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Archaeology and Dams in Southeastern Turkey: Post-Flooding Damage Assessment and Safeguarding Strategies on Cultural Heritage

Nicolò Marchetti[1], Gabriele Bitelli[2], Francesca Franci[3] and Federico Zaina[4]

[1] Department of History and Cultures, University of Bologna, Piazza San Giovanni in Monte 4, 40124, Bologna, *Italy*
E-mail: nicolo.marchetti@unibo.it

[2] Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Viale del Risorgimento 2, 40136, Bologna, *Italy*
E-mail: gabriele.bitelli@unibo.it

[3] Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Viale del Risorgimento 2, 40136, Bologna, *Italy*
E-mail: francesca.franci2@unibo.it

[4] Department of History and Cultures, University of Bologna, Piazza San Giovanni in Monte 4, 40124, Bologna, *Italy*
E-mail: federico.zaina@unibo.it

Abstract

The construction of dams is an ever-growing threat to cultural heritage, particularly in an age of climate change and narrowly focused development policies. In analyzing as a case study three major reservoirs in the Middle Euphrates river valley in southeastern Turkey (Atatürk, Birecik and Karkamış), we developed a Post-Flooding Damage Assessment (PFDA) to evaluate the impact of dams on archaeological sites. Our PFDA, consisting of an analysis of cross-correlations between multi-temporal Landsat imagery, geographical spatial datasets and archaeological data from surveys and excavations, provides an unprecedented detailed overview of the loss of especially significant cultural landscapes, and also highlights the limited accuracy of pre-flooding archaeological surveys and excavations. We conclude with recommendations for improving how rescue archaeological projects targeting endangered cultural landscapes are designed, with an immediately achievable target of better documenting cultural heritage threatened by dams.

Keywords: archaeological sites, cultural heritage, dams, Landsat imagery, policies, Turkey

Introduction: Current Issues and Debates on Archaeology and Dams

It is a truism that development often entails the destruction of historical landscapes, including both natural and cultural heritage. In particular, the construction of large infrastructure, such as dams and similar water-related facilities, represents a major threat to archaeological sites and monuments (Cunliffe *et al.* 2012; Marchetti *et al.* 2018; Zaina 2019). Today, the countries of the Middle East and North Africa (hereafter MENA) are undertaking an ever-increasing number of major dam projects, with the largest currently under construction or being planned in Egypt, Ethiopia, Iran, Iraq, Sudan and Turkey.

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The negative impact of such dams is becoming more apparent, and awareness of this issue is increasing worldwide. Such infrastructure projects are recognized as being among the socioeconomic drivers of the 'Great Acceleration' of humanity in the twentieth century, the period which it has been argued represents the start of the Anthropocene as the next epoch in the history of the earth (Steffen *et al.* 2015). Thanks to academic publications and the spread of information through social media and newspapers as well as civil movements (such as the *Blue Heart* project launched by the outdoor clothing brand Patagonia and the similar *Save the Blue Heart of Europe* project, both concerned with dams in the Balkans[1]), there is a growing consensus about the damage caused by dams. Within the academic world, the construction of dams and reservoirs in MENA countries has sparked numerous studies, focusing primarily on issues of population displacement (Fernea 1994; Komurcu 2002; Akyürek 2005; Strzepek *et al.* 2008; Hopkins and Mehanna 2010), environmental impact (White 1988; Zeid 1989; Akyürek 2005; Turkmen *et al.* 2005; Goubachi 2012) and geopolitics (McCully 1996; Komurcu 2002; el Gammal *et al.* 2010; Dissard 2011; n.d.). These studies and the numerous civil movements have contributed to some improvement of policies by individual governments, as is the case with Turkey (Komurcu 2002; Akyürek 2005; Shoup 2006), as well as by funding bodies including supranational institutions, such as the World Bank (2014) and the European Commission (2007), on reducing the damage caused by the construction of dams.

However, the debate as regards threats to cultural heritage caused by the construction of dams has had little attention on social, political and scientific agendas; this reflects a lack of understanding of the quantitative and qualitative damage entailed, and also the absence of effective policies to protect archaeological sites and monuments. As recently argued (Marchetti *et al.* 2019), awareness and safeguarding initiatives at academic, institutional and popular levels regarding endangered heritage emerge mainly when important sites and monuments are threatened by dams: examples here include Samsat (Atatürk Dam—Serdaroğlu 1975; Özdoğan 1977), Zeugma and Halfeti (both in the Birecik Dam reservoir—Algaze *et al.* 1994) and Hasankeyf (Ilısu Dam—Tuna *et al.* 2001; 2004; 2011b), all in Turkey, and most famously the temples of Philae and Abu Simbel in Egypt (both flooded by the Aswan Dam—Adams 1977; Dezzi Bardeschi 2002). Moreover, among the few studies attempting to analyze the impact of dams after their in-filling (Shoup 2006; Hafsaas-Tsakos 2011; Kleinitz and Naser 2013), only a few have presented and discussed quantitative data (Marchetti *et al.* 2019; Zaina 2019), thus making it difficult to estimate properly the degree of threat or destruction. Consequently, although cultural heritage is nowadays recognized as an issue by international institutions such as the World Commission on Dams (2000), existing national (on Turkey see Akyürek 2005; Komurcu 2002) and supranational regulations (World Bank 1986; 2006; Brandt and Hassan 2000; World Bank and UNESCO 2011; 2017) are still too limited and often too vague, which means their effectiveness is far from satisfactory (Komurcu 2002 provides criticism on the lack of policies at the World Bank, the International Monetary Fund, the Asian Development Bank and the Inter-American Development Bank).

The current strategies put in place by public and private bodies to document and protect endangered heritage in MENA countries include pre-flooding risk analysis, followed by fieldwork activities such as different types of survey (of varying degrees of precision), archaeological excavations at selected sites and, in a few cases, conservation and relocation. A shared protocol, however, has not yet been developed, and in most cases only some of the aforementioned activities have been carried out. In addition, no comprehensive analysis of the impact of the

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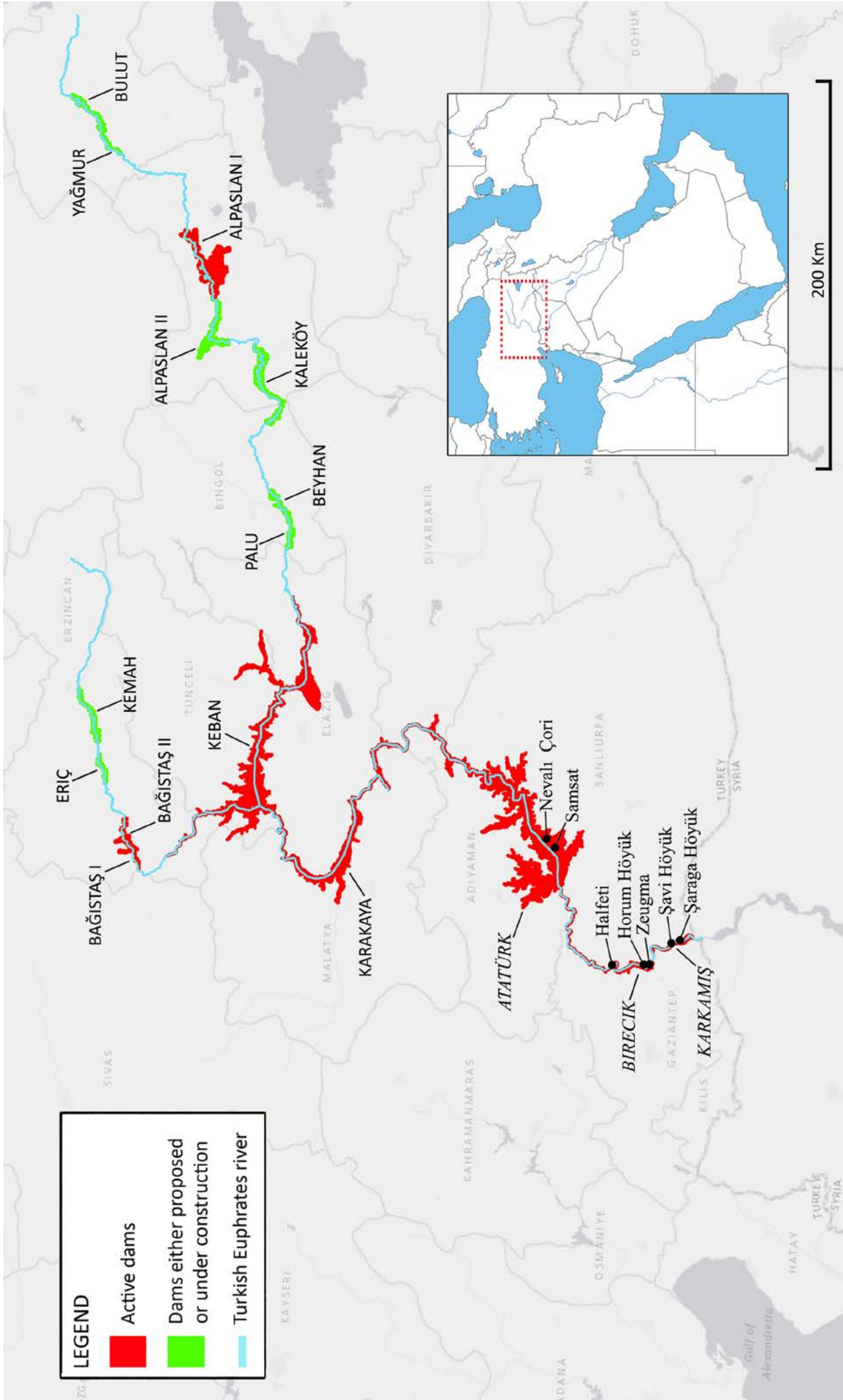

