Journal of Cultural Heritage xxx (2016) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Uncovering the ancient canal-based *tuntian* agricultural landscape at China's northwestern frontiers

Lei Luo[a,b], Xinyuan Wang[a,b,*], Jie Liu[a,b], Huadong Guo[a,b], Rosa Lasaponara[c], Wei Ji[a], Chuansheng Liu[a,b]

[a] *Key Laboratory of Digital Earth Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100094, China*
[b] *International Centre on Space Technologies for Natural and Cultural Heritage under the Auspices of UNESCO, Beijing 100094, China*
[c] *Institute of Methodologies for Environmental Analysis (IMAA), CNR, C.da Santa Loja, 85050 Tito Scalo (PZ), Italy*

ARTICLE INFO

Article history:
Received 3 February 2016
Accepted 30 April 2016
Available online xxx

Keywords:
Tuntian
Agricultural landscape
Canal
Remote sensing
GIS
Archaeological

ABSTRACT

The *tuntian* system was a state-promoted system of military–agriculture, which originated in the Western Han dynasty (206 BC–9 AD). All the imperial dynasties in Chinese history adopted the practice of *tuntian* to cultivate and guard frontier areas as an important state policy for developing border areas and consolidating frontier defense. This paper describes the use of satellite remote sensing data to uncover an ancient canal-based *tuntian* system located in an oasis agricultural landscape adjacent to the ancient Kingdom of Loulan at the southern margin of the Tarim Basin. The remote sensing data examined include Chinese Gaofen-1 (GF-1) VHR imagery, Landsat-8 (LS-8) OLI data and ASTER Global Digital Elevation Model Version 2 (ASTER GDEMV2) products. The effective irrigated tuntian area was estimated to be 2800 ha and the maximum irrigated tuntian area was found to be more than 8000 ha during the area's most prosperous period. The overall spatial structure of Milan's tuntian agricultural landscape was explored using the patch–corridor–matrix model. By detailed analysis of satellite remote sensing data, this study reconstructed a 3D view of Milan's tuntian agricultural landscape in a GIS.

1. Research aims

The aim of the research presented hereafter is the application of satellite remote sensing and GIS to *tuntian* system in order to explore the ability of an integrated prospection approach to investigating, mapping and reconstructing cultural landscape and provide new insights for agricultural archaeology in arid area.

2. Introduction

During the Han Dynasty (206 BC–220 AD) the ancient Silk Road from Dunhuang to Central Asia [1,2] was extended through the Tarim Basin between the Kunlun Mountains and the Tianshan Mountains (Fig. 1). To establish a military presence along these frontiers and to ease the problem of transporting food grain to these remote areas, the Han government sponsored military–agricultural colonies [1,3,4], known as the *tuntian* system, in northwest China in order to ensure the safety of traders along the Silk Road. The tuntian system grew out of the Han Dynasty policy of having garrison troops or newly settled peasants bring undeveloped land under cultivation [2]. The Han government first implemented the tuntian system in the Hexi Corridor [1–3], and soon extended it to the empire's western regions (including today's Xinjiang and Central Asia) after it proved to be a great success. It is known from Han records written on bamboo slips discovered at Xuanquan in 1990 that ancient Milan was one of the major headquarters of this system [4]. In the second year of the Han Emperor, Zhaodi (77 BC), Weituyan, the King of Shanshan (the state of Loulan) asked the Han government to send troops to develop the wasteland and to plant grain [1]. A *sima* (minister of war in ancient China) and 40 soldiers were then dispatched to garrison Milan and to farm there.

Following the initial success of the Milan tuntian system, the Han government wasted no time in extending it to all of its frontiers; as a result the positive effects of this organized military farming were soon felt all over the ancient Xinjiang, which the Han dynasty unified for the first time [2]. In 1907, the British archaeologist, Stein, first unearthed the Milan archaeological site [5] and discovered a large number of sculptures and frescoes. In the 1950s, a Chinese exploration team discovered an intact system of irrigation canals as well as vast fertile fields buried under the desert [6]. In

* Corresponding author at: Key Laboratory of Digital Earth Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100094, China.
E-mail address: wangxy@radi.ac.cn (X. Wang).

