Land use and irrigation works in Kazakhstan in the present and in historical times. Geo-archaeological investigations throughout GIS and Remote Sensing

Maurizio Forte (1), Sofia Pescarin (1), Renato Sala (2), Jean-Marc Deom (2), Konstantine
(1) CNR-ITABC, Istituto per le Tecnologie Applicate ai Beni Culturali, Roma.
(2) Academy of Sciences , Institute of Archaeology, Almaty, Kazakhstan

Abstract

General goal of the project, coordinated by CNR-ITABC and supported by INTAS (International Association for the Promotion of Co-operation with Scientists from the New Independent States of the Former Soviet Union) is to reconstruct the present conditions and the historical evolution of the land use and irrigation works in three main areas of settlements today exposed to a sensible process of aridisation: Semirechie, South Kazakhstan, Central Kazakhstan (settlements, fortresses and ancient irrigation works from the Early Middle Ages till the rule of the Kazakh hordes VIII-XV AD). The hypothesis of research is that the three regions have always been particularly sensitive to environmental fluctuation; that proper irrigation always played a stabilizing economical role during the last two millenniums; that climatic and anthropogenic reasons have been responsible of the building, restructuring and disrupting of past irrigation works. The goal is to understand the weight of natural and anthropogenic factors behind the actual trend of aridisation and degradation in these areas; the factors that lead to the changes during history; and to compare the present and the past events. The complexity of the project embraces multidisciplinary applications: GIS, GPS, remote sensing, integrated geo-archaeological investigations. This paper constitutes the report of the scientific activity of 2002 and it concerns very preliminary results.

1. The Project

General goal of the project is to reconstruct present conditions and historical evolution of land use and irrigation works in three main areas of settlements today exposed to a sensible process of aridisation: Semirechie, South Kazakhstan, Central Kazakhstan.

1. Semirechie: Ili valley (Ili delta, Tianshan foothills, Chu-Ili mountains); and the delta of Talas river. There settlements and ancient irrigation works have been found from the PostSaka-Wusun period (200 BC-300 AC) till the last century.
2. South Kazakhstan, at the confluence of the Arys and Syr-Darya rivers where fortified settlements, towns and sophisticated irrigation networks were in use from the II AC till the XVIII AC
3. Central Kazakhstan, region of Djezkazgan where have been found settlements, fortresses and ancient irrigation works from the Early Middle Ages till the rule of the Kazakh hordes (VIII-XV AC)

The hypothesis of the research is that the three regions are today and have always been particularly sensitive to environmental fluctuation; a proper irrigation always played a stabilizing economical role during the last two millenniums; that climatic and anthropogenic reasons have been responsible of the building, restructuring and disrupting of past irrigation works. The goal is to understand the weight of natural and anthropogenic factors behind the actual trend of aridisation and degradation in these areas; the factors that lead to the changes during history; and to compare the present and the past events. The project (n.699) is supported by INTAS for the period 2002-2004. INTAS is an independent International Association formed by the European Community, European Union's Member States and like minded countries acting to preserve and promote the valuable scientific potential of the NIS partner countries through East-West Scientific co-operation.

The partners of the project are: CNR ITABC; Oxford University, Dept of Environmental Archaeology; Southampton University, Institute of Irrigation and Development Studies; Institute of Archaeology of Kazakhstan; Institute of Engineering and Telecommunication of Almaty; Institute of Geology of Kazakhstan; Dept of Archaeology of Kemerovo (Russia).

