Using multitemporal remote sensing data for evaluation of the Kuibyshev reservoir bank transformation (Laishevo and Ostolopovo archaeological sites, Tatarstan, Russia)

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Abstract

The paper presents the results of studies of medieval archaeological sites, the Laishevsky and Ostolopovsky settlements, and the Ostolopovsky hillfort, using multitemporal remote sensing data and modern field research methods. The studied sites are located in the zone of active bank transformation and have been destroyed since the creation of the Kuibyshev reservoir. To assess the dynamics of the coastline, multitemporal remote sensing data were used. Shoreline positioning for the historical period of the 1950s was interpreted from archival aerial images (Kazan University Library). 1975 satellite images obtained during the Corona reconnaissance space program KeyHole-9 Hexagon satellite (10.06.1975). For their georeferencing very high-resolution satellite images were used (2019). The maximum errors of georeferencing are less than 3 pixels for both sites. In 2018-2019, field surveys of the shoreline fragments at the Ostolopovsky and the Laishevskoe settlements were carried out in 2020-at Ostolopovo hillfort placement. For field studies, a DJI Phantom 4 drone and GNSS receiver with real-Time kinematic corrections were used. The Digital Shoreline Analysis System (DSAS), as an extension module of the ArcGIS software, was used to quantify shoreline displacement. Shoreline indicators such as linear retreat rate (m/year), shoreline displacement (m) were automatically calculated. A quantitative assessment of the Kuibyshev shoreline transformation makes it possible to evaluate the damage caused to archaeological sites and the risk of their further destruction.

Keywords

Archaeological sites, CHM, DSAS, multitemporal remote sensing data, Reservoir bank transformation, UAV

References

[1] Pantusa, D., D?Alessandro, F., Riefolo, L., Principato, F. and Tomasicchio, G.R., Application of a Coastal Vulnerability Index. A Case Study along the Apulian Coastline, Italy, Water 10(9), 1218 (2018).

[2] Westley, K., Refining Broad-Scale Vulnerability Assessment of Coastal Archaeological Resources, Lough Foyle, Northern Ireland, J. Isl. Coast. Archaeol. 14(2), 226-246 (2018).

[3] Nicu., I.C., Mihu-Pintilie, A. and Nau, E., Cultural Heritage and Natural Disasters (2021). 10.3390/books978---0365-1079-8.

[4] Pourkerman, M., Marriner, N., Morhange, C., Djamali, M. Amjadi, S., Lahijani, H., Beni, A.N., Vacchi, M., Tofighian, H. and Shah-Hoessein, M., Tracking shoreline erosion of at risk coastal archaeology: The example of ancient Siraf (Iran, Persian Gulf), Appl. Geogr. 101, 45-55 (2018).

[5] Lombardo, L., Tanyas, H. and Nicu I.C., Spatial modeling of multi-hazard threat to cultural heritage sites, Engineering Geology 277, 105776 (2020).

[6] Dillenia, I., Troa, R. and Triarso, E., In situ preservation of marine archaeological remains based on geodynamic conditions, Raja Ampat, Indonesia, Conserv. Manag. Arch. 18, 364-371 (2016.

[7] Jazwa, C.S. and Johnson, K.N., Erosion of coastal archaeological sites on Santa Rosa Island, California, . West. N.Am. Nat. 78(3), 302-327 (2018).

[8] Howard, P. and Pinder, D., Cultural heritage and sustainability in the coastal zone: Experiences in south-west England, J. Cult. Herit. 4(1), 57-68 (2003).

[9] Cenci, L., Disperati, L., Persichillo, M.G., Oliveira, E.R., Alves, F.L. and Phillips M., Integrating remote sensing and GIS techniques for monitoring and modeling shoreline evolution to support coastal risk management, GIScience & Remote Sensing 55(3), 355-375 (2018). DOI: 10.1080/15481603.2017.1376370

[10] Miaomiao, Q., Xiaojun, Y, Shiyin, L., Yu, Z., Yongpeng, G. and Baokang, L., Dynamic change of Lake Qinghai shoreline from 1973 to 2018, J. Lake Sci. 32(2), 573-586 2020. DOI:10.18307/2020.0225

[11] Dewidar, K.M. and Omran E. F., Automated techniques for quantification of beach change rates using Landsat series along the North-eastern Nile Delta, Egypt, Journal of Oceanography and Marine Science 1(2), 028-039 (2010).

[12] Ramalingam, G. and Renganathan, M., Coastal geomorphology and its evolution-A case study in Agniar basin, Tamilnadu, Indian J Geomorph 3(2), 146-156 (1998).

[13] Stockdonf, H.F., Sallenger, A.H. Jr., List, J.H. and Holmanet, R.A., Estimation of shoreline position and change using airborne topographic lidar data, Journal of Coastal Research 18(3), 502-513 (2002).

