GEODETIC METHODS FOR LANDSLIDE DETERMINATION

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***Abstract**: The precise and low cost determination of the landslides is an actual problem as the multitude of these kinds of events is growing. Using the digital images as first source for the digital terrain model and its integration into a GIS medium with high analyzing properties could represent an efficient solution in this case. All over, this method could represent a monitoring solution and not only when digital images exist but other geodetic measurements. The newest methods of producing the digital images and also the available post processing and GIS software could bring efficient analysis and quick action when landsides effects appear.*
***Keywords**: digital images, digital terrain model, GIS, monitoring, landslides*

1. Introduction

Given spatial data sets of high resolution, GIS, remote sensing and powerful computers with large capacity and high speed of computation, now it is possible the partial automation of determination of areas affected by landslides [Temesgen, 2001], [Gritzner, 2001], [Ayalew, 2005], [Guinau, 2005], [Fall, 2006], [Zolfaghar, 2008], [Yalcin, 2008]. The quantitative predictive models are based on a spatial database consisting in thematic layers that represent occasionally factors for the landslides occurrence.

There were developed three theories for risk description from mathematical point of view: probability theory, Fuzzy theory and probative theory of Dempster-Shafer.

Corresponding to those three theories, the used functions are: the conditioned probability function, the fuzzy function and the trust function. These functions, named also favorability functions, are used to represent a quantitative measure of the predisposal for landslide production.

2. General considerations

In the various branches of human activity, particularly in construction, people are facing slope stability problem, both in naturally occurring and those made from artificial excavations. By disturbing the stability of slopes sliding phenomenon under terrestrial gravity action, moving land masses being driven down the slope. Landslides are considered movements of land masses in motion that are separated from the stable with a clear plan of slipping.

Sliding phenomenon are usually studied from two different points of view. Geologists study the slip phenomenon as one of the main processes of denudation, the link between causes, developments and structural modeling surface displacements. [Andrei, 1974]. Engineers and engineering geologists position is completely different. They investigated slopes in terms of building safety to be raised on them. Therefore, they try to determine the slope for slopes, to determine the maximum allowable slope of excavated slopes and find methods to evaluate certain slope stability, and stabilization and corrective measures are necessary. Slope stability quantitative research emerged from the need to build high embankments and deep to dig dibble for railway lines, roads or canals.

Obviously, best results are obtained when both lines of research complement each other. For the quantitative determination of the stability of slopes by mechanical methods is essential to know the land geological structure of the area, composition and orientation layers and geomorphological history of the landscape. On the other hand, geologists can better express terms emergence and evolution of slip phenomenon when facing their considerations and static analysis results obtained from research conducted by means of earth and rock mechanics.

Therefore, both engineer and geologist, study the theoretical and practical matter slip, and knowing the causes, nature and size evolution to assess landslide hazard and finding the right method to stabilize sliding land.

3. Landslides

Landslides are the result of the massive disposal of land. Some slides are not forming a boundary between the stable and unstable. There are also numerous slides, with areas of detachment, which was preceded or rupture caused massive internal processes and sometimes excessive deformation.