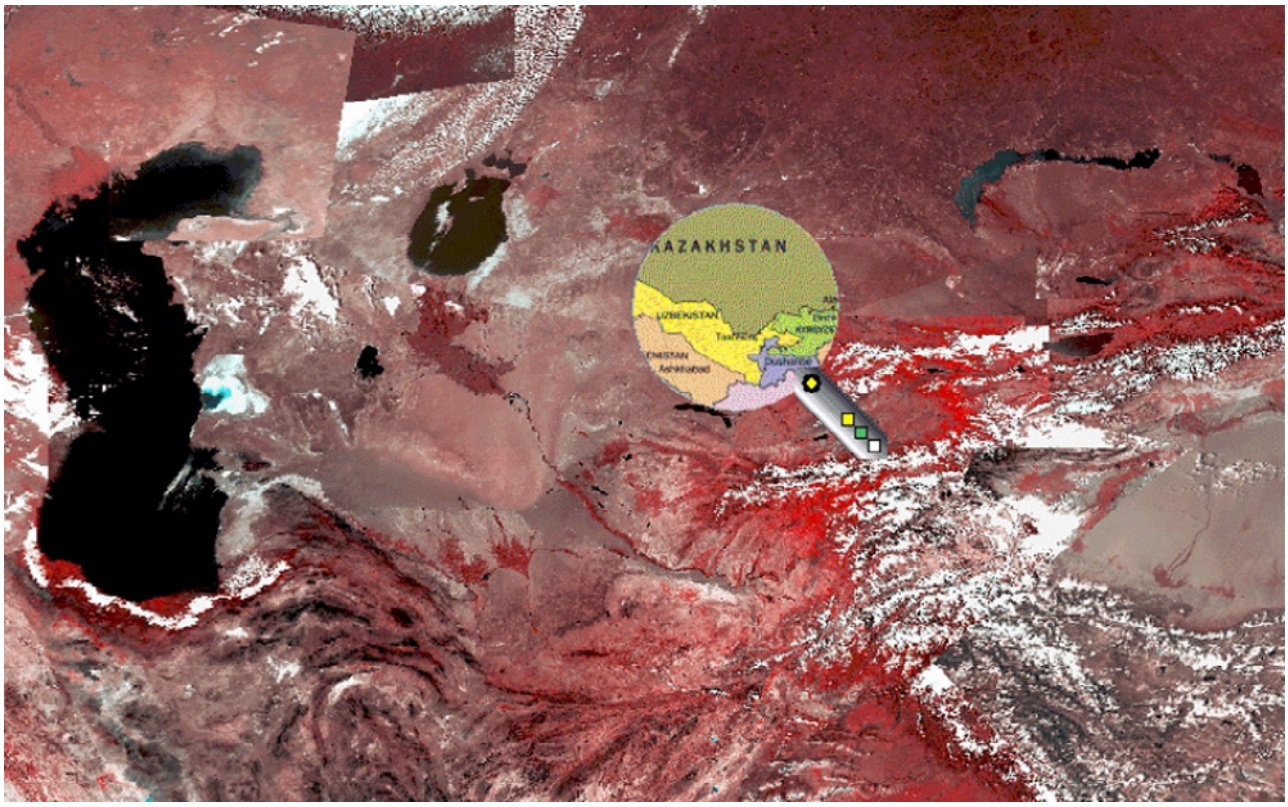

fig01 - Satellite images and surveyed areas

1.1. General goals

Main goals of the project are:

- to study the actual state of land use and the irrigation systems in the three different regions;

- to evaluate the actual process of aridisation by analysing the stressing effects of natural factors and human negligence;
- to provide a contemporary reference (talon) for the study of the past conditions and disrupting agents in the same sites (aridisation, erosion, siltation, floods, etc.);
- to create a reconstruction of environmental variations (geological, climatic, botanical, zoological) in the chosen sites, during a period going from the late Iron Age to the present time;
- to reconstruct a general historical background of the human occupation of the areas by surface archaeological surveys: detecting settlements and works and analysing their character (temporary or permanent, etc) ;
- to find out where and when ancient irrigated lands have rose and disappeared and to reconstruct the evolution of the types and techniques of water collection (wells, etc) and irrigation;
- to reconstruct the evolution in the land use: kinds of crops, type of agriculture, and their changes under climatic and historical changes.

In terms of digital activities, we are working on remote sensed data (Landsat TM, 7 bands) and on GPS-DGPS survey with Arcpad installed on PDA. All the spatial collected data are publishing on line through Timemap.

