Thinking beyond the Tool

Archaeological computing and the interpretive process

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Deconstructing and Reconstructing the Landscape of Oxyrhynchus Using Textual Sources, Cartography, Remote Sensing and GIS

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Abstract
In this study, we present the work done within the project ‘The organization of space in Greco-Roman Egypt’, carried out with the support of the Plan I + D + I (HAR2008 -01 623) and the additional grant HAR2010-10 368-E, both of which were provided by the Spanish Ministry of Science and Technology. Our study involved the collection and analysis of data on archaeological sites and traces on the landscape. All this information was recorded using cartography and satellite images in order to reconstruct the ancient nomos of the Greco-Roman city of Oxyrhynchus (el-Bahnasa, Al Minya). Our work is the result of reading and analysis of texts written in the nineteenth and twentieth centuries on management of the flooding of the Nile and the reforms in the irrigation systems in the Middle Nile Valley. By amalgamating this information we were able to reconstruct the Egyptian landscape as it was before the arrival of Napoleon Bonaparte's expedition in 1799. We also use these results to discuss the application of remote sensing in archaeology.

Keywords: GIS; Remote Sensing; Description of Egypt; Oxyrhynchus; CORONA; ASTER; LANDSAT; PCA; TTC.

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1. Introduction

The study of the landscape of ancient Oxyrhynchus inevitably involves a process of ascertaining and consideration of the workings and management of the flooding of the Nile. This is understandable when we consider that Egypt has always depended on the seasonal and cyclical flooding of the Nile in all its facets. Its effects, apart from those of a natural cause, had a cultural, visual, social, economic, and religious impact on the entire country, creating a unique society that was different from other Mediterranean cultures. Control and management of the waters has been essential in ensuring food supplies and social order from the Predynastic era until the present day.

An understanding of the how the procedures, techniques and methods for managing and controlling flooding developed, especially during the nineteenth century when the country modernised the way it irrigated its land, is a prerequisite for any application of other landscape analysis techniques.

This assumption, which is the cornerstone for this project, is based on the tradition begun by the Besançon School in the 1970s. According to this school of thought, a process of understanding and analysis of major anthropic transformations of the natural landscape is necessary. These processes, which are related to the ways in which territories are organised and exploited, leave their imprints in the form of paths, land divisions, dikes and irrigation or drainage channels, and determine the organisation and structure of the anthropised landscape of the present and future. They are types of landscape which, become ‘morphogenic’ after they are created, due to their tendency to become widespread especially among the subsequent forms constructed with the passing of time (Levau 2000, 559-560). This morphological approach will enable us to recognise and contextualise them. However, this approach must be ‘historicised’ if it is not merely to be an exercise in detecting and modulating the traces (Orejas *et al.* 2002, 290)

The nineteenth century is therefore important to us due to the major changes and projects that took place, first under the French engineers directed by Mehmet Ali and then under the British protectorate. All these factors contributed to the major transformation and modernisation of the way the Nile's water was managed, in terms of both seasonal flooding and perennial irrigation. In the twentieth century, the construction of the Aswan Dam in the mid-1960s led to the final transformation and the end of a natural, social and cultural way of understanding and conceiving of the Nile.

The most spectacular example of this change is nineteenth-century Cairo. In August every year, after the announcement of the annual flooding by the Nilometer on Rhoda Island, the flooding began by breaking the dike that held the waters of one of the channels that crossed the city: the *Khalig al-Masri* (Linant de Bellefonds 1872, 39; Norden 1755, 44). The floodwaters entered the city, turning some of its streets and squares into canals and lagoons. The French artists and engravers that accompanied Napoleon's expedition to Egypt (Figure 1), who must have been influenced by the 'vedute' pictorial genre as painted by Canaletto, Guardi and Carlevarijs, depicted a city of Cairo affected by flooding which was completely adapted to the urban environment. However, the changes made to the Nile's flooding system in the nineteenth and the twentieth centuries drastically changed this phenomenon, banishing it not only from the landscape, but also very probably from social memory.

Figure 1 'Vedute' of the named Birket-el-Fyl square, in Cairo, during the flood. (Martin 1822, 80, plate 39)

Using this knowledge of the flooding and management of the waters of the Nile, we worked with an archaeological map of the area of the project, and recorded the archaeological sites and traces of water management (channels, dikes, etc.). These were recovered using map interpretation, photointerpretation, and remote sensing techniques, using first modern and historical maps, and then the medium and high resolution satellite images available.

We can use these traces and texts, which tell us about major irrigation projects, to reconstruct the landscape as it was prior to the nineteenth century. By ascertaining the major nineteenth-century projects that reformed or changed the landscape, we can identify the features that existed beforehand. Taking this as our starting point, and by reading primary sources, we attempted to interpret and reconstruct the landscape as it was in the ancient world, in anticipation of confirmation on the ground and corroboration of data using geomorphological and paleoenvironmental techniques.

2. From the eighteenth to the twentieth century: transformation and continuity in the management of irrigation in Middle Egypt.

2.1 *The sources*

The regressive study of the irrigation system in Egypt was based on an exhaustive review of a series of publications dating from the eighteenth, nineteenth, and early twentieth centuries. It should be noted that some of the nineteenth-century works were written by authors who were directly involved in the study, analysis, transformation, management, and improvement of the irrigation system by means of flooding or the perennial supply of water.

The sources studied from the nineteenth century were first, the series of works about Egypt published between 1809 and 1829 entitled *Description de l'Égypte, ou Recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de l'armée française*. This major work provided an encyclopaedic and scientific overview of ancient and modern Egypt. It was a collective work by a number of scientists, researchers, artists, and technicians, known as the 'Savants,' who accompanied Napoleon Bonaparte's expedition between 1798 and 1801.

The second source, which was also very important, was written by Linant de Bellefonds (1872) who was the Minister of Public Works and a member of Muhammad Ali's private council. His book, published in 1872, is a memoir of his experiences dating back to 1817. The text, which at some points is merely a narrative, goes into considerable depth at other points, presenting reports, budgets, and essential reference information on the irrigation system before the major changes, to which the author was a first hand witness and one of the parties involved, took place during the nineteenth century.

J. Barois (1887), the first Secretary to the Minister of Public Works, gives us essential information on the hydraulic management of irrigation in the Middle Valley of the Nile in 1887, almost 14 years after the construction of the Ibrahimiya Canal. This canal provided perennial irrigation to the eastern half of the Middle Valley and had therefore completely changed the water distribution channels and drainage system. The study was subsequently reprinted in 1904, with the details on the flooding by basins completed and updated.

Finally, Sir William Willcocks published the book 'Egyptian Irrigation' just two years after Barois, and it was reprinted in 1913 with James Ireland Craig (Willcocks, Craig 1913). This reprint is of major interest as it lists the changes and projects that took place between the end of the nineteenth century and beginning of the twentieth century. Willcocks began working in the Egyptian Public Works Department in 1883 onwards, and the projects in which he was involved included the supervision of the construction of the Aswan and Assiut dams. His work, divided in two volumes, is an exhaustive review of the defining features of the geographical, geological, and natural features of the Nile and its irrigation system. His work also defines, describes and classifies the dams, canals, dikes, and regulators and all the other items necessary for management of hydraulic engineering in Egypt, and how they were built.

2.2. *Flooding in the eighteenth century*

A review of some texts dating from before Bonaparte's expedition in 1799 gives only limited evidence of how the flooding of the Nile took place and the country's spectacular seasonal transformation. It should be noted that these impressions, which are sometimes written as travel memoirs, are part of the spirit of discovery of the *Grand Tour*, which had previously been limited to Italy. Some of these publications therefore take the form of expeditions or journeys, and contain a mixture of geographical, ethnographic, naturalistic, and archaeological descriptions, as well as mere anecdotes. Agriculture and flooding are therefore described in general terms, without entering into any detail, and the works are therefore not of a specialist nature. A meticulous description of flood management mechanics is only provided in a few cases.

Among the more interesting works is that of the impressions of Benoït de Maillet (1740, 87), who was Consul General in Egypt between 1692 and 1708. His perspective, which was that of a traveller, mentions the flooding from the point of view of a spectacle:

‘La vue de l'Egipte dans les terms d'inundation est sans contredit un spectacle le plus charmans du monde. C'est alors que du haut des montagnes on découvre une vaste mer, d'ou s'elevent des villes et bourgardes sans nombre qui n'ont de communication entr'elles que par des chausées élevées a ce dessein. Les eaux quelquefois sont si abondantes, qu'elles inondent les chausées mêmes. Alors la communication se fait en bateaux and ce n'est pas un mediocre agrément de voir, tout le pais couvert des maisons flotants.’.

This text, published in 1735, basically presents a situation very similar to that described by Herodotus two thousand years previously *(Hdt,* II, 97):

‘When the Nile comes over the land, the cities are alone and are seen rising above the water, resembling more nearly than anything else the island in the Aegean Sea; for the rest of Egypt becomes a sea and the cities alone rise above water. Accordingly, whenever this happens, they pass by water not now by the channels of the river but over the midst of the plain.’

It is obvious that the flooding created the same sense of astonishment despite the centuries that had elapsed. De Maillet (1740, 88) tells little more, except for the canals' role as an essential part of the flooding process:

‘C'est par là que l'Egypte approfite les acroissements du Nil; c'est par là que ses eaux son repandues dans tout cette contrée, and i portent la fertilitée’.

Louis Frederic Nörden, a Danish ship's captain, who explored Egypt and Sudan between 1737 and 1738, gives us a more specific view of the flooding of the Nile and its management and use (1755, 61-62):

‘Ces moyens consistent en des Digues and en des Calichs, ou canaux, que l’on coupe, on creuse dans les endroits, òu le bord de le Nil est bas. On les conduït jusqu’a les montagnes, au travers des provinces entieres; de sorte que, quand le Nil croît, les eaux entrent dans les Calichs qui les introduisent au dedans du pais, à proportion de la hauteur du Fleuve(...)’.

‘Quand il est cru a son point, and qu’il repandu ses eaux sur la surface de la terre; c’est alors qu’on pense de les retenir durant quelque tems, afin de que les terres ayent le loissir de s’abbreuver sufissanment. Pour cet effet, on practique les digues, apellées Giffer, qui empêchent que l’eau ne s’ecoule, and l’arretent auntant que le tems qu’on le juge à propos. Enfin quand la terre est assez arrosé, on coupe le Giffer, pour faciliter l’ecoulament des eaux(...)’.

This Danish author enables us to imagine how the flooding of the Middle Nile Valley was undertaken. During the flooding, excess water from the Nile was channelled into canals, which flooded the land that they surrounded after they overflowed. The dikes held back the water and stored it long enough for its supply to enhance the fertility of the harvest.

Jean Baptiste D’Anville, the great eighteenth-century geographer, presented a vision of Egypt in 1766 which was subsequently rejected by the *Savants*. According to the French author, the Middle Nile Valley had three major watercourses: the Nile, the Bahr-Yusef, and the *Bahr Baten*. The latter, which he mistakenly identified as the Lake Moeris mentioned by classical sources, ran parallel between the Bahr-Yusef and the Nile. The *Bahr Baten*, which came from the Nile somewhere between Minia and Samalut, continued until Benisuef. A series of canals ran across the valley between the Nile and the Bahr. D’Anville (1766, 154-156) makes the assumption based on classical sources that perhaps the *Baten* was not a natural phenomenon and there had been a series of dikes to hold back its waters. However D’Anville does not describe the phenomenon of flooding and when he observes the *Baten* he apparently does not understand its seasonal nature. His preoccupation with identifying and reconstructing the territory of ancient Egypt based on source materials prevented him when considering the *Baten* as a natural phenomenon and analysing it its anthropic management, as Norden had suggested.

Finally, in 1789, Claude-Etienne de Savary briefly described the effect of the flooding and tells us about canals as a means of distributing the floodwaters, and about the dikes that held back the waters (Savary 1789, 198-199).

Over the eighteenth century the various authors who mention the flooding of the Nile did not, therefore, go into exhaustive detail about the mechanics of the canals and dikes. They did know that the canals distributed floodwater in the Valley, while the dikes were used to contain the water and as a means of communication between towns and villages. Some of them justified the changes and transformations that took place over the subsequent century in terms of neglect and lack of maintenance of the canals and dikes, and the serious danger that this entailed for the country's future (Norden 1755, 62; Martin 1813, 199).

2.3. *Management of flooding in the early nineteenth century*

Dikes and basin flooding

All the nineteenth-century authors agreed that the control of flooding by means of dikes and canals had begun earlier in Egypt's history (Barois 1887, 8-9). However, nothing remained of these hydraulic structures, according to Barois, as neglect and disuse had destroyed any traces of their existence. However, Linant maintained that some ancient features of hydraulic engineering could still be seen on the landscape. This was true of the Kocheïche dike, located 6 km to the south of the modern town of Maidum, or the stone structures on both sides of the Nile between the cataracts of Aswan and Wadi Halfa in Nubia. Linant's experiences on his travels, when he explored the country for years before becoming a civil servant for the Egyptian government, confirms this.

