Monitoring the Aral Sea Landscape Change

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Abstract: The overall aim of this research project is to develop the basis for a long-term ecologic research to investigate the temporal and spatial pattern of airborne salt-dust deposition across Central Asia. The study of aeolian processes manifested by sand and dust storms require disperse and different technical backgrounds of researchers. The development of a unified geographic information system (GIS) for data storage and analysis descrease operational cost and provides map and data for all scientific community. The monitoring information system uses an Internet-based GIS (WebGIS) technology, and has obtained information about soil erosion in Aral Sea area through: high temporal resolution remote sensing imagery concurrent with ground data collection and analysis; land use and land cover change using Envisat and MERIS data; wind data and volume of sand/dust transportation. The paper also describes how the WebGIS application was developed, implemented and used.

Key-words: Aeolian erosion, Desertification, Central Asia, Dust storms, Landscape, Geographic information system.

1 Introduction

Climate changes may result from natural internal processes, from changes in natural external forces, or anthropogenic origin. Human activities affect climate through the emissions of greenhouse gases to the atmosphere and through profound changes in land use. Climate change has led us into an era in which the widespread extinction of species approaches catastrophic proportions and whole regions and countries will be lost beneath the swelling seas and the expanding deserts of a rapidly warming world.

Of all the hazards that the climate can throw at us, none equals the power of an angry storm. According to insurance companies world wide more than a third of all natural disasters are caused by windstorms. It also accounted for a third of all fatalities and economic losses from natural disasters. Aeolian processes (wind driven transport) as manifested by sand and dust storms are natural events that occur world-widely in arid and semi-arid regions. Dust storms can be both a symptom of serious anthropogenic land degradation, and a problem in its own right.

This article describes how a web-based geographic information system for monitoring aeolian soil erosion in Aral Sea was developed, implemented and used.

2. The study area

The research is carried in the three largest Central Asian States – Kazakhstan, Uzbekistan and Turkmenistan (Fig. 1), which refer to a specific geopolitical region having much in common: the physical environment, similar traditions in agriculture, similar culture, religion, and economic heritage [1]. The Newly Independent States inherited the problem of desertification from the past. Large-scale irrigation development led to the ecological catastrophe in the Aral region. The environmental and economic situation was aggravated after the Soviet Union collapse in 1991.

In Central Asia, where the sand and dust storms are common phenomena due to the presence of vast areas of sandy and clayey deserts, scarcity of vegetation cover and strong winds, large-scale anthropogenic changes lead to the formation of new dust-raising sites. For example we can mention three major anthropogenic events, where the first can be compared in scale to the USA 1930s dust bowl and the latter two are not far behind in their consequences.

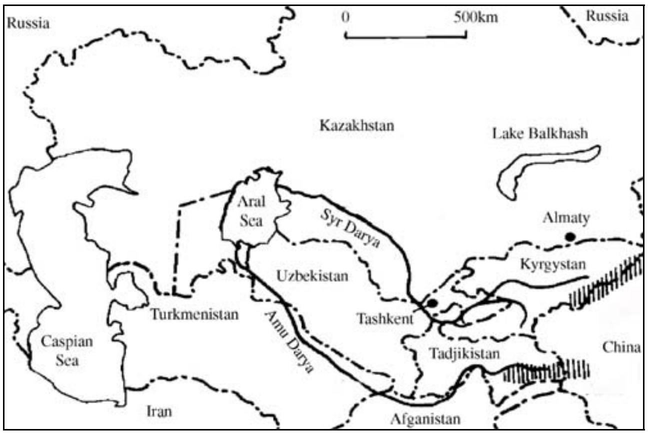

Fig. 1 The study area.

In the 1950s ploughing of virgin lands in Kazakhstan occurred bringing to the rise of severe dust storm events and land degradation. In the 1970s with the construction of the dam in Kara-Bogaz-Gol Bay in the Caspian Sea and following a severe drying-up of the Bay lead to the rise of the anthropogenic caused salty dust storms; and the third event to be mentioned is the large-scale development of l irrigated lands in the Aral Sea basin; an environmental issue which is still of concern to all the region. If the earlier anthropogenic dust-and salt-transfer sources were more or less successfully mitigated, the activity of the third anthropogenic event of salty dust storms originating in the Aral Sea basin is consistently increasing.