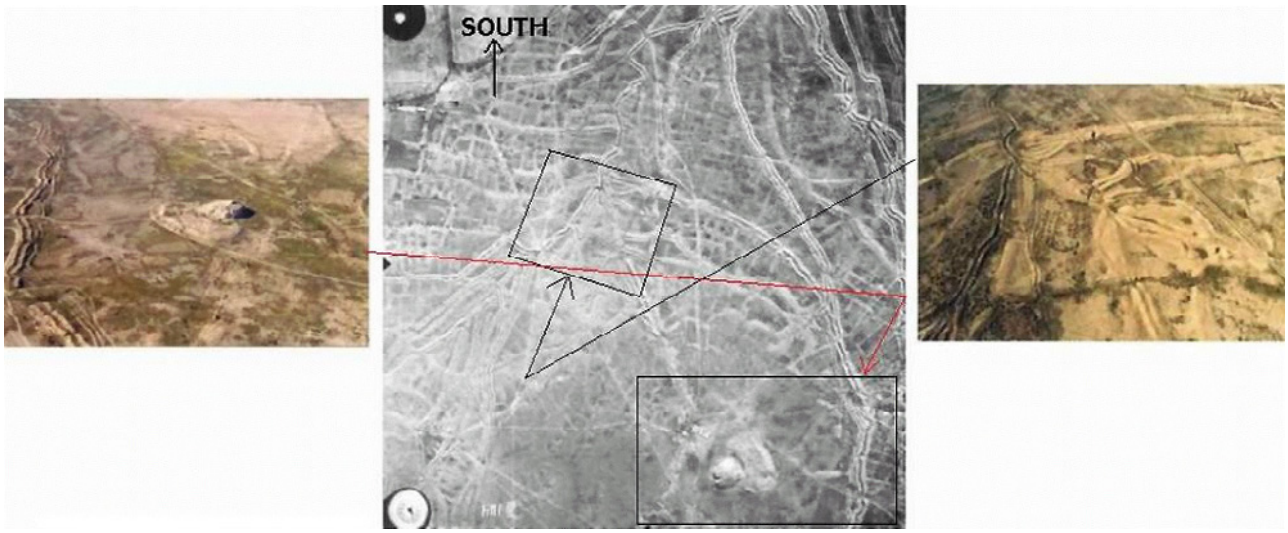

fig02 - Altyn-Tobe's Landscape: irrigation systems

1.3. The expeditions

In the INTAS Expeditions we pointed out three main working area:

1) Otrar oasis, in the middle part of Syrdarya river
2) Delta of Talas river
3) Western valleys of Chu-Lli mountains

As a method, every land-survey and fieldwork is followed (when possible) by aerial (microlight) survey and photo-documentation implemented by the team (*Inst Arch-KZ*).

Georeference and rectification of the aerial photos provide an extensive digital photo-mosaic of the region, integrated with satellite data (*CNR-IT*).

In the season 2002, aerial-documentation has been provided for the sites of south-Kazakhstan: oasis of Otrar, oasis of Turkestan, valley of the middle course of the Arys river.

The oasis of *Otrar* have been documented by aerial and topographic surveys in cooperation with a UNESCO team engaged in situ for conservation works. Important information has been provided on contemporary and ancient hydrology, canals stratification, distribution of agricultural fields. In the oasis of *Turkestan* the aerial survey was intended to analyze general landscape features, to document the surface remains of 2 underground water galleries (karez) and to explore the possibility of undiscovered karez (eventually 2 new karez have been discovered and documented). In the valley of the middle course of the *Arys* river landscape, hydrology and plans of 2 early medieval towns with their surroundings have been aero-investigated.

GPS data have been collected and experiments of survey have been done. The GPS survey has been done with a Trimble Pocket PC antenna connected with ESRI - Arcpad in order to provide all the vectorial data and points in GIS format (shape file): it concerned several areas of geo-archaeological interest and first of all the identification of *training regions* for supervised classification of the most interesting spectral signatures.

fig03 – A phase of data collection with GPS and ESRI Arcpad installed on a Compaq PDA.

