

From Africa to Ifriqiya: Changing landscapes in Early Arab Tripolitania (Libya)

Deutsches Archaeologisches Institut (DAI) – Durham University GIS Training Course

1-17 March 2015

University of Sfax - Tunisia

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REPORT: Anna Leone, Ralf Bockmann, Marco Nebbia (Trainer:)

THE COURSE

Overview

Following the GIS training course of last year, we met again at the Department of History, Faculty of Arts of the University of Sfax, Tunisia, where we delivered a second training course directed to the same 5 members of staff of the two Department of Antiquities (Tripolitania and Cyrenaica).

The attendees were: Ahmed Alemmary (Tripoli), Hassan Hamoud and Nader Elkandi (Gadames), Salah Mahmud (Benghazi) and Moncif Ouadh (Shahhat). Dr. Hafed Abdouli organized the logistics in Sfax and arranged a room for the course at the Department of History, Faculty of Arts of the University of Sfax. Dr. Moftah Haddad, from the Centre of Documentation and Digitization of Cultural Heritage in Tripoli helped with the translation from English into Arabic and assisted with several discussions around different topics addressed during the course.

Aims

Training: As a follow up course, this year, the aim was to refresh the basic concepts of GIS and then to move forward on discussing how to use it with actual fieldwork data. After importing field data into the GIS database we focused on how to spatially display and query the data. Furthermore the introduction of Remote Sensing has been targeted to its potential for mapping - already known as well as potential - archaeological sites and to conceive the archaeological record as a complex system where not just single sites, but also the encompassing landscape needs to be recorded and protected. The final main topic tackled this year has been the creation of risk maps, where some of the disturbances and threats registered on the field has been compared to threats and risks (such as urban expansion and areas under high risk of landslide or water erosion) mapped from the satellite images.

Research: the focus of the course was on the Gebel Nefusa. The territory, on the border with Tunisia, was essential for the Arab Expansion to the North. The area preserves a large numbers of ancient mosques and 9th?10th c. fortified granaries. It had never been investigated systematically and the aim was to record and catalogue all the early Arab sites and reconstruct the trade routes and the settlement patterns through time.

Course program:

The course has been structured more like a workshop, so that staff members of the CDDCH could address topics related to specific tasks they have to undertake within their work at the Centre. It is important that the attendees can see the direct applications to their job, as GIS is

such a vast tool with a lot of functions and sometimes can be dispersive. Therefore after a first revision of basics covered last year we focused the course on the processing of data collected in the field during the survey carried out in April-May 2014 in Gebel Nafusa, Libya.

We started with two days revision of basics GIS notions covered in the course last year. Working on historical maps from the Italian Geographic Military Institute (IGM) of the territory of Tarhuna, produced in 1933, we reviewed the concepts of Georeferencing a raster dataset, creating a Geodatabase, creating and using Domains, digitizing Feature Classes and finally querying the database using selection by attribute and selection by location. The theory behind these operations was clear to the attendees but the practical side needed to be refreshed a bit. After mapping different features from the historical cartography we discussed the utility of having the information stored in a geodatabase and the possibility that GIS gives to analyse spatial patterns of data.

The following days we introduced Remote Sensing as a general discipline as well as its potential for archaeological applications. We focused on an area of the Gebel Nafusa, which has been surveyed last year, and took it as a case study for the rest of the course. Having a specific study area, known to the attendees, helped them understanding the applications of GIS and Remote Sensing to archaeological data. Moreover, a “ground” knowledge of the area helped in assessing the potential of satellite imagery mapping for site detection and interpretation.

After discussing the theoretical background of Remote Sensing we concentrated on mapping archaeological sites from the images we purchased (Pleiades) that cover the surveyed area. We learnt how to interpret sat images and how to store information about remotely sensed features into a bespoke geodatabase (Fig. 1).

