT FCC mosaic image was constructed from three scenes with path-rows 267-304, 268-303, and 268-304 gathered in 1995. The Landsat 7 ETM+ image cover one scene with path-row 128-44 dated 1999. The Space-borne Imaging Radar-C (SIR-C) gathered the SRTM-3 data in January 2000. Each SRTM product file covered an area of 1^{o} N and 1^{o} E, and in the study area there were 4 files were used for DEM generation given as follows: n22e104.htg, n22e105.htg, n23e104.htg and n23e105.htg. GIS information employed in the analysis included geological maps of 1:500 000 and 1:200 000 scale, and data collected by drilling field survey.

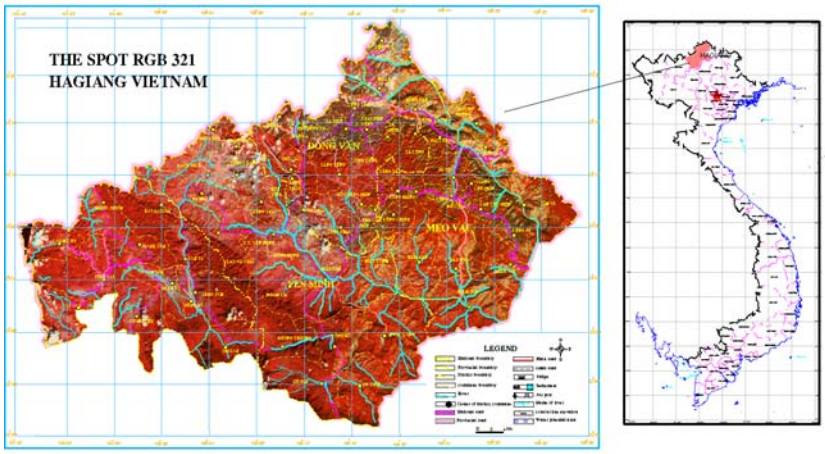

Figure 1. SPOT image of the study area

2.3. Model setting

The step of model setting in this study shows in Figure 2.

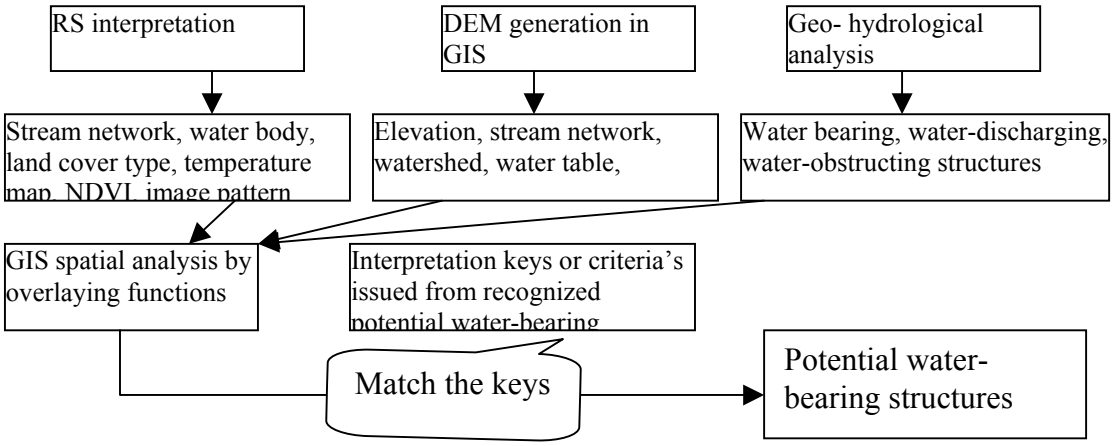

Figure 2. Modeling steps for hydrological analysis

2.4. RS image interpretation

The mosaic SPOT FCC 321 image was interpreted used in order to find out the potential of water-bearing structure defined by image pattern and landform characteristics. The interpretation keys used for image analysis are tone, color, feature association, and arrangement of the river and or stream flowing directions determined by topography of the area. One of the interpretation keys used in the process of image interpretation for finding the potential ground water-bearing structures is a key based on rock type and faults structures. The overlaying operation of GIS vector layer dealing with digital geological map on to SPOT FCC 321 was applied for determining the relationships of image color pattern and rock composition. An additional in RS image interpretation was used in this study is enhancing the

Landsat ETM^+ multi-spectral bands using false color composite RGB for 432 and true color composite 321.