The situation in Egypt prior to hydrographic management in the early nineteenth century was something that Linant, Barois, and Willcocks mention vaguely and without going into detail. Taking into account that there are no exhaustive details from the eighteenth century, and in some cases they are even confusing, only the *Description* by the *Savants* provides us with enough data for a reconstruction. The team of scientists that accompanied Napoleon's expedition to Egypt described how the system worked in the following terms (Girard 1823, 496-497):

'Ces canaux sont diriges dans le haut Egypte plus ou moins obliquement, vers les deux chaines de montagnes qui ordent la vallée: parvenus a leur pied, ils se prolongent parallèment au desert; mais des diques transversales en interrompen le cours, de sorte que ses eaux interropes par ces diques s'élevent contre elles et submergen une partie des terres qu'elles enferment.'.

'(...)Quand cette submersion atteinte sa plus grande hauteur on coupe la dique qui soutenait les eaux; elles s'ecoulent alors au-delà de cette digue, en suivant le même canal, qui se prolongue lui-même sur la limite du desert, jusq'a un second barrage qui, arretant de noveau les eaux, les oblige de se gonfler, et de se repandre, sur une partie de l'espace renferme entre deux digues tranversales consécutives.'.

'On coupe la seconde digué comme on avait coupé la premiere; les eaux descendent de la même maniere contre una troissieme ; qui produït à son tour la submersion d'une certaine étendue du terrain; et ainsi de suite (...)'.

In other words, the irrigation system consisted of a series of natural basins, separated by dikes, which were flooded by canals during the flooding season. Full advantage was therefore taken of the gradient of the Nile Valley until its mouth, in order to facilitate a uniform distribution of water loaded with sediment. As well as holding back the waters, the dikes, which were built with reinforced earth, also acted as a communications system during flooding periods (Girard 1823, 497; 1813, 352-353). These flood basins were known by the English and French respectively as *irrigation basins* or *bassins d'inoundation*.

In the early nineteenth century, the mechanics of this system consisted of the basins being flooded one after the other, so that when one of them was full and the water had been held back long enough for the sediment to be deposited, the dike was then breached. The water was allowed to pass along the canal that had flooded the first basin to drown the fields in the next one, until it was once again held back by another transverse dike.

These dikes, and especially the older ones, have a winding layout due to the fact that the breaches in the circulation points of the flow meant that the walls had to be repaired by moving them backwards or forwards from their original position. As a result, the dikes ceased to be arranged in a straight line as time passed (Barois 1904, 265-266).

The waters were not only controlled by breaching the dikes. In some dikes, brick bridges had been built with arches 3 metres long, with each pillar acting as a regulator. These enabled the water to circulate after it had been held back for a sufficient length of time in the previous basin.

The same work, when describing the hydrography of the province of Benisuef, lists three types of dikes: large, medium and small. The large dikes crossed the valley from one side to another, with the largest being the dike of Oukechechy or Kocheicha (Martin 1813, 198-199) and the other dikes being:

'(...)Behabchyn, Safanyeh, Saftrachin, el-Noueyreh, Choubak, Ehoueh, Badahal ou el Chantour, Samalout, Menbaâl et Bardanoah.'

This list is very valuable and useful as it is the first time that a source provides a list of dikes prior to the nineteenth-century reforms. A comparison with other lists for the basins in operation during the nineteenth century has enabled us to date some of them as modern. The same classification distinguishes the medium-sized dikes as those originating in the Nile, and the large dikes, which ended in towns built on mounds.

The flood canals

Part of the seasonal flooding of the Middle Valley was due to the flooding of the Bahr-Youssef. This natural canal follows a very winding course, with a width of between 50 and 60 metres and a maximum depth of 6 to 8 metres. With the flooding of the water, the high water level is confined by dikes and by the mountains defining the valley at all points to the west. Its waters reach the Fayoum, but it also acts as a feeder for the flooding of basins and as an overflow channel for their drainage when the waters fall (Linant de Bellefonds 1873, 14).

However, this natural course was not the only one involved in the water's flooding. *The Bahr Baten*, which was mentioned by D'Anville some years before, was studied by scientists on the French expedition. The Arab term *Baten* was a generic name applied to:

‘(…)presque tous les canaux qui parcourent l’interieur des terres dans direction du sud au nord’ (Martin 1813, 206).

However, the expression *Fyad Baten* was used to refer to large canals. The largest of these, according to the *Description*, was the source of some confusion with Lake Moeris by Granger, Sicard and D’Anville. The French scientists on Bonaparte's expedition say that the Middle Valley was crisscrossed by large canals running parallel to the Nile, which easily flooded the fields when the waters rose. Another *Fyad Baten* in the Middle Valley is described as follows:

‘(...)dont l’origine sur le Nil est entre le village de Nazlet-Abou-Esné et celui de Qalousaneh. Il passe au pied du village du Matâtyeh, ou il se divide en deux branches, dont l’une a l’est devient petit Bathen, et se perd, à deux lieus de là, dans les terres d’Abou Girgeh; l’autre, al’oest comunique pendat l’inundation avec le Bahr-youssef, au village d’El-Houeh: mais il n’a plus de trois lieues de longueur’ (Martin 1813,206).

We have been able to identify this *Fyad Baten* as one of the restored traces by studying the cartography and remote sensing. This canal follows a similar route to the one described by the Frenchmen (Figure 2). However, the *savants* do not all agree with each other about the use of this term. Jomard (1809, 104, note 2) says that

‘On dit un bâtin et plusieurs batin [el-bâtin, el-baouâten] ; ce mot Arabe, qui signifie intérieur, est parfaitement bien appliqué aux bas-fonds dont Je parle, puisqu'ils forment la partie la plus basse et la plus intérieure du pays : ils conservent de l'eau presque toute l'année, et ils offrent, par endroits, l'aspect d'un canal continu.’

They were therefore not natural canals, but instead low-level locations which retained the water throughout the year after the flooding took place. The explanation for this phenomenon was the unusual layout of the Middle Valley. It was defined by two sloping plains, one from the Nile, and the other from the Bahr-Youssef. Where they came together, they formed a basin or lower-level area which allowed water to be retained for a long period of time and which is why it was called *Bahr Baten* (Martin 1813, 201), i.e. Inner River. In some cases, these low-lying beds ended up becoming natural canals due to overflows from the Nile. *Bahr Baten* was therefore a generic name, although if it was necessary to distinguish a large canal, the term *Fyad Baten* was applied.

In another volume of the *Description* Jomard (1818, 260) once again describes the phenomenon of the *Bahr Baten*. According to the text, it flowed irregularly from near the ruins of *Hermopolis* to further south of Minieh, and was known as *Tera’t el Ghouetat* and *Tera’t el-Sebakh*. Both Linant de Bellefond and one of the cartography plates in the *Description* depicted this canal in great detail (Figure 3). Taking into account that the first major canal to be built in the in Middle Nile Valley was the Ibrahimiya, which was constructed in 1873, and Linant mentions no earlier canal in this area in his memoirs in the nineteenth century, we must assume that it already existed at that time and was one of the preexisting *Fyad Baten* canals that crossed several provinces.

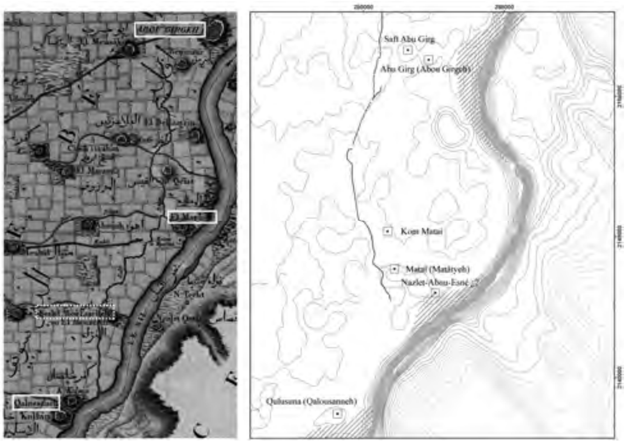

Figure 2 Identified traces of the *fyad Bathen* described by Martin 1813,206

Another plate in the *Description* (Martin 1822, 14, Plate 6) depicting the hydrography of the Middle Valley shows us a plan that places this *Baten* between Hermopolis and Minieh. The authors produced a whole series of sections of various stretches of the valley which included the Nile, the Bahr-Youssef and the Bahr-Baten. Unfortunately, the work only focused on the area between Samalout and Minieh, which is beyond the scope of our study.

Almost sixty years later, Linant de Bellefonds (1873, 3) gives us another perspective on how the flooding of the Nile worked before the nineteenth-century reforms:

‘Lorsque les eaux coulaient librement dans les plaines, celles ci se trouvaient ravines partout par les eaux des crues, et plusieurs de ses ravines conservaient pendant les etiages una certain quantite d’eau courante; aujourd’hui meme il existe beaucoup de ces ravines ou cours d’eau naturales dans toute l’Egypte.’

‘En descendant du sud vers le nord, on recontrait de ces cours d’eau considerables pendant les crues, et a peu a près dans le même état qu’ils étaient avant que des travaux fussent venus régulariser les débordaments du fleuve; mais aujourd’hui ils sont en grand partie maîtrises et utilisés pour les arrosages.’

In other words, the flooding consisted of allowing the water that overflowed from the Nile to be channelled naturally along natural streams or watercourses and the valley was flooded from those. Some courses retained part of the water throughout the year, while the rest stayed dry. Linant therefore stressed the natural character of these canals as a consequence of the retention and regulation of water by means of dikes. Once they were opened or if they originated in the regulators, built, the waters were channelled seasonally by natural means (Linant de Bellefonds 1873, 4):

‘Plusieurs autres ravines ou cours d’eau naturels existent dans les plaines de la Haute-Egipte et surtout dans la Moyenne, mais ils sont de bien moindre importance que les deux precedents (Sohagieh y Bahr Youssef). Souvent ils prennent leur origine en aval d’un des nombreux deversoirs pratiques dans le diques des bassins d’inondation; les eaux, qui echapent par ces déversoirs ravinent la plaine et forment alors des bas fonds que l’on nomme Bathen , ce qui veut dire lieu bas.’

Figure 3 The Bahr Bathen: 1) Jacotin 1826, 44, plate 14. 2) Linant de Bellefonds 1854. 3) 60's CORONA image, detail of the same area.

Linant de Bellefonds also uses the term *Bathen* to refer not to the canals, the *Fyâd Bathen* in the *Description*, but instead to the riverbed where the waters accumulated. The water from one of the flood basins was channelled and distributed by means of natural watercourses, forming natural lagoons at the lowest points above sea level. However, one can assume that these watercourses or streams were part of a system of canals of anthropic origin which had become natural due to the lack of maintenance mentioned by various eighteenth century authors.

However, these natural courses were not the only ones, as according to Linant (1873, 19-20) there were canals called *Nili*, which were only used during the Nile floods. They were dug at four metres below the water circulation level and their depth decreased until they reached the land to be flooded, at which point the canal disappeared. Some crossed entire provinces and channelled water by means of diversions that were used for floods. Linant made a distinction between these canals and those known as *sefi* which supplied perennial irrigation, and which he attributed directly to Mohammad Ali's government, as there were no references to the contrary. However, by doing so Linant shows us that the *Nili* were canals that predated Mohammad Ali's government. Linant's description matches the *Fyad Baten* or the *Bahr Baten* in the *Description*.

2.4. *Subsequent transformations*

The Ibrahimiya Canal was opened in 1873, beginning perennial irrigation in the Middle Valley and leading to the introduction of sugar cane (Barois 1887, 28).The head of this 268-km long canal is at Assiut, and it waters the higher land near the Nile, from which it takes its water. This canal, which runs parallel to the river, was built using some of the old stretches of canal (Barois 1887, 40), in the same way as many of the sefi canals built during the reign of Muhammad Ali were built using stretches of the old Nili canals. Its discharge provides water during the summer, together with that of the Bahr-Yussef. The latter's head was changed to receive the discharge of the Ibrahimya.

During flooding, the Bahr Youssef was used to feed the basins that covered the area between the dikes located in Derout and the dike of Kocheicha, in the north of the province of Beni-Souef. In the second half of the nineteenth century, the Bahr-Youssef itself acted as a feeder for a series of 16 basins that covered a distance of 200 km.

The basins flooded by the Bahr-Youssef and the land irrigated by the Ibrahimiya were separated by a large longitudinal dike called *mohit* (Barois 1904,94), which ran from Derout until the end of the canal. This is very interesting, as it gives us details of a landscape adapted to the two different systems for water management and cultivation which were separated from each other by a line set at a right angle.