Figure 1. Map showing all the dams along the Turkish Euphrates mentioned in the text: the three study cases analyzed are in italics.

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resulting reservoir after its in-filling is carried out. Consequently, the true extent of the damage that dams have caused to heritage in MENA remains unclear. Based on these observations and considering the total number of archaeological sites flooded (highlighted by the present study), in this paper we argue that pre-flooding methodologies for documenting and safeguarding sites have not been adequately applied and the results have been disseminated only patchily, thus preventing a comprehensive understanding of the degree of damage actually caused. To confirm this assumption, we developed an approach we call Post-Flooding Damage Assessment (henceforth PFDA) to establish the detail and accuracy of current pre-flooding documentation strategies on archaeological sites and monuments. Approaches similar to our PFDA have been already recognized as valuable for assessing the different impacts caused by the construction of dams, including on cultural heritage (Molinari *et al.* 2014; 2017; Ballio *et al.* 2018).

To test our arguments and methodology, we selected the last three dams heading south on the upper stretch of the Euphrates River course, which is now largely submerged by the dams of Bağıştaş I, Bağıştaş II, Alpaslan I, Beyhan, Keban, Karakaya, Atatürk, Birecik and Karkamış, with very few kilometers of the original Turkish Euphrates river valley left intact (Figure 1). Our PFDA of the Atatürk, Birecik and Karkamış dams consisted, first, in assembling a robust quantitative array of geographical and archaeological datasets. Archaeological data were then cross-correlated with multi-temporal Landsat (NASA / US Geological Survey [USGS]) satellite imagery in order to shed light on the chronological evolution of the dams' impact on archaeological sites. We then used the resulting data to provide feedback on the methodology that had been used to document archaeological sites and monuments. From this, we developed recommendations for improving documentation and safeguarding strategies. The evidence provided by our research will hopefully contribute to raising awareness of the danger to heritage entailed in development projects and of the ensuing need for proper documentation protocols. It may serve both as a cautionary element in future assessments of archaeological evidence in affected areas, and as an additional critical and practical tool for policy makers.

Documenting the Impact of Dams on the Archaeological Heritage: The Potential of Remote Sensing and GIS

Due to its synoptic view and repeatability, satellite remote sensing offers a powerful and effective means for monitoring and interpreting environmental changes at global, regional and local scales (Kuenzer *et al.* 2015; Ban 2017), and hence for supporting decision makers in providing better landscape management. Satellite images have provided data for the interpretation of abrupt changes caused by disasters such as earthquakes (Voigt *et al.* 2007; Dong and Shan 2013) and floods (Franci *et al.* 2015; 2016) and for gradual (spread over years or decades) phenomena such as such as urbanization (Franci *et al.* 2015; Thomas *et al.* 2003), melting glaciers (Kaab 2009), soil sealing (Casciere *et al.* 2014), deforestation (Reiche *et al.* 2015) and desertification (Zanchetta and Bitelli 2017).

A large number of earth-observation satellites equipped with both optical and radar sensors have been launched in recent decades, and they provide huge volumes of multitemporal data with different characteristics. The continuous improvement of spatial, radiometric, spectral and temporal resolution has significantly increased interest in image time series processing for a growing spectrum of applications. Of the various examples, the US Landsat program has the longest history in optical earth observation. Landsat multispectral imagery provides medium resolution image coverage, with an average temporal repeatability of 16 days. The spectral bands cover the visible, near infrared, medium infrared and thermal portions of the electromag-

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netic spectrum. After 45 years, the long-term time series derived from the Landsat archive constitutes an invaluable source of information on changes that have occurred on the Earth's surface over this period (Casciere *et al.* 2014). Furthermore, since 2008 these images have been freely available, thus significantly enlarging the number of potential users (Wulder *et al.* 2012).

Further, thanks to automatic or semi-automatic classification techniques, it is possible to derive from multispectral images a thematic representation of land cover at a scale suitable for regional studies. When appropriately georeferenced, the original images or the derived thematic maps can provide the basis for a change-analysis procedure conducted in a GIS environment. This allows the overlaying of different layers with different contents to provide a spatiotemporal evaluation of the relationships between phenomena and events that have occurred over time.

Remote sensing has found a large range of multidisciplinary applications, and its use in archaeology is increasingly promising (Scollar *et al.* 2009; Lasaponara and Masini 2012; Cerra *et al.* 2016). Applications include the mapping and documentation of large areas, the discovery and identification of archaeological features, site monitoring and preservation and the integration of geophysical surveys (Giardino 2011; Orlando and Villa 2011; Rowlands and Sarris 2007). The methodology has been tested successfully in the last decade, especially for areas made inaccessible by conflict. MENA examples include extensive use in Cyprus (Agapiou *et al.* 2013), Egypt (Parcak 2015; Parcak *et al.* 2016; Fradley and Sheldrick 2017), Iraq (Fisk 2008; Stone 2008; 2015; Richardson 2011), Libya (Rayne *et al.* 2017a; 2017b), Syria (Casana and Panahipour 2014; Cunliffe 2014; 2016; Casana 2015; Danti 2015; DGAM 2013) and Yemen (Banks *et al.* 2017).

Additional valuable support is also represented by old declassified satellite images including from U2 flyovers and from the CORONA program developed during the Cold War (Kennedy 1998; Philip *et al.* 2002; Wilkinson 2003; Goossens *et al.* 2006; Bitelli and Girelli 2009; Casana and Cothren 2013; Hammer and Ur 2019). Such images were mostly taken during the 1950s and 1960s, thus making it possible to extend the chronological range provided by Landsat for historical analysis.

This paper presents a different use of remote-sensed imagery for archaeology, employed here as a means to explore the relationship between the development of dams and the destruction of archaeological sites in the Middle Euphrates river valley that have been flooded by water reservoirs in southeastern Turkey over several decades.

Study Area and Previous Archaeological Fieldwork

Since the end of the 1970s, economic development strategies promoted by the Turkish government in the context of the GAP (Güneydoğu Anadolu Projesi, Southeastern Anatolia Project) masterplan have led to substantial economic improvement in the previously low-income region of southeastern Anatolia (GAP-RDA 1997; Altınbilek and Tortajada 2012). Particularly notable is an increase in farmland and power generation, achieved through a range of mid- and long-term measures including the construction of a network of dams and water reservoirs along the region's main rivers and some of their tributaries (Biswas and Tortajada 1997).