When we are dealing with availability of water supplying, the vegetation index was taken in consideration. Ignoring the factor that, the surface water should have a value of Normalized Derived Vegetation Index (NDVI) equal to –1, we will also consider the area with high NDVI value for vegetation. In the drought region like Dong Van-Meo Vac area, the area of dense vegetation cover should have more water supplying. An NDVI map created from Landsat TM+ was produced and was taken in image interpretation with aiming to find out the potential ground water-bearing structure. The information of surface land temperature is also important for diagnosis whatever the area having high water content or not. The areas with more moisture content would have less temperature value in comparing to other areas of same elevation, vegetation and geological characteristics.

2.5. Geological analysis setting

Geological analysis includes structural and stratigraphical analysis. Geological analysis to define whether the rock composition in the study area having a capacity of storing ground water or being as a homogenous limestone massive of complex karst caves forming a ground stream so that the raining water runoff to other low land region beyond of the study areas.

Geological structural study is important issue in analyzing water-bearing features. Dong Van highland in term of geological structure is complicated in spatial arrangement and stratigraphical layering and petrographical changes. Dong Van highland has inverse structural characteristics of vocalic Song- Hien-depression forming in Middle Triassic. The structural of the study area can be divided in three part: (i) Song Hien depression central zone, (i) the Nho-Que River wing, developed along Nho-Que fault and expanded to the China areas consists of Ordovician, Silurian and Devonian formation with majority of metamorphic compositions, and (ii Quan Ba structural zone formed by Devonian formations. The central zone of depression were highly differentiated formed the higher structural separated elements having different demonstrations. Among the carbonate stratigraphical complex of Carbonaceous-Permian and Triassic complex discovered the continental volcanic constituent.

The strata: Devonian formation composes of strata sediment of black color, midle in thicknes, layer mixed with thin clay layers overlaid on the clay layer. This strata can be a good water-bearing trap. Early cacbonaceous formation of limestone thin layers of 10 – 15 cm mixed with clay layer. This formed a good water-bearing trap. Midle-Late Cacbonaceous formation of massive limestone, purly, white color and highly fracturing.This limestone strata having the high water discharging. Permian formation consists of limestone layer of midle and thin thickness mixed with clay layer of 5 – 10 m in thickness and bauxit lens. This formation with clay composition can be an important water-bearing structrures in area. This often formed an small fold structures and small water-bearing valleys. Triasic formation consists of continental volcanic sediment served as water obstructing structure. The surface running waters in this formation was surplyed to the water-bearing structure/reservor. Quatenary formation consitsts of aluvial, proluvial coluvial constituent and soil served as upper water-bearing and water-obstructing layer.The strata of the study area formed the water-bearing mixed with water–obstrucking structures has ability to reserve the water surply for the regions.

2.6. Spatial analysis in GIS

The spatial modeling was performed in a GIS environment (ARCVIEW, ARC/INFO, and IDRISI) in order to generate DEM used for analyzing of water flows direction and acumination and to delineate the watershed boundaries. The water table map of the study area was created using river network and DEM. These GIS layers were overlaid with the other spatial layers, including geological map layer and spatial layers interpreted from RS image interpretation, to find out the spatial relationship between these layers with the location of ground water-bearing structure. The results of overlaying operation in GIS are statistic information in attribute tables database file containing all interpretation criteria. Those combination key match to the recognized water-bearing structures will be used to find out the area of potential water-bearing and or water-obstructing structures.

3. RESULTS AND DISCUSSION

3.1. The water-bearing sturctures

The water-bearing structure in Dong Van Meo Vac highland are shown in Figure 3 and Figure 4.