OBJECTID	SHAPE	SHAPE_Length	Feature_ID	Region	Location	Dataset	Feature_shape	Spectral_signature	Anomaly	Origin	Interpretation	Certainty	Ground_truth
16	Polyline	80.583703	16	Gebel Nafusa	Haraba	Pleiades	polygonal	dark	shadowmar	don't know	Mound	mid-low	yes
17	Polyline	49.523725	17	Gebel Nafusa	Haraba	Pleiades	polygonal	<Null>	shadowmar	antropic	Structure	mid	yes
18	Polyline	14.037171	18	Gebel Nafusa	Haraba	Pleiades	linear	<Null>	shadowmar	antropic	Wall	mid	yes
19	Polyline	45.323704	19	Gebel Nafusa	Haraba	Pleiades	quadrangular	<Null>	shadowmar	antropic	Structure	mid-high	yes
20	Polyline	26.30982	20	Gebel Nafusa	Haraba	Pleiades	polygonal	light	shadowmar	antropic	Hilltop structure	mid-high	yes
21	Polyline	94.160774	21	Gebel Nafusa	Haraba	Pleiades	polygonal	dark	solmark	antropic	Mound	mid-high	yes
23	Polyline	32.903213	23	Gebel Nafusa	Haraba	Pleiades	polygonal	dark	shadowmar	antropic	Structure	mid	yes
24	Polyline	41.331495	24	Gebel Nafusa	Haraba	Pleiades	sub-circular	dark	shadowmar	antropic	Structure	mid-low	yes
25	Polyline	48.015429	25	Gebel Nafusa	Haraba	Pleiades	polygonal	<Null>	shadowmar	antropic	Hilltop structure	mid-high	yes
26	Polyline	157.012623	26	Gebel Nafusa	Haraba	Pleiades	sub-circular	dark	solmark	don't know	Mound	mid	yes
27	Polyline	22.36095	27	Gebel Nafusa	Haraba	Pleiades	quadrangular	<Null>	shadowmar	antropic	Hilltop structure	mid-high	yes
28	Polyline	127.25244	28	Gebel Nafusa	Haraba	Pleiades	circular	dark	solmark	antropic	Mound	mid-high	yes
29	Polyline	17.635802	29	Gebel Nafusa	Haraba	Pleiades	quadrangular	dark	shadowmar	antropic	Structure	mid-low	yes
30	Polyline	26.700261	30	Gebel Nafusa	Haraba	Pleiades	polyline	light	shadowmar	antropic	Wall	mid	yes
31	Polyline	43.186384	31	Gebel Nafusa	Haraba	Pleiades	polygonal	dark	shadowmar	antropic	Structure	mid-high	yes
32	Polyline	35.422377	32	Gebel Nafusa	Haraba	Pleiades	quadrangular	light	shadowmar	antropic	Structure	high	yes
33	Polyline	34.987725	33	Gebel Nafusa	Haraba	Pleiades	polygonal	light	shadowmar	antropic	Structure	high	yes
34	Polyline	16.052283	34	Gebel Nafusa	Haraba	Pleiades	quadrangular	light	shadowmar	antropic	Structure	mid-high	yes
35	Polyline	41.698854	35	Gebel Nafusa	Haraba	Pleiades	polygonal	light	shadowmar	antropic	Structure	high	yes
36	Polyline	80.52762	36	Gebel Nafusa	<Null>	Pleiades	polygonal	light	shadowmar	antropic	Structure	mid	yes
37	Polyline	26.124658	37	Gebel Nafusa	<Null>	Pleiades	sub-circular	light	shadowmar	antropic	Structure	mid-high	yes
38	Polyline	50.362431	38	Gebel Nafusa	<Null>	Pleiades	polygonal	dark	shadowmar	antropic	Structure	mid-high	yes
39	Polyline	54.991868	39	Gebel Nafusa	<Null>	Pleiades	quadrangular	light	shadowmar	antropic	Structure	mid-low	yes
40	Polyline	10.646857	40	Gebel Nafusa	<Null>	Pleiades	polygonal	dark	shadowmar	antropic	Caern	low	yes
41	Polyline	31.56219	41	Gebel Nafusa	<Null>	Pleiades	quadrangular	light	shadowmar	antropic	Structure	mid-high	yes
42	Polyline	32.181928	42	Gebel Nafusa	<Null>	Pleiades	quadrangular	dark	shadowmar	antropic	Structure	mid	yes
43	Polyline	18.118061	43	Gebel Nafusa	<Null>	Pleiades	polyline	light	shadowmar	antropic	Structure	mid	yes
44	Polyline	38.692351	44	Gebel Nafusa	<Null>	Pleiades	quadrangular	dark	shadowmar	antropic	Fortification	mid-high	yes
46	Polyline	25.092383	46	Gebel Nafusa	<Null>	Pleiades	linear	<Null>	shadowmar	don't know	Wall	low	yes
48	Polyline	36.105469	48	Gebel Nafusa	<Null>	Pleiades	quadrangular	dark	solmark	antropic	Structure	mid-high	yes
49	Polyline	41.577664	49	Gebel Nafusa	<Null>	Pleiades	circular	light	solmark	don't know	Mound	mid	yes
50	Polyline	49.785703	50	Gebel Nafusa	<Null>	Pleiades	quadrangular	light	shadowmar	antropic	Structure	high	yes
51	Polyline	24.619723	51	Gebel Nafusa	<Null>	Pleiades	linear	light	shadowmar	don't know	Wall	mid	yes
52	Polyline	32.621096	52	Gebel Nafusa	<Null>	Pleiades	polygonal	light	shadowmar	antropic	Structure	mid-high	yes
53	Polyline	52.217229	53	Gebel Nafusa	Sherwes	Pleiades	quadrangular	light	shadowmar	antropic	Structure	high	yes
54	Polyline	73.644135	54	Gebel Nafusa	Sherwes	Pleiades	quadrangular	dark	shadowmar	antropic	Structure	high	yes
55	Polyline	58.247135	55	Gebel Nafusa	Sherwes	Pleiades	quadrangular	dark	shadowmar	antropic	Structure	mid-high	yes
57	Polyline	19.190537	57	Gebel Nafusa	Sherwes	Pleiades	linear	dark	shadowmar	antropic	Wall	mid	yes
58	Polyline	37.261394	58	Gebel Nafusa	Sherwes	Pleiades	quadrangular	dark	shadowmar	antropic	Structure	mid	yes
59	Polyline	30.962306	59	Gebel Nafusa	Sherwes	Pleiades	linear	light	shadowmar	antropic	Wall	mid	yes
60	Polyline	33.520344	60	Gebel Nafusa	Sherwes	Pleiades	linear	light	shadowmar	antropic	Wall	mid	yes
61	Polyline	29.204599	61	Gebel Nafusa	Sherwes	Pleiades	linear	dark	shadowmar	antropic	Wall	mid	yes
62	Polyline	42.127874	62	Gebel Nafusa	Sherwes	Pleiades	polyline	light	shadowmar	antropic	Wall	mid-high	yes
63	Polyline	6.669	63	Gebel Nafusa	Sherwes	Pleiades	linear	light	shadowmar	antropic	Wall	mid	yes
64	Polyline	16.993507	64	Gebel Nafusa	Sherwes	Pleiades	polyline	light	shadowmar	antropic	Structure	mid	yes
65	Polyline	27.049557	65	Gebel Nafusa	Sherwes	Pleiades	polyline	<Null>	shadowmar	antropic	Structure	mid-high	yes

FIG. 1

The data stored describe each mapped feature with various attributes; **location** provides information about the municipality where the feature has been mapped, **dataset** indicates which image has been used to map the feature, **feature shape** describes the shape of the feature (linear, curvilinear, circular, quadrangular, polygonal, etc...), **spectral signature** describe the appearance of the feature in the image as dark or light, **anomaly** defines why we can see the feature (as a cropmarks, shadowmarks, soilmarks, etc...) and that helps understanding the nature of the feature itself, **interpretation** tries to explain what we are seeing in the image based on all the previous information and on the context, **certainty** states the level of certainty of the interpretation and finally **ground truth** simply defines whether a feature has been checked on the ground or not.