In 1897, work also began on the conversion of the basins system in Upper Egypt to perennial irrigation. In 1904 Barois reprinted his work and says that both systems operated separately but that there were some exceptions to the rule. First, there was the low-level land in the flood basins which could extract water from the water table using a water pump, a *sakia* or *shaduf* (1904, 51-52). Crops could therefore be irrigated before the flooding took place. This system was called a qedi. The canals used for the flooding, the *nili* mentioned by Linant that were only used when waters rose, were also used to channel the water extracted using pumps or waterwheels located near the Nile and the Bahr-Yusef (Barois, 1904, 97-99).

Willcocks says that ideal model for a basin would be one with perennial irrigation from the subsoil enabling the cultivation of sugar cane for one or two years, which would then be flooded for one year (Willcocks, Craig, 1913, 347)

Finally, in 1894, a technical committee of the Ministry of Public Works produced a report to ascertain which of the locations in the *Wadi* proposed by the government engineers in Cairo (including Willcocks) would be chosen for the construction of a large dam (Willcocks, Craig, 1913, 681). This committee's unanimous conclusion was that Aswan was the only possible location for a reservoir that could store enough water from the flooding and which could supply a sufficient volume of flow to the Nile Valley during the summer. After the plan was approved, work began in 1898 and the Aswan Low Dam was completed in late 1902. It was nearly overtopped in 1946, and it became apparent that a larger project was necessary. This project was not planned until 1954, as part of the shift towards Egyptian nationalism under Nasser. Work did not begin until 1960, the first planned dam was completed in 1964, and the project was finished in 1976, when the reservoir reached its full capacity, providing all of Egypt with perennial irrigation. It appears that the flood basin system was still in operation in 1964, and that the dikes were no longer used after that date, and the flooding that was a feature of the Egyptian landscape until that point passed into memory.

3. Methodology

The sections above show that the process of transformation and change in the Middle Valley was a complex one. The large hydraulic infrastructures, irrigation and drainage channels built during the nineteenth century overlaid and concealed the systems dating from before the 1799 expedition. We therefore know how the flood basins structured by dikes operated, the various definitions applied to the term *Baten*, the difference between a *sefi* and a *nili* canal and we know that the valley was transformed in various stages over more than one hundred years, with each change leaving its imprint on the land. In view of these assumptions, we applied methods and techniques, which we used to reconstruct the various landscapes of the Middle Valley in the nineteenth century, as well as an initial consideration of the area around the Oxyrhynchus site.

3.1. *Data sources*

Cartography

Our work, based on the premises and methods of an archaeomorphological study above all required a regression analysis and synthesis of the modern and historical cartography of the territory studied.

Using this criteria, we compiled the modern topographical maps of the province of Minieh and Beni Suef (scale 1:50K) produced by the Egyptian Survey Authority.

As for cartography produced prior to the construction of Aswan Dam, we digitised and georeferenced the topographical plans (1:50K, 1:100K, 1:200K) produced by the Survey Department of Egypt between 1906 and 1939, when the country was a British protectorate. The precision and detail of these maps was essential in the detection of the structures used in the country's hydrographic management.

In both cases, the use of these sources facilitated the location of place names of settlements mentioned in documents from the nineteenth century, despite the variation they have undergone over the past two hundred years. All the features recognised using this medium were added to the SIG, creating the appropriate vector layers: cities, current place name, hydraulic infrastructures, courses of the Nile and Bahr-Youssef, etc.

The nineteenth-century cartography used was based mainly on the *Carta Hidrographique de la Moyenne Egipte* by Linant de Bellefonds, produced in 1854 and revised in 1883. This plan was very useful in the reconstruction of the Middle Valley during the nineteenth century due not only to the quality with which it was produced over a large area, but also because it includes very useful place names and details such as the location and structure of dikes and regulators, and the location of several planned construction projects in 1854.

A problem for which we did not find a solution was involved in the 51 1:100K scale plans that accompany the *Description de l'Egypte*. The problems and errors in its location of settlements and the location and paths of dikes and canals (highlighted by Gomà) were sufficient grounds not to use them as a main source of work or as support cartography in the research. We only occasionally used some of the plates in the work by the *Savants* for the purposes of illustration of the discussion on the *Bathen.*

Satellite images and DEM

Remote sensing was the second means of study, due to the spatial information it provides and which is not subject to conceptual filtering by cartographers.

Its application in archaeology can be dated back to the aerial photographs of Stonehenge taken by Sharpe on the Salisbury plain in 1906. In subsequent years, the various wars in the international arena, the length of combat fronts and the need to ascertain military and industrial logistics on the opposing side during the Second World War led to large-scale aerial photography. Archaeologists were recruited to the secret services to help interpret them, and at the end of the conflict they used these resources and knowledge to publish their observations during the 1950s.

The Cold War and the Space Race led to satellites being placed in orbit that were able to generate global coverage of the planet, and these coincided with the first publications on multispectral treatment of applied images in archaeology in the early 1970s. The spatial resolution of satellite images and multispectral capacity is now the latest major technique that archaeology that has been used to locate smaller scale structures (Parcak 2009, 13-39).

Over the years, the publications on remote sensing applied to the Egyptian landscape have focused above all on the areas of the delta, the Middle Nile Valley and the Sinai peninsula (Parcak 2007; Parcak, Mumford 2002), the reconstruction of the course of the Nile at Karnak and Memphis (Hillier *et al.* 2007; Bunbury *et al.* 2008; Lutley, Bunbury 2008); the formation of the island of Edfu during the New Kingdom (Bunbury *et al.* 2009), and the detection of a Canopic channel (Stanley, Jorstad 2006).

During our project, we carried out a meticulous search and selection of images from various satellites, and endeavoured to include photographs from various times of the year. This latter consideration was in order to increase the probability of detection of traces that probably appear during specific seasons.

Most of the images were obtained from the USGS Earth Explorer server available on the Internet. In specific terms, the images were captured by the LANDSAT and CORONA sensors. The ASTER 1B images were purchased from the company ERSDAC (Japan).

The CORONA images, which were declassified in 1995 by the Clinton administration, are one of the first series of images on a satellite with global coverage obtained during the Cold War in the period between 1960 and 1975. The KH 4B series provides the best results due to its high quality and the fact that the images were taken at resolutions of around 2 metres/pixel. Their global coverage, especially in Asian and African regions, makes them an essential benchmark in any landscape study (Parcak 2009, 52-57).

In the case that concerns us here, the major point of interest is that it is an extraordinary source of information about the Middle Nile Valley between 1960 and 1976, the period during which the Aswan Dam was constructed. The images show features and traces in the basin flooding system. The landscape captured was still unchanged by the urban and territorial development of the 1980s and 1990s. Its use combined with more modern images from other sensors show the major transformations that have taken place over the last thirty years.

However, it was necessary to acquire Quickbird (5-02-2009) and Worldview 2 (23-06-2010) scenes with resolutions of 0.6 and 0.5 m/pixels respectively for a more detailed study of the area closest to the city of Oxyrhynchus. The multispectral features of WV2 (8 bands) were used, applying various types of analysis which will be discussed in the sections below. We also used these images to georeference the Corona images taken in the Oxyrhynchus area.

Furthermore, analysis of the topography of the Middle Nile Valley, and some operations such as orthorectification of images requires digital elevation models (DEM). In these cases, it was necessary to use public servers such as CGIAR-CSI, which provides a 90 m/pixel DEM, STRM-90 which has global coverage and the recent ASTER GDEM product ERSDAC with resolutions of 30 m/pixel.

Problems with GDEM

Using Aster GDEM showed us a series of anomalies that are not visible on high-resolution images or on Google Earth. We initially thought these anomalies were old dikes or large deposits of water. However, the ERSDAC GDEM website contains a recent update which provides information on anomalies in the product similar to those we saw, and emphasises its ‘experimental’ nature, which therefore forced us to discard the hypothesis.

Generating our own DEM

These problems forced us to seek other solutions. One of these was to create our own DEM using ASTER 3N and 3B bands. These two bands, captured at the same time but with a stereoscopic timelag, use photogrammetry techniques to create stereo images and to extract a DEM with a resolution of 15 m/pixel. Other projects have used 3N and 3B bands to generate a DEM of the area near the city of Zagora, in southern Morocco (Lee *et al.* 2008).

Another source used to create the DEM was the images from the CORONA sensor as it simultaneously captures two stereoscopic images (Dashora *et al.* 2007). Other projects have applied this technique to generate high resolution digital elevation models (Galiatsos *et al.* 2008).

Database and GIS

We created a database containing the sites included in the study by Farouk Gomaà, Renate Müller-Wollermann and Wolfgang Schenkel (1991). This database was imported in ArcGis 9.3 with the basic cartography and the satellite images. By superimposing all this information, we created layers matching the traces of canals or dikes we found in the observation and analysis of both the cartography and the images.

3.2. *Spectrum analysis techniques*

Thanks to the software ERDAS Imagine 2010, it was possible to apply various spectrum analysis techniques to the series of selected images. The different spatial resolutions provided by each type of sensor meant that it was possible to use various approaches depending on the working scale we were adopting.

Combination of bands

The multispectral images were composed of bands capturing various regions in the electromagnetic spectrum. Each of these bands acts on natural or geological features in a different way. It is initially only possible to combine three bands in one image, highlighting differences and contrasts such as those resulting from different vegetation growth. For example, it is possible to use LANDSAT images to combine the 4-3-2 (IR-R-G) bands to produce a new image in which the IR band highlights cases in which there is a greater or lesser density of vegetation, related to greater wetness (Mumford, Parcak 2002; Altaweel 2005)

Normalized Difference Vegetation Index (NDVI)

It is also possible to use an image to work with its constituent bands so the result only highlights specific characteristics recorded within their spectrum. For example, this is the case with the Normalized Difference Vegetation Index (NDVI), which is associated with the health of the vegetation and therefore the existence of walls, trenches or canals beneath sediment. The presence of these structures implies a higher or lower level and decomposition of organic components that retain humidity to a greater or lesser extent, and therefore highlight their existence by means of changes in the density of vegetation (Parcak 2009, 92-94). NDVI is therefore an analytical technique that compares the IR and R bands from multispectral images. We used this technique with images obtained from medium and high resolution multispectral sensors: Landsat, Aster, and WV2. The problem arises when it is applied to areas in which there is a high level of desertification or the presence of dunes. In these circumstances, which apply in the area we studied, we found that it was better to apply another type of analysis, such as PCA or Tasseled Ca

By using NDVI, we located some canals that had silted up through disuse or which were replaced in the nineteenth century by deep canals designed for permanent irrigation (Merola et al., 2006; Rowlands, Sarris, 2007; Masini, Lasaponara, 2007)

Principal Component Analysis (PCA)

One way of eliminating the redundancy in the electromagnetic spectrum captured by a scene from a multispectral sensor is to reduce the bands to a series of new components that contain much of the original information. This method, known as Principal Component Analysis (PCA), enables the identification of both the features recorded on most bands and those that are specific to a group of them. The synthesis capacity of PCA makes it a very useful technique for filtering the images as a step prior to other multistation analyses. It is this capacity which is useful in the selection of the most significant information from each period or season studied (Chuvieco, 1996). Its application in archaeology has led to the detection of sites (Stafford et al 1992), buried walls (Garbuzow 2003) and archaeological anomalies on images from the IKONOS sensor.

Tasseled Cap (TTC)

Tasseled Cap (TTC) is a transformation applied to multispectral images which obtains new bands from the linear combination of the original bands, enhancing the features of interest in each scene. The difference compared to PCA is that TTC shows components with specific physical characteristics; in other words, regardless of the type of image that is being analysed.

Kauth and Thomas (1976) created this technique as part of the LACIE project (Large Area Crop Inventory Experiment) developed by NASA and the US department of agriculture (USDA) in the 1970s. The basic variation components in a Landsat MSS image were analysed and their physical characteristics described from the perspective of monitoring crops. The authors of the study made a distinction between three components in the series of images: one called brightness, which is the pondered total of the four original Landsat bands; another called greenness, related to vegetation growth; a third known as yellowness which was used to describe the decline in the vitality of vegetation, and, finally, a fourth, *nonsuch*, with no apparent meaning. They began to be more widely disseminated in the 1980s, and were applied to other sensors, particularly the LANDSAT TM and the AVHRR (Crist and Cicone, 1984b; Cicone and Metzer 1984). This application led to the detection of a fifth component related to wetness.

The technique was also applied to high spatial resolution multispectral sensors such as IKONOS, with the territory of Metapontum selected for its application (Horne 2003).

Fusion of images

One of the problems we found when working with multispectral images was that some of the bands of which they are composed are captured at a different spatial resolution, thereby hindering the combination and treatment of the bands as a whole. For example, it was impossible to combine the SWIR and TIR bands in an ASTER scene with the UNIR bands because the former had resolutions of 60 and 90 m/pixel compared to 30 m/pixel in the latter. In another case, if we applied a combination or PCA to the multispectral bands in a WV2 scene, the resulting resolution would be 1.8 m/pixel instead of 0.5 m/pixel in the panchromatic image.

