Complex approaches for the study of landslide areas in mountainous pilot areas of Uzbekistan using remote sensing data and GIS techniques

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Abstract Landslide danger is well known and improved prediction can save lives and property. To predict the landslide danger for every geological structure, the government and geological organizations use geoindicators which monitor the sites and warns the scientist that "in Baybaksay there is a dangerous situation " or "Earth movement occurred 124 km southwest by the Tashkent–Charvak road". All this is done with the help of geological indicators and some factors for the current geological Earth structure. Methods of measurements are done with the help of special equipment on site, which transfers information via GPS or mail or other methods of information transfer. The whole world uses Black bird satellites or others, which makes images of the surface of the world, and can see the changes which happened in the place scanned. Changes in places can be seen on different light spectra and changes in the Earth which happened can also be seen within 4–5 hours with the help of remote sensing. The method we used is a combination of geoindicators (humidity of ground, quantity of deposits lately, shifts in ground and other) and remote sensing—monitoring from the satellites so we can have one centre in the world—which has databases with all geoindicators of the structure of the ground of the world. Some say that it is impossible to watch over the ground from satellites, it is suggested that all the work must be done at the ground surface, but we have never tried to do this. The greatest improvement in this case would be that every government would not need to buy new satellites or expensive equipment, they would just need to pay a monthly fee (much cheaper). The information centre, which will be only one on Earth, will process all the data from satellites and will compare it with geoindicators and tell us where dangerous processes are going on and will show the model of what will/can happen, and if there is a need to evacuate local citizens.

Key words geoindicators; landslides; remote sensing

INTRODUCTION

Natural hazards such as landslides, avalanches, floods and debris flows can result in significant property damage and loss of life. Uzbekistan has a long history of these natural hazards, especially in its mountainous areas, and recently has experienced a number of these events that have lead to substantial loss of life and damage to property, infrastructure, cultural heritage and environment.

Remote sensing and Geographic Information System (GIS) science have been widely applied to solve a broad spectrum of environmental and natural hazard issues, especially in the area of landslide research, and as it is applied to addressing related problems in society. This paper discusses approaches for the comprehensive assessment of landslide hazards, including prediction, in mountainous pilot areas of Uzbekistan.

APPROACHES TO THE STUDY AND DETECTION OF LANDSLIDE AREAS

Evaluation and analysis of landslide hazards is highly complex, and requires the systematic study of a multitude of interrelated factors. The efforts described in this study were focused on developing remote sensing techniques for deriving the spatial distribution of parameters that characterize the primary landslide triggers in the study area. The availability of higher-resolution multi-temporal and multi-spectral remote sensing data has made these investigations possible. Hazard zoning maps were developed from field reconnaissance data (Turrabaev & Kamaletdinov, 1997). Various spectral band combinations are being tested in an attempt to relate these spectral signatures to observable land surface features that are related to landslide occurrence. These analyses are currently ongoing, but preliminary results appear promising.

The theoretical method that we are trying to use for estimation

Landslide susceptibility maps can be prepared in a variety of ways. Many geoscientists favour the use of an overlay model approach in which several map layers are combined by some empirical system to determine the potential for sliding in a given region (Turrabaev & Kamaletdinov, 1997; Kamaletdinov, 2000). The resulting susceptibility maps, although based on a subjective weighting of relevant factors, can often be of high accuracy and utility. In order to obtain the relevant input data for this type of analysis, remotely sensed data are often used. To date, susceptibility mapping, just as the mapping of historic and individual landslides, requires the use of higher-resolution imagery, and has somewhat limited the application of landslide susceptibility mapping. While high-resolution air photo or satellite imagery is superior to lower-resolution imagery for the purpose of mapping historic and individual landslides, such higher levels of resolution may not always be required for the development of landslide susceptibility maps. In order to determine if medium resolution satellite imagery, such as SPOT or ASTER, or SAR for movement detection could provide the needed data for landslide susceptibility mapping, a comparison was undertaken of landslide susceptibility model output resulting from the use of stereo NAPP aerial photography *vs* the use of data obtained from stereo SPOT imagery. The test area selected for this study consisted of two watersheds, Birchumla (Sulisai) and Baybaksay areas (both near Burchmulla), located west of Tashkent along the eastern shore of the Charvak reservoir. Both watersheds have a long and well-documented history of landslide activity and sufficient geological variability and complexity to provide a good test site. The specific overlay model used in this evaluation required input data consistent with the needs of many other models of this type. The model outputs derived from the two different data sources and presented here in the form of susceptibility maps were virtually identical.

