Qualitative evaluation of COSMO SkyMed in the detection of earthen archaeological remains: The case of Pachacamac (Peru)

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A B S T R A C T

Archaeological prospection of earthen buried structures, namely non-fired sun-dried mud bricks mixed with organic material, is a critical challenge to address. In fact, this building material exhibits a very low geophysical contrast compared to its surroundings and, therefore, earthen structures are very complex to be identified using remote sensing. In order to cope with this issue, in this paper, we focus on the evaluation of satellite X-band radar data (COSMO-SkyMed) capability for detecting earthen buried structures in a desert area. The results obtained from satellite radar data have been validated for a test site in Pachacamac (Peru) by using unmanned aerial vehicle (UAV) and geomagnetic techniques. The test site is outside the fenced protected zone of Pachacamac, today in the tentative UNESCO list. This paper is the first attempt made until now in evaluating the detectability of earthen archaeological remains using satellite Synthetic Aperture Radar (SAR) data. Outcomes from our investigations clearly point out that the approach we adopted can be useful applied for preventive archaeology and for the planning of future excavation campaigns.

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1. Research aims

In the field of archaeological prospecting, a challenge of great importance and utility is the detection of features related to the presence of deep and shallow buried structures made of earth, that characterize a large amount of archaeological sites of different ages and civilizations all over the world.

The paper shows the first results of the application of X-band COSMO-SkyMed data in an Inca test site of Pachacamac (Peru), characterized by the presence of a wall in adobe, partially emerging and for the rest barely visible (as micro-relief) or buried under sand.

In this paper, the integrated use of diverse remote sensing tools, as optical satellite pictures, geomagnetic techniques and aerial surveys using drone, made it possible to qualitatively evaluate the X-band COSMO-SkyMed data capability in the identification of earthen archaeological features in the desert area of Pachacamac.

2. Experimental

2.1. Introduction

The digital tools nowadays available for archaeology enable us to get extremely precise results speeding up the work during the diverse phases of archaeological investigations ranging from survey, mapping, excavation, documentation and monitoring, moving from artifact to landscape scale. In particular, the use of satellite radar data in archaeological investigations can offer great potential for site detection, especially in desert areas, where optical data are generally strongly limited for the identification of subtle microrelief due to the shadow as well as for the detection of buried remains due to the absence of the archaeological vegetation marks [1,2].

Even if today a huge amount of SAR data are available, they are still underexploited in the archaeological operational practice. One of the main reasons for the underuse of radar technology is linked to the difficulty in interpreting the data, even though they are finely processed, and thus generating skepticism among archaeologists,

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and the belief that the complexity of this technology is not proportional to its real usefulness in archaeology. Efforts are needed for improving the ability to interpret the radar data, with the support of archaeological data source and additional information obtainable by other remote sensing methods [3].

Therefore, this work provides a first contribution in evaluating the potential of X-band satellite radar data in archeology by using other remote sensing techniques. We focus our attention on the joint use of a fully finished Geocoded Cosmo SkyMed product with the detailed topography, obtained by processing aerial photographs captured from UAVs, and magnetic maps, for detecting adobe remains in a desert area of Pachacamac, which is one of the largest archaeological sites of Peru. For more than 2000 years, Pachacamac was one of the main centers of religious cult keeping this role unchanged in different historical periods and for different cultures such as Chavin, Lima, Huari, Ychma and Inca (for the historical overview the reader is referred to paragraph 2.2.2) [4]. A test site was selected for our investigations. It includes very thick walls built in adobe, which are part of an ancient city wall, enclosing a residential area and cemeteries, dating back to a period ranging from Ychma to Inca ages. With such regard, it is reasonable to believe that a larger part of the wall is under the current ground level, the rest is shallow or emerging.

The paper shows the results of a multiscale and multisensor approach, including satellite optical and SAR remote sensing, geomagnetic prospection and UAV, aimed at qualitatively evaluating the capability of X-band COSMO SkyMed data in detecting buried remains to the ancient earthen walls.

2.2. Pachacamac: history and state of the art of investigations

2.2.1. Brief historical overview

Pachacamac is located on a desert hill about 31 km South East of Lima, on the right bank of the Lurin river near its mouth, 800 meters from the Pacific Ocean (Fig. 1). The site covers a total area of around 465 hectares, among which the 30% is occupied by monuments such as temples, pyramids with ramp and palaces.

The first human settlements in the area of Pachacamac date between the end of the Initial Period and the beginning of the Early Horizon (1000-800 BC) at the age of Chavin culture, which developed until the 2nd century BC. The first monument is the so-called Templo de los Adobitos (or Lima Temple), made by small bricks of adobe, which is attributed to the Lima Culture (100-650 AD). Under Huari (650-900 AD) Pachacamac reached its apogee. The sanctuary area became a city used also as administrative center of great importance throughout the Andes. The Huari influence can be seen in ceramic objects, paintings and architecture (an example is the “Painted Temple”, see 4 in Fig. 2).

The Ychma (900-1450 AD) civilization followed after the collapse of Huari. During the Ychma period Pachacamac continued its expansion becoming a city-state and, later, the capital, known as Ychma, of a region which included the river valleys of Rimac and Lurin. The most important witnesses of the presence of Ychma culture could be found in the architecture, with the so-called “pyramids with ramp” [4], and in the urban structure which was completely renovated and structured around two perpendicular road axes oriented along North-South and East-West, respectively. Later, during Inca Empire (1450–1532), the city, renamed Pachacamac, became an important ceremonial and administrative center. The Incas maintained the sacredness of the place and allowed the priests of Pachacamac to continue to profess their religion and their rites. In the 15th century, the Incas built the Temple of the Sun, and the palaces of Acclahuasi, Taurichumpi and other buildings.

With the Ychma, before, and the Incas, after, Pachacamac reached the current extension of the archaeological area, including sectors I and II (for additional information see section 2.2.2). In the same period, further settlements (see sectors III and IV in Fig. 2) including residential area and cemeteries were built at North of the archaeological area.

2.2.2. Archaeological area

Spatially, the archaeological site is divided into four sectors, defined by two concentric walls and two outer walls. The first wall (known also as Holy Wall) defines sector I including the Temple of the Sun, the “Painted Temple”, the Old Temple [5,6] and cemetery, for an extension of 18.8 ha (see 1, 4 and 5 in Fig. 2, respectively). The second wall, defining sector II, contains roads, cemeteries, many squares and courts, pyramid with ramp [7,8], the Acclahuasi and the Taurichumpi Palace. The two above described sectors embrace a total area of around 130 ha.

At North of the archaeological area and the Panamerican road, at South and West of the District of Pachacamac, there is a desert hill of archaeological interest, conventionally divided in two sectors (III and IV).

Fig. 1. DEM from Shuttle Radar Topography Mission: detail of Lima region including Lurin river and Pachacamac.
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