The aim of the database is to have a full set of information regarding the potential of recovering archaeological sites in a specific area without going in the field. This helps prioritising and planning future fieldwork in territories where the archaeology is more likely to be found.

The advantage of having field survey data is that we have been able to test the visibility of the sites recorded on the ground, in different satellite images. It is fundamental to understand the potential of satellite mapping as it depends on many variables such as shape and size of the site, nature of the site, location of the site, contrast between the land use of the surroundings and of the site itself, state of preservation of the site, spatial and spectral resolution of the image, time of acquisition of the image and different satellite sensors.

We used two different high resolution types of imagery: Orbview-3 (panchromatic 1 m resolution, acquired between 2000 and 2001) and Pleiades (4 bands: Blue, Green, Red and Near Infrared – pansharpened to 0.5 m resolution, acquired between 2013 and 2014).

The results showed that the smaller sites such as graves, small cisterns or wells are not visible from the images at all, for a number of reasons; first of all the small dimensions of these object prevent them from being described by more than few pixels so that we cannot see them, moreover the landuse of the sites is not in contrast with the surroundings and finally the objects don't have a sufficient topographical expression to produce shadows that can be seen on the image.

Small structures like mosques or small buildings are indeed visible on both images, although better defined on Pleiades as the spatial resolution is higher and the colours make such objects more visible; however the certainty of the sites being archaeology is still rather low as the general state of preservation is quite good so it's hard to distinguish them from in use buildings. Bigger and more complex sites such as fortifications of different sorts and tells are quite distinguishable on the satellite imagery due to their dimensions, shape and topographical expression, although sometimes not clearly visible as the natural topography can disguise their presence. In conclusion, the awareness of remote sensing potential and limits for site recognition is fundamental to work out the percentage of archaeology represented by the remote mapping in contrast with the actual presence of archaeological remains.

After assessing the potential of recovering archaeological features from the imagery we looked at the area around the site of Sherwes, south west of the town of Haraba.

The photo-interpretation revealed a number of features defining a complex system which comprises the main settlement, traces of roads/pathways and fields systems (Fig.2).

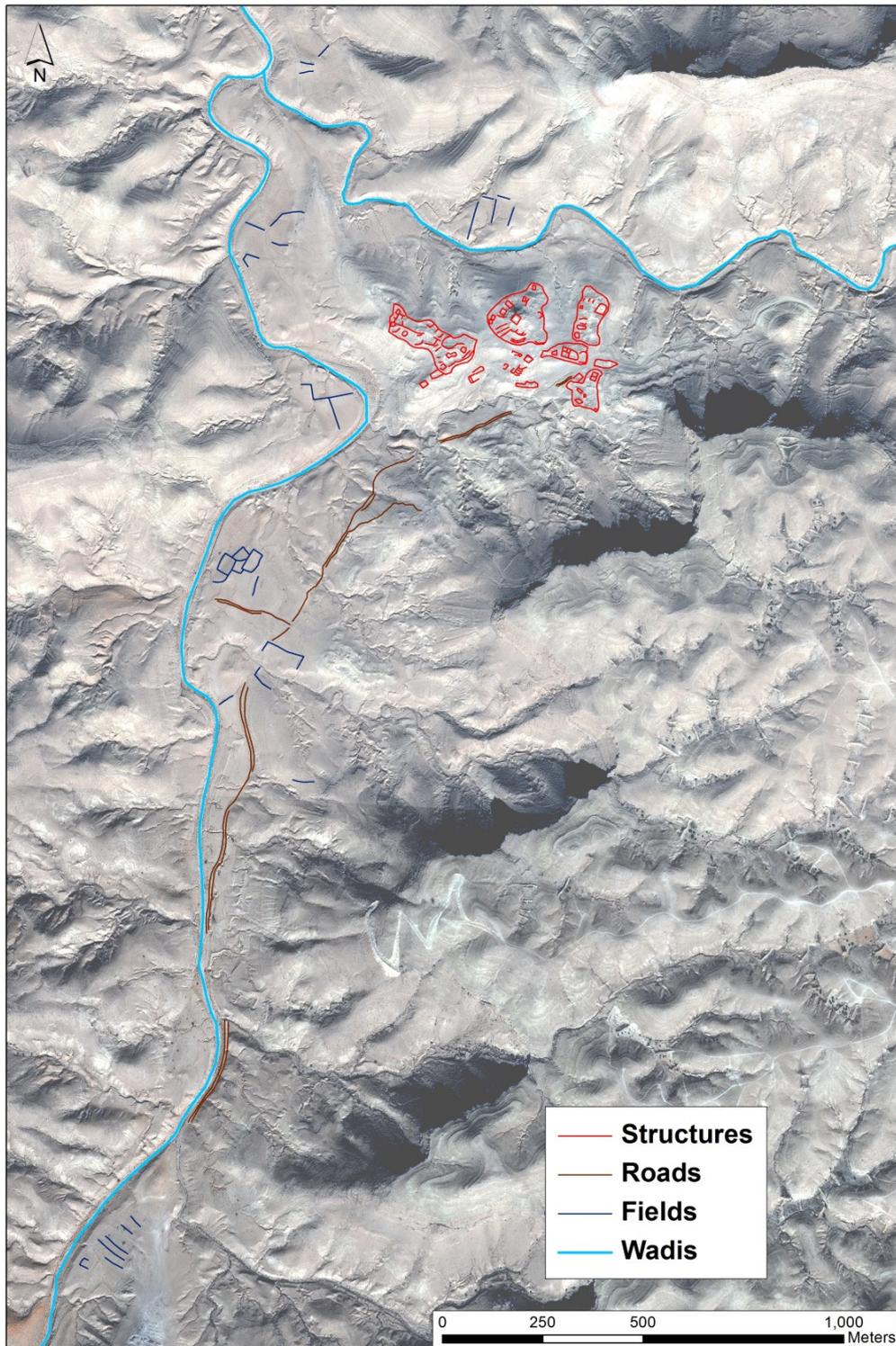


FIG.2

The main settlement consists of four major neighbourhoods; the central one hosts a fortified building (qasar) and several other structures surrounding it on the mound slopes, including storing installations. From the survey data we know that in the middle of the site there is a mosque and