These projects, however, had a dramatic impact on the natural and cultural landscape of the region. Among the most tangible effects, thousands of people were relocated when their villages were flooded, the natural environment (including riverbeds and forests) was massively modified and hundreds of archaeological sites were partially or totally engulfed. While the resettlements and land seizure sparked a heated debate (Tigrek and Altınbilek 2004; Akyürek 2005; Shoup 2006; Akça *et al.* 2013), there was a remarkable dearth of studies and post-flooding risk reports (GAP-RDA 1997; DSİ 2009;

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Table 1. Technical data on the three Turkish dams considered in this paper (DSİ 2014).

Name	Construction period	Dam height	Reservoir extension	Reservoir volume	Energy produced	Irrigated area
Atatürk	1983–1992	169 m	817 sq km	48,700 cu hm	8,900 GWh	872,385 ha
Birecik	1985–2000	63 m	56 sq km	1,220 cu hm	2,518 GWh	92,700 ha
Karkamış	1996–2000	21 m	28 sq km	157 cu hm	652 GWh	-

Marchetti *et al.* 2019) estimating the number of endangered archaeological sites and proposing solutions for their systematic documentation and safeguarding.

The three dams considered in this paper—the Atatürk, Birecik and Karkamış dams—are located along the Euphrates river in the southeastern Turkish administrative provinces of Adıyaman, Şanlıurfa and Gaziantep (Table 1). They have been selected for several reasons.

First, the available archaeological data on these three dams—including details pertaining to the survey methodology and the positions of sites and their dimensions—were sufficient to make the kind of study we envisaged possible; second, the research methodologies applied in the three archaeological surveys were similar to one another, allowing a degree of consistency in our analysis (this would not have been the case with Keban Dam in Turkey, the Tishrin and the Tabqa dams in Syria or the Haditha and Delmej reservoirs in Iraq); third, the periods of construction of the three dams meant that we have enough spatial data and satellite imagery to perform multi-temporal analysis; and fourth, the three dams represent a consistent group, extending one after the other along the Euphrates and thus permitting us to analyze a coherent stretch of the river.

Atatürk Dam

Atatürk Dam is located on the Euphrates river, on the border between the Adıyaman and Şanlıurfa provinces. Construction began in 1983 and was completed in 1990, and the dam went into service in 1992, when the filling of the reservoir created the third-largest lake in Turkey (GAP-RDA 1997; DSİ 2009). Aside from its recognized benefits, Atatürk Dam had a significant impact on the local population, the environment and cultural heritage along an approximately 170 km stretch of the Euphrates river valley (Tortajada 2000; Brismar 2002; Akyürek 2005: 70-71; Açka *et al.* 2013: 102).

In order to document threatened archaeological sites in the area, between 1975 and 1977 the METU (Middle Eastern Technical University, or ODTÜ by its Turkish acronym) Keban Project team, in collaboration with the DSİ (Devlet Su Işleri, State Hydraulic Works), undertook the Lower Euphrates Basin Archaeological Survey (LEBS – Serdaroğlu 1975; Özdoğan 1977; see also Table 2). On paper this project continued the rescue archaeology approach initiated with the construction of Keban Dam (1966–1975) and defined by Dissard (2011; n.d.) as 'the turning point' of Turkish archaeology. Different survey methods were applied in the prospective reservoir areas, including intensive survey, random survey and visual search (Özdoğan 1977; for a detailed description, see below). A second medium-scale survey project was carried out by the British Institute of Archaeology at Ankara (Blaylock *et al.* 1990) in the central and northwestern part of the future Lake Atatürk between 1985 and 1991. Further and more intensive survey projects in the central part of this area were undertaken as part of the Gritille (Stein 1998) and Kurban Höyük projects (Marfoe *et al.* 1986). Moreover, a long-term international program of salvage excavations was carried out at 17 sites between 1977 and 1991 (see Table 2), involving universities and research centers. As a result, the Atatürk reservoir area revealed

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Table 2. List of archaeological surveys and excavations carried out in the three dams' reservoir areas.

Dam	Project	Type of project	Institution	Period
Atatürk	LEBS	Survey	Middle East Technical University	1974–1988
Atatürk	Adıyaman survey	Survey	British Institute of Archaeology at Ankara	1985–1991
Atatürk	Gritille project	Survey	Bryn Mawr College	1982–1984
Atatürk	Kurban Höyük project	Survey	Oriental Institute of Chicago	1980–1984
Atatürk	Burhan Höyük	Excavation	Urfa Museum	1983
Atatürk	Cavi Tarlası	Excavation	Deutsches Archäologisches Institut, University of Munich Şanlıurfa Museum	1983–1984
Atatürk	Gritille	Excavation	Gritille Project	1981–1984
Atatürk	Hassek Höyük	Excavation	Deutsches Archäologisches Institut University of Munich	1978–1986
Atatürk	Hayaz Höyük	Excavation	Netherlands Historical Archaeological Institute in Istanbul	1979–1984
Atatürk	Horis Kale	Excavation	Şanlıurfa Museum	1979
Atatürk	Karadut Mevkii	Excavation	Bryn Mawr College University of North Carolina University of Pennsylvania	1984
Atatürk	Kumartepe	Excavation	Netherlands Historical Archaeological Institute Şanlıurfa Museum	1983
Atatürk	Kurban Höyük	Excavation	Oriental Institute of Chicago	1980–1984
Atatürk	Lidar Höyük	Excavation	University of Heidelberg	1979–1987
Atatürk	Nevalı Çori	Excavation	University of Heidelberg	1983–1991
Atatürk	Samsat	Excavation	Middle East Technical University	1964–1989
Atatürk	Şehremuz	Excavation	University of Tübingen University of Ankara	1982
Atatürk	Suruk Mevkii	Excavation	Bryn Mawr University	1982–1984
Atatürk	Tatar Höyük	Excavation	University of Ankara	1979
Atatürk	Tille Höyük	Excavation	British Institute of Archaeology at Ankara	1979–1990
Atatürk	Yeniköy	Excavation	Elazığ Museum	1972
Birecik/ Karkamış	TEARP	Survey	University of Chicago	1988–1991
Birecik/ Karkamış	Turco-French survey	Survey	University of Lyon	1986–1987
Birecik	Horum Höyük	Excavation	Institute Français d'Études Anatoliennes, Istanbul	1996–1999
Birecik	Tilbes Höyük	Excavation	University of Alicante Şanlıurfa Museum	1996–2000
Birecik	Zeugma	Excavation	Gaziantep Museum Oxford Archaeology Ltd	1987, 1993–present
Birecik	Tilobur Höyük	Excavation	University of Alicante Şanlıurfa Museum	1996–2000
Karkamış	Harabe Bezikan H.	Excavation	Gaziantep Museum	1998
Karkamış	Akarçay Tepe	Excavation	University of Istanbul	1998–2005
Karkamış	Şaraga Höyük	Excavation	Gaziantep Museum	1999–2000
Karkamış	Şavi Höyük	Excavation	University of Münster	1999–2001

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a rich historical and archaeological landscape chronologically spanning from at least the Neolithic (confirmed by the Pre-Pottery Neolithic [8400–8100 BC] site of Nevalı Çori—Hauptmann 1991), through the Bronze Age and Iron Age, the Classical period (as documented at the multi-period mega-site of Samsat Höyük, ancient Samosata—Özgüç 2009) and down to the Ottoman period.

Birecik Dam

Birecik Dam lies about 100 km downstream from Atatürk Dam and 8 km west of the modern town of Birecik. It is one of the last barrages built as part of the GAP project. Begun in 1985 as part of the GAP's Border Euphrates Project, it was completed in 2000, its impoundment having started in December 1999.

Several actions were carried out in order to document and protect the threatened cultural heritage of the prospective reservoir area (Table 2). Initial attempts to assess and document fully the archaeological sites and monuments to be flooded by the dam were carried out starting in the late 1980s, undertaken by the Tigris-Euphrates Archaeological Reconnaissance Project (TEARP—Algaze *et al.* 1994) and a Turco-French survey of Paleolithic and Neolithic sites in the Gaziantep region (Minzoni-Deroché 1987). Two survey methods were applied by the TEARP team: intensive survey along the wadis, and random survey in the rest of the area to be flooded (Algaze *et al.* 1994; more detailed description below). Moreover, from 1987 to 2000 salvage excavations were carried out at four sites to be flooded by the dam (Table 2). Documented sites in the dam area extended chronologically from at least as early as the Early Bronze Age (3100–200 BC) up to the Ottoman period. Among the most significant sites, the reservoir submerged the Roman (first–fourth centuries AD) twin town of Zeugma-Apamea (Kennedy 1998; Aylward 2013). The two banks of the ancient city were differently affected by the flooding; Zeugma on the western side was only partly submerged, while Apamea on the opposite eastern bank completely disappeared after the in-filling of the reservoir. Another notable site submerged was the Bronze Age and Iron Age site of Horum Höyük (Tibet *et al.* 1999; Marro *et al.* 2000).