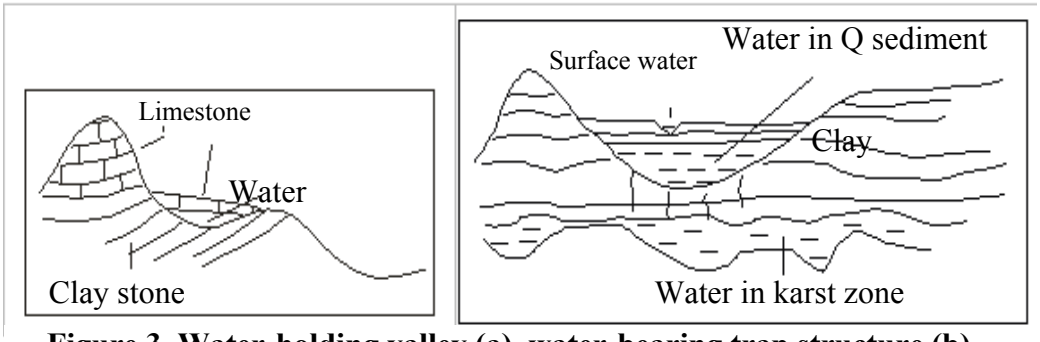

Figure 3. Water-holding valley (a), water-bearing trap structure (b)

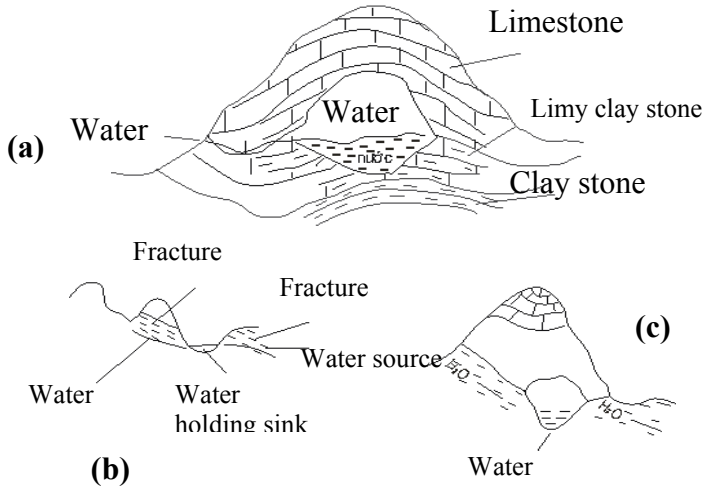

Figure 4. Perminian water bearing structure (a); water traps: opening (b) and ground (c)

3.2. The landform and hydrological system

The landform of Dong Van Meo vac can be describeb in Figure 5.

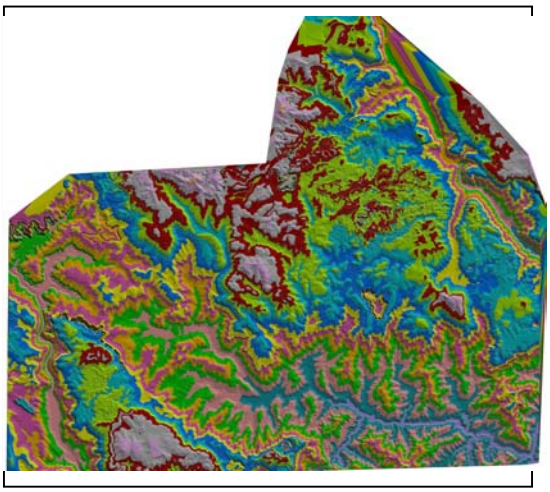

Figure 5. Landform generated by GIS

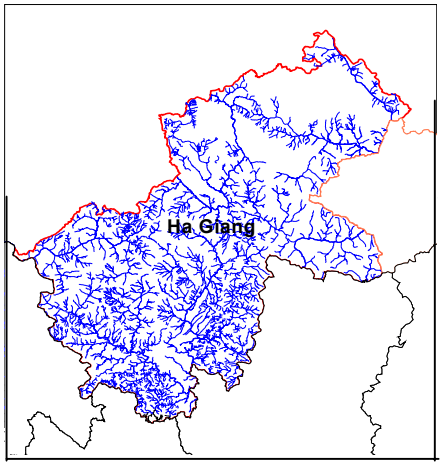

Figure 6. Stream network

The hydrological characteristics of the study areas defined by the main river basins included the Nho Que River, the Nhiem River and the Mien River. The Nho Que is oriented along the China border with direction NW-NE. The Nhiem River has Lung Thau and Yen Minh branches. This river has the ground stream under the mountainous area.