To solve this problem, we used fusion tools in order to combine a high resolution image (such as WV-2 Panchromatic 0.5 m/pixel) with the other multispectral bands at a lower resolution (1.8 m/pixel). One of the techniques applied was Ehlers Fusion, designed and implemented by Manfred Ehlers at the University of Osnabrück (Ehlers, 2008).

However, version 9.3 of ArcGIS includes a feature for online fusion of a multispectral image with a high resolution panchromatic image (Pan-Sharpening), thereby avoiding the need to create large new files.

3.3. *The Oxyrhynchus landscape: working scales*

We used several strategies to study the Oxyrhynchus landscape, applying different working scales depending on the various sources used.

We considered that before undertaking an archaemorphological study based on traces of division, paths, smaller dikes, and canals, we needed a regression which reconstructed the flood basin system and the changes that took place due to the construction of knowledge irrigation channels such as the Ibrahimiya canal.

The study of the basins system in the Middle Nile Valley first required a large scale approach, using written and surveyed nineteenth century sources. We used this approach to reconstruct the various phases and transformations that changed this region in the arrival of Bonaparte's expedition in 1799 and the end of the nineteenth century. The area studied (Figure 4, label 1) is the valley between Samalout and Maghagha, with an approximate total area of 1,304 km2.

Using a smaller scale and in the absence of detailed historical cartography for Banhasa and Sandafa el Fahr, the two settlements that have emerged near Oxyrhynchus, we worked on the landscape directly by analysing the satellite images. In this second approach, we organised the study based on three approaches or open windows on the project area. The first (Figure 4, label 2) begins one kilometre to the south of Oxyrhynchus and covers an area of 80 km^2 between Bahr-Youssef and the foothills of the Libyan mountains. The second (Figure 4, label 3), a smaller area of 5.25 Km^2, is located to the west of the site, and our intention was to analyse the immediate physical area surrounding the Greco-Roman city. Finally, the third area on which we used this approach was the site itself (Figure 4, label 4).

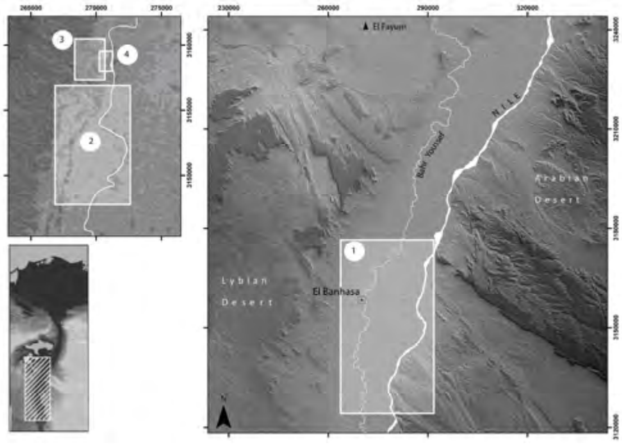

Figure 4 Project area.

In all three areas, we first applied TTC and PCA techniques to the images captured by various multispectral sensors (Landsat 4-5 TM, MSS) between 1984 and 1999. The result (Figure 5) showed various traces of paths, *wadi*s, canals, and unidentified features which we analysed using a diachronic process, eliminating those that did not exist prior to 1984 the first date for which scenes are available. At the same time, we recorded the degree of transformation of the rural area near the modern town of Bahnasa.

In practical terms, the application of TTC to this area has shown that the best results were obtained with a combination of the components 2-3-4 (greenness, yellowness, and wetness) and the components 3-4-6 (yellowness, wetness, and the unidentified component 6).

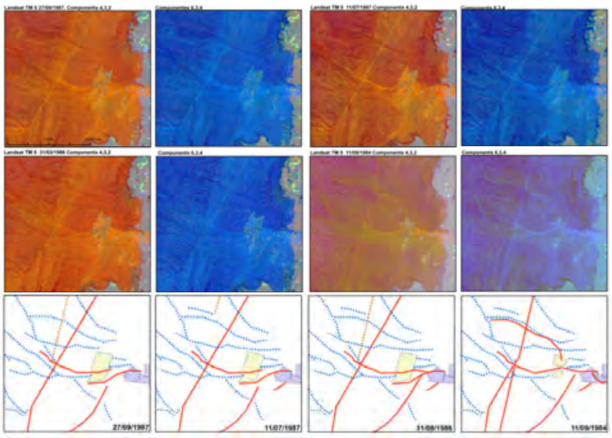

Figure 5 PCA applied on diferent Landsat images.

These detected marks and the synthesis and elimination of the inherent redundancy between the various bands in a single image were then superimposed on CORONA, QuickBird and WV-2 high resolution scenes. PCA and TTC techniques were also applied the latter case in order to analyse them in greater detail.

4. Results

4.1 *The large-scale approach: The Middle Valley in 1800*

The reconstruction of the basin system as it was in 1800 is more interesting. In the absence of documentation about the Mamluk period, we found sufficient items in the *Description de l'Egipte* to give us some idea of the hydraulic organisation of the Middle Valley. Unfortunately, the data were not compiled directly from the cartography in the Description, which, as mentioned above, is impossible to use due to its errors in the location and representation of dikes and canals. Furthermore, the list of the dikes in the text is not based on any geographical order enabling direct identification. However, a combination of Linant's 1855 plan, which is more precise, and the list of the dikes by the authors of the Description helped to reconstruct the landscape as it was in 1800. There are indeed phonetic variations between the place names used in the two sources and this means that the location of some of the dikes may be open to argument. However, we found no others in Linant's cartography that fit the description better. The list of large dikes includes those that existed in 1800 and which could have structured the flood basins system in the Middle Valley. The Savants' assumption is very clear - a large dike is one that crosses the Middle Valley transversally from the Nile to the Bahr-Youssef. On the 1855 plan, Linant labels dikes that meet that condition, but which were not listed in the Description. These dikes can therefore be included in Mehmet Bey's remodelling programme that took place in the Middle Valley between 1820 and 1855.

A comparison of the two sources shows the following place name equivalents:

Description de l'Egypte	***Linant de Bellefonds***	***Actual***
Behabchyn	*Babechine*	Haud Bahbasin
Safanyeh	*Saffannie*	Safaniya
Saftrachin	*Safi Rachine*	Saft Rachine
el-Noueyreh	*Nonewere?*	Haud an-Nuwaira? Nuera?
Choubak,	*Chobak*	¿?
Ehoueh,	*Elloué*	Helwa?
Badahal, Chantour	*Bedal, Chantour*	Badah, Ash-Shantour
Samalout	*Samalout*	Samlut
Menbaâl	*Minbal*	*Minbal*
Bardanouâh	*Bardanou*	Bardanuha

Based on the traces found and the previous studies Faruk Gomà, we followed a north-south order for the location of the eleven dikes in the Description.

First, we identified the dike known as Samalout in the *Savants*' list (Figure 6, label 1). On Linant's cartography, a little further to the north of the old city of Dehir-Samalout is the dike which we identified as the Samalout named in the *Description*.

The second and third dikes (Figure 6, label 2, 3) are easier to identify as they are either match operating flood basins on Barois' list or place names that still exist: Bardanoah or Berdanou according to Linant (today Bardanuha), and Menbaâl, today the village of Minbâl. On his plan, Linant draws two dikes near these settlements.

The fourth dike in the Description is called Ehoueh (Figure 6, label 4). In our opinion, it matches the settlement labelled by Linant as Elloue, which could be what is known today as Hilwa or Helwa. Linant also shows a large transverse dike a short distance from the town.

The traces detected match two dikes located between Garnus and Tambidi. We found no place names that we were able to assign to any of the dikes listed in the *Description*. However, on Linant's plan these two dikes are clearly shown next to an important system of regulators.

Safanyeh is another dike named by the Savants (Figure 6, label 5). Linant draws a dike near a settlement labelled as Safaniya which is today the town of Safania. This dike still follows the same route between the Nile and the Bahr-Youssef.

There are then three dikes Linant draws on his plan but which do not match any of those mentioned by the French expedition, and must therefore date from after 1800. The first still follows a significant part of its course to the south of the modern town of Muzura, the second must be located near El Fashn, and the third, which we were unable to identify, must be in Ifaqhs.

Continuing northwards, we find the sixth dike in the Description (Figure 6, label 6) for which the *Savants* gave two possible names for reference: Chantour and Badahal. On Linant's plan, the first place there has the same phonetic and is a town today known as Ash Shantour. There is greater variation in the second place name, as Linant labels it as Bedal and we can identify it as the modern town of Badah.

The seventh dike (Figure 6, label 7), called Saftrachine or Saft Rachine, retains almost the same name today.

To the north is the eighth dike (Figure 6, label 8), Choubak, in a settlement that Linant calls Chobuk.

The ninth dike (Figure 6, label 9) is the one that could cause the greatest problems due to its phonetic variation. The *Description* calls it Noueyreh, while Linant labels a settlement with the name of Nonewere, located between the settlements of Dindil (today Dandil), Bouche Cora (Bush), Ennasi el Medina (Ihanasya el Medina) and Beni Souef. Monitoring of this dike of Noueyreh by remote sensing provided us with data that could date it from prior to 1800. To the south west of Ihanasya el Medina, at the western end of the dike, is the tell of Herakleopolis Magna. The idea that the city had a large dike for holding back the waters that also acted as the main communication system for travellers on foot during the floods is thought-provoking.

It is followed (Figure 6, label 10) by the dike of Behabchyn or Babebchine. Its location is confirmed by the name that Barois (1887, 42, table) uses for the flood basin located immediately to the south: Bahahshin or Bahahehin. The modern place name is Haud Bahbasin.

Finally (Figure 6, label 11), there is the dike of Cocheicha or Oukchechy, about which there is no argument, as it is mentioned by all the sources as being ancient (Barois 1904, 267). Linant includes it on his map and labels it Cocheicha. It is located approximately 6 km to the south of the town of Maidum, running from the Nile between the modern towns of Al Maslub and Bani Ghunaym to the desert at Kom Abou Radi.

There is a significant gap on our list. The scientists who wrote the *Descripton* do not include the dike of Garnus on their list. It is surprising that, despite the dike of Garnus meeting the requirement of running from the Nile to the Bahr-Youssef, it is not mentioned in the *Description*, but is shown on Linant's plan. Based on the criteria of the Savants, we must assume that at least one of them was built between 1820 and 1855.

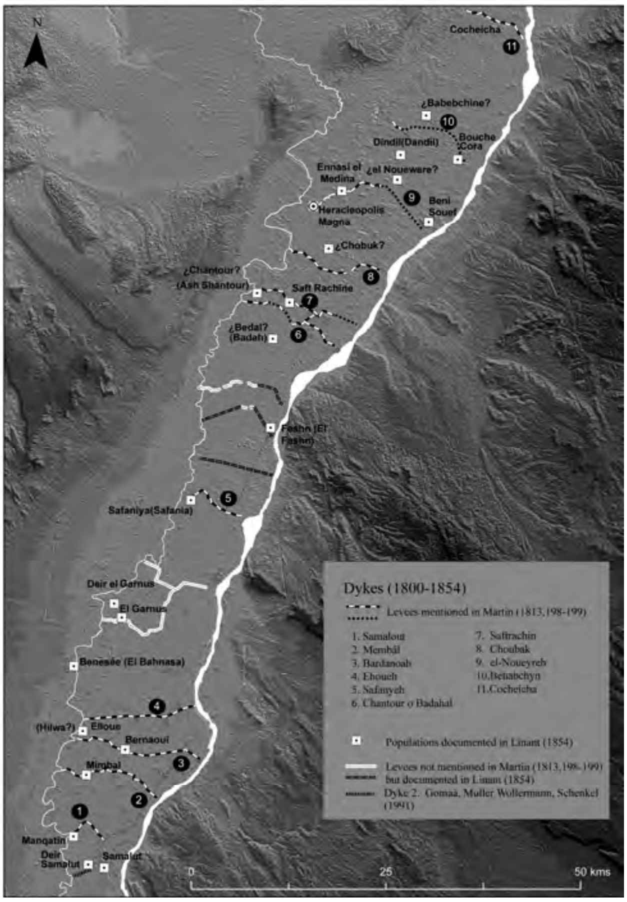

Figure 6 Dikes identified on middle valley.

This line of reasoning does not concur with the study by Wolfgang Schenkel (1994) which identified this dike using a text dating from the Roman era. Given their configuration, these dikes came together at a point where the modern town of Tambidi is located, which could suggest an error in appraisal by the *Savants*, who, it must be remembered, classified the dikes originating in the Nile that were linked to another large dike or with a settlement located on a mound as medium-sized. As a result, taking into account Schenkel's hypothesis, they may have assumed the two dikes to have been three medium-sized dikes. However, Butzer (1976, 12) says that the dikes built prior to the nineteenth century had been used to make the alluvial plains into natural flood basins, which were longer than the nineteenth-century subdivision of the basins. Butzer's opinion is of particular importance given the large area covered by the two continuous basins separated by the dikes of Elloue, Safaniya, and Badahal if our hypothesis is correct. However, assuming that these really were the basins that were operating, the problems arising from the long time required for the basins to fill suggest that the system was changed in order to share them with other dikes.