in the north east quarter possibly a synagogue. More interestingly from the satellite image it was possible to map traces of a pathway (partially still in use) that leads from the settlement to the wadi valley bottom and goes upstream. The written sources say that the wadi was one of the main routes that linked the upland plateau of the gebel to the coast in the north and that the valley bottom was cultivated at the time of the occupation of the settlement in the 10th-11th century. Extraordinarily, some remains of a fossil landscape of fields systems are still visible on the images, alongside the main wadi in areas where the valley opens up; these structures are clearly abandoned nowadays but it looks like they have been part of an agricultural system linked to the near Islamic settlement of Sherwes; obviously we can say nothing for certain, before checking on the ground, but still we have a few evidence suggesting a possible function and chronological horizon for these features.

This case study gives important insights into the perception of the archaeological record conceived not just as single sites but as a more complex organization of the landscape where a number of elements can be physically and functionally linked together. Moreover, the case of Sherwes represents a good example that shows how much more has to be *recorded, monitored, protected* and *preserved* in terms of cultural heritage, namely not just the single building or site, but the whole contextual landscape these objects are part of.

As we don't have the possibility of purchasing high resolution imagery for the entire country of Libya, we then learnt how to map features using Google Earth and then import them into GIS. Google Earth is a great source of satellite images, as it has high quality datasets and covers a time period of nearly ten years with a series of imagery acquired at different time of the year for different years, so that to cover a wider range of light conditions, land uses and times of acquisition. The latter is particularly important to monitor and record changes in the landscape over the last 10 years, fundamental for mapping hazards to archaeological sites such as urban expansion or rapid encroachment of quarrying activity (see *infra*).

In the second week we started focusing on how to import field data into the GIS using the geodatabase data model.

The field survey carried out in April-May 2014 on the Gebel Nafusa, produced an excel spreadsheet with 126 sites recorded using the template developed by the CDDCH. The information stored relates to locations, typology of the sites, topographical settings, chronologies, and hazards threatening the sites, among others.

First we prepared the spreadsheet in order for it to be suitable for GIS, then we imported the excel file into GIS and converted it to a point Feature Class stored inside a Geodatabase thus having a dot representing each recorded site (Fig.3). Moreover having the information, listed above, been coded, we could create a series of Domains, one for each attribute (Fig.4). This helps avoiding any redundancy in the data and allows statistical analysis within the database.

At this point we reapplied the selections by attribute and by location, revised during the first two days, to explore the data spatially – e.g. select all the qsars threatened by erosion or select all the different sites which are threatened by urban expansion and locate them on the map.

In this way the awareness of the spatial distribution of the archaeological record increases to a degree that is unconceivable with a traditional “non-spatial” database. The simple action of displaying the information stored in the database helps enormously the site monitoring and preservation and the attendees found this application already very useful.