Statistical and difference analysis will be confirmed, and preliminary results suggest that satellite imagery, such as SPOT and Landsat, could potentially be used in lieu of conventional air photos or other high resolution imagery to evaluate landslide susceptibility.

The use of Synthetic Aperture Radar (SAR)

Data acquired by SAR systems can provide three dimensional (3-D) terrain information and can be used to assist in regional-scale analyses, e.g. evaluating the susceptibility of slopes to failure. Under favourable environmental conditions, the Permanent Scatterers (PS) technique (Colesanti, 2006), which overcomes several limitations of conventional SAR differential interferometry (DInSAR) (Gataullin, 2005) applications in landslide studies, is highly suitable for monitoring slope deformations with centimetre precision. The PS technique combines the wide-area coverage typical of satellite imagery with the capability of providing displacement data relative to individual image pixels. However, with the currently available radar satellites only very slow ground surface displacements can be reliably detected and measured.

The presented case study of a landslide from the Baybaksay area west of Tashkent, indicates that the most attractive and reliable contribution provided by this remote sensing technique lies in the possibility of wide-area qualitative distinction between stable and unstable areas and qualitative (relative) hazard zonation of large, slow landslides based on the identification of segments characterized by different movement rates. Since only the radar line of sight projection of the displacements can be detected, a quantitative exploitation of the PS data is only possible where sufficient ground truth is available. In site-specific or single landslide investigations, the PS data can represent a very useful complementary data source with respect to the information acquired through ground-based observations and in site surveying. However, the difficulties associated with the feasibility assessments of the applicability of SAR data to local-scale problems, as well as with the interpretation of PS results, require a close collaboration between landslide experts and specialists in advanced processing of radar satellite data. The interpretation of the exact geotechnical significance of small, radar sensed ground surface deformations is challenging, especially where ground truth is lacking. Although any ground deformation is potentially of interest to an engineering geologist, detection of movements in both vertical and horizontal directions is needed in the case of landslides to evaluate slope failure mechanisms. However, with their high radar viewing angles the current space-borne systems can only detect a fraction of the horizontal component of movement. It is expected that the upcoming SAR dedicated missions with new sensors and different acquisition geometries, combined with the rapid developments in the field of advanced radar data processing, will allow a full 3-D reconstruction of deformation data and help to further reduce the current limitations of the PS and similar DInSAR approaches.

RESULTS AND DISCUSSION

Algorithm and processing results

Landslide hazard areas map were made with help of the ArcView3.2 program. The vectoring of topographical map (Fig. 1) on a scale of 1:25 000 was made on the basic