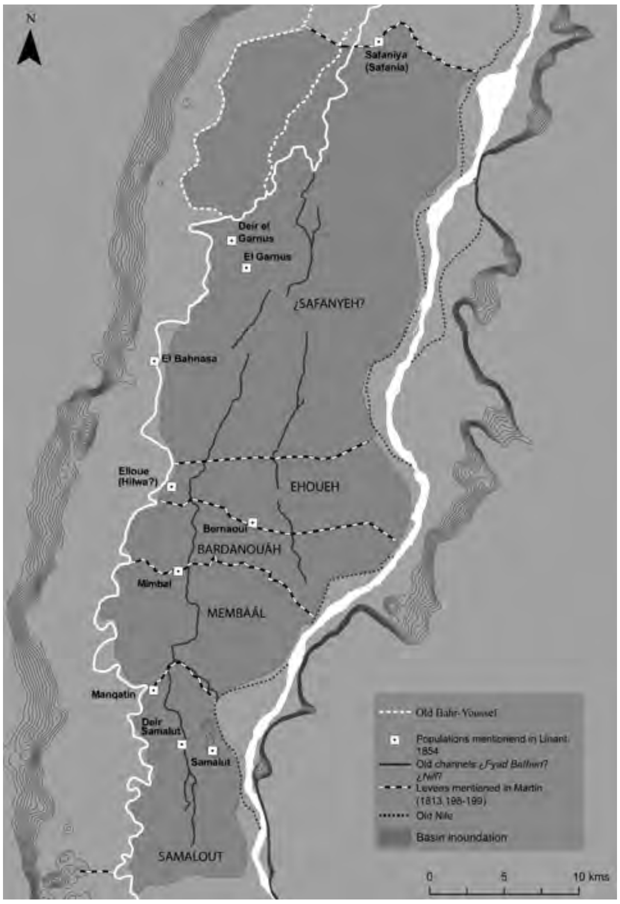

Figure 7 1800's Bassin inundation system on middle Valley

The observation of Barois (1904, 60) is interesting in this respect, as he says that the last basin in a chain is always the longest and widest. The reason for this was that if an unanticipated disproportionate flooding took place or mistakes were made in the emptying manoeuvres, the solution was to create successive breaches in the chain of dikes, thereby relieving the overflow. The last basin bore the excess water as its area was the largest. However, a smaller basin meant that the dikes were subject to less tension and stress from the water stored. They also solve the problem caused by sharp gradients, thereby making the water easy and economical to distribute. According to this argument, the smaller basins of Bardanoah, Menbâal, and Ehoueh, and the larger basin defined by Safaniya most probably by Chantour would form a chain of basins fed by the Bahr-Youssef, the Nile and the various Fyad Baten.

The intermediate nature of the area between these two large basins separated by the dike of Safaniya is interesting. Rough calculations suggest that the distances between the dikes of Elloue and Safaniya and the latter and Chantour are around 26/27 and 27/30 Km respectively. These data could suggest that this was a rational structuring of the space prior to the nineteenth century reorganisation. In this previous design, the

Safaniya dike would have been an important feature in the definition of spaces as it is almost equidistant from the dikes of Elloue and Chantour.

Based on this analysis, we agree with Schenkel (1994, 29) who believed that the dike of Safaniya (the seventh dike on our list) dated from before 1800, and he identified it as the Seper-merou in Wilbour's Ramesside papyrus.

Using these data, we constructed a final plan (Figure 7) showing the flood basin organisation of the Middle Nile Valley in 1800. In the layout of these basins, one is of particular interest due to its size. We have called it Safanieh as it is the oldest dike and due to the tendency to use the name of the northern enclosing dike for the basin as a whole.

On this basis, we included the traces of the canals identified by map interpretation and remote sensing. We saw above how one of them matched the Fyad Baten in the Description, and we assume that the other trace also does so. The westernmost enabled the floodwaters to be distributed in the basins of Samalout, Membaâl, Bardanoah, Ehoueh, and Safanieh, finally overflowing into the Bahr-Youssef; while the second, described by the Savants, enabled the flood waters of the Nile to be distributed directly into the basins of Bardanoah, Ehoueh, and Safanieh, with its water discharged into the latter as the water level fell.

Finally, we have shown the old course of the Bahr-Youssef on the plan, which the Savants mistakenly thought was the real course of the canal.

4.2. *A smaller scale study of the Oxyrhynchus landscape: a study in remote sensing*

The area located to the south of Oxyrhynchus

The outstanding geographical feature in this framework begins at a distance of 4.5 kilometres to the south of Oxyrhynchus, between the settlements of Dayr as-Sanquiriyyha and Hilwah, where the Bahr Youssef forms a large meander (Figures 8 and 10). The composition of bands with Landsat images, NDVI analysis and CORONA images shows that the west bank of the meander is crisscrossed by a series of canals similar to the *Nili* canals described by Linant. Some are today silted up as they no longer channel and distribute irrigation in the area during flooding. Others were channelled as part of the change that took place in the 1960s with the construction of the Aswan Dam.

To the east of the meander, the topography shows a slight longitudinal elevation (Figure 11, label 10) which is a large sandbank or dune, the width of which varies between 300 and 500 metres in a NE-SW direction. According to Butzer (1959,75-76), these dunes are aeolian deposits limited to the western side of the valley, which extend longitudinal and on an irregular basis over the 128 kilometres between Gebel Deshasha (Biba) and the monastery of Deir al-Miharraq (Qusiya). In the same study, Butzer (1959, 78-79) also analysed the geological sequence of the Middle Valley, identifying two layers of aeolian sand deposited on the Greco-Roman levels. The first, which he called the *Upper Younger Dunes,* began to be deposited in the early eighteenth century on top of alluvial soils dating from the fifteenth and seventeenth centuries. The second, the *Lower Younger Dunes,* was formed between 300 and 1450 with a break between 800 and 1200 caused by the accumulation of alluvial soils due to the high levels of flooding in the Nile during this period.

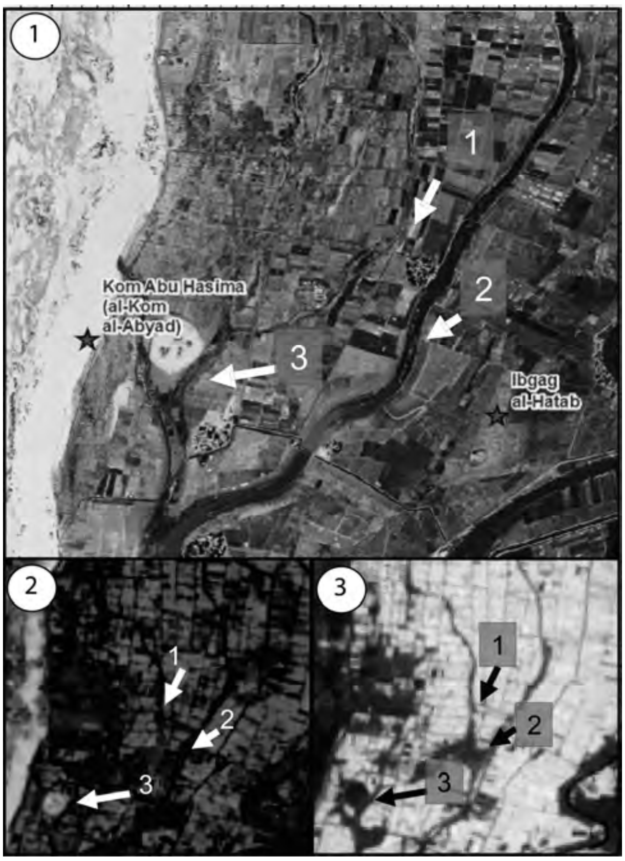

Figure 8 Flooding channels (*nili*) near the meander at south of Oxyrrinchus. 1) CORONA image 2) LANDSAT 4-3-2 bands 3) NDVI analysis.

Furthermore, the lateral dike that accompanies the Bahr Youssef is aligned east-west to the north of the meander (Figure 11, label 7). When the Bahr completes its meander, returning to its N-S alignment, the dike no longer accompanies it, but instead continues in a W-E direction until it reaches this series of longitudinal dunes. The enclosure of a basin is thereby completed. At the same level, at the confluence of Bahr-Youssef with one of the flood canals, there is the regulator of El-Miheigra (Figure 11, label 8). After the flood waters had been held back for a sufficient period of time, the water was drained directly into the Bahr-Youssef by opening the regulator. Significantly, from this point onwards there are no large accompanying dikes in the stretch adjacent to the towns of Sandafa and el-Bahnasa.

This series of data suggests that there was a flood basin that linked the Bahr Youssef meander, the possible *Nili* canals and the western elevation mentioned above, covering an area of 15.9 km^2.

This flood basin does not match any of the main basins named by Barois or Willcocks. However, as mentioned above, the two authors discuss the flood basin system to the west of the Bahr Youssef without giving them any names.

A little further to the west, between this longitudinal elevation and the foothills of the Libyan mountains, there is a series of depressions, with minimum elevations similar to those of this flood basin. When the Corona and Aster images and modern maps are analysed, these depressions present an area with wetland vegetation (Figures 9 and 11).

Careful observation of the series of images shows a series of canals (Figure 10, label 6) running across the longitudinal elevation, creating a network that provided the series depressions with a water supply. The form of these canals appears to suggest that they are not *Nili* canals, but instead canals dug at some depth. We are therefore unable to say that it was used as an area for flooding and that it was used to make these lands available for cultivation, as is apparent in more recent images. The supply of water with mud would enable this land to be made fertile.

Further north, between Banhassa and flood plain of the meander of the Bahr-Youssef, some CORONA images show a longitudinal trace (Figure 11, label 5 and 12, label 6) distinguished by an off-white colour which sets it apart from the surrounding area. Due to its width, we believe that it could be a possible paleochannel of the Bahr-Youssef. Furthermore, the particular shape of the crop plots in this area defines the course that this canal would have followed (Figure 12, label 7).

Of particular interest is the width of this paleochannel, which is similar to that of the Bahr-Youssef. To the west of the detail, we can see how a trace emerges to the north in the form of an incision that could be a canal (Figure 11, label 4). However, the image in this area is not clear enough, and more modern scenes from Quickbird and WV2 provide no more information due to the profound changes that have taken place in this area.

These wetlands were perhaps planned in order to relieve surplus flooding. As a result, they would have supplied the depressed areas adjacent to the desert. As well as the presence of trace of the paleochannel, the El-Miheigra regulator, and the lack of large accompanying dikes in the space between the enclosure dike of the meander basin until Benhesue and Sandafa to the north reinforces the idea that the changes to this basin were also aimed at preventing flooding.

It is impossible for us to date when this basin was built, as we do not have textual or cartographic information that is specific enough, or a field study. It is possible that it is part of the reforms that took place in the second half of the nineteenth century for improving the existing flood basins system on the left bank of the Bahr-Youssef, which was operating when Linant de Bellefonds published his plan in 1854. However, if we use Butzer's study as our starting point, which dates the formation of the series of longitudinal dunes from 1700 onwards, this suggests that the basin was not constructed prior to that date.

Other marks on the landscape.

As mentioned above, the traces detected in the Landsat scenes were superimposed onto high resolution scenes from Quickbird, Crown and WV2.

Initially, we found a structure with a function that we were unable to identify, but which could be a possible dike, a channel or a path (Figure 10, label 1 and 12, label 1). This is longitudinal, running SW-NE. We thought that it was these used when the CORONA scene was captured, as a series of breaks or discontinuities in some of the traces is visible. However, when superimposed on the topography, they may also be due to irregularities in the terrain.

Figure 12.4 shows a detailed view of a WV2 scene taken in 2010. The remains of the same structure are visible, and it is now very dilapidated and ruined due to the recent construction of a motorway a short distance away. The structure appears to consist of a slope with a road on top, delimited by two possible walls. Its width at its highest point is approximately 3 metres.

Two transversal alignments in the structure are also visible (Figure 10, label 2, 12, label 3, 4). Each one of these in turn consists of two possible walls that are approximately 10 metres wide. They are both aligned SE/NW, and funnel out when they come into contact with the longitudinal structure.

The TTC analysis also vaguely reveals a series of linear forms (Figure 12, label 5) with an alignment similar to that of this longitudinal structure. This alignment is different to that of the divisions of the modern fields of crops.

Further to the north, we found other traces (Figure 11, label 3) of a possible road documented in the 1908 cartography, linking Bahnasa with another transversal road running along the edge of the Nile Valley on the western side and located further to the west.

