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Beyond modern landscape features: New insights in the archaeological area of Tiwanaku in Bolivia from satellite data

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ABSTRACT

The aim of this paper is to investigate the cultural landscape of the archaeological area of Tiwanaku (Bolivia) using multiscale, multispectral and multitemporal satellite data. Geospatial analysis techniques were applied to the satellite data sets in order to enhance and map traces of past human activities and perform a spatial characterization of environmental and cultural patterns.

In particular, in the Tiwanaku area, the approach based on local indicators of spatial autocorrelation (LISA) applied to ASTER data allowed us to identify traces of a possible ancient hydrographic network with a clear spatial relation with the well-known moat surrounding the core of the monumental area. The same approach applied to QuickBird data, allowed us to identify numerous traces of archaeological interest, in Mollo Kontu mound, less investigated than the monumental area. Some of these traces were in perfect accordance with the results of independent studies, other were completely unknown. As a whole, the detected features, composing a geometric pattern with roughly North–South orientation, closely match those of the other residential contexts at Tiwanaku.

These new insights, captured from ASTER and QuickBird data processing, suggested new questions on the ancient landscape and provided important information for planning future field surveys and archaeogeophyical investigations.

1. Introduction

The investigation of ancient land-use patterns represents an important issue in a number of disciplines ranging from archaeology, botany, forestry, soil science and hydrology, etc. Information on the impacts of human actions upon the environment can be widely used to address issues in human settlement, to better understand environmental interaction, climate change, the Earth's system, etc.

The term cultural landscape is frequently used by archeologists to indicate the human action on environment and the subsequent modifications occurred over the following centuries and millennia. Although traces of human impact may still today be fossilized in the modern landscape, their identification and interpretation is one of the most complex archaeological and historical issues.

Remote sensing technologies offer a synoptic view and reliable data sources which are very useful to extract information about the contemporary landscape and make possible, in some conditions and to some extent, to infer changes in the former environment.

Since the thirties of the last century (Lasaponara and Masini, 2011), aerial photography has been the first remote sensing technique employed to reveal lost landscape. Beginning from the eighties, early studies on palaeo-environment and archaeological landscapes were conducted using satellite data acquired from both active and passive sensors.

In the last decade, the availability of very high resolution (VHR) satellite images (Ikonos in 1999, QuickBird in 2001, WordlView1 in 2007 and GeoEye in 2008) opened new perspectives in archaeology. These data sets appeared particularly effective in recording archaeological spatial features (Lasaponara and Masini, 2011) because human activity leaves distinctive marks on the surface. These are generally called damp, soil and crop marks (Masini and Lasaponara, 2007) and are due to the differences in moisture content, porosity, vegetation phenology and/or status caused by the presence of buried archaeological remains. In particular, the presence of stones or buried walls determines a limitation on moisture and nutrient content, thus causing an increase in the rate of germination and differences in vegetation growth patterns. Vice versa pits and ditches induces an increase in the rate of vegetation growth being that they are characterized by a greater depth of soil, major concentration of water and nutrient compared to the surroundings. Crop marks are most easily visible during specific periods of the year according to the specific plant phenology and meteorological conditions.