Further attempts to preserve the cultural heritage of the region were made in the late 1990s by the GAP team in collaboration with local authorities, universities and international institutions. This collaboration resulted in the signing of a general protocol outlining guidelines for heritage documentation in the region (The Research of Cultural Assets at Risk Due to Water of Birecik and Karkamış Dams, signed by the GAP project and the Ministry of Culture—Akyürek 2005).

Karkamış Dam

Karkamış Dam lies 32 km south of Birecik Dam, along the border between Gaziantep and Şanlıurfa provinces. Its construction began in 1996 and was completed in 2000 in the context of the GAP's Border Euphrates Project (Akyürek 2005). Since the archaeological sites along this stretch of the Euphrates river valley were going to be damaged or submerged by the reservoir, the TEARP (Algaze *et al.* 1994) and the above-mentioned Turco-French survey project (Minzoni-Deroché 1987) intensively explored the area from the late 1980s onward (Table 2). As was the case for Birecik Dam, the TEARP team again undertook intensive survey along the wadis and random survey in the rest of the area to be flooded (Algaze *et al.* 1994; for a detailed description see the following section). Further investigations carried out by the GAP project included salvage excavation projects in the area of the Karkamış Dam reservoir between 1998 and 2005 (Tuna and Öztürk 1999; 2002; Tuna *et al.* 2001; 2004; Tuna and Doonan 2011a; 2011b) (Table 2). Relevant sites submerged by the dam include the Bronze Age Iron Age towns of Şavi Höyük (Dittmann 2007) and Şaraga Höyük (Sertok *et al.* 2007). This dam

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was also included in the two abovementioned protocols for heritage documentation signed by the Turkish authorities (Akyürek 2005).

Research Aims and Methods

Our research was underpinned by questions relating to three issues: (1) What kind of threats do the construction of dams present to cultural heritage? What is the current state of conservation of archaeological sites and monuments affected by dams?; (2) Which strategies have been and are currently being put in place by both national or international archaeologists and institutional bodies to document and safeguard endangered archaeological sites and monuments? What are the current methodological pitfalls?; and (3) What recommendations can be proposed to improve the documentation and safeguard the methodologies related to an endangered cultural heritage?

In order to answer these questions, we developed a Post-Flooding Damage Assessment (PFDA) consisting of the following steps applied to the case study depicted in Figure 2: (1) archaeological data collection, site positioning, database creation, evaluation of the quality and quantity of data; (2) geographical data collection and image processing; and (3) cross-correlated multi-temporal analysis.

Archaeological Data Collection, Site Positioning, Database Creation, Evaluation of Data

We collected archaeological data from publications and online spatial datasets (Table 3) and integrated them into a GIS environment. Specifically, we used publications of the Lower Euphrates Basin Survey Project (LEBS— Serdaroğlu 1975; Özdoğan 1977) and the Tigris-Euphrates Archaeological Reconnaissance Project (TEARP—Algaze *et al.* 1994), and spatial data from the Türkiye Arkeolojik Yerleşmeleri (Archaeological Settlements of Turkey) online project (TAY GIS),[2] to determine the position and dimensions of the archaeological sites and the total surveyed areas in the regions of the three dams. We linked each archaeological site to an attribute table includ-

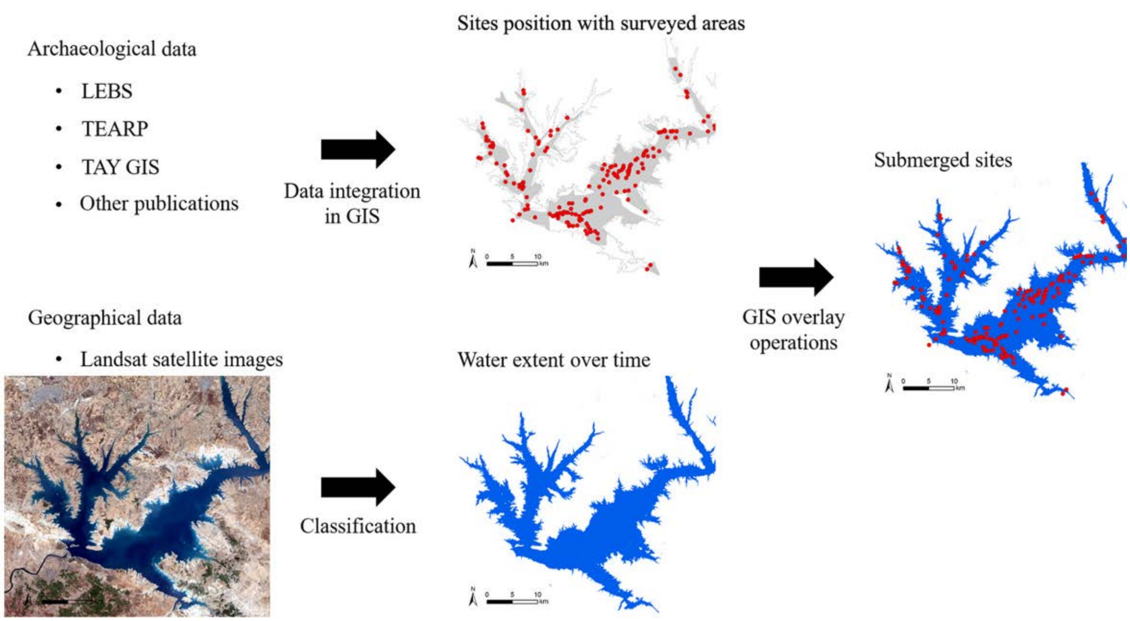

Figure 2. The workflow, from data collection to the identification of archaeological sites flooded by the water reservoirs (detail of the Atatürk Dam).

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Table 3. Archaeological and geographical sources used for this research.

Name	**Data**	**Reference**
Archaeological sources		
LEBS and others	Topographic maps and detailed info on the archaeological sites of Atatürk Dam area	Serdaroğlu 1975; Özdoğan 1977; Blaylock *et al.*, 1990; Wilkinson 1990; Stein 1998
TAY GIS	Georeferenced points of archaeological sites	http://www.tayproject.org
TEARP and others	Topographic maps and detailed info on the archaeological sites of Birecik and Karkamış dams area	Minzoni-Deroché 1987; Algaze *et al.* 1994
Geographical sources		
DSİ	Information on dams	http://en.dsi.gov.tr/
FAO	Georeferenced points of Near Eastern dams	http://www.fao.org/nr/water/aquastat/dams/index.stm
Ormansu	Georeferenced shapefiles on Turkish hydrology and dams	http://taskinyonetimiportal.tarimorman.gov.tr/
Landsat	Multitemporal satellite imagery of the three dams (1984–2016)	https://earthexplorer.usgs.gov/

ing non-spatial information provided by the LEBS and TEARP publications. This information includes location (district, province and UTM coordinates), chronological range of occupation (from the Neolithic to the Ottoman period), nature of research conducted (survey or excavation, period, institutional affiliation), dimension of the site and references (Table 3). We then georeferenced the survey areas and categorized them by the method of investigation used by surveyors (Serdaroğlu 1975; Özdoğan 1977; later adapted by Algaze *et al.* 1994) as follows: (1) *intensively surveyed*, indicating research conducted by walking at established intervals and distances; (2) *surveyed*, meaning that the survey team acquired information from local people about the most promising areas for archaeological evidence and only then visited the places indicated; and (3) *searched*, indicating areas and sites documented from a distance but without actually surveying them.