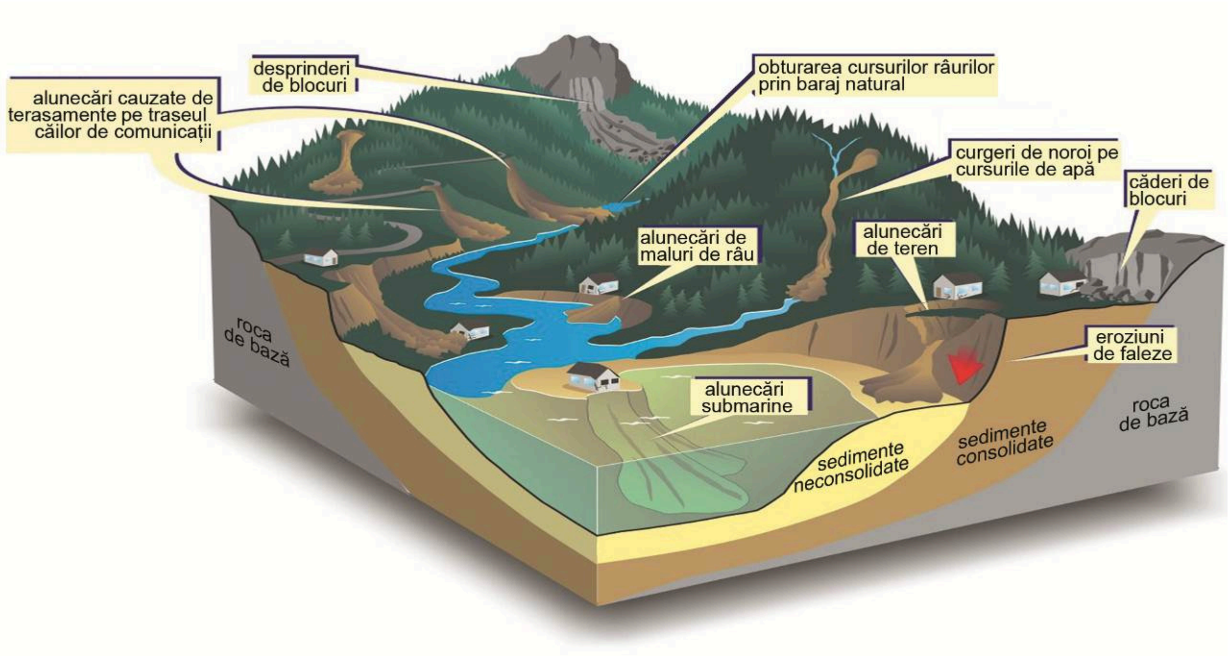

Figure 1. Types of landslides

Thereby, the causes and dynamics of complex landslides involving the examination process including the transfer of land without causing deformation phenomenon of surface separation and the breaking, characterized by the appearance of discontinuities in the mountain land.

Landslides are a class of natural disasters by triggering which can cause considerable human and material losses. Therefore, reducing these damages requires forecasting landslides or preventing their onset. Remedy products is already slipping only action to recover land affected. At the launch slip therefore is very important to identify the primary and is in direct correlation with how to mobilize the shear resistance as a parameter controlling geomechanical stability.

Mobilization of shear resistance shift highlights, reported at first failure, a major resistance area that mobilizes the small displacement is known as the resistance at the top, and feature heavily in any slope. The slopes in this stage are pre-lendslides [Paunescu, 2000].

Pre-landslide stages, first slip and specific reactivation of cliff instability, rotational and translational slides and slides with side extension. Of these, rotational and translational landslides are most common in Romanian conditions.

Geomorphologic configuration forms gentle slopes highlights from the sedimentation followed by erosion of the slope [Paunescu, 2000]. Any forms that deviate from this typical configuration can be interpreted, whether the image is bedrock surface configuration geomorphological or cues can be suspected early primary slip or slide cues old post. Analysis of these abnormalities can provide useful information in the forecasting landslides underpinned the techniques that we propose in this paper.

Satellite and aerial platforms is like a modern technique to investigate the early instability and landslides over large areas, which are techniques by which it can demarcate areas that will form the subject of detailed investigations [Richards, 1986].

Aerial platforms are systems consisting of sensors and ancillary equipment acquisition that you take collections of data. Acquisition sensors can be panchromatics, multi-spectral, hyper-spectral, radar or lidar.

Satellite platforms are composed of several subsystems, each with a clearly defined [McGlone and others, 2004], namely: a structural subsystem, a subsystem for altitude determination and control, a power subsystem, a thermal subsystem, a communication subsystem and a sensor system for remote sensing. All modern platforms are equipped with inertial (INS / IMU) and GNSS implementation guidance operation outside of the images taken [Grejner-Brzezinski, 2001].

Investigation of digital terrain model provides all information required to draw remedial studies due to terrain conditions where ground investigations are not possible. In this case no longer seeks landslide forecasting, but is aimed at restoring mechanisms resulting in slippage and can guide the development of technical solutions for remediation and rehabilitation of affected land.

Landslides can be investigated using digital terrain model and the images obtained can be divided into three categories in direct correlation with the stages of slipping:

Category 1 includes slides of pre-landslide stage. Are associated with depression areas in succession incipient ebullient decreasing the elevation, the mechanisms rotational obvious and less obvious to the translational. These cues are usually undetectable to the naked eye, but are very useful because it enables prediction of landslides long before their occurrence. In terms of topographic anomalies are found in uniformity contours, their withdrawal in the depression areas and coastal areas preembullent advancement in the valley. Technology is valid only if coupled with the growth areas of preembullent, only in this series on elevation. The presences of the depression areas can only be caused by local subsistence phenomenon have no connection with landslides. Pre-landslides appearance is most often attributed to the accumulation of slip and very little material on tectonics. Should be considered progressive or regressive mechanism, for slides incipient can make the depression areas predominate, respectively preebulments areas. Elevation changes described above can be identified by comparing existing digital terrain model with a previously created either by monitoring the displacement of three-dimensional mark.