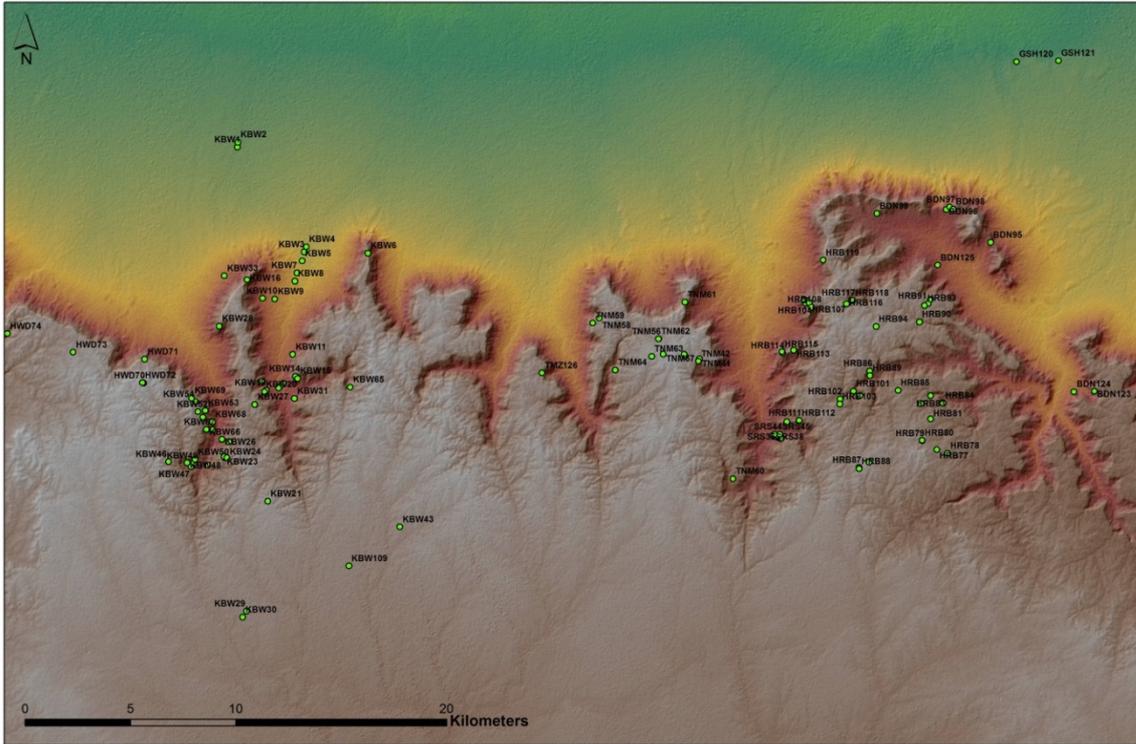


FIG.3

OBJECTID*	Shape*	رقم النقطس	رمز الموقع	الرمز الطب	رمز الفترة	الاصحلات	X	Y	منطقة المس	اسم الموقع	اسم آخر تل	نوع الموقع
1	Point	KBW1	Well	Valley bottom	Islamic	Bulldozing	11.26539	31.94686	كانبو	سانية الغرعة	بانر	بانر
2	Point	KBW2	Grave	Wadi bank	Unknown	Vandalism	11.26554	31.94879	كانبو	سانية الغرعة	قبر	قبر
3	Point	KBW3	Cave	Wadi bank	Prehistoric	Dumping	11.30073	31.90246	كانبو	وادي بورغرة	كهوف	كهوف
4	Point	KBW4	Mosque	Hilltop	Islamic	Vandalism	11.30165	31.90474	كانبو	مسجد قذروي	مسجد	مسجد
5	Point	KBW5	Settlement	Hilltop	Islamic	Pipeline	11.29982	31.89852	كانبو	مدينة بورغرة القديمة	مستوطنة	مستوطنة
6	Point	KBW6	Palace	Mountain top	Islamic	Water erosion	11.33262	31.90286	كانبو	راس الوادي	قصر	قصر
7	Point	KBW7	Grave	Hilltop	Unknown	Ploughing	11.29753	31.89332	كانبو	راس الوادي	قبر	قبر
8	Point	KBW8	Grave	Hilltop	Islamic	Vandalism	11.29655	31.88961	كانبو	راس الوادي	قبر	قبر
9	Point	KBW9	Public building	Plateau	Islamic	Vandalism	11.22682	31.86172	كانبو	ياغن صاهلي	مبنى عام	مبنى عام
10	Point	KBW10	Public building	Hilltop	Islamic	Water erosion	11.23061	31.88185	كانبو	ياغن صاهلي	مبنى عام	مبنى عام
11	Point	KBW11	Habitato/Military	Hilltop	Islamic	Water erosion	11.29673	31.85816	كانبو	ابو بوق	مستوطنة	مستوطنة
12	Point	KBW12	Mosque	Hilltop	Islamic	Water erosion	11.29248	31.84458	كانبو	مسجد لوريم	مسجد	مسجد
13	Point	KBW13	Mosque	Wadi bank	Islamic	Vandalism	11.29113	31.84427	كانبو	مسجد الشارون	مسجد	مسجد
14	Point	KBW14	Palace	Mountain top	Islamic	Water erosion	11.29841	31.84873	كانبو	قصر ابينان	قصر	قصر
15	Point	KBW15	Mosque	Wadi bank	Islamic	Water erosion	11.29952	31.84785	كانبو	مسجد الشارون	مسجد	مسجد
16	Point	KBW16	Palace	Mountain top	Islamic	Water erosion	11.27248	31.88963	كانبو	قصر انطرس	قصر	قصر
17	Point	KBW17	Temple	Mountain top	Unknown	Water erosion	11.2819	31.84616	كانبو	قصر قنطر	قصر	قصر
18	Point	KBW18	Well	Valley bottom	Islamic	Water erosion	11.29024	31.84357	كانبو	بانر حاضرين	بانر	بانر
19	Point	KBW19	Palace	Wadi bank	Unknown	Water erosion	11.28411	31.84231	كانبو	قصر	قصر	قصر
20	Point	KBW20	Temple	Slope	Roman	Reuse of mansony	11.28327	31.84158	كانبو	قصر	معد	معد
21	Point	KBW21	Grave	Plateau	Unknown	Vandalism	11.28674	31.79452	كانبو	ساحة العثونة	قبر	قبر
22	Point	KBW22	Mosque	Wadi bank	Islamic	Water erosion	11.26454	31.81267	كانبو	مسجد البكية	مسجد	مسجد
23	Point	KBW23	Oil press	Wadi bank	Islamic	Water erosion	11.26413	31.81311	كانبو	مسجد	مسجد	مسجد
24	Point	KBW24	Palace	Hilltop	Islamic	Vandalism	11.28562	31.81266	كانبو	قصر البكية	قصر	قصر
25	Point	KBW25	Agricultural structu	Hilltop	Islamic	Water erosion	11.26617	31.81962	كانبو	قصر البكية	مستوطنة	مستوطنة
26	Point	KBW26	Settlement	Hilltop	Islamic	Water erosion	11.26271	31.82051	كانبو	مستوطنة تل	مستوطنة	مستوطنة
27	Point	KBW27	Stone tool	Hilltop	Prehistoric	Water erosion	11.27861	31.83601	كانبو	مستوطنة تل	مستوطنة	مستوطنة
28	Point	KBW28	Palace	Mountain top	Islamic	Water erosion	11.25944	31.86923	كانبو	مستوطنة تل	مستوطنة	مستوطنة
29	Point	KBW29	Mausoleum	Plateau	Roman	Bulldozing	11.27803	31.74685	كانبو	القصور	ضريح	ضريح
30	Point	KBW30	Cistern	Plateau	Roman	Urbanization	11.27623	31.74416	كانبو	القصور	قصر	قصر
31	Point	KBW31	Religious structure	Hilltop	Islamic	Wind erosion	11.2983	31.83919	كانبو	الاجيات	الواد	مستوطنة
32	Point	KBW32	Palace	Wadi bank	Islamic	Water erosion	11.25599	31.80919	كانبو	ووروي	قصر	قصر
33	Point	KBW33	Fortress	Wadi bank	Islamic	Dumping	11.26105	31.89099	كانبو	ووروي	حصن	حصن
34	Point	SRS34	Mosque	Valley bottom	Islamic	Water erosion	11.53988	31.82952	شروس	مسجد محمد فرج بن معروف	مسجد	مسجد
35	Point	SRS35	Well	Valley bottom	Islamic	Water erosion	11.54158	31.82908	شروس	شروس	بانر	بانر
36	Point	SRS36	Settlement	Wadi bank	Islamic	Water erosion	11.54255	31.82866	شروس	شروس	مستوطنة	مستوطنة
37	Point	SRS37	Klin	Wadi bank	Islamic	Water erosion	11.54317	31.82906	شروس	شروس	قصر	قصر
38	Point	SRS38	Cistern	Wadi bank	Islamic	Water erosion	11.53874	31.83002	شروس	مسجد ابو منصور الباس	مستوطنة	مستوطنة
39	Point	TNM39	Mosque	Hilltop	Islamic	Water erosion	11.49338	31.86294	تندمية	قصر بو منصور الباس	قصر	قصر
40	Point	TNM40	Palace	Hilltop	Islamic	Urbanization	11.4928	31.86372	تندمية	قصر بو منصور الباس	قصر	قصر
41	Point	TNM41	Mosque	Wadi bank	Islamic	Urbanization	11.50055	31.86195	تندمية	مسجد بو منصور الباس	مسجد	مسجد
42	Point	TNM42	Settlement	Hilltop	Islamic	Urbanization	11.50021	31.86093	تندمية	قوة تندمية	مستوطنة	مستوطنة
43	Point	KBW43	Grave	Plateau	Roman	Bulldozing	11.35324	31.78532	تندمية	ساحة النخلة	قبر	قبر
44	Point	SRS44	Palace	Wadi bank	Islamic	Grazing	11.53961	31.83044	شروس	قصر	قصر	قصر
45	Point	SRS45	Cistern	Wadi bank	Islamic	Water erosion	11.54198	31.83058	شروس	شروس	مستوطنة	مستوطنة

