

## Space Archaeology for military-agricultural colonies (*tuntian*) on the ancient Silk Road, NW China

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The ancient Silk Road, a pioneering work in the history of human civilization, contributed greatly to the cultural exchange between China and the West. It is the precious cultural heritage should be shared by the whole humanity. Although there were countless archaeological sites along the ancient Silk Road, most of the existing researches just focused on the sites, lacking the overall understanding of the relationships between sites and their supporting environment. Space archaeology provides a new viewpoint for investigating, discovering, reconstructing and documenting the archaeological sites under different scales. The *tuntian* system was a state-promoted system of military-agricultural colonies, 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 defence. This study describes the use of Chinese GF-1 imagery, LS-7 ETM+ data and ASTER GDEM V2 products to uncover an ancient irrigated canal-based *tuntian* system located in Milan oasis adjacent to the ancient Kingdom of Loulan at the southern margin of the Tarim Basin. The GF-1 and LS-7 data were first processed following atmospheric and geometric correction and enhanced by Gram Schmidt pansharpening. The linear archaeological traces of *tuntian* irrigation canals were extracted from the morphologically enhanced GF-1 PAN imagery using our proposed automatic method which adopts mathematical morphological processing and Canny edge operator. Compared with the manual extractions, the overall detection accuracy was better than 90%. In addition, the functions of the trunk, primary, secondary and tertiary canals were each analyzed and the spatial extent of Milan's *tuntian* landscape were analyzed with the help of the NDVI derived from the GF-1 multispectral imagery. The effective irrigated *tuntian* area was estimated to be 2, 800 ha and the maximum irrigated *tuntian* area was found to be more than 8, 000 ha during the area's most prosperous period. The overall spatial pattern of Milan's *tuntian* landscape was explored using the patch-corridor-matrix model. The features and functions of *tuntian* landscape elements in Mountain-Oasis-Desert Ecosystem (MODES) were discussed in detail. By detailed analysis of satellite remote sensing data, this study reconstructed a 3D view of Milan's *tuntian* agricultural landscape in a GIS. Milan's *tuntian* system reveals the basic organization pattern of the ancient *tuntian* system in Xinjiang, and provides a solid foundation for understanding the military, cultural, economic and geopolitical values of ancient *tuntian* system for China frontiers.