Category 2 includes slides in proximity to first slip where tension cracks, small increases associated downstream sliding compression cracks ebulments better defined. All these transmissions can be identified by viewing carefully orthophotomap or digital terrain models. With the use interferometry may provide more useful information.

Category 3 includes slides already produced (after landslide or postfactum and subsequent reactivation) and which are visible as ridges and terraces all cues sliding, transverse and longitudinal cracks, fissures affected ebulments defined by inflection.

Landslides greater magnitude occurred in the past decade in Malul cu Flori (June 1979), Zemes (1992) Bacau, Izvoarele (August 1993) Galati, Pârcovaci (December 1996) and Ocnele - Valcea (2001).

4. Determination of areas affected by landslides

Malul cu Flori village is located in the north-west of the county Dâmbovița. Actual name of the village dates in 1900, probably after the name given after the bat bushes that are on the right entrance road.

Existing cartographic products purchased from the National Geodetic Fund and OCPI Dâmbovița was:

- Orthophotomap common scales 1:5000 Malul cu Flori - edition 2005;
- Digital terrain model resolution 30 m - edition 2005;
- Topographic and cadastral plan scale1: 10000;
- Topographical Plan scale1: 2000.

The existence of landslides and territories slip is an objective reality, created by the region and complicated evolutionary development of man's economic activity. To reduce potential damage, it requires knowledge of spatial distribution of these phenomenon, carrying out strict safeguards. This will reduce the probability of new landslides and reactivation of existing ones, will reduce the danger of destruction of engineering and land targets by sliding processes.

Identifying these areas is made through spatial analysis. Digital model of deformation is presented in shades of brown, resulting digital terrain model by comparing the 1976 edition with 1967 edition digital terrain model.

The digital elevation differences (deformations) results reflect changes in relief due to the landslide which took place in 1972. This pattern of deformation is superimposed on the 1976 edition 1:2000 cadastral plan (Figure 2).

The landslide of 1972 is characterized by a broad valley in the ridge (the dark brown) and ebulments (colored area) limited Valea Larga and large probably eroded between the time slip and time of the 1976 map edition.

Located in the western area of the landslide it shows numerous undulations relatively consistent contours which could be interpreted as a stage that is pre-landslide area. The presence of a ridge area confirms the initial conclusion. Located in the eastern area of the landslide it highlights many alterations to the lift down which interpretation should be done in conjunction with bedrock configuration. Even beyond the left flank of the main terrace of the landslide, crest and forehead lift to be affected which cannot be explained only by tectonic causes, the presence of faults in the bedrock that covers deposits subdivided into two massive totally different behaviors. Second, image analysis highlights and streams routes whose erosion effect is well shown.

To emphasize the size of deformation during 1976 - 1967 saw a digital model of their values divided into nine classes (Figure 3). It should be noted that after the 1972 slide area was free, without buildings and young orchards which made it possible to achieve accurate image.