The area to the west of Oxyrhynchus

In this second study area, we also applied TTC and PCA analysis techniques to Landsat images. Both showed the system of *wadi*s and the network of paths that converge on Oxyrhynchus. The *wadi*s are of particular interest due to component 4 of the TTC analysis, which has a tonality that may be due to higher levels of wetness and therefore higher values of that component.

The confluence of the *wadi*s at Oxyrhynchus could be a good reason to undertake studies on possible occupancy during the predynastic period. This work would involve a geomorphological analysis and examination of the area on the ground, based on the studies carried out in Nag-el-Qarmila in Upper Egypt (Gatto *et al.* 2009). These authors believe that the structure of the *wadi*s was used for irrigation during this period. During this period, the flooding of the Nile reached the height of the *wadi*s which were used as reservoirs or reserves of water for irrigation during the rest of the year, after the water subsided.

In this area we first found two marks on the landscape. The first (Figure 13, label 1) is a *wadi* in the Landsat analyses. It follows an E-W path, continuing beyond the modern quarry until it reaches the area around el-Bahnasa. The second (Figure 13, label 2) is a path which in the 1980s connected the quarry with a transversal road that ran along the edge of this part of the valley, and was abandoned after the construction of a new road from el-Bahnasa. We believe that this old path initially runs along a *wadi* and continues after the transversal road as its traces are still visible, despite being concealed by a field of crops (Figure 13, label 2b). We also found two longitudinal signs (Figure 13, label 2d, 2d') at an angle of 60º to the *wadi* from the fields of crops located a little further to the north. Other longitudinal marks can also be seen further to the east (Figure 13, label 2e, 2e'). The four are all connected by a perpendicular fifth with a SW-NE alignment which runs towards the site of Oxyrhynchus.

A little further to the north (Figure 14), we found another possible *wadi* aligned towards the site. TTC analysis of the Landsat images shows that it was used starting from the transversal road, and is still used in the same manner today. The same TTC, but applied to the WV2 image, shows in the combination of the 4/3/2 bands the width of the *wadi* that can be seen by the lighter shades (Figure 14, label 1) and which appears to be divided into two parts - one in a straight line towards the north of the site (14.1a) and a second makes a sharp turn to the NW-SE towards el-Bahnasa (Figure 14, label 1b) This analysis is confirmed by verifying the data shown by the TTC with the Corona images (Figure 15).

Finally, these *wadi*s converge towards the site of Oxyrhynchus. We can see some degree of relationship between the orientation of the *wadi*s when they reach the outskirts of Oxyrhynchus, and some longitudinal outcrops with a darker colour than the predominant colour of the land (Figure 16). These outcrops, which are generally aligned in a SW-NE direction and appear to be modulated, are located to the NW of the Oxyrhynchus archaeological area, and do not follow the orientation of the urban insulas suggested by the various images analysed.

The urban context: some key traces

Combining 8-3-2 World View multispectral Image bands and applying TTC and PCA functions to the Oxyrhynchus archaeological area provides two key pieces of evidence, among others, located elsewhere in the site.

The analyses applied to the area in the immediate vicinity of the theatre (Figure 17) showed a quadrangular trace and a N/S alignment located to the north of the site which runs towards it. The combination of the 8-3-2 bands shows a greater tonality of the colour red in the first, indicating better health among the vegetation and therefore an area with high wetness levels. In the TTC analysis of the wetness component, there is again a difference that shapes the quadrangular form.

The second piece of evidence (Figure 18) is an alignment with an approximate width and length of 16 and 258 metres respectively. This would reveal the possible existence of a canal entering the urban area. The tonality of the 8-3-2 combination of the image and component 3 of the PCA shows that there may be a trench or canal that has been silted up, which could contain more humus than the surrounding area, thereby fostering the growth of vegetation.

5. Discussion

According to Rippon (2008, 3), the term 'historic landscape analysis' is used to cover a range of approaches focused on resolving the issue of how today's landscape was constructed. This means it is necessary to include an extensive and varied range of materials to ascertain the process or processes that led to changes in the landscape.

Based on this assumption, GIS and ICTs are ideal tools given their capacity to store geospatial information and the ease of superimposing and checking various sources from various origins (maps, DEM, remote sensing images, etc.).

These varied sources of information can be deconstructed, reconstructed and synthesised to create new information about the landscape. However, in the way we worked with the information, the GIS on its own does not produce any new knowledge as it would do if a Viewshed, a prominence analysis, a flooding simulation or Least Cost Route was applied. In this specific case, it is not a positivist tool which provides quantitative results based on data entry (Chapman 2009, 129). On the contrary, it more closely resembles qualitative confirmation of the digital information with the knowledge acquired on the Middle Valley.

An essential consideration is that the research must be 'past oriented' (Bloemers 2002), i.e. we need to understand the processes of change that take place in the landscape. The nature of GIS as a means of storing multitemporal information contributes to regression analysis. However, it is only possible to reinterpret the information based on the researcher's prior knowledge of the ancient landscape. The restoration of the landscape as it was in 1800 was a process which involved various sources of information. The superposition of historical maps was useful for collecting place names that have undergone a great deal of variation in only 200 years. These enabled us to locate the eleven dikes listed in the *Description.* These eleven dikes had previously been identified using the CORONA images. However, we first had to ascertain the shape of a dike.

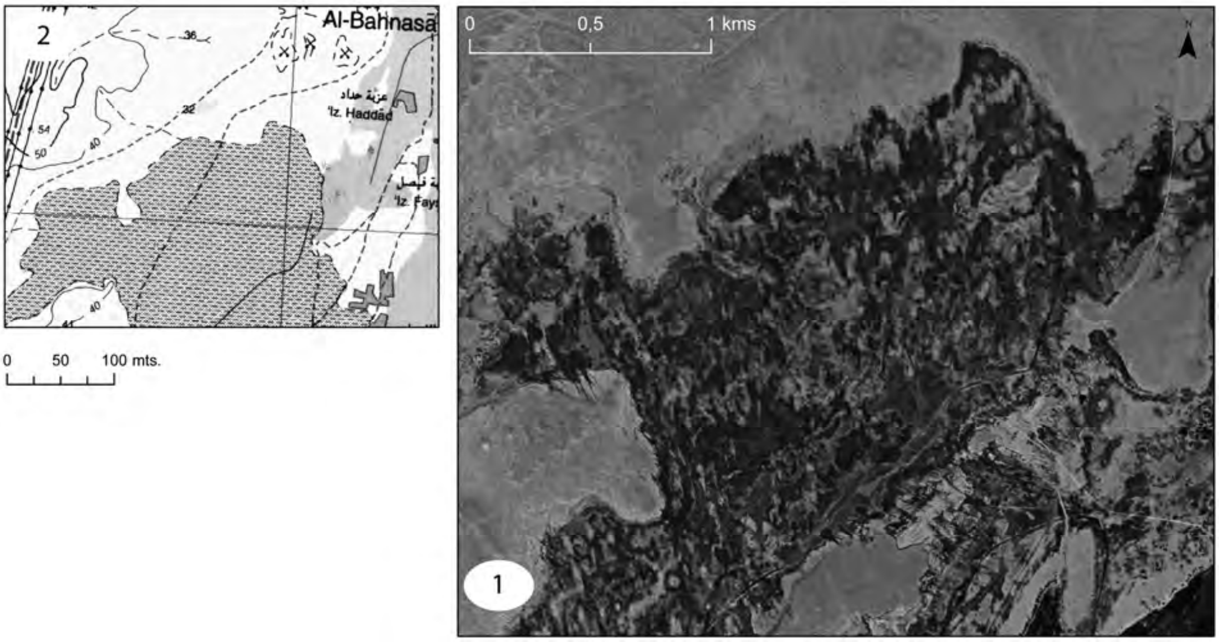

Figure 9 Wetland vegetation.

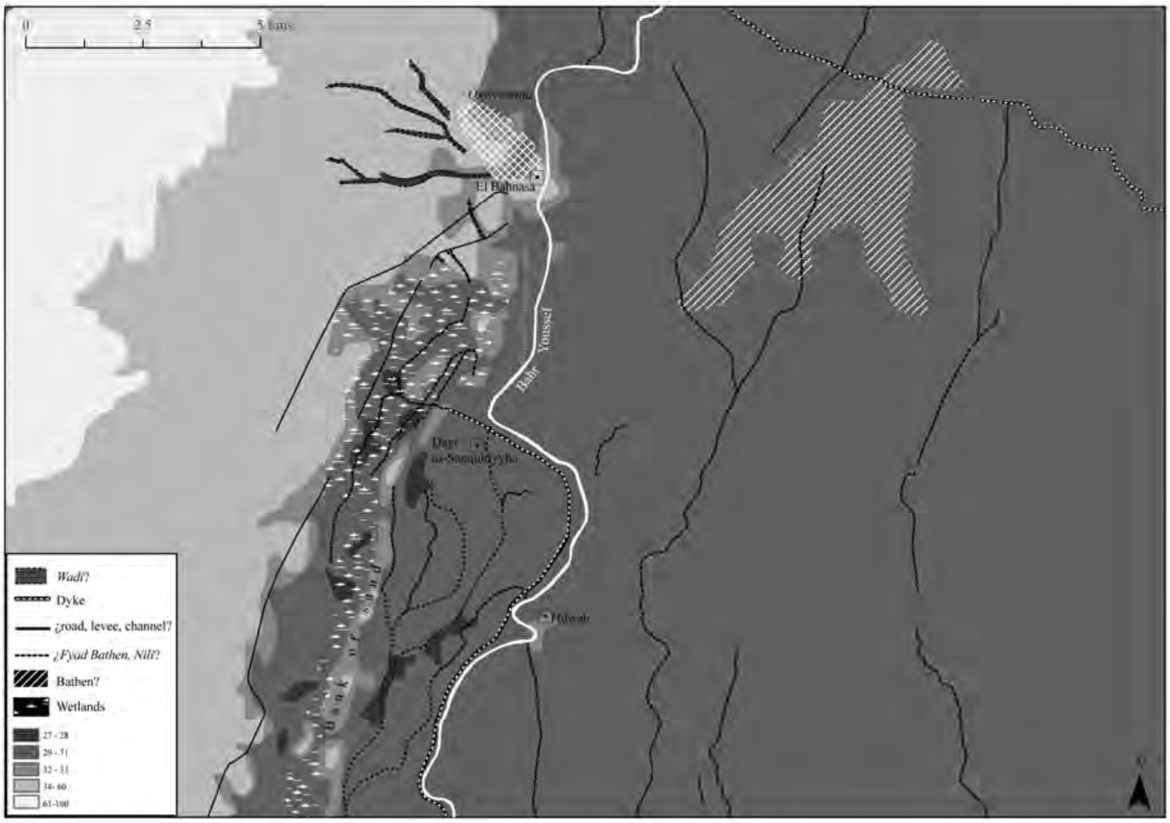

Figure 10 South area.

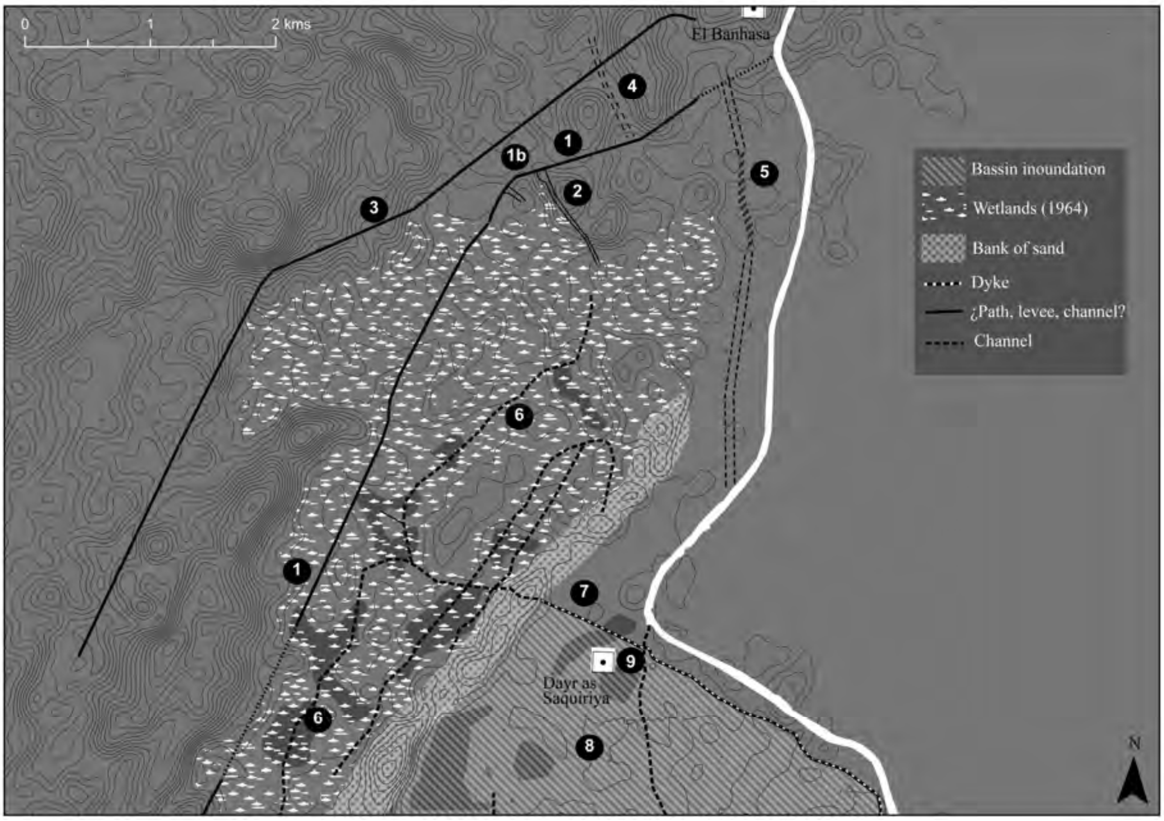

Figure 11 Landscape features identified.