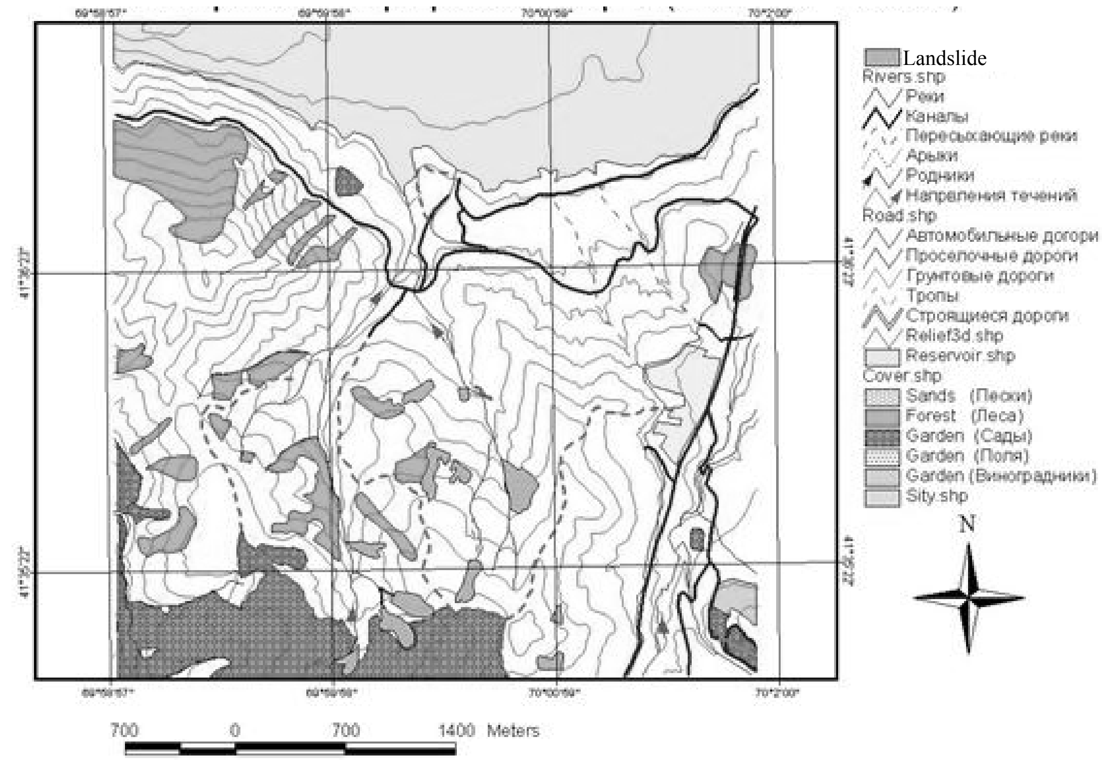

Fig. 1 The vector topographical map of Bostanlik region (scale 1:25 000).

geographical objects (the hydrographic, settlements, an evaluation, the planted trees and shrubs files, landslide circuses). A 3-D model of the district with the application of SRTM (Shuttle Radar Topography Mission) data was constructed. To reveal landslide hazard sites on initial territory an exposition function and a bias function of a surface are used.

Calculation of curvature of a surface

Bias function defines a slope or the maximal degree of value change from a pixel to the next pixel. The target grid-theme of a slope can be calculated in percentage (for example a 10%-slope) or in degrees (for example a 45-degree slope).

The steeper the slope, the more considerable the component of gravity, aspiring to overcome the force of coupling of rock particles and displacing them downwards. The stir features help gravity of a slope structure: durability of rocks, alternation of various layers structure and their inclination, the underground waters weakening forces of coupling between particles of rocks. Subsidence is typical for the abrupt slopes combined dense cracked rocks (e.g. limestone). Depending on a combination of these factors slope processes are various shapes. Abrupt slopes (pixels of darker colour) are located there, where in the initial model the transition of colours is replaced more sharply (Fig. 2).