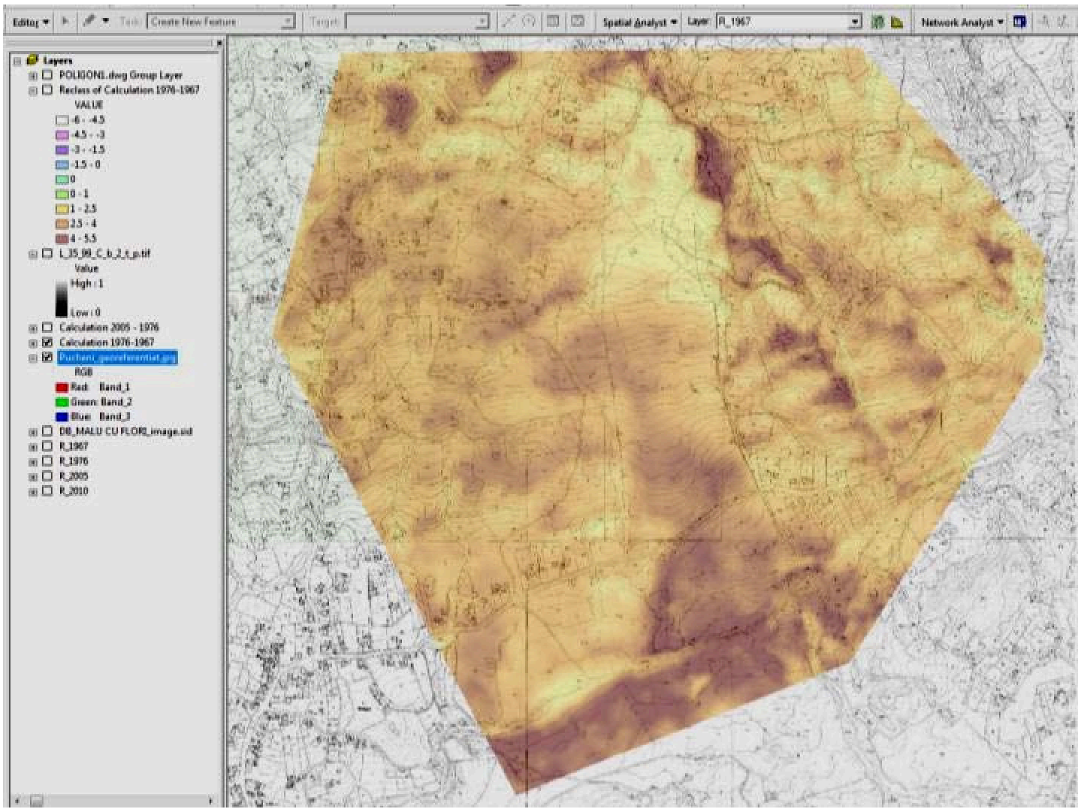

Figure 2. Digital model of deformation (in shades of brown) between 1967 and 1976 editions represented on 1:2000 topographic plan , 1976 edition

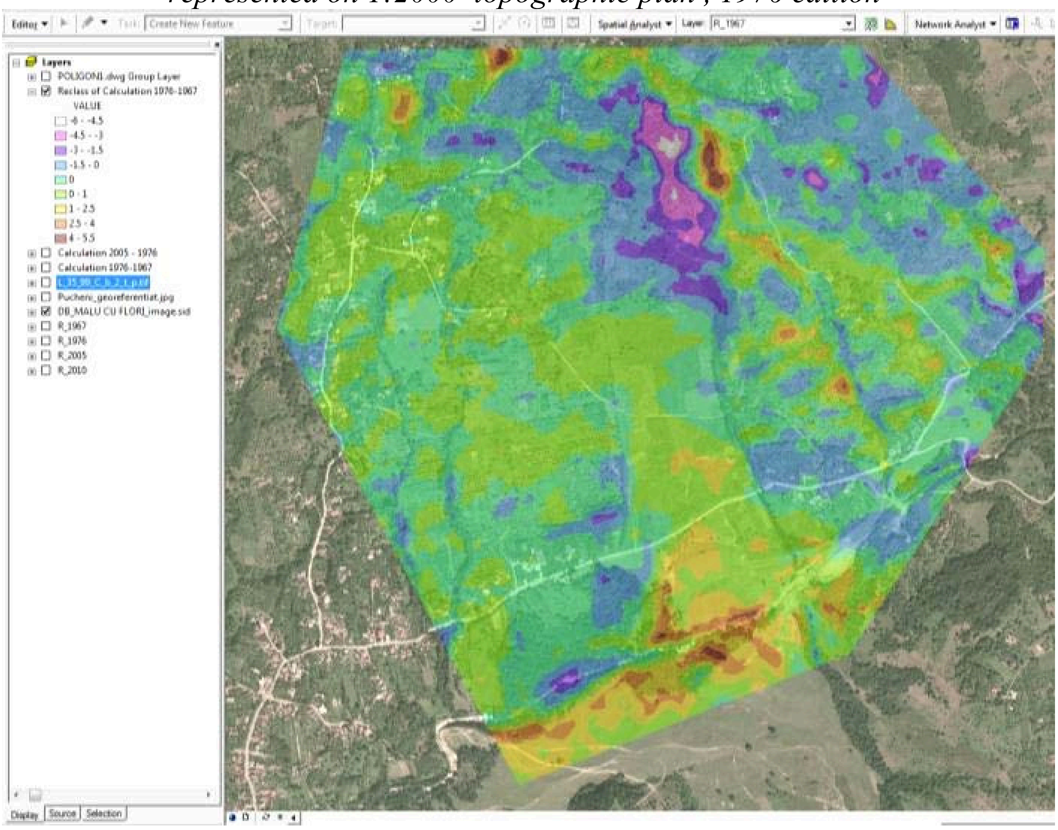

Figure 3. Digital model of the deformation (9 classes of values) between 1967 and 1976 represented on orthophotomap 2005 edition