1.4 Otrar Survey

In 2002 started Otrar expedition with the participation of the team leaders, of the specialists of five teams NIS and of the coordinator ITABC-CNR, Maurizio Forte. The work consisted in a detailed geographical, geo-morphological and archaeological exploration of the oasis (channels, *tobé* and fields) and of its surroundings, north and south.

We collected GPS data and we did a few survey experiments. The GPS data were collected with a PDA, a small-antenna (by Trimble) and the software Arcpad (ESRI) (fig.2): in this way it was possible to collect the data, directly during the survey, in a vectorial format and the points, lines and polygons immediately in GIS format (such as SHP). The GPS survey was done for different areas with particular geo-archaeological interests and, moreover, it was used to identify the *training regions*, useful to obtain the supervised classifications of interesting spectral signature. This elaboration was done with Landsat TM satellite imagery, provided directly by NASA, whose help was possible thanks to its collaboration with CNR ITABC, started times ago for bilateral researches.

Two trenches were dug in a channel and in a field, in order to collect data useful to the paleo-climatic reconstruction and to different laboratory analysis. A general planning of the works was discussed; the planning for the second expedition in Otrar, in October 2002, was done even to keep on working on the same topics and research lines.

Irrigation systems: a systematic reconstruction attempt

Up to now information on the irrigation works of the Otrar oasis has been collected by surveys limited to the surroundings of ruined towns, so that documentation was provided of settlement patterns and of the technical aspects of water management, from the size of the canals down to the kinds of conduits and containers. A systematic reconstruction of the irrigation system as a whole and of the related localisation of fields and crops has never being attempted. Nevertheless this system of canals and fields is by itself the main protagonist of the history of Otrar, the one that best explains the localisation of towns and villages and fortresses.

Moreover the final decay during the XVIII century of the 2000 years old oasis, synchronic with a contemporary improvement of the irrigation schemes in neighbour oases like Sairam and Turkestan, supports the hypothesis of a major management crisis.

The sites show different hydrological and climatic characters and cycles, with different irrigation facilities which predispose them to different irrigation techniques: with different chances and with different evolution patterns. Their features span from being wet by very big riverine flows likes the Syrdaria, Talas and Ili rivers, to being wet by small streams like the case of piedmonts of Tienshan, west Chu-Ili mountains and Dzhizkazgan. Moreover running in steppes or semi-desert or desert zones. Together they represent the main kinds of hydrological systems of KZ where irrigation works are possible.

2 The technological approach

2.1. Remote Sensing and GIS

At present we are finishing, in our digital lab at CNR, the topological overlay of the entire set of data, collected during the survey, in GIS format. A very useful result was the integration of all the spatial data collected during the fieldwork with remote sensed imagery and 1:10,000 Russian cartography. In this way we are starting to draw a new cartography of the areas of interest with a very detailed geo-archaeological mapping.

In the near future we will plan supervised and unsupervised classification in order to investigate the relations between soils, water resources, environment, canals, settlements, and oasis systems. Sharing the spatial data on line will permit to start a real cooperative work between eastern and western scientific partners. Finally, a virtual interactive reconstruction of the geo-archaeological landscape will represent the main focus of the digital processing.