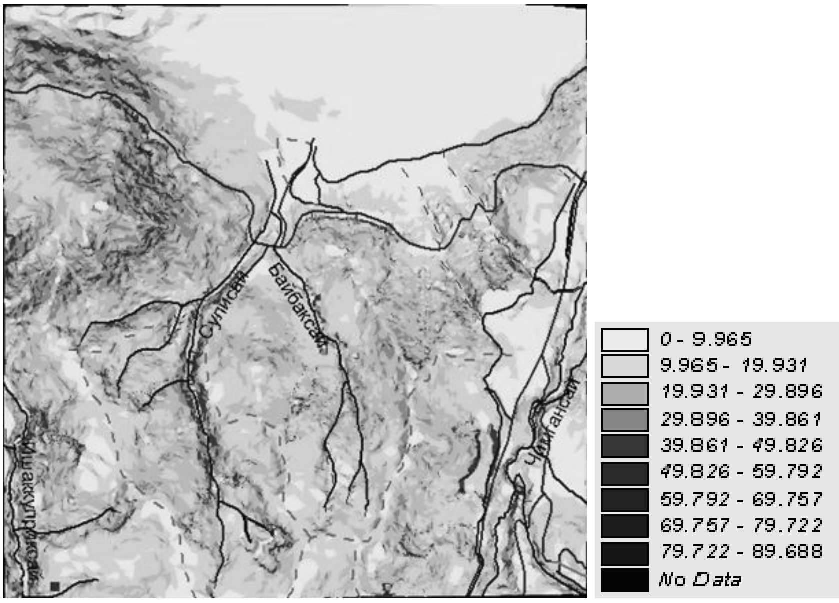

Fig. 2 Slope resulting map, taken from 3D area model, built previously (in degrees).

Degree of light exposure of slopes

A degree of light exposure is also an important factor for the occurrence of a landslip as a brighter slope has lower humidity. Values of light exposure are defined on a sun-falling angle (Fig. 2), in this case at midday. Pixels of more dark colour specify insufficiency of light exposure, and accordingly, slower drying of ground (Garbuk, 1997).

The relief shading function is used for the definition of the hypothetical light exposure of the surface for analysis and for graphic representation. At the shading analysis a relief is used to define duration and intensity of solar illumination in the given place. Display shading considerably improves presentation of relief display. The analysis can be carried out on an entrance grid-theme. In Fig. 3 the relief with values of azimuth and heights are 142 and 42 degrees. Azimuth (specifies where a source of radiation is in relation to an entrance grid-theme) and height (the inclination or an angle of a source of radiation above the horizon) can make various effects. Figure 4 illustrates before and after landslide conditions.

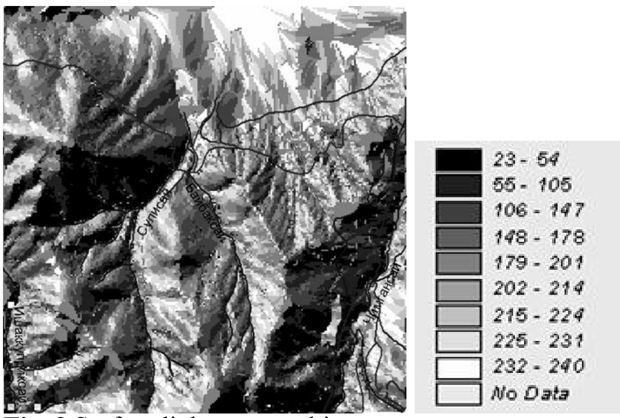

Fig. 3 Surface lightness resulting map.