FIG.4

The last two days of the course have been devoted to the “mapping of risks and hazards” for the cultural heritage, using Remote Sensing.

Relying on the latest enhanced land elevation dataset generated from the Shuttle Radar Topography Mission (SRTM) – 30 meters resolution – it was possible to automatically map the steepest slopes along the cliff line, for the area in the Gebel Nafusa which has been surveyed. These areas are affected by wind erosion, water erosion and landslides and they represent natural hazards to archaeological sites which need to be mapped in order to be integrated with archaeological data (Fig. 5).

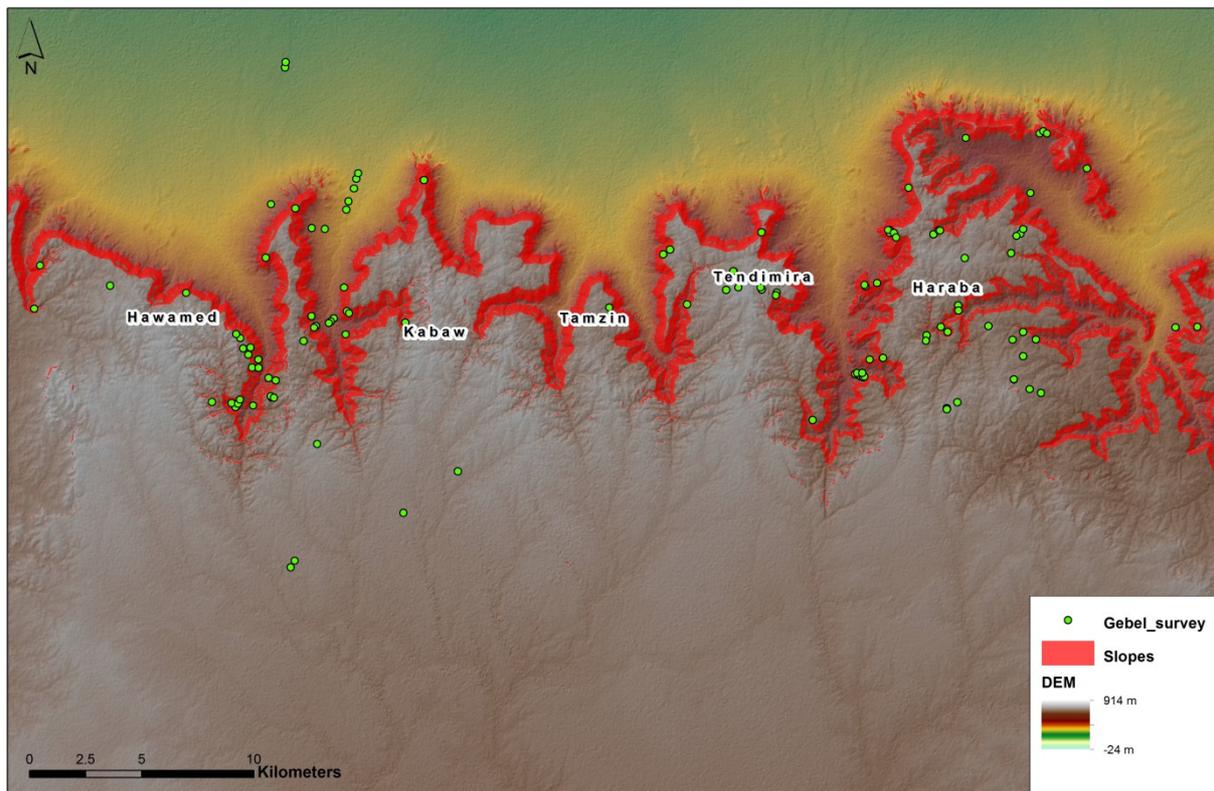


FIG. 5

Finally, we tackled an anthropic threat to cultural heritage – urbanization - and we mapped the urban growth using a time series of Landsat imagery acquired over the last 40 years (1 MSS from 1972, 5 TM from 1987 and 8 OLI from 2015).

Furthermore, the main road network that links the urban centres has been digitized from the latest image, so that we could analyse the different trends of urban development and expansion (Fig.6).