Geographical Data Collection and Image Processing

The geographical data came from different kinds of open-access spatial datasets as well as georeferenced satellite imagery. The former were retrieved from the official websites and GIS platforms of the Turkish Ministry of Agriculture and Forestry, the DSİ and the Aquastat project of the Food and Agriculture Organization (FAO) of the United Nations.[3] The data from these sources included river streams, the georeferenced positions of existing dams and the reservoir extensions of existing dams as well as the hypothetical reservoir areas of prospective dams or dams under construction (Table 3). Satellite images consisted of Landsat time series available from the USGS for multi-temporal analyses of the three reservoir areas before and after dam construction. This made it possible for us to understand the evolution of the reservoirs between 1984 and 2016. To this end, we selected Landsat images acquired during one season (i.e. between June and August) and with zero cloud coverage (Table 4). The Landsat data are L1T products that are consistent with each other, being orthorectified through the same dataset (GLS2000). Table 4 shows the main characteristics of the Landsat imagery used in this study.

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Table 4. Detailed description of the multispectral satellite images.

Date	Satellite	Sensor	Spatial resolution	Product level
29 July 1984	Landsat5	TM	30 m	L1T
20 June 1987	Landsat5	TM	30 m	L1T
30 July 1990	Landsat5	TM	30 m	L1T
04 Aug 1992	Landsat5	TM	30 m	L1T
04 July 1998	Landsat5	TM	30 m	L1T
25 July 2000	Landsat5	TM	30 m	L1T
28 July 2001	Landsat5	TM	30 m	L1T
10 July 2006	Landsat5	TM	30 m	L1T
21 July 2016	Landsat8	OLI	30 m	L1T

We calibrated Landsat bands to top-of-atmosphere (TOA) reflectance. Then, in order to detect changes in the size of the three reservoirs, we classified the images by applying a density-slicing approach to the near infrared (NIR) band (Jain *et al.* 2005). The NIR band allowed us to identify most major water features (Frazier and Page 2000): water reflectance in the NIR band is minimum, and as water absorbs or transmits most of the electromagnetic energy in the NIR wavelength, we used low reflectance areas to identify water bodies. Once the representation of the reflectance values for water and non-water surfaces was clear, we determined a threshold value of digital numbers within the NIR band to discriminate between these two categories. We used a 1984 Landsat image to delineate the course of the Euphrates river before the opening of the three dams.

Cross-Correlated Multi-Temporal Analysis

Next, we integrated the multi-temporal data representing the water surfaces of each reservoir with the data for the archaeological survey, in order to detect progressive damaging or submersion of the sites due to dam construction and the increase of reservoir area. The resulting picture also made it possible to distinguish between sites completely flooded and those that were partially damaged (although still subjected to water erosion) or even destroyed by the construction of dam infrastructure. This step was performed in a GIS environment by means of overlays of the increasing water bodies' extensions resulting from the density-slicing approach applied to the NIR, cross-correlated with archaeological site areas. Damaged sites were generally those where the upper part of the *höyük* (mound) remains unsubmerged or the highest side lies farthest from the river bank and is thus still visible in the Landsat images.

Results and Discussion

The PDFA analysis allowed us to create a geospatial dataset of sites, including their position and dimensions, as well as a detailed set of non-spatial information. In outlining the surfaces covered by archaeological surveys, we were able to assess the actual extent of the surveyed area. Landsat time series classification provided spatial information on water surface over the three decades under consideration. We identified the sites submerged over time by integrating these geospatial data into the GIS. Table 5 shows the results obtained for each dam in terms of flooded sites and the corresponding total submerged area. Results for each dam are presented in the sections following.

Atatürk Dam

Basing our calculations on the average surface area of the Atatürk Dam reservoir—about 817 sq km (Figure 3)—we determined that only 14% of

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Table 5. The impact of the three selected dams on the Euphrates on archaeological sites and river courses.

Dam	Flooded sites	Damaged/ eroded sites	Sites destroyed due to dam infrastructure	Archaeological hectares flooded	Flooded river courses (approximate)
Atatürk	187	3	1	288.04*	178 km
Birecik	17	2	0	111.58	102 km
Karkamış	1	6	1	42.70	30 km

**Due to lack of information about the total surface area of the sites discovered by the Adıyaman Survey Project, the total submerged hectares could be higher.*

it had been intensively surveyed, 39% had been surveyed and 7% had been searched, while 40% had remained unexplored. It should be noted that the results of the Adıyaman survey (Blaylock *et al.* 1990) have to be regarded as preliminary, since the surveyors provided no data about the dimension of the sites. The total area of the submerged sites thus could be larger than what is assumed here. Among the 338 sites identified by the survey projects in the area expected to be flooded by the Atatürk Dam, 191 (56%) were affected by the rising waters (Figure 3). The great majority of the sites (187, or 98%) were fully submerged, while only three sites (1.5%) were partially flooded and are now subject to gradual erosion by the reservoir water; one single site (0.5%) was destroyed during the construction of the dam infrastructure.

As a result, approximately 288.04 ha of the archaeological area has been affected by the rising waters. Our analysis of the 1984–2016 Landsat imagery revealed that the majority of the sites (161, corresponding to 84.7%) were flooded or damaged between 1987 and 1992 (Figure 4), while approximately 178 km of the original Euphrates riverbed was flooded by the creation of Lake Atatürk (see Table 5, above). Most of the flooded sites showed multiple periods of occupation, with the highest densities in the Hellenistic (fourth–first centuries BC), Roman (first–fourth centuries AD) and early Byzantine (fourth–seventh centuries AD) periods. In over 40% of the excavated sites, archaeological activities were carried out for only a single season, while only 35% of sites were excavated for more than five seasons. There is no direct correlation between the size or chronology of a site and the time spent by archaeologists in excavating it.

Birecik Dam

Approximately 20% of the Birecik Dam reservoir area was intensively surveyed, while 74% was surveyed and 2% remained unexplored (Figure 5). The PFDA analysis revealed that 19 sites out of 35 identified by the TEARP (about 53%) were affected by the dam in-filling. As in the case of Atatürk Dam, according to our classification of the 1984–2016 Landsat images (Figure 6) about 90% of the sites (17) were fully flooded or damaged in 2000, while the remaining two sites (10%) were partially flooded and are now subject to gradual erosion by the reservoir. Approximately 102 km of the Euphrates riverbed was flooded by the resulting water reservoir (see Table 5, above). As a result, the total area of lost archaeological land amounts to 109.24 ha. Half of the sites showed multiple periods of occupation, with the Hellenistic (fourth–first centuries BC), Roman (first–fourth centuries AD) and early Byzantine (fourth–seventh centuries AD) being the best represented.

In the case of Birecik Dam a higher level of commitment has been shown by archaeologists, as confirmed by the fact that the few excavation projects were all carried out over at least four years or more. Moreover, in this case, there is no direct correlation between the size or chronology of a site and the time spent by archaeologists in excavating it.

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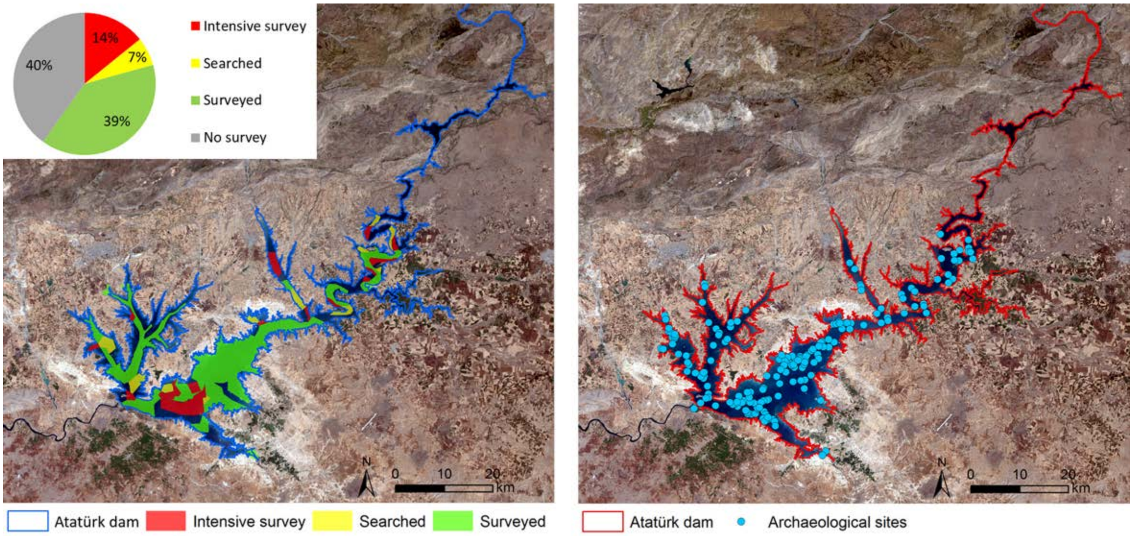

Figure 3. Atatürk Dam. Left: survey field methodology and the area covered; right: archaeological sites affected by flooding.