Further, it achieved another digital model of deformation for the period 1976 to 2005. Foot area adjacent downstream right bank of the river valley is steep terrain Large and full of high vegetation, which may induce errors in the implementation from the 2005 model cannot be accepted as lifting area of several meters per route stream (natural dam would be created). In ridge area of landslide such inaccuracies also occur, all in areas with high and very dense vegetation. Therefore this model has been used to perform further spatial analysis. Chronologically, was achieved another digital model of deformation for the period 2010 to 2005. As a result of the landslide area appeared likely the same inaccuracies, we considered the 2005 digital terrain model does not allow accurate representation of natural terrain altitudes (no vegetation) and cannot be used for analysis. For these reasons, we had to analyze the landslide in 2010 taking as reference the digital terrain model obtained from the 1976 edition map.

Another digital model of the deformation was created specifically for the period 1976 - 2010 (Figure 4), presented in different ways.

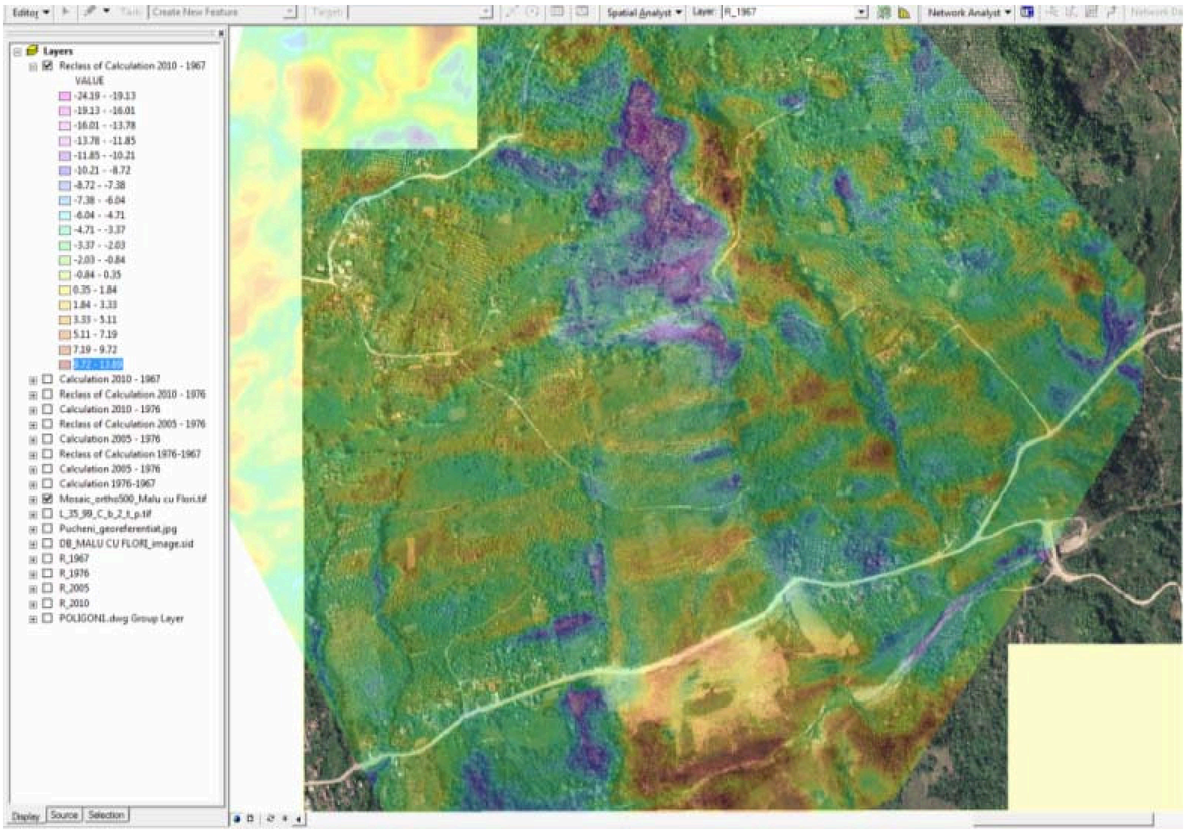

Figure 4. Digital model of deformation (19 classes of values) between 1976 and 2010 represented on orthophotomap 2005 edition