3.3. The potential ground water source

The potential areas of ground water in the study area is shown in Figure 7

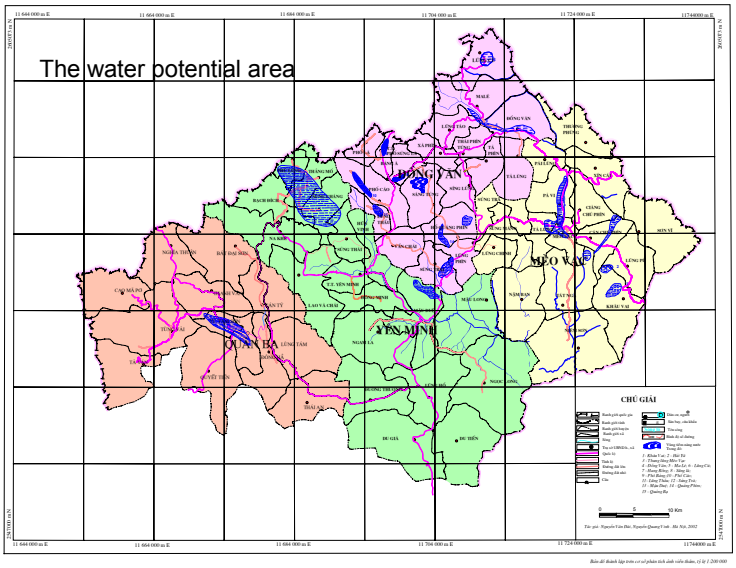

Figure 7. The potential area of water resource

3.4. Depth-to-water table map

DEM derived from STRM data and interpreted river and stream network data were used for modeling of depression flow direction and accumulation and creating water table map (Figure 8). The depth-to-water table map for the study area is ranging from 0 – 645 m. This explained that, the area with high contrast of depth-to-water table. The majority of area

of Dong Van-Meo Vac has the depth-to-water tables ranging from 0-129 m. The small

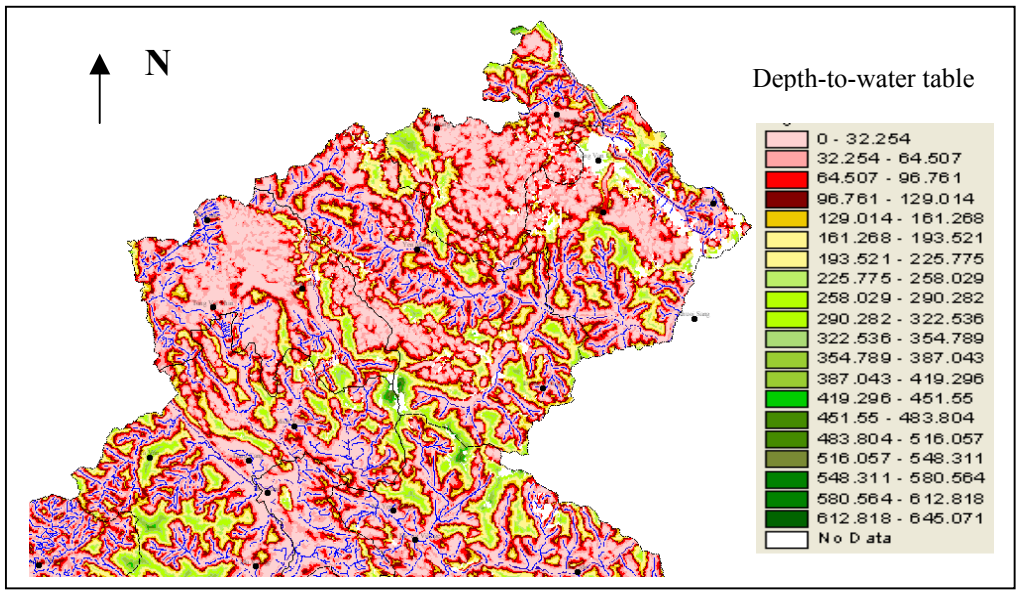

Figure 8. Depth-to-water table map

portion of the study area (the green color) gains a very high value of water table depth.

4. CONCLUSION

- Remote sensing and GIS integration is a valuable tool to for modeling water resource and finding the potential area of water-bearing structure.

-. Dong Van- Meo Vac highland, an area of complicated stratigraphical structures with different water separating strata in the base of the folded stratigraphic complex and high value of depth –to-water table, has a potential of water-bearing structure.

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