The Aral Sea, a completely enclosed sea, is located in the semi-arid and desert areas of Central Asia [2]. This large continental water body, the fourth largest in the world, it has been fed by two major perennial rivers, the AmuDarya and the SyrDarya [3].

In order to achieve "cotton independence" of the former USSR, intensive development of irrigation was started in the late 1950s – early 1960s creating one of the major ecological catastrophes of the 20th century as well as a socioeconomic tragedy [4].

The main consequences of this policy were:

1. Fast increase of the area of irrigated lands in the Aral Sea basin - from 3.442 million hectares in 1950s to 7.86 million hectares at the end of 1990s – a twofold increase [5];
2. A decrease from 55-60 cubic km per year in 1960 to 4-5 per year currently of the water discharge of Amudarya and Syrdarya Rivers;
3. An intense drop of the sea level from 53 m AMSL in 1960 to 33.8 m MSL in 1999 [6];
4. an rapid increase of sea water salinity from 10 to 30 g/l [7];
5. Formation on the exposed and dried bottom of the sea of the sandy-solonchak desert “Aralkum” within the total area of 40,300km² [8];
6. Pollution of the sea water and dried bottom by herbicides, pesticides and defoliants as a result of years of uncontrolled use of these chemicals during the Soviet era [9];
7. Formation of sufficient available material for intense and long-term active aeolian processes which favour the development of salt and dust removal from the dried up bottom of the Aral Sea and distribution of salt and dust over significant parts of the basin [8];
8. Transformation of the Aral Sea from a receiver of salts into a deliverer of the latter to the neighbouring regions [10, 11];
9. Increased of seasonality in the regional climate and deterioration in the quality of drinking water supplies [12];
10. A dramatic increase in health problems [3]. Health problems affects mostly children and women during the pregnancy [13], but are also related with the decreased of life expectancy and the increased of several diseases including a wide range of physiological disturbances [9, 11].

3. Objectives of the research project

There are many natural and anthropogenic sources of salty dust in the Aral Sea Basin. The main objectives of the CALTER research project are to:

1. Study the frequency, distribution and seasonality of the salty, dust, and sand storms in Central Asia;
2. Monitor dust storms using remote sensing imagery from NOAA-AVHRR and SeaWifs sensors concurrent with data from local weather stations;
3. Reveal and monitor the dust-salt emission sites using Landsat, SPOT, and EnviSAT satellite images;
4. Monitor the relevant changes in land use and land cover using Envisat and MERIS data. Specifically we will look at transition from agricultural to abandoned open land and its implications on the generation of new dust/salt emission sites.

5. Study the potential sand drift in the region and its spatial variability using model and real wind data.
6. Develop a spatial and temporal model of the distribution and redistribution of dust, salt, and sand emission sites and emission frequency.
7. Elaborate recommendations for phyto-ameliorative measures in the active dust-salt emission sites for reducing the amount of blown salts-dust and sand.

4. The web-based GIS

Geographic information systems are accepted as power full and integrated tools for storing, manipulating, visualizing and analyzing spatial data [14]. Spatial planning requires a combination of software tools for geographic analysis and presentation.

Like many other rapidly evolving technologies, the GIS has in part migrated to the World Wide Web and is commonly referred as WebGIS. This allows for a rapid dissemination of data, and sharing of maps between users in different locations [15, 16, 17].

Several types of WebGIS can be found in the literature, in some cases it was used for tracking the development of disease [18, 19], for ground water risk assessment [20], for land use monitoring [21] and environmental monitoring [22, 23].

The use of WebGIS makes geographic information available to larger audiences than conventional GIS packages or data files stored in a simple server it also enables the integration of geospatial datasets or other spatial information, this allows for real-time access to a high volume of data for all users that need it [24].

This article presents the web-based geographic information system for monitoring aeolian soil erosion in Aral Sea. The aeolian soil erosion monitoring information system is dynamic, interactive and was developed based on Open-Source licensing. The back-end database uses Linux distribution Suse 10.0 as operating system running an APACHE server for HTTP requests to store spatial data in an integrative and relational database management system (Fig. 2).

A GIS database was created. Data types and sources include: 1:50000 topographic map, DEM, slope map, aspect map, land use map, soil type, TM images, rainfall map etc. All data provide the real-time and accurate information related to soil erosion. In order to capitalize on differences in the signal of the different vegetation cover types, Landsat5 TM scenes were used. The images were georeferenced and calibrated. All images were acquired with a cell size of 30m.