Digital model of deformations obtained reveal morphological changes (as identified in the field visit and especially in the digital terrain model edition 2010), namely depression and ebulments areas. Area located beyond the western flank of the landslide has not changed dramatically as confirmed by reality, but small changes are specific to a stage pre-landslide limit, which should be submitted to the local government area because many buildings are located, ways of communication and population. The area beyond the eastern flank of the landslide reveal a troubled terrain, compounded fault probably talking about the beginning and are visible in this interpretation.

Between 1976 and 2005 County Road 724 has been restored, its position is changed (which is revealed by orthophotomap 2005). By comparing the position of the shaft road leading to the following maximum horizontal displacement:

- For the landslide of 1972 a maximum displacement of 38.98 m;
- For the landslide of 2010 a maximum displacement of 35.81 m

5. Conclusions

The landslide at Malu cu Flori scientific and social interest due to its scale (about 1400 m long, 400 m wide and sometimes 25 m depth) which means the affected area over 50 hectares and perhaps a volume of over 10,000. 000 m3. Although located in a rural area, passivity towards this sliding could mean damage to the only access to town Pucheni and isolation of over 2500 inhabitants, creating natural dam on the Broad River Valley flooding of properties upstream and downstream area by breaking at some point the dam created. Scientific interest derives from the fact that the first slip occurred in 1972 and in 2010 to reactivate the same shape, possibly with some development retrogresive to crest. Before and between the moments slipping numerous topographic photogrammetric flight culminating in 2010 made even two months after reactivation. Existence of all such information capable of being converted into digital images, is a case study designed to confirm requirements landslide specialists to investigate, inventory and forecast these phenomenon by addressing the broad areas.

Comparative analysis for 1976 to 1967 of 1972 shows typical slip and adjacent areas that are at the stage of pre-landslide. Interpretation areas and lowering the lift can eliminate general erosion and the streams that stream path in Valea Larga. Linking areas down to the lifting points clear areas stretching and compression suffered by deposits in the sliding cover and any irregularities on the bedrock surface. What is surprising are areas of ridge lift or slip on the eastern flank can not be explained only by the presence of levels of fault in the bedrock, which is impossible to detect any field by visual inspection or measurement.

Comparative analysis of 2010 compared to 1976 shows cues of typical landslide in 2010 identified both visual inspection and digital model created from the query (terraces sliding speed of 4-6 m high, ebulmente of 10-12 m height). Comments on neighboring areas remain valid which means that movements of the stage that continue pre-landslide or not triggered landslides in these areas may be on grounds tectonic (fault steps to streaky party cover) or hydrostatic level in May lowered.

Comparative analysis should be considered very carefully in order to be eliminated parasitic values that may compromise the entire concept. This happened with the 2005 model of scientific being happy incident as a lesson on how the selection of primary data. Note that technical progress will bring images of increasingly powerful, and the difficulties of adjusting their old maps will remain as a pioneering step.

Monitoring of unstable slopes or potential instability are in phase prior to disposal, the post-landslide or reactivation may provide calibration data necessary mathematical forecasting models. Effective forecasting of landslides requires an advanced capacity to anticipate the behavior of slopes in the main trigger factor forecasting conditions or combination of favorable factors. In this sense, becomes a more extensive development in the world creating a Central Monitoring predict landslides that trigger factor is sufficient in predicting the onset of slipping due to prior analyzes mathematical models accurately calibrated measurements based platforms satellite and airborne.

In conclusion, the interpretation of digital images compared to slopes over large areas using GIS provides valuable information on the geomorphological dynamics, signal and surprising phenomenon, representing a very useful tool in the investigation, particularly inventory and forecasting landslides over large areas . Based on these analyzes can crystallize a clear detailed investigation and monitoring, which is impossible with conventional techniques of investigation.

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