http://dx.doi.org/10.1016/j.culher.2016.04.013
1296-2074/

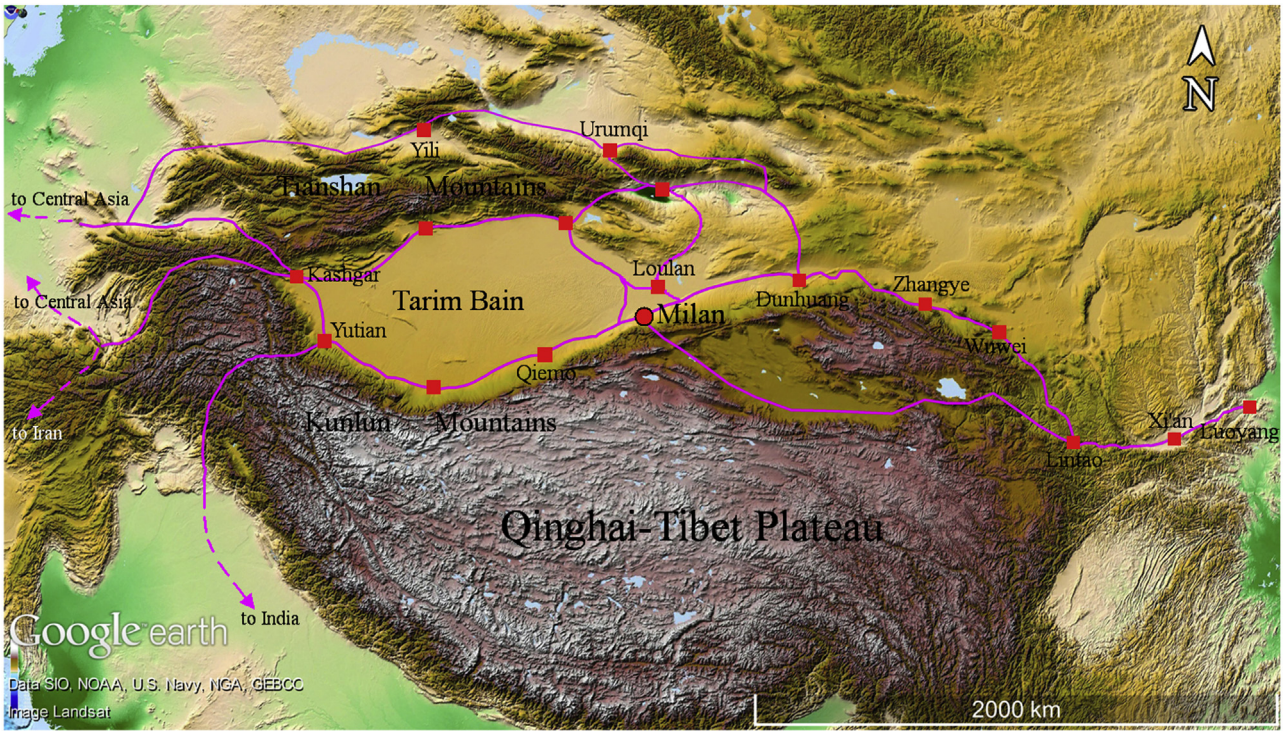

Fig. 1. The location of ancient Milan and the main routes of the ancient Silk Road. Pink lines indicate the Silk Road; the base map is the ETOPO1 Global Relief Model, which can be downloaded from http://maps.ngdc.noaa.gov/viewers/bathymetry.

1973, Xinjiang archaeologists unearthed Milan Castle at the center of the Milan site [6,7]. Early Buddhist sculptures and frescoes excavated from the site show stylistic similarities to the traditions of Central Asia and North India [8] and other artistic aspects of the paintings found there suggest that Milan had a direct connection with ancient Rome [9,10].

Studies that involve the investigation of cultural heritages and archaeological features increasingly employ aerial photographs and satellite remote sensing imagery [11–23]. The combined application of remote sensing and GIS have made it possible to realize agricultural archaeological detecting [24], mapping [19,25] and monitoring [26,27] in landscape investigation, but they're far from meeting the demands of past landscape reconstructing [28–30]. It's a great challenge for researchers (e.g. environmentalists, agriculturalists, ecologists, geographers and archaeologists), not only should they have a better understanding of satellite remote sensing and GIS, but they should know the environmental and geographic conditions [31], agricultural and soci-cultural characteristics [32] and past human activities [33].

As one of the most important state-promoted polices in ancient China, tuntian system was viewed as the symbol of arid agricultural development. It is important to try to map the tuntian system so that the defensive and agricultural policies employed along the northwestern frontiers of ancient China can be better understood. Section 3 introduces the materials and methods; the results and discussion are presented in Section 4 and Section 5, respectively and conclusions are drawn in Section 6.

3. Materials and methods

3.1. Archaeological site description

Located at the eastern end of the Tarim Basin in Xinjiang Uyghur Autonomous Region, China, Milan was formerly one of the main stops on the ancient Silk Road (Fig. 1). The Milan site is adjacent to the new oasis of Milan town (Fig. 2), which was established by the Xinjiang Production and Construction Corps (XPCC) after the foundation of the People's Republic of China in 1949. The Milan site is located approximately 75 km east of Ruoqiang County and 165 km southwest of ancient Loulan (Fig. 2a).

The Milan site is now one of the most important archaeological sites in the greater Lop Nor areas [6,7,34–36]. The current conservation area of the Milan site consists of Milan Castle together with cultural relics from the Han–Tang period (206 BC–907 AD), which are scattered around the surrounding areas [35,36], as well as the tuntian canals that were used for irrigating farmland and water conservation when the area was garrisoned during the Han Dynasty (Fig. 2b). Archaeological excavations since the Stein's expedition have uncovered an extensive Buddhist monastic site that existed between the 2nd to 5th centuries AD [5], as well as Milan Castle (Fig. 2c), which was a Tibetan fort during the 8th and 9th centuries AD [6]. Based on the available historical records [1,2] and archaeological discoveries [5–7,34–36], archaeologists consider that Milan's tuntian systems were continuously used from the Han Dynasty to Tang Dynasty (618–907 AD).

3.2. Satellite remote sensing data

Gaofen (GF) images, acquired by the GF-1 satellite, were obtained from the China Centre for Resource Satellite Data and Applications. GF-1 is equipped with two panchromatic–multispectral (PMS) cameras, which can generate 2 m panchromatic (PAN) data and 8 m multispectral (MS) data (Table 1) across the same 60 km swath. Because Chinese GF-1 data have a very high-resolution, they are ideal sources for mapping the tuntian landscapes found at the Milan archaeological site. The GF-1 data used in this study were acquired on September 18th, 2014 at 5:22:54 UTC.

LS-8 Operational Land Imager (OLI) data were acquired from the Institute of Remote Sensing and Digital Earth of the Chinese Academy of Sciences (http://ids.ceode.ac.cn/). This imagery is composed of nine bands covering the visible to the short-wave infrared

Please cite this article in press as: L. Luo, et al., Uncovering the ancient canal-based *tuntian* agricultural landscape at China's northwestern frontiers, Journal of Cultural Heritage (2016), http://dx.doi.org/10.1016/j.culher.2016.04.013