[14] Seenipandi, K., and Chandrasekar N., Spectral recognition techniques and MLC of IRS P6 LISS III image for coastal landforms extraction along South West Coast of Tamilnadu, India, Bonfring International Journal of Advances in Image Processing 293, 01-07 (2012).

[15] Ciavola, P. Relation between river dynamics and coastal changes in Albania: An assessment integrating satellite imagery with historical data. International Journal of Remote Sensing 20.3 (1999): 561-584;

[16] Yang, X., Damen, M.C.J., and Van zuidam R.A., Use of Thematic Mapper imagery with a geographic information system for geomorphologic mapping in a large deltaic lowland environment, International Journal of Remote Sensing 20(4), 659-681 (1999).

[17] Mitra, S.S., Mitra, D., and Santra, A., Performance testing of selected automated coastline detection techniques applied on multispectral satellite imageries, Earth Science Informatics 10(3), 321-330 (2017).

[18] Bamdadinejad, M., Ketabdari, M.J. and Chavooshi, S.M.H., Shoreline Extraction Using Image Processing of Satellite Imageries, Journal of the Indian Society of Remote Sensing, 1-11 (2021).

[19] Bayram, B., Erdem, F., Akpinar, B., Ince, A. K., Bozkurt, S., Catal Reis, H. and Seker, D. Z., The efficiency of random forest method for shoreline extraction from LANDSAT-8 and GOKTURK-2 imageries, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences 4, 141-145 (2017).

[20] Sarp, G., and Ozcelik, M., Water body extraction and change detection using time series: A case study of Lake Burdur, Turke, . Journal of Taibah University for Science 11(3), 381-391 (2017).

[21] Zhang, N., Yongsheng, W. and Zhang, Q., Detection of sea ice in sediment laden water using MODIS in the Bohai Sea: A CART decision tree method, International Journal of Remote Sensing 36(6), 1661-1674 (2015).

[22] Gafurov, A.M., and Yermolayev, O.P., Automatic gully detection: Neural networks and computer vision, Remote Sensing 12(11), 1743 (2020).

[23] Murali, R.M., Ankita, M., Amrita, S. and Vethamony, P., Coastal vulnerability assessment of Puducherry coast, India, using the analytical hierarchical process, Natural Hazards and Earth System Sciences 13(12), 3291-3311 (2013). doi:10.5194/nhess-13-3291-2013.

[24] Thieler, E. R., E. A. Himmelstoss, J. L. Zichichi, and A. Ergul, Digital shoreline analysis system (DSAS) version 4.0-an ArcGIS exten-sion for calculating shoreline change, U.S. Geol. Survey Open File Rep. 2008?1278 (2009).

[25] Sheik, M. and Chandrasekar, A shoreline change analysis along the coast between Kanyakumari and Tuticorin, India, using digital shoreline analysis system, Geo-Spatial Information Science 14(4), 282-293 (2011). doi:10.1007/s11806-011-0551-7.

[26] Gaynullin, I., Sitdikov, A. and Usmanov, B., Destructive abrasion processes study in archaeological sites placement (Kuibyshev and Nizhnekamsk reservoirs, Russia), International Multidisciplinary Scientific Conference on Social Sciences & Arts SGEM, 3(1), 339?346 (2014). DOI: 10.5593/SGEMSOCIAL2014/B31/S9.044;

[27] Usmanov, B., Nicu., I.C. and Gainullin, I., Monitoring and assessing the destruction of archaeological sites from Kuibyshev reservoir coastline, Tatarstan Republic, Russian Federation. A case study, Journal of Coastal Conservation 22(2), 417-429 (2018). https://doi.org/10.1007/s11852-017-0590-9;

[28] Nicu, I.C., Usmanov, B., Gainullin, I. and Galimova, M., Shoreline dynamics and evaluation of cultural heritage sites on the shores of large reservoirs: Kuibyshev reservoir, Russian Federation, Water (Switzerland) 11(3), 591 (2019).

[29] Gafurov, A., Gainullin, I., Usmanov, B., Khomyakov, P. and Kasimov, A., Impacts of fluvial processes on medieval settlement Lukovskoe (Tatarstan, Russia), Proc. IAHS 381, 31-35 (2019) https://doi.org/10.5194/piahs-381-31-2019.

[30] Gaynullin, I.I., Sitdikov, A.G. and Usmanov, B.M., Abrasion processes of Kuibyshev Reservoir as a factor of destruction of archaeological site Ostolopovo (Tatarstan, Russia), Advances in Environmental Biology 8(4), 1027-1030 (2014).

[31] Rudenko, K.A., Some results of researches of the Ostolopovo settlement in the area Alekseevskoe of the Republic of Tatarstan, Povolzhskaya Arkheologiya 2(2), 123-145 (2012).

[32] Rudenko, K.A., Cultural and Chronological Aspect of Slavonic Ceramics Utilization in the 13th ? 14th Centuries in the Bolgar Region of the Golden Horde (on the basis of Laishevo settlement materials), Povolzhskaya Arkheologiya 2(28), 96-114 (2019).