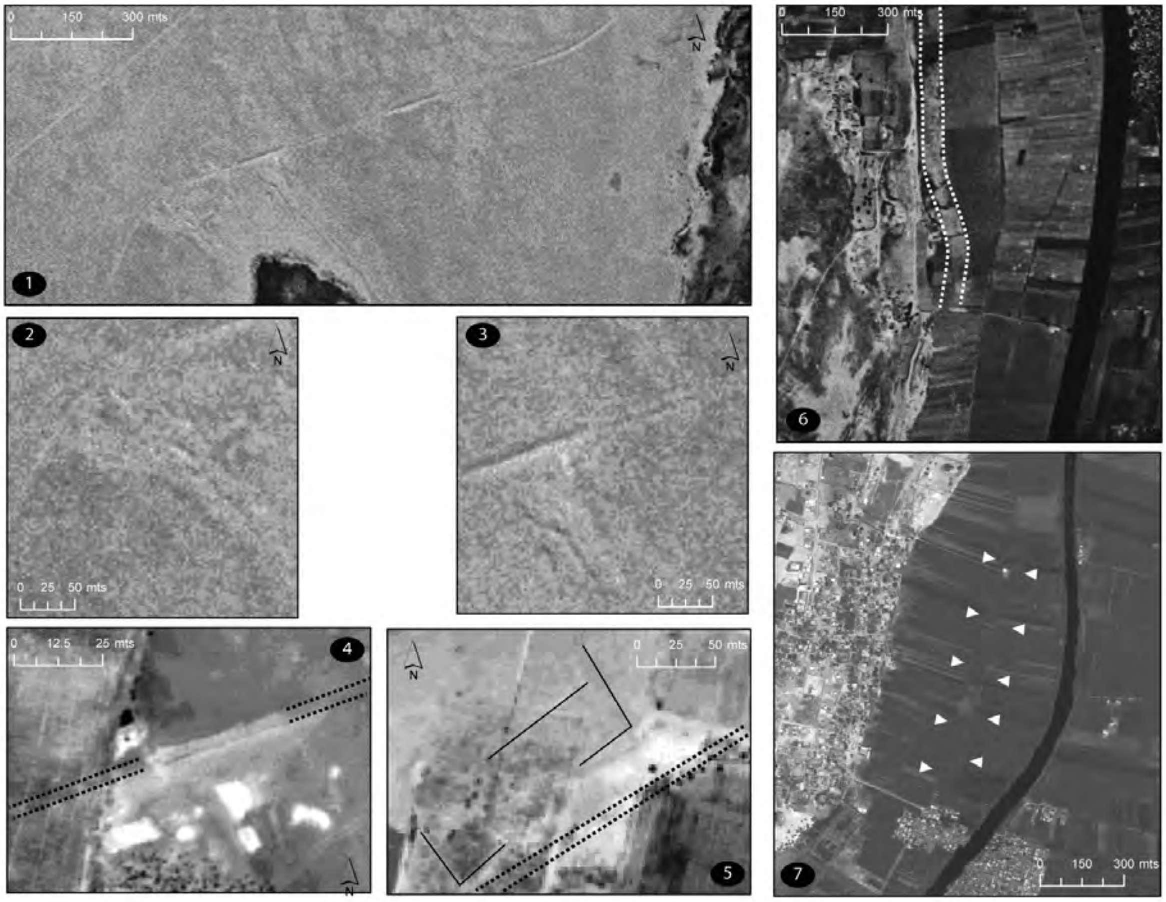

Figure 12 West of Oxyrrinchus archaeological area.

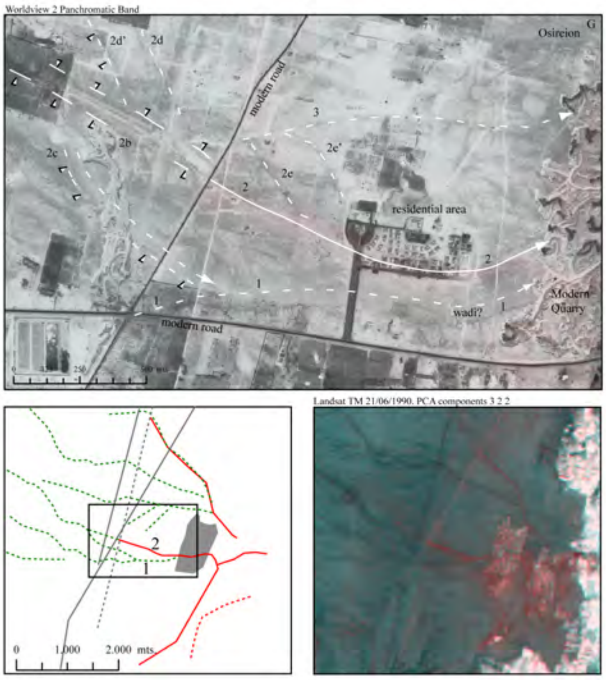

Figure 13 West of Oxyrrinchus archaeological area.

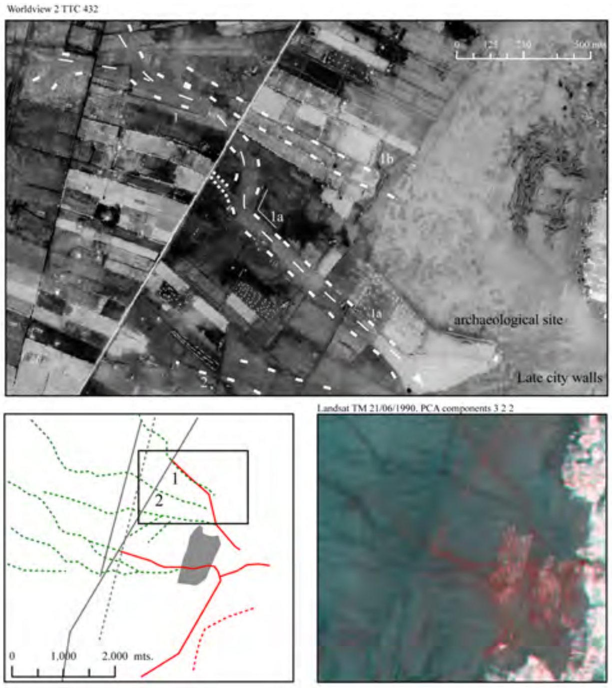

Figure 14 West of Oxyrrinchus archaeological area.

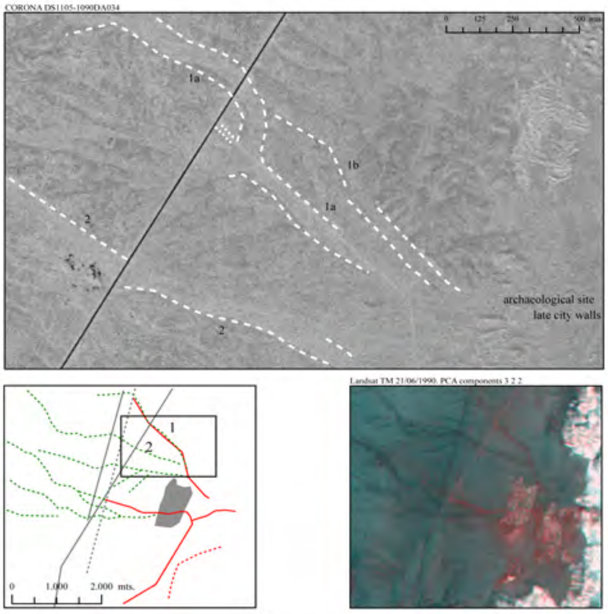

Figure 15 West of Oxyrrinchus archaeological area.

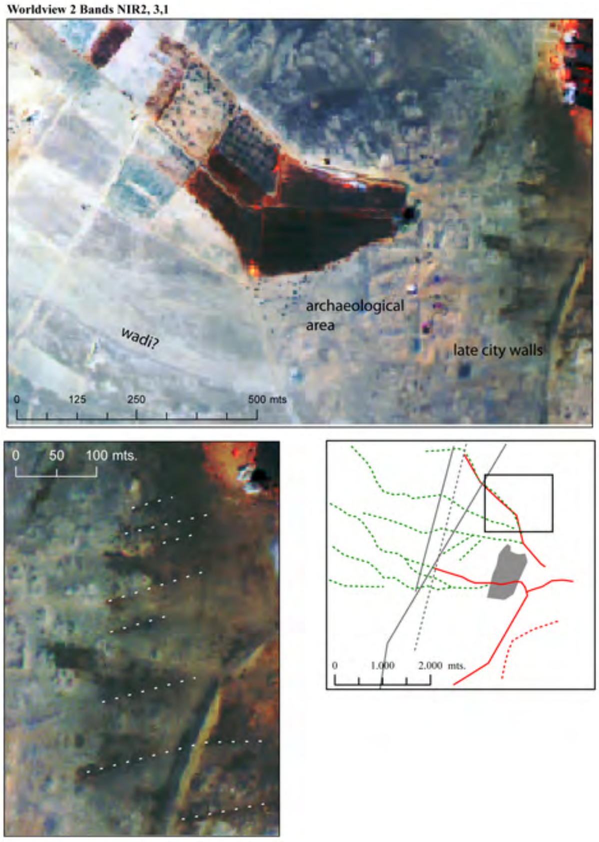

Figure 16 West of Oxyrrinchus archaeological area.

The same occurred in the identification of canals. In our case, we found a semi-silted canal between *Matay* and *Abou Girge*. If we do not know how the flooding behaves, or that in eighteenth and nineteenth century it was channelled through the *Fyad Baten* and the *Nili*, it is impossible to generate new knowledge. Based on this perspective, the GIS is the ICT medium that provides new knowledge, but it is not directly involved in the Thesis-Antithesis-Synthesis sequence at any point. From the other perspective, the observation of a semi-silted up canal without any relationship to other larger, deeper, longer canals running in a straight line, may lead us to contextualise and identify the point at which they were planned or their possible natural source.

A second factor should be taken into account. Some of the traces are taken from images or plans dated from periods in which the landscape had not yet undergone the major transformations of the nineteenth and twentieth centuries. These features may therefore not be recognised and directly analysed on the ground today, as the surrounding area was completely transformed. In these cases, selection and analysis in the field is only possible for those that remain in today's landscape. In this case, GIS can provide the solution as its geospatial database contains a diachronic series of images.

We believe that the identification of forms and their morphological interpretation is an essential part of our work. As mentioned above, this is because they can tell us about how a landscape was structured at specific points in time, and the nature of the major changes that took place. The data collection methodology used is vital in this respect.

Chapman (2009, 91-98) mentions two methodological approaches: the contour survey and the hachure survey. The first, the contour survey, is an objective method as it requires no interpretation when a trench or wall is observed. Some functions of GIS enable the surface to be created in order to visualise and identify topographical irregularities in the area. The use of GPS and the creation of high resolution topographies are a major breakthrough in this area (see for example Sanjuan *et al.* 2009, 163-168).