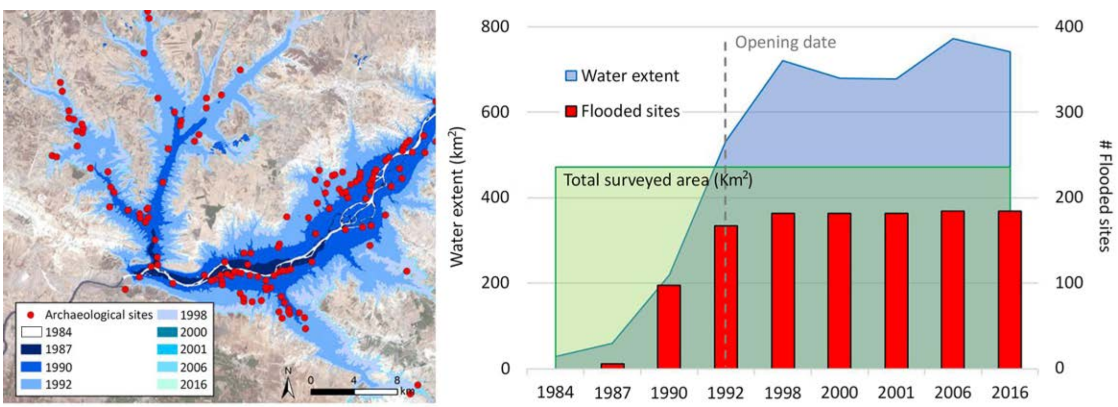

Figure 4. Temporal evolution of the Atatürk Dam. Left: growth of the reservoir; right: archaeological sites affected by flooding.

Karkamış Dam

The TEARP project intensively surveyed 13% and surveyed 87% of the total area of Karkamış Dam (Figure 7). Our analysis indicated that eight sites (16% of the total number of recorded sites) were totally or partly affected by the dam waters, with a loss of roughly 13.42 ha of archaeological land. In the case of this dam, the cross-correlated analysis indicated that the majority of the sites have been only partially damaged (six, or 75%), while only one was fully submerged (12.5%) and another was destroyed during the construction of the dam infrastructure. The majority of these sites revealed multiple periods of occupation, with the Chalcolithic (4th millennium BC), Hellenistic (fourth–first centuries BC), Roman (first–fourth centuries AD) and early Byzantine (fourth–seventh centuries AD) being the best attested. Our analysis of multi-temporal Landsat data for the Karkamış reservoir (Figure 8) indicates that more than half of the sites (five, or 62.5% of the total) were flooded or damaged in 2000. In addition, approximately 30 km of the Euphrates riverbed

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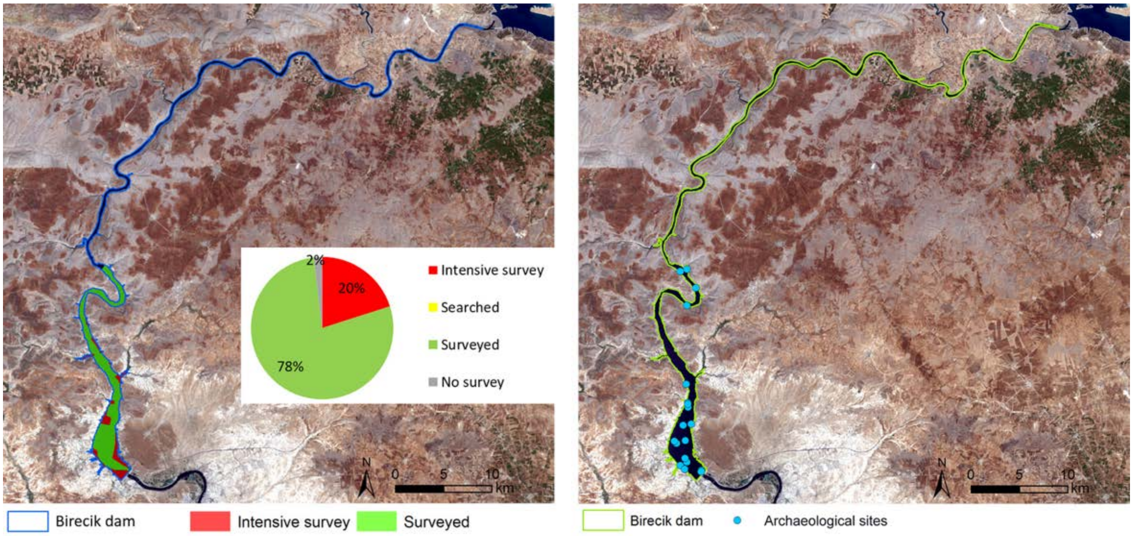

Figure 5. Birecik Dam. Left: survey field methodology and the area covered; right: archaeological sites affected by flooding.

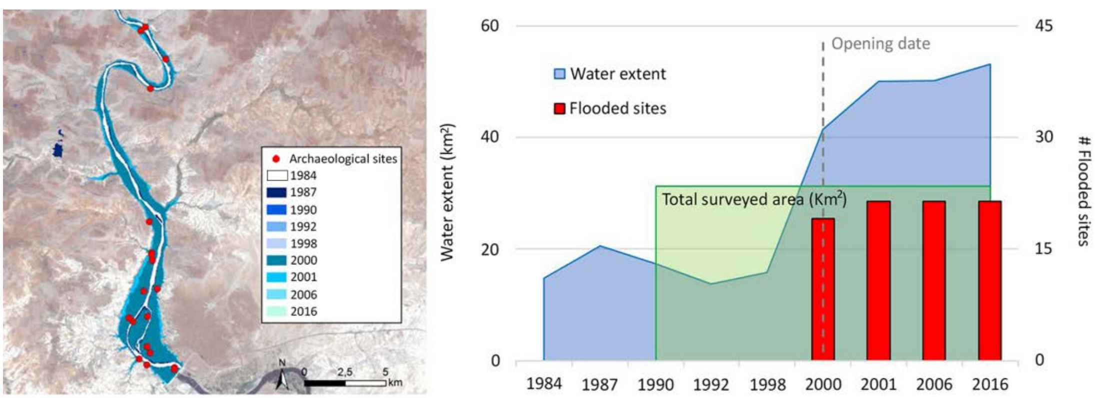

Figure 6. Temporal evolution of the Birecik Dam. Left: growth of the reservoir; right: archaeological sites affected by flooding.

were submerged due to the construction of the dam (see Table 5, above).

In most of the excavated sites, no more than three campaigns were carried out; only at Akarçay Tepe were seven excavation campaigns conducted. As with the other study cases, there is no direct correlation between the size or chronology of a site and the seasons spent excavating it.