The results show how, considering the urban extents between 1972 and 2015, in some cases we have a minimum 10% increase (e.g. Tendimira) or a moderate-high 250% increase (e.g. Kabaw), or a substantial 540% increase in the urban extent in major towns like Nalut. This information is already fundamental to understand and estimate the level of threat that archaeological sites are subjected to if located in the surroundings of inhabited areas. Moreover, by looking at the road

network it is clearly observable how in most cases the expansion of modern towns occurs along the main ways of communication especially on the gebel uplands, whereas on the northern plain the growth of settled areas is more isotropic.

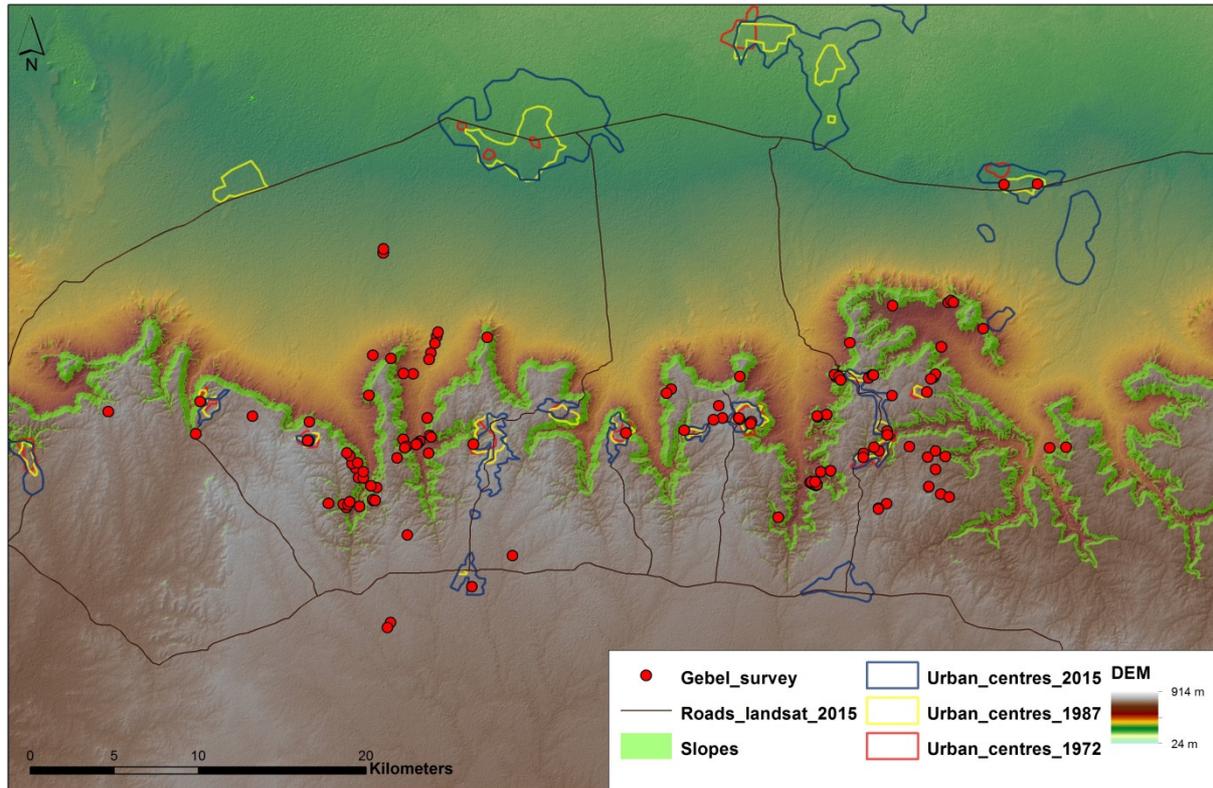


FIG. 6

As illustrated in Fig. 6 the advantage of GIS is that we are always aware of the big picture of what has been recorded and what are the different threats affecting the cultural heritage and we are able to distinguish between natural and antropic hazards which develop and evolve in different ways. Having the data mapped and stored all in a single platform helps in locating the more risky areas for the archaeology and supports the planning of fieldwork in a more targeted and prioritized manner. If we look at Fig. 7, for instance, we can see the distribution of surveyed sites and the location of the major towns in the area of Kabaw; it is clear that the territory around the modern settlements of Kabaw, Fersta and Tamzin has not been covered by the survey so that the archaeological sites threatened by the expansion of these three towns are still unrecorded. Moreover the map shows in green the sites which have been recorded in the field as threatened by urbanization, but looking at the overall distribution of sites there are probably more to be included in this category as they are adjacent to urban areas (e.g. Haraba).