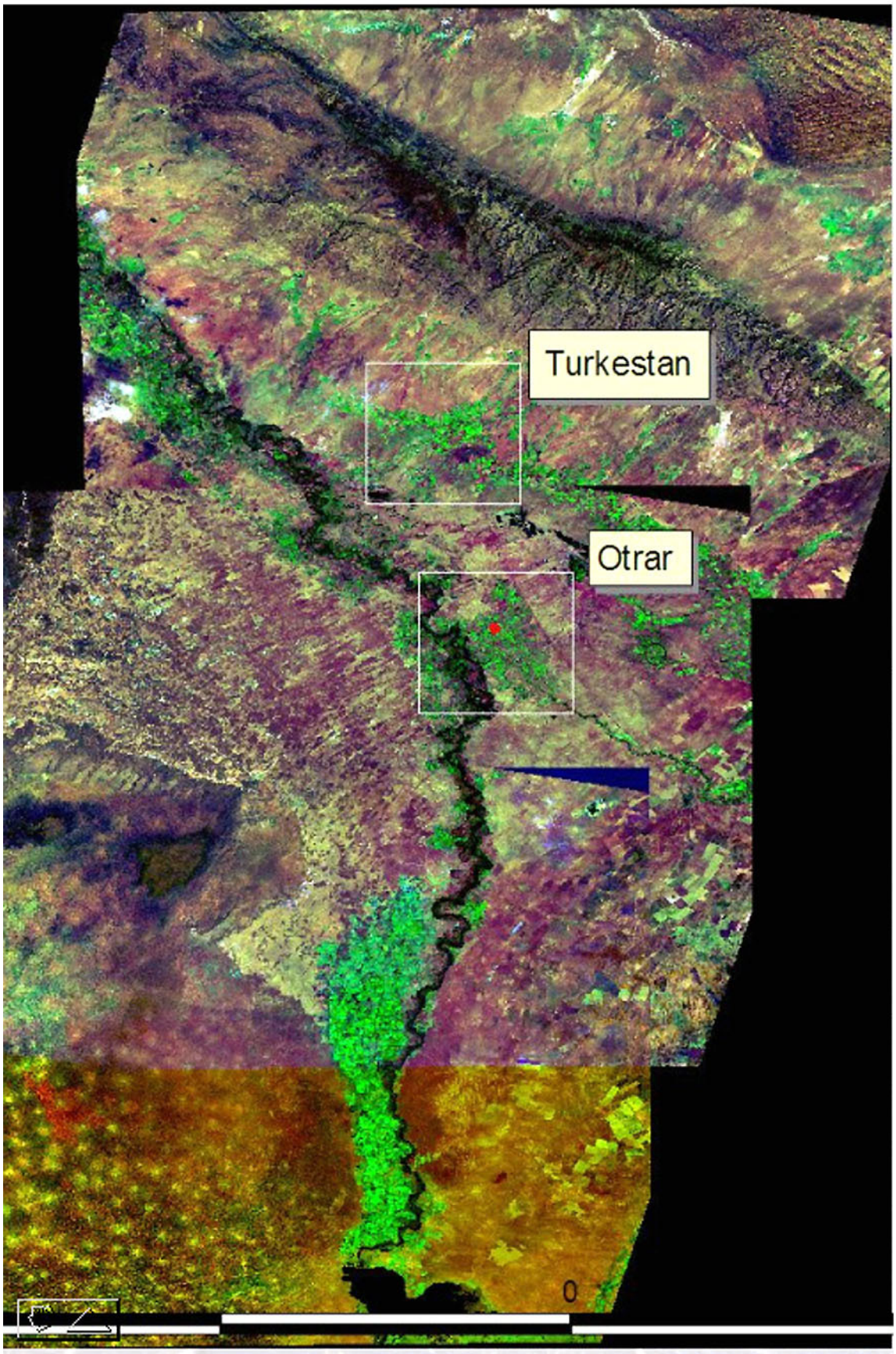

fig04 – Remoted sensed satellite images.

2.2. Cooperative work: Timemap and Ecai project

Together with GIS and Remote Sensed analysis, we are also preparing the descriptive metadata for each themes (*shp*) overlaid in GIS (not just vectors but also raster images), in order to use a free web tool, based on Java Web-GIS interface, called TIMEMAP (in cooperation with some American researchers of Berkeley, that work in the ECAI project). This tool is quite useful indeed to share the same GIS information with all the partners of the project, through an *on line* data visualisation, even during the phases of data elaboration, done in different and distant laboratories (UK, Russia, Italy and Kazakhstan). With Timemap, moreover, it's possible to simplify the operations of data and information exchange among the groups, and to define areas of interest for further investigations.

Ecai and Timemap

ECAI (Electronic Cultural Atlas Initiative, USA, University of California, Berkely) is an international project aimed to develop and distribute geo-data based on historical and archaeological sources. It uses data, cartography and imagery of the world in connection with their content and it is based on a digital technology that combines complex data that come from different disciplines (www.ecai.org).[1] ECAI offers one of the financial support to TIMEMAP (www.TimeMap.net).