The resulting data on the archaeological surveys and excavations highlight the general lack of coordination in the assignment of excavation and survey projects by the Turkish government and a lack of commitment to investigate fully the sites and the regions by archaeological field projects. Considering the reservoirs' extensions, 38% of the three dams' reservoirs were not surveyed and among the area explored by the archaeologists only 15% was intensively surveyed. In addition, only 11% of the 218 archaeological sites flooded, damaged or destroyed were investigated, and 33% of these were excavated for no more than a single campaign. It is noteworthy that the majority of the short-term excavation projects were conducted by local

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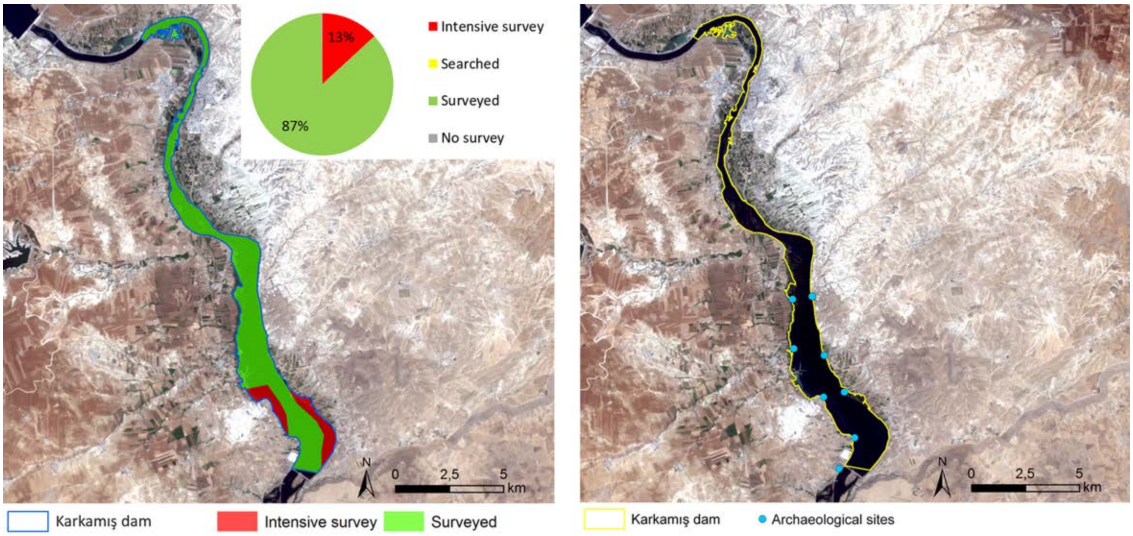

Figure 7. Karkamış Dam. Left: survey field methodology and the area covered; right: archaeological sites affected by flooding.

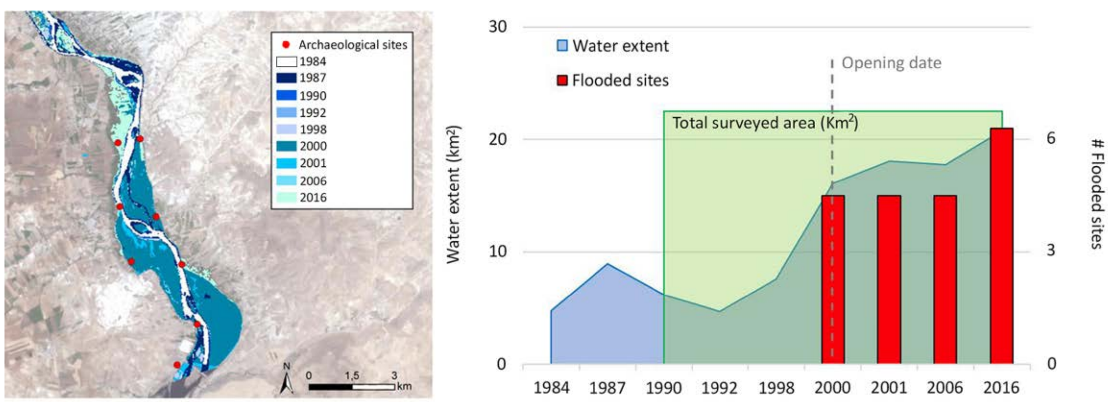

Figure 8. Temporal evolution of the Karkamış Dam. Left: growth of the reservoir; right: archaeological sites affected by flooding.

museums. This evidence further underlines the minimal commitment by the central state in supporting its own local institutions, including museums and universities, to document and safeguard the national heritage.

In light of the above, one primary conclusion is that the 'turning point' proposed by Dissard (2011; n.d.), which occurred with the first systematic rescue archaeology project at Keban Dam, has had only a partial follow-up, at least as far as the dam sector is concerned. As demonstrated elsewhere (Marchetti *et al.* 2019), the percentage of reconnaissance area at Keban Dam (60%) is in fact greater than that at Atatürk Dam (54%) and the survey methodologies applied to investigate Keban Dam (Whallon 1979), in particular the greater use of intensive survey, were skipped, all or in part, in successive projects. In addition, during the 40 years following the survey and excavations of Keban, pre-flooding activities have no longer been carried out at the majority of dams (Marchetti *et al.* 2019).

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Current National and International Legislation in Turkey

As anticipated in the introduction, although current legislation in Turkey as well as at the international level is problematic, it does at least clarify the importance of heritage and provide general recommendations for the protection of cultural heritage in the case of the construction of large infrastructure such as dams (Brandt and Hassan 2000; Komurcu 2002). The main reference points here are the Turkish Constitution, along with various international treaties signed by the Turkish government to protect cultural heritage. The Constitution of 1982 and its amendments define and protect this heritage according to guidelines laid out in Article 63, and more in detail in Article 2863, later substituted by Article 3386 (Komurcu 2002). According to these laws, any archaeological site or other heritage monument in the country is defined as a 'Protected Area' and as such belongs to the Turkish government; those considered to be of greatest historical or artistic importance are elevated to Class I and are protected by the Ministry of Culture and Tourism. Article 17 of Law 2863 requires all Protected Areas to have a 'Landscaping Project and Conservation Development Plan' (Tecirli 2014). In certain cases, such as the Hittite capital of Hattusa, archaeological sites may be also registered as National Parks, thus falling within the sphere of legislation issued by the Ministry of Environment and Forest (Somuncu and Yiğit 2010; Tecirli 2014).

At the national level, the main body involved in the management of the dams is the Turkish government, through the DSİ. According to their latest report (DSİ 2018), since its establishment DSİ has completed six projects for the preservation of archaeological sites and monuments—the first of which are the Keban and LEBS projects—while another eight are in progress. Although these activities are praiseworthy, the low number and the extended time span over which they have been carried out show a scarce and patchy level of commitment.

At the international level, Turkey has ratified several agreements, such as the Recommendation Concerning the Preservation of Cultural Property Endangered by Public or Private Works (UNESCO 1968), the Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property (UNESCO 1970) and the Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO 1972). Such conventions do not contain any specific focus on dams but clarify the importance of heritage and the necessity of protecting it (Komurcu 2002). Turkey has also ratified some agreements issued by the European Union, such as the European Convention on the Protection of Cultural and Natural Heritage (European Union 1992), providing similar definitions and some guidelines. All the international conventions and agreements signed by the Turkish government have legal status at the national level thanks to Article 90 of the Constitution (Komurcu 2002).

An in-depth analysis of the completeness of the current legislation has already been carried out by Komurcu (2002). In his study he stressed how the level of detail in both international conventions and national Turkish legal articles is far from satisfactory, especially due to the lack of any defined action protocols. These shortcomings have been further highlighted by Tecirli (2014), who has pointed out the lack of proper management plans despite the requirement provided by Law 2863. In addition, Shoup (2006) has emphasized the contradictory behavior of the government, which violates its own laws, as in the recent case of Hasankeyf.

Therefore, by cross-correlating the existing laws defining the concept of cultural heritage and the need to protect it with the results of the present study in terms of archaeological sites experiencing flooding and destruction, two types of problems in Turkey can be observed: (1) the laws are not applied systematically; and (2) no practical lines of action for the protection of cultural heritage have been put forward.

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Conclusions: Towards New Strategies for Documenting and Protecting Flooded Heritage

The results of the PFDA show the dramatic impact of the dams considered in this study on the archaeological sites within their basins. In particular, the vast majority of sites affected by dams (94%) have been completely flooded. The strategies put in place by Turkish and foreign archaeologists and institutional bodies to document and safeguard endangered archaeological sites and monuments have targeted only some of those sites and monuments. The methodologies deployed have been applied patchily, with large portions of the resulting reservoir areas unexplored and 89% of the flooded sites unexcavated. Some of the main pitfalls observed include lack of coordination, a limited interest in the preservation of cultural heritage, incomplete coverage of the areas expected to be flooded and inefficient working methods.