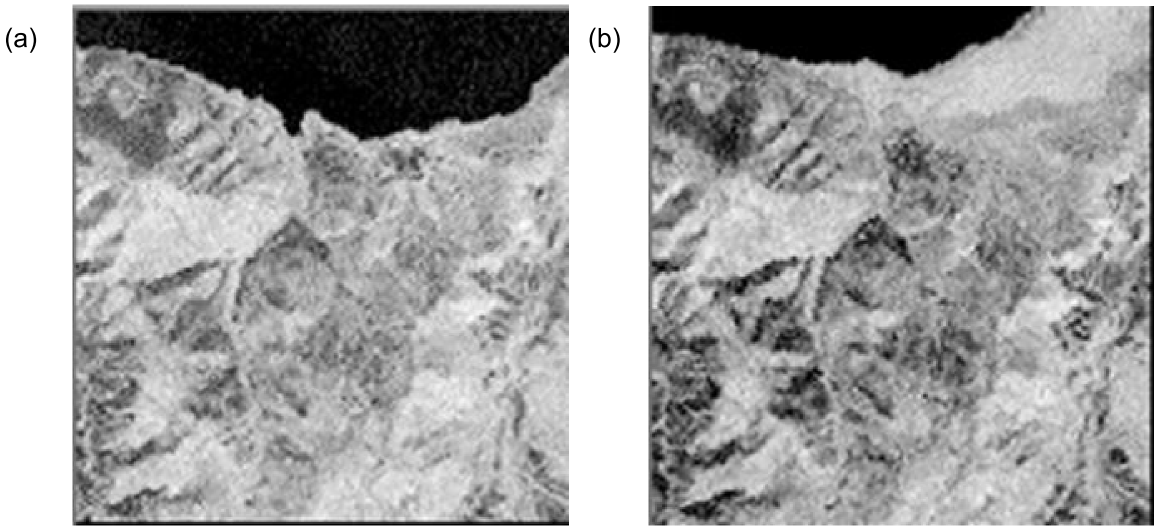

Fig. 4 Before and after landslide occurrence: (a) 14 September 2000 and (b) 29 September 2002.

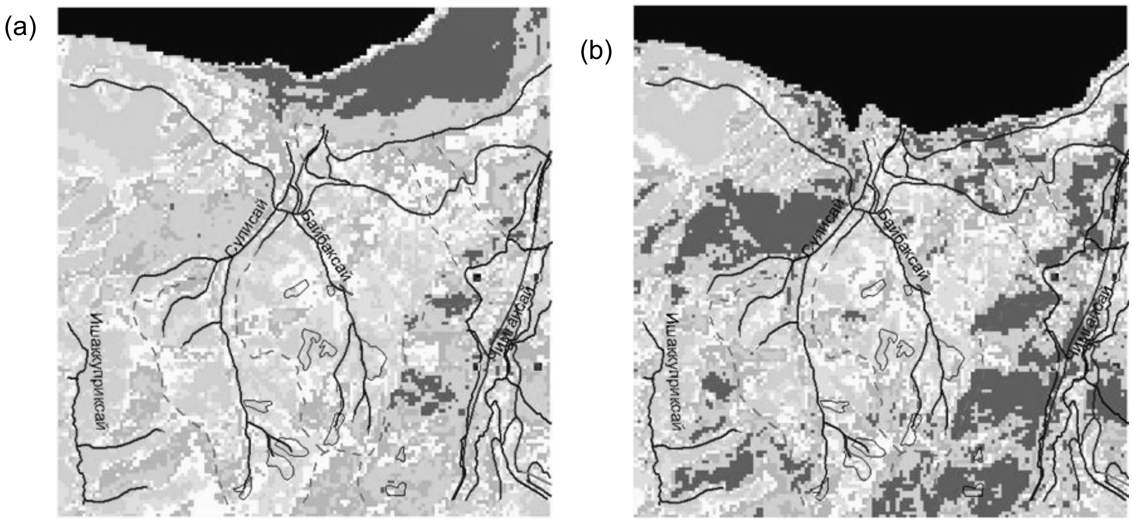

Fig. 5 Landsat 7 images of (a) 14 September 2000 and (b) 29 September 2002, with soil classifications and Landslide areas indicated.

Preliminary classification of landslide hazard areas

Classification—is a process of sorting (distribution on classes) elements of the image (pixels) on the final number of classes on the basis of values of their attributes (DN, digital numbers). If the pixel satisfies one of the conditions of the class, it relates to the particular class which corresponds to it. For example if the limit of convergence is equal to 0.95, it means that the process of clusterization ends as soon as the quantity of pixels is unchanged, the class between iterations will reach 95%. In other words if only 5% or less of pixels change, the class process of classification will end (the centres of classes will be established equal to what participated in clusterization on last iteration).

According to Landsat imagery preliminary classification with training (Fig. 5(a),(b) on seven basic classes has been. Values of fields for the signature were set on sites of the card presented by the customer where already occurred landslides have been reflected.

CONCLUSIONS

This study proposes the detection of landslide areas with remote sensing and GIS analysis application techniques. Theoretical methods, approaches, use of Synthetic Aperture Radar in landslide detection, algorithm development, and processing are described. In many situations, especially in the case of remote locations and/or developing countries, this capability should result in substantial savings in terms of time, financial resources, and overall viability.

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