TIMEMAP is a project created by the Archaeological Computing Laboratory of Sydney University, Australia. The methodology used for TM was first developed in 1995 under the direction of Ian Johnson.

But what is Timemap? It is a free system that distributes geographical maps, updateable and interactive, together with thematic overlays connected with Time dimension and distributed through the Web.

What can we do with Timemap? Thanks to the Georeferenced data and the Time-Component, it's possible, for instance, to visualise and understand the development of a site or of a city, allowing the user, at the same time, the get detailed meta-information on the data visualised. It's possible to create and to build new hypothesis, new conceptual models just activating and overlaying different thematic layer, coming from different digital sources (vector or raster, images, web pages, databases, multimedia).

Which is at the base of Timemap? It is based on GIS to develop a clear methodological approach that allows the registration of cultural data not only in the Space (longitude and latitude values) but also in a Time-line (lower limit of date and upper limit of date). TimeMap Toolkit program provides the tools necessary to:

1. create metadata (in xml mode, based on Dublin Core);
2. register datasets with the ECAI metadata clearinghouse (just metadata will be in ECAI server[2], while the physical shape files or imagery remain in our server);
3. upload the data to a remote data server
4. Example of registration of metadata with TimeEdit

5. View the data in the Web with a simple user interface, based on Java programming language (http://www.timemap.net/clearinghouse).

Privacy and copyright

We found this tool quite useful to work in a team that is quite widespread in the world. And even if the data and the digital analysis are easily available over the Web, in the project phase we decided to upload files with a password. This means that just the équipe that knows the username and the password can see data, information, have access to our database or upload new data.