This situation confirms the need to place cultural heritage on the same level of discussion as other issues pertaining to the construction of dams, such as environmental impact and the displacement of people. Such improvement in the status of heritage must be followed by more conscious planning, involving stakeholders such as archaeologists, conservators, cultural heritage experts and local communities. Most of these stakeholders, foremost among them local communities, today play an important role in decision making about the construction of dams in Europe (e.g., the above-noted German-led *Save the Blue Heart of Europe* project), while as underlined by Shoup (2006) the academic community has often avoided this debate.

Previous studies (Brandt and Hassan 2000; Ozdoğan 2000; Komurcu 2002; Shoup 2006) and projects (such as Eduu or CRANE 2.0) have emphasized a group of themes that need to be taken into account in order to improve the current situation: (1) research quality; (2) legislation and policies; (3) funding; (4) capacity building; and (5) public outreach and education. In this study we make recommendations for the first three points. In particular, we see a need to strengthen existing legislation, with specific working protocols providing guidelines on the identification, documentation and safeguarding of cultural heritage. These protocols must be supported by the state, which in turn must require their implementation by the bodies involved in the construction of the dams, such as the World Bank, the International Monetary Fund, the Asian Development Bank or the Inter-American Development Bank. This would improve research quality, provide a greater level of detail for the existing legislative base and address the bodies involved in construction.

Our system develops and deepens (1) pre-project planning, identification and scoping, as well as (2) project-specific and (3) post-project issues (the last of these already identified by Brand and Hassan [2000] for the World Commission on Dams). In particular we suggest the creation of three protocols corresponding to three phases of action:

(1) preliminary analysis of the archaeological evidence defined as Pre-Construction Risk Assessment (PCRA);

(2) archaeological activities carried out during the construction of the dam defined as Pre-Flooding Rescue Archaeological Program (PFRAM); and

(3) analysis of the resulting impact of the dam and possible actions to improve PFRAM activities, defined as Post-flooding Damage Assessment (PFDA).

Archaeological survey should not be perceived as an action aimed at saving heritage that will otherwise be destroyed by the construction of infrastructure (UNESCO 1968); rather, it must be considered as part of the decision-making process when projects are being considered. We therefore suggest that in relation to dams, a PCRA, consisting of archaeological survey of the area to be submerged should be carried out before any final construction decision has been made. Further, the bodies involved in the construction of dams must cover the cost of

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the PCRA activities. Following current Turkish regulations, rescue archaeological surveys and excavations (thus including PCRA) are conducted by local museums with the possibility of having national and foreign expeditions in support, although government funding is—illogically—reserved only for national teams. This kind of operational structure may have originated from the Turkish refusal to provide a contribution in kind in the form of a selection of excavated materials to foreign expeditions, as is the practice of other countries in the case of emergency projects. The activities foreseen by the PCRA must include preliminary site reconnaissance through remote sensing followed by random surveys to allow decisions to be taken in a reasonable timeframe but without compromising the quality of the resulting data. Random surveys should be conducted according to the most up-to-date methodologies (Banning 2002; Banning *et al.* 2017).

If, nonetheless, after careful evaluation, the national institutions and bodies involved in a construction decide to proceed with building a dam, documentation activities and, if possible, safeguarding of the archaeological heritage must be carried out. We therefore propose a second phase of rescue archaeological activities under a protocol we call a PFRAM. This must include intensive surveys of the entire reservoir area, and excavation probing at all sites. As with the PCRA phase, the bodies in charge of the dam construction would cover the costs of PFRAM activities. Considering the Turkish case, the leadership assigned to local museums in coordinating emergency excavations can only be justified if it results in greater flexibility in incorporating external scientific cooperation, speeding up processes such as the filing of applications (currently there is a rigid deadline at the end of each solar year for the following year), the assignment of inspectors, minimum required durations on the field, etc. At present, this is not what happens and the overall bureaucratic application process is long and difficult, not to speak of the insufficient number of museum personnel, who cannot guarantee fulfilling their many different duties. What is also lacking, in Turkey and also in so many other MENA countries, is a centrally coordinated effort to manage this continuing emergency, both in terms of an effective public web-GIS and effective forms of publicity (in the form of appeals, for example) about the areas where rescue archaeology is needed.

The involvement of local communities is fundamental both in the PFRA and PFRAM phases; many archaeologists acknowledge the usefulness of local people for the identification of sites during the survey (Blaylock *et al.* 1990) due to their knowledge of the landscape. The support of NGOs to communicate to people the history of the places that are going to be lost must be also considered, in order to avoid further stress already emerging from displacement (Akyürek 2005).

At the end of the dam in-filling, a third protocol of activities should be adopted: this is the above-described Post-Flooding Damage Assessment (PFDA), carried out to understand the actual extent of the damage caused by the reservoir created by the dam and to detect possible discrepancies between the resulting reservoir area and that identified by the PCRA and documented in the frame of the PFRAM. The working model of the PFDA is the one presented in this article. PFDA should also include the possibility of further excavations, in case the analysis reveals evidence of sites not completely destroyed but damaged or subject to erosion. Considering the three case studies presented here, 11 sites corresponding to 5% of the total were damaged but not completely flooded. In light of this evidence and in order not to lose permanently the few remaining sites, further excavations and possible conservation activities should be planned.

In order to monitor the quality of the work as a whole the Turkish government should create a commission of international experts in the field of heritage with the purpose of monitoring

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the various projects from the proposal phase to completion of the last protocol.

With regard to funding, previous studies have already proposed legislation or policies that entail a fixed percentage of total dam construction costs be allocated exclusively for rescue archaeological activities (World Bank 1999; Brandt and Hassan 2000; Komurcu 2002; Marchetti *et al.* 2019). We suggest that an amount ranging between 2% and 5% of the total cost of a dam should be explicitly devoted to the implementation of PFRA, PFRAM and PFDA.

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Endnotes

1. For *Blue Heart*, see https://blueheart.patagonia.com/intl/en/; for the *Save the Blue Heart of Europe* project, see https://balkanrivers.net/en/studies.
2. For details of the project, see http://tayproject.org/habereng.html
3. For the GIS of the Turkish Ministry of Agriculture and Forestry, see http://geodata.tarimorman.gov.tr/index.html?lang=en; for the State Hydraulic Works, see http://www.dsi.gov.tr/, and for Aquastat project of the FAO, see http://www.fao.org/aquastat/en/
4. For details of the project, see https://www.eduu.unibo.it/
5. For details of the project, see https://crane.utoronto.ca/ and Harrison 2018.

About the Authors

Nicolò Marchetti is Professor of Archaeology of the Ancient Near East in the Department of History and Cultures (DiSCi), University of Bologna. He currently directs the excavations of Karkemish in Turkey and of Nineveh East in Iraq and has also directed excavations in Palestine and Turkey and the QADIS survey in Iraq. He has also coordinated several national and international research projects, including the EU-funded *Archaia*, *HeAT*, *Waladu*, *Eduu* and now *Banuu* projects.

Gabriele Bitelli is Professor of Geomatics at the University of Bologna and responsible for the Surveying-Geomatics Area of the Department of Civil, Chemical, Environmental and Materials Engineering (DICAM). He has been responsible scientifically for the EU-funded research projects *SubCoast* and *EnergyCity* and the national Italian research project *Geomatics Data Acquisition and Management for Landscape and Built Heritage in a European Perspective* (GAMEHer). His research interests include geomatics applied to cultural heritage and environmental change detection.

Francesca Franci is Research Fellow in the Department of Civil, Chemical, Environmental

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and Materials Engineering (DICAM) at the University of Bologna. Her research interests include satellite image processing for flood risk mitigation and damage assessment, multi-criteria GIS-based analysis of geospatial data and change detection procedures for land monitoring at large scales. Her research activities are also concerned with the use of data derived from interferometric analyses for the monitoring of subsidence phenomena and slope instability.

Federico Zaina is Research Fellow in the Department of History and Cultures (DiSCi) at the University of Bologna. He has participated in archaeological excavation projects in Syria, Turkey and Iraq. He has been a member of international research projects including the EU-funded projects JPI CH *HeAT*, *Waladu, Eduu* and now *Banuu*. His research interests include Iron Age Syro-Anatolian material culture, Bronze Age landscapes of southern Mesopotamia and cultural heritage at risk.

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