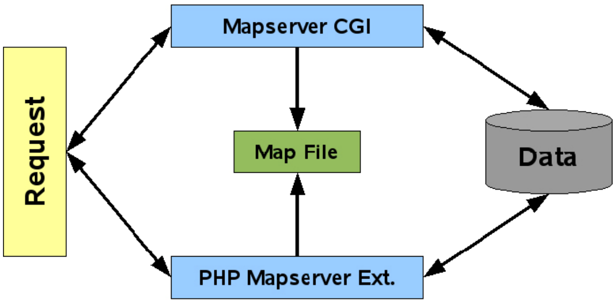

Figure 2-General scheme of Mapserver interaction between requests and data.

The monitoring information system allows users to query the data spatially through the map interface using select by point, line, rectangle or polygon tools. The attribute data can be queried using a query tool that allows Boolean logic to be applied to each of the data fields within the attribute table. Figure 3 is showing a sequential of satellite photos of the Aral Sea presenting the decision of the last 40 years.

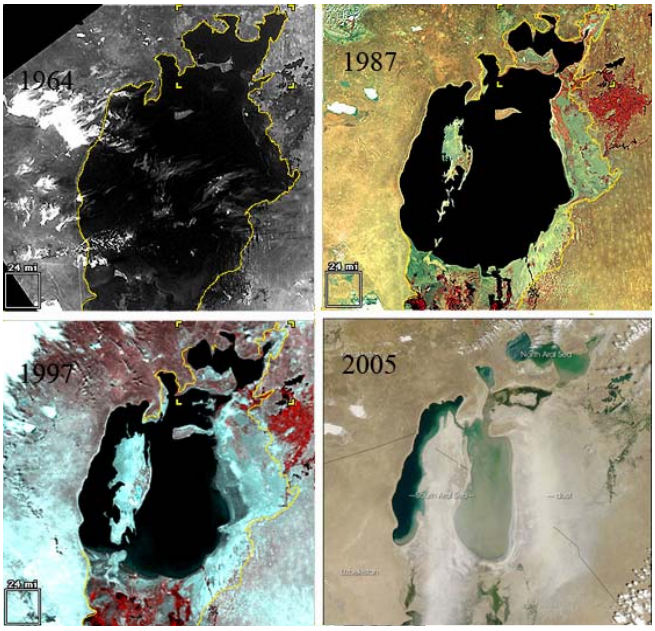

Figure 3-Evolution of the Aral Sea recession from satellite images (Source: USGS and NASA Earth observatory).

Figure 4 has the WebGIS initial display with background the NASA's SRTM images that contain the elevation values of the planet. Several layers are also displayed: countries, rivers, water bodies and major cities. All selected data can be downloaded. Zoom in, zoom out, pan, query, measure etc. can be found in the monitoring information system. The user can turn on and off data layers and the WebGIS responds to the selections by updating the map.

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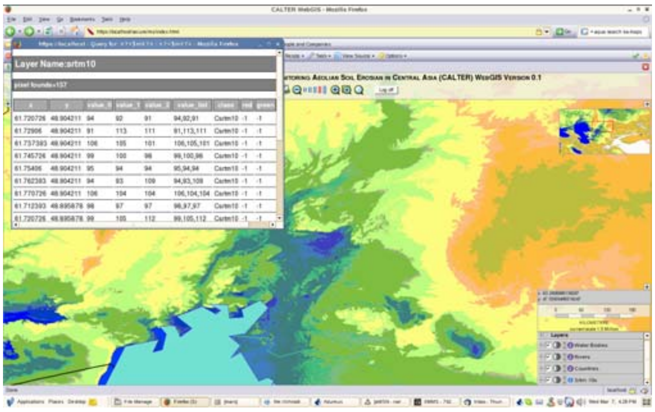

Figure 4-The WebGIS initial display with background the NASA's SRTM images (can be seen some tools like pan, print, zoom, legend docking panel showing the current cursor position in degrees of lat/log, the scale and layers.

5. Conclusions

The soil erosion results, climate data and phyto-amelioration results can be accessed and analyzed by researchers and decision-making officers. WebGIS and remote sensing are useful methods of aeolian soil erosion monitoring. A web-based monitoring application have involved at the online presentation of monitoring results. More research is needed in soil erosion monitoring by combining WebGIS, remote sensing, and access through the Internet. The present web-based monitoring application provides Central Asia desert storm map and data services for all scientific community.

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