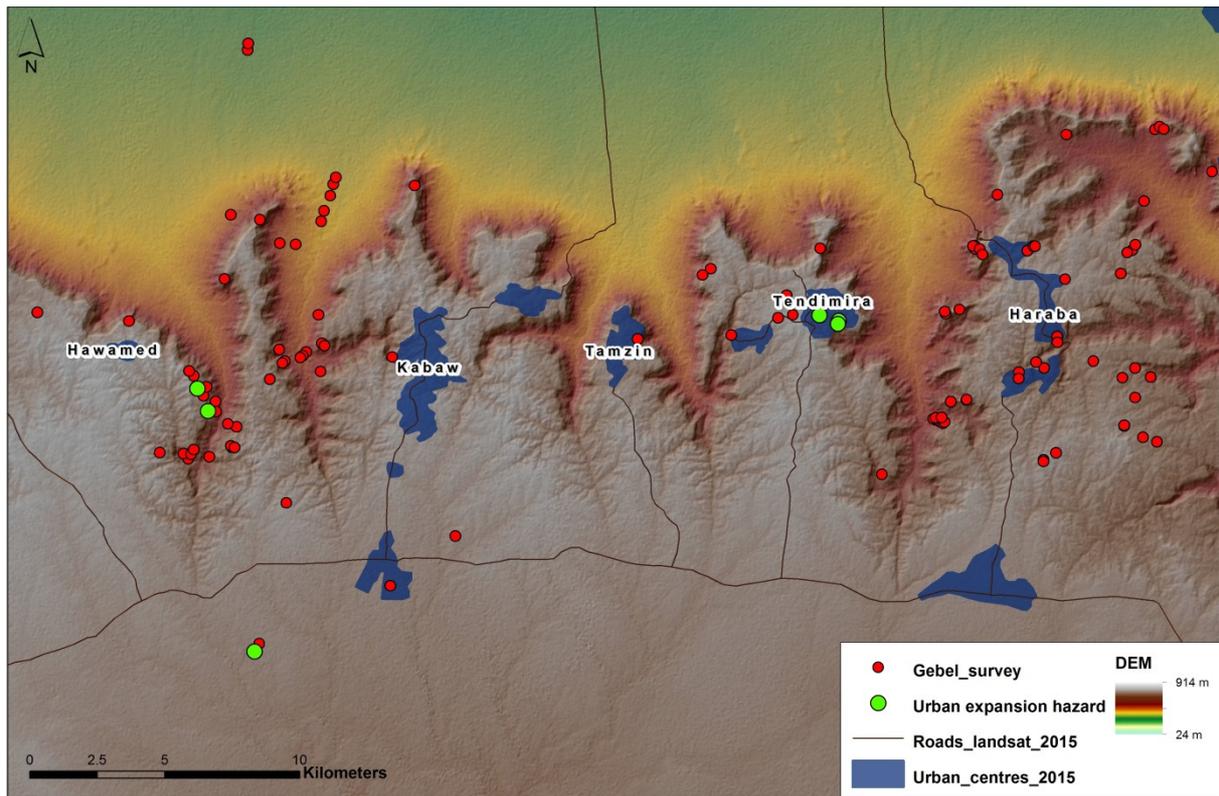


FIG. 7

The last example of how Remote Sensing can be used for mapping of hazards and risks was shown for the area of Msellata, where an impressive encroachment of quarrying activity is destroying the entire landscape, threatening any sort of archaeological remain. Fig. 8 displays the extent of gravel quarries in 2001 and in 2013 (mapped respectively from Orbview-3 and WorldView-2 imagery). The overall exploited area has increased by 280% in 12 years. Moreover we can see that the expansion of quarrying activity is following the two main wadi valleys of the region. In Fig. 9 is visible the distribution of archaeological sites mapped from satellite images and the extent of the quarries in 2013 (bright patch in the middle of the image).

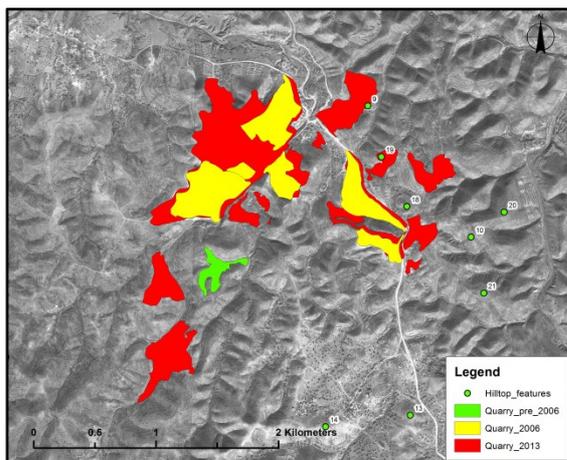


FIG. 8

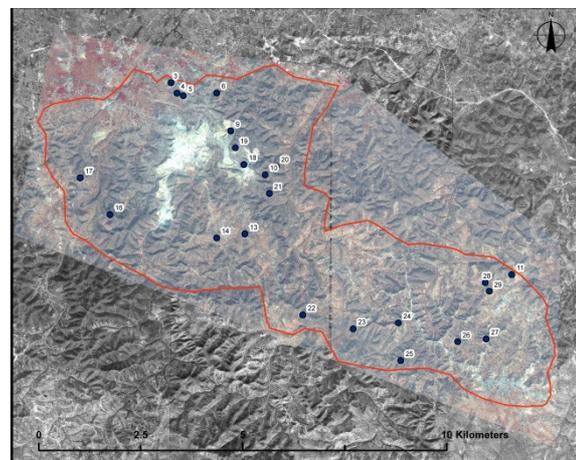


FIG. 9

Conclusions

The main objectives of the course were:

- To establish a new way of conceiving and visualizing the archaeological record as a complex system that comprises different elements of the landscape such as sites, roads, wadis, field systems, etc...
- To learn a new way of recording and storing archaeological information as spatial data into a GIS platform and to acquire basic skills of database spatial queries.
- To learn how to use Remote Sensing to identify and map archaeological sites both using high resolution imagery and Google Earth.
- To learn how to use Remote Sensing to map hazards and threats to the cultural heritage.

We covered all the topics, listed above, during the two weeks spent in Sfax and it seems that the attendees grasped the theoretical concepts behind the practical tasks and improved their use of basics tools introduced last year. The learning curve is long and the applications of GIS in archaeology are many, therefore we deem that from now onwards in future training courses for Staff need to work on their own data, so that we can discuss the specific applications they need.

The course/workshop of this year 2015 focused on the area of Gebel Nafusa and more specifically on the way to manage and handle field survey data at a regional landscape scale of analysis. There are other contexts and scales to tackle in the future such as excavation data or museum data, which have different ways of recording, mapping and storing information into a GIS platform. Considering the variety of datasets that they have to manage, we believe that focusing on definite tasks is the way forward.

As for the work on Gebel Nafusa, the future overall objective will be to create archaeological risk maps comprehensive of the whole variety of hazards and threats of the area.

Homework in preparation for the next course

Cyrenaica:

Using the case study of Tolmeita (for which a GIS has been already designed) they will work locating all the excavations and will monitor through the use of satellite images the expansion of the modern settlement.

Tripolitania:

They will work entering in the database all the surveys they have already completed so that in the next course they will be able, through remote sensing, to analyse the data

For the two regions:

Ancient mosques and Marabouts are under threat and therefore the mapping of these monuments will be carried out in parallel.