SPATIAL ANALYSIS OF LAND COVER PROPERTIES FOR AN ARCHAEOLOGICAL AREA IN AKSUM, ETHIOPIA, APPLYING HIGH AND MEDIUM RESOLUTION DATA

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INTRODUCTION

Aksum, in the Tigray highlands of northern Ethiopia, was the political, cultural and commercial centre of the Aksumite state in the first millennium AD. Tadesse (1981) reported that more than 200 towns, urban centres, towns, and villages were established throughout the region, and large areas were used for agriculture and livestock grazing. These anthropogenic activities have continued to the present time and have caused landscape transformations affecting soil, lithology, and vegetation. As a result, land degradation is a major problem and affects the natural resources as well as social and economic conditions for living in this region (Feoli et al., 2002; Nysen et al., 2004).

The Aksum region has so far not been systematically mapped in terms of its geo-environmental characteristics. This work presents a preliminary investigation of the geologic and pedologic characteristics of Bieta Giyorgis hill and its surroundings in Aksum and is based on two field trips conducted in May 2001 and May 2006. The investigation consisted of mapping main landscape units and land cover classes from field surveys, aerial photographs and high- and medium-resolution images (IKONOS, ASTER), collecting soil samples for laboratory analysis; and creating a digital elevation map (DEM) from topographic maps for terrain analysis. An important objective is to establish the relationship between the landscape and the archaeological sites.

The Aksum area is composed of two main lithologic units of Tertiary age. The Koyeta volcanics (stratified flood basalts) are intruded by numerous volcanic necks belonging to the Adwa trachyte formation (trachytic and phonolitic plugs). These stands out as circular hills (Figure 2) due to their rock composition that is more resistant to erosion than the surrounding plateau basalt. Bieta Giyorgis hill is one of the most widespread volcanic activity in the early Cenozoic covered large parts of the Tigray highland with a thick layer of Tertiary basalts (flood basalts). Beneath the basalt layer is a sequence of Paleozoic and Mesozoic sedimentary rocks that overlay unconformably the Precambrian basement rocks.

DATA ACQUISITION AND METHODOLOGY

Field survey in and around Bieta Giyorgis:

1. In 2001, a joint archaeological expedition was conducted as part of a project carried out by the University of Naples ‘L’Orientale’ (Italy) and Boston University (USA).
2. In 2006, Boston University in collaboration with Mekelle University and the Geological Survey of Ethiopia conducted a survey.
3. Soil surface cover samples and field observations of abiotic and biotic characteristics were taken and complemented with soil and mineralogical analyses of the samples.
4. Pre-processing of the data included system, geometric and atmospheric corrections.
5. Geographic Information System (GIS) database:
6. Topographic maps (1:50,000), Digital Elevation Map (DEM) and derived products.
7. Archaeological sites with attribute data.

The following classification procedure was carried out:

1. ASTER: Numerous training sites were first selected through visual interpretation of the ASTER image and subsequently resampled in the field during the May 2006 survey.
2. Representative training sites were utilized to test several supervised classification methods of which the maximum likelihood classifier gave the best result in terms of distinguishing main lithologic and pedologic groups.
3. Fifteen training sites or Regions Of Interest (ROIs) and a probability threshold setting of 0.0000000001 were used.
4. The spectral separability of the selected ROIs was further verified using a statistical method based on Jeffries-Matuska and Transformed divergences separability measures.
5. Image-based lithologic and pedologic classification maps were the first of their kind to be presented for the study area and can be further used as a valuable information layer in a GIS.

IKONOS:

1. A vegetation mask was built using a common vegetation index algorithm (NDVI) and applied to the image bands to separate vegetated from non-vegetated areas.
2. An unsupervised classification ISODATA method was implemented.
3. Post-classification labeling was performed where individual classes were related to field observation points and photographs as well as to a digital elevation model (DEM) in order to determine their nature and label them (Figure 4).

RESULTS AND DISCUSSION

The ASTER classification (Figure 3) shows that the parent material of the soils is directly related to the geoology of the area, where the chemical and mineralogical compositions of the major rock formations are the main responsible for the soil formation. A diversity of soil types is found in this area due to the physical and chemical weathering of the rocks and minerals. In this case, soil properties such as clay minerals reflect this diversity and form an important role in the soil-forming processes of the area. Spectral characteristics of the selected soil cover (Figure 3) obtained in the laboratory represent iron oxide and phyllosilicate absorption features (0.87 μm and 2.2 μm, respectively). The latter feature is clearly identifiable with the ASTER spectra and the corresponding mineralogical analysis (X-ray diffraction) indicates very abundant phyllosilicates with smectite and kaolinite in decreasing order of abundance.

The IKONOS classification result (Figure 4) shows six distinctive groups, which correspond mainly to surface classes and their respective color shades represent slight variations within a surface class. Because the classification procedure was designed to detect and classify mainly soil surface classes, all classes except the color black represent soil groupings that are spatially distinguishable by the IKONOS sensor. These image-based lithologic and pedologic classification maps are the first of their kind to be presented for the study area and can be further used as a valuable information layer in a GIS for correlation analysis of settlement patterns, land use and soil types as shown in Figure 5.

CONCLUSIONS

This study represents the first image-based lithologic and pedologic characterization of the greater Aksum area. Our goal is to map the physical environment of this region in order to understand the dynamics of the environment relations or interactions, and to understand how the impact of human activities has affected the evolution of the landscape up to the present time.

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REFERENCES


Figure 2. Vegetation map of the study area.

Figure 3. Spectral characteristics, soil and mineralogical analyses for a soil surface.

Figure 4. Soil group map of the study area.

Figure 5. Soil group map of the study area.