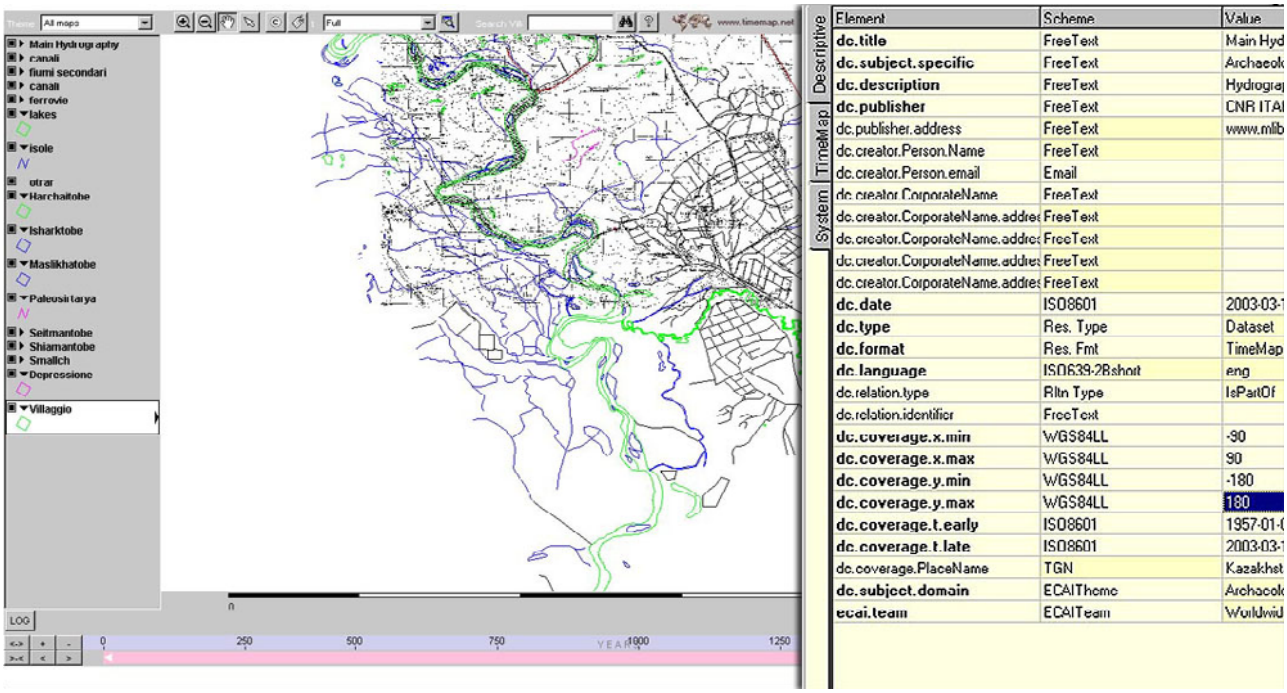

fig05 - Example of Internet access to the data (left) and data preparation

3 Archaeological analyses

3.1 Laboratory analyses and data entry and documentation

Laboratory analyses have been done in Almaty by *Inst SoilSc-KZ*, *Inst Geol-KZ*, *UN-Kemerovo* and they are based on samples, collected in 4 pilot points, during the expeditions to Otrar done in June and October. They are supposed to arrange laboratory methods and procedures for the extensive researches of the second season. Digital analyses of GPS and photo-documentation are in progress by *CNR-ITABC* and *Inst SoilSc-KZ*.

The analyses have been the following:

- palinology and paleoclimatic reconstruction of the last 5,000 years in the polygon of Otrar;
- analysis of sediments (alluvial and Aeolian), for the evaluation of the geo-morphological transformation of the territory of the oasis caused by Aeolian processes, by the river activity and by the implementation of irrigation activities;

- Physical-chemical analyses, for measuring the presence of minerals, salts and other chemical components*(Inst SoilSc-KZ, Inst Geol-KZ)*;
- pedological analyses for determining the character of agricultural soils; and micromorphological analyses for pointing out micro-traces of ploughing or other anthropogenic activities *(Inst SoilSc-KZ);*
- carpological analyses for studying traces of anthropogenic organic remains *(Inst Geol-KZ, UN-Kemerovo)*;
- analysis of pottery for the localization, stylistic and EPR absolute dating of settlements *(Inst Geol-KZ)*
- the topological overlay of all the data collected in GIS-Timemap is actually in progress, in the digital laboratories of *(CNR-ITABC)*, in cooperation with ECAI of Berkeley-USA and with *(Inst SoilSc-KZ)*, so that to share them on line with all the participants of the project.
- Data entry of all the spatial data in GIS format in Arcview. These archives include: remote sensed imagery, Russian cartography, geo-archaeological topographic surveys, unsupervised classifications, paleo-environmental interpretations, etc..

4 Conclusions

The project is still at the beginning but it underlines remarkable gaps in the geo-archaeological knowledge of the steppe's environment.

The study of the very articulated sequences of relations between settlements and irrigation/oasis systems will show new perspectives in the territorial analyses of these areas through the time; in this context the archaeology could give a strong reply to the modern territorial and environmental disasters of these areas. Because of these difficulties the support of remote sensing integrated with geo-archaeological surveys and with DGPS/GIS mapping is giving us important results or in the creation of predictive maps, whether in the construction of a solid geo-archaeological basis.

Finally, the next use of VR systems integrated with databases and spatial archives will contribute to visualise a very detailed virtual landscape of Kazakhstan mainly in the region of Otrar as "beta-test" for the other territories of investigation.

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[1] ECAI is an international consortium of scholars developing electronic and web-based materials relating to cultural (primarily historic) information, such as texts, art, artefacts and sites, with the aim of making this information available across the WWW or through specific products such as CD-ROMs. Regional focus is primarily Asia. The Electronic Cultural Atlas Initiative is a collaborative project, which will combine global mapping, imagery, and texts. ECAI provides scholars and other users with a research resource based on digital technology which can present complex combinations of data from multiple disciplines visually and immediately. ECAI/TimeMap Project Documentation (August 2001).

[2] ECAI metadata is stored in an Internet-searchable database known as the ECAI Metadata Clearinghouse. Anyone with a web browser can search the ECAI metadata clearinghouse database. TimeMap Project Documentation (August 2001) http://www.timemap.net/clearinghouse/clearinghouse_login.html.