However, in the application of our project, the DEM we used were generated and made freely available on the Internet by various international institutions. However, their low resolution, with a minimum of 30 metres per pixel, prevents an analysis of this type, as it requires data to be acquired on the ground, which is in some cases difficult to obtain. First, the work scales make such an approach impossible to undertake. Our project studies the Middle Nile Valley and we would therefore have to undertake a survey gathering data for the entire valley, which would involve costs in resources and time that are impossible to meet for a team. There are also administrative (Parcak 2009, 186-187) and logistical difficulties hindering such an approach. Other solutions need to be found, such as the acquisition of high-resolution stereo pair Quickbird or WorldView scenes. Under these conditions, applying photogrammetry functions, it is possible to extract a high resolution DEM. If a Quickbird image has a resolution of 0.5 m/pixel, the resolution of the DEM will therefore be similar. It will obviously be necessary to set control points by DGPS, but the number of points necessary will be much lower. In these cases, it is a question of assessing the costs of these high resolution images and comparing them with the time required for the high resolution topographical surveys carried out on the ground. We found a lower resolution (5 metres/pixel) in the CORONA images. This is a solution that reduces costs in the acquisition of the product, but requires a longer processing time. The images were captured with panoramic analogue cameras. This generates very distorted scenes without any geo-referencing. It is therefore necessary to pre-process them, in order to subsequently extract the high resolution DEM (5 metres/pixel). In these cases, image analysis and treatment programmes such as ERDAS 2010 and ENVI 4.7 2010 are the tools that we have to use. We are still in a trial phase with the CORONA images, and have generated a DEM at 5 m/pixel, but only in a small working area. In the future we will generate total coverage of our project at high resolution.

The experimental nature of the GDEM product was also noteworthy. According to a validation report written by the institutions participating in the METI/ERSDAC project, NASA/LPDAAC, USGS/EROS (2009, 22-23) two types of anomalies were found in the product. The first takes the form of a series of longitudinal elevated shapes (pits) and the second are elevated circular forms with a depression in the centre (bumps). We saw these anomalies in the work area at the beginning of our project. We were unaware of the existence of the report mentioned above, and interpreted the pits as dikes or canals that were not recognisable in the satellite images. In the second case, the error was more serious as we found the text of an Oxyrhynchus papyrus, the 44.3167(BL 9), which specifically mentioned the use of circular constructions for water storage. These large constructions were allowed to flood during the flooding season. When the water reached the top of the construction the sluices were closed to prevent it from leaving the construction when the water levels fell. As mentioned above, the report emphasised the experimental nature of the product GDEM (METI, NASA, USGS 2009, 27) and as a result we gave up studying shapes in the landscape relief using GDEM.

Other solutions such as LIDAR are applicable in European or American contexts, but are currently impossible in the Middle Valley due to a number of issues which are beyond the scope of this article.

Our work was therefore based on cartography and satellite images, and was a qualitative and interpretative study. GIS is part of this approach, and is almost a part of the mechanism for processing the information, and contributes to the deconstruction and reconstruction of new knowledge. We have seen how a flood basin which used the system of side dikes in the Bahr Youssef and the sandbank located on the western side of the valley was located to the south of Oxyrhynchus. However, there was no direct evidence for the existence of such a structure. It is not shown on any of the images or plans, either in writing or visually. This system was deduced from various indicators (such as the side dikes and the network of flood canals). However, we did not know of any possible western enclosure.

By determining the latter, we confirmed the need for precision topography. The modern and older cartography does not provide sufficient information. In this case, the capture of DEMs such as ASTER GDEM and STRM-90 and the creation of our own DEM based on ASTER scenes gave us a detailed topography of the work area. In other words, the resources provided by remote sensing contributed new information that led to continuity in the analysis. The DEM study confirmed that this flood basin was enclosed by the longitudinal elevation of the sandbank identified by Butzer and located on the western side of the Nile Valley.

It is at this point where prior knowledge could lead to error if it is not complemented with other data. Initially, direct viewing of satellite images, and NDVI analysis showed that there was indeed this longitudinal trace of sand which we did not initially identify as a system of dunes. We mistakenly assumed that it could be an old course of the Bahr-Youssef, now part of the desert. However, it was not until we superimposed the DEM and saw the positive increase in elevation that we identified it as the sandbank. Reading Butzer's study enabled us to confirm its aeolian origin, its chronology, and that of the nineteenth-century flood basin. It also gave us very interesting data about the workings of a secondary flood basin, used for local irrigation by one or several communities.

Another issue to take into account is work scales. High and medium resolution satellite images can be adapted to various approaches for landscape analysis that may be local or regional, and these substituted the missing detailed cartography, one of the main problems with this project.

On a regional scale, analysis of the flood basins followed a top-down process (Rippon 2008, 26). This consists of identifying the large divisions that fit a consistent description. In this case, the large divisions are determined by the flood basins and dikes. Various systems of land division were structured around them, and changed annually after the flooding since the Pharaonic era.

The remote sensing analysis techniques applied (PCA and TTC) showed traces of paths, *wadi*s, canals, and other features. These techniques enabled some information to be highlighted, and other redundant information to be suppressed. However, they cover the regional work scale when medium resolution images are applied. The solution involving working with Landsat and Aster images is therefore the most appropriate. For example, application of the NDVI index filters the traces that structure the landscape (river, canals, paths, etc.) and therefore helps to identify large divisions quickly.

On a local scale, we considered acquiring high resolution scenes, from either Quickbird (0.5 m/pixel) or WorldView 2 (0.6 m/pixel). Our work area is not covered by cartography or orthophotography produced by the appropriate Egyptian institution available for consultation.

As mentioned above, remote sensing analysis of the Oxyrhynchus archaeological area provides two details for consideration. The first is a quadrangular structure highlighted by the combination of the NIR band and the TTC wetness component. This shows a structure for accumulating and using water, or as they are generally constructions made of adobe, a series of demolished walls belonging to a large building. Adobe is high in humus content and facilitates the development of vegetation and the accumulation of wetness. We know from the topographical reconstruction by Krüger (1990) based on the Oxyrhynchus papyri that there were large public baths near the theatre. Let us assume that the structure is one of the infrastructures of those public baths.

The second structure had a longitudinal shape and was aligned towards the theatre. The trace, detected by the NIR-1 component of WV2 and TTC analysis, also shows a structure dug to a depth that facilitates the growth of vegetation, which is unusual in an area in which vegetation is sparse. In this case we assumed that it was infrastructure constructed to enable the circulation of water. This would control the entry and supply of surplus water caused by the flooding of the Bahr-Youssef at an urban level.

Both cases show how the data from the analysis of images provide information for the reconstruction of the urban topography of Oxyrhynchus. In view of the problem with resolving or validating the reconstruction of Kruger, remote sensing analysis provides evidence for where to apply an archaeological examination which would confirm it.

As regards the study of the landscape at a regional level, no work has been done on the ground to date. Our work has strictly speaking been a laboratory study. In theoretical terms, it runs counter to the approach and experimentation with the landscape established by Tilly (1994). We are lacking confirmation on the ground for the canals and dikes, stratigraphic drilling, geomorphological studies, and paleoenvironmental restoration. They will all be new GIS layers.

6. Conclusions

Regression analysis of the sources and cartography enabled us to reconstruct the dikes that were operational when the French expeditionary forces arrived in 1799. Our study also clarified how the flooding was channelled and distributed by the *Fyad Baten* and the *Nili* canals before being channelled or added to sections of other new canals such as the Ibrahimiya as part of the programme of nineteenth century transformations. We have seen how these can still be found on cartographic plans and satellite images despite the years that have passed since the construction of the Aswan Dam.

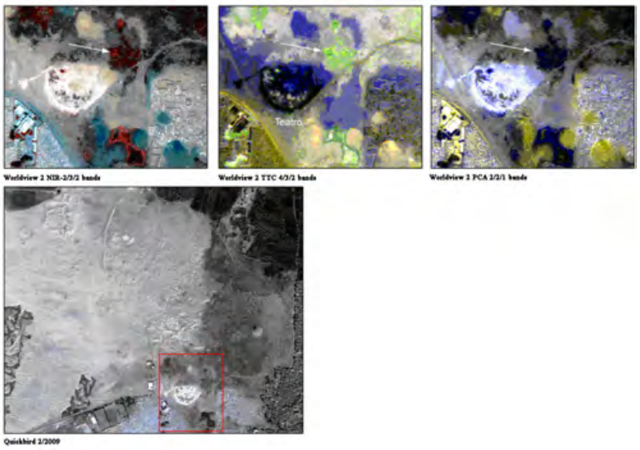

Figure 17 Theatre area.

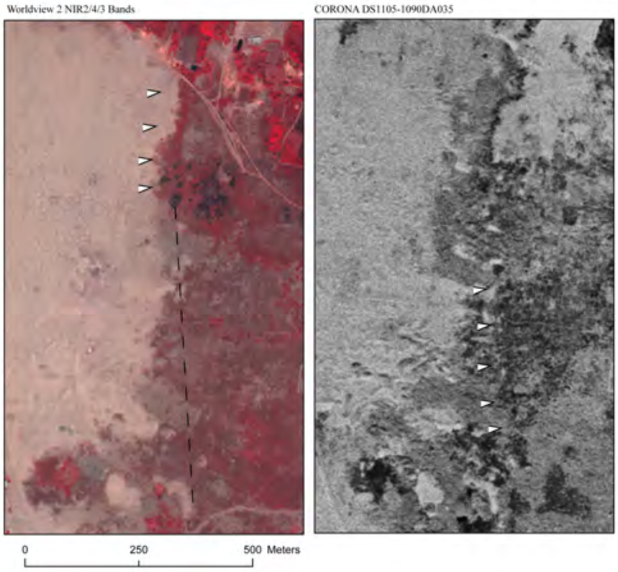

Figure 18 Archaeological area. 1) Wordview 2 NIR-2/4/3 bands. 2) CORONA.

Considering the magnitude of the transformations that took place during the nineteenth century (perennial irrigation, partition of existing basins, changes in the flooding, irrigation channel and drainage system) one might assume that the reconstruction of the flood basins that took place in 1800 was similar to the system that existed in the Greco-Roman period. During the flooding, these basins were fed by a network of traces from the *Bahr Baten*, or the low-lying beds that we found. It remains to be ascertained whether these inner canals or rivers are of natural or anthropic origin, although Jomard stated that he had not found any remains of hydraulic infrastructures (Jomard 1809, 105, note 1) However, we must also consider the possibility of finding ourselves in a similar situation to that identified by Lutley and Bunbury (2008) further to the north. According to the study undertaken by their team, these canals are really the result of the Nile's migration across the valley's entire width. These variations have been calculated for the Memphis area and are in the region of 9 km for every thousand years. When the seasonal flooding occurs, these paleochannels or abandoned courses regained their volume and naturally fed the constructed flood basins. In the area that concerns us here, we should also add the variability in the course of the Bahr-Youssef.

The latter possibility is reinforced by the fact that the two sloping plains from the Bahr-Youssef and the Nile formed basins or low-lying beds - Linant's *Bathen*. This layout would encourage migration of the two courses, leading to the formation of abandoned courses or paleochannels. Future geomorphological studies will have to resolve these questions and establish chronologies that enable the landscape to be reconstructed in greater detail.

However, the Muslim invasion and the Mamluk government occurred between the two points in time. This period is too long for there to have been no changes and modifications to the preceding system. If the eighteenth and nineteenth century sources talk about the decline and neglect of the infrastructures, then they must have been maintained at least until that point in time.

The restoration of the basins system in 1800 allows us to define two large basins that were interlinked and separated by the Safaniya dike, which was identified by Schenkel as the *Seper-merou* mentioned in the Wilbour Ramesside papyrus. It was possibly a very large system of basins, which were perhaps subdivided by means of smaller dikes. These basins would have been defined by the enclosure dikes located to the north and to the south (Ehoueh and Chantour) which were constructed almost equidistant from the Safaniya dike.

Our analysis on a larger scale enabled us to determine that continuity and intensity in archaeomorphological studies to re-establish the systems of division prior to the arrival of French expedition must focus on the eastern banks of the Middle Valley, and above all on the *mohit* dike created after the construction of the Ibrahimiya Canal. This does not mean that the western bank should be ignored, but the main changes and alterations took place there, and as a result the introduction of sugar cane and cotton accompanied by perennial irrigation must have changed the pre-existing systems of division.

Meanwhile, our work based on remote sensing in the Oxyrhynchus area has enabled us to reconstruct the system of *wadi* which was the cornerstone of the Greco-Roman population structure and we have shown the presence of a possible displaced paleochannel to the west of the Bahr-Youssef.

The routes of *nili* canals on the western bank of the Bahr and low level points and enclosure dikes show that a flood basin was built to the south of el-Bahnasa in around the mid-nineteenth century, which enhanced an area affected by the sands and dunes of aeolian origin that had accumulated since the eighteenth century.

Detected traces of the canals and dikes nili have helped us also to reconstruct the irrigation system during the Greco-Roman period (Subias, Fiz, Cuesta in press)

Finally, TTC and PCA analysis provided us with information on the hydraulic features and structures in the Oxyrhynchus archaeological area. These are explained in Subias (in press).

Remote sensing remains a technique that is based on distance, taking advantage of the extensive spatial coverage of the sensors used. However, this distance cannot be the only method that is used. This study, which was carried out on various working scales, will not be complete until the routes located have been confirmed on the ground, and accompanied by exploration in the territory. This work must be complemented by geomorphological and paleoenvironmental perspectives that complete the overview of the landscape of the Oxyrhynchus area.

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