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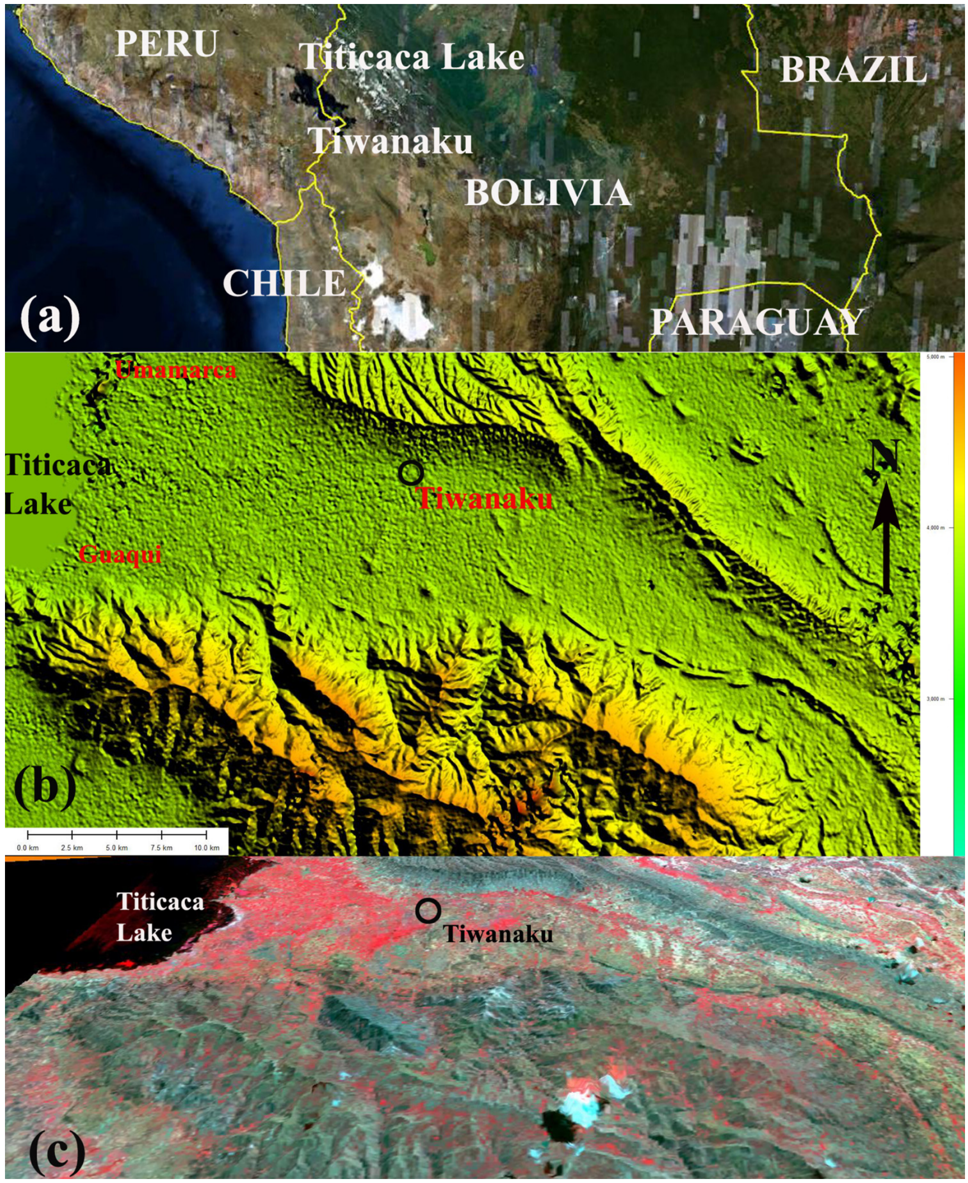

Fig. 1. (a) Location of Tiwanaku and Titicaca Lake; (b) DEM provided from ASTER data acquired on April 2008; and (c) RGB composition of ASTER bands V3, V2 and V1.

For bare soil the presence of buried walls or pits and ditches may be visible due to the diverse characteristics and surface conditions of topsoil, such as, diverse grain sizes and/or different colors compared to the surrounding topsoil. Therefore, soil marks are most easily visible from space or aerial view in low light conditions, or after raining due to the diverse spatial patterns of moisture content.

Nevertheless, It is worth to note that as for other applications also in archaeology, features of interest are generally not isolated, but mixed with others and may also appear quite different within the same image due to their diverse physical characteristics.

Moreover, archaeological features generally do not exhibit clear and clean patterns and/or edges even in high-resolution data sets acquired from both active and passive sensors. This is due to the fact that archaeological marks are characterized by subtle spatial/spectral signals. In addition, it must be considered that there are numerous factors, such as noise, atmospheric contaminations, etc. that tend to further distort subtle edges and features. To face these challenges and collect as much information as possible, the use of robust data processing techniques is required.

In this paper, geospatial analysis techniques were applied to the satellite data in order to enhance and map trace of past human activities in the archaeological area of Tiwanaku (Bolivia).

Investigations based on ASTER and very high-resolution satellite data (QuickBird) were conducted mainly in a sector located at south of the monumental core area, less investigated compared to other sector of Tiwanaku.

2. Study area

2.1. Geographycal and geological setting

Tiwanaku is located on a valley at 3880 m above sea level, near the southern shoreline of the Titicaca Lake (Fig. 1). It is geologically characterized by 10–20 m of Quaternary lacustrine and fluvial deposits laid on a bedrock composed of andesites and basalts. The valley is bordered by the Cordilerra Real and Cordillera Blanca, and it is composed of Paleozoic andesites, sandstones, and red mustones (Argollo et al., 1996; Knudson, 2008)