BASIC CONCEPTS OF LANDSLIDES MONITORING USING EARLY WARNING SYSTEMS

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***Abstract**: The human being is living permanently in an environment that is exposed to a wide range of situations more or less dangerous, generated by many factors. Extreme manifestations of natural phenomena such as storms, floods, drought, landslides and diving, strong earthquakes and others, plus technological accidents (serious pollution, for example) can have direct influence on the life of each individual sand society as a whole.*

Only a precise knowledge of the phenomena, called disaster and/or hazard, allow to the authorities to take the most appropriate measures for mitigation and reconstruction of the affected regions. The effect of disasters can be reduced involving interdisciplinary study of hazards, vulnerability and risk as well as information and public education. Even if to prevent adverse effects of extreme natural events were probably taken measures from the first contact between man and nature, over time, scientific world was concerned to find solution or warning systems to prevent/to provide full information about hazards. Warning systems contain important information and can provide, by analyzing the events that took place using the implemented models, the estimation of the probability of producing of a new event, while allowing a classification of as according to the invulnerability.

***Keywords:** monitoring, warning systems, landslides.*

1. Introduction

The human being is living permanently in an environment that is exposed to a wide range of situations more or less dangerous, generated by many factors. Extreme manifestations of natural phenomena such as storms, floods, drought, landslides and diving, strong earthquakes and others, plus technological accidents (serious pollution, for example) and the conflicts can have direct influence on the life of each individual sand society as a whole.

Only a precise knowledge of the phenomena, called disaster and/or hazard, allow to the authorities to take for the most appropriate measures for both mitigation and reconstruction of the affected regions. The effect of disasters can be reduced involving interdisciplinary study of hazards, vulnerability and risk as well as information and public education. In this area, the informatics is required to contribute.

In this context, the hazard is the likelihood, in a certain period, of a phenomenon potentially harmful to human beings and the environment. So random is a natural phenomenon or anthropogenic, harmful for humans, due to the consequences which are exceeding the safety measures that any society have.

Natural hazard is a form of interaction between humans and the environment in which adaptation thresholds are exceeded. For their production, must be present human society. If an avalanche occurs in Antarctica, this is only a natural phenomenon. If the same phenomenon is recorded in the Făgăraş Mountains, for example, where a hut or a road is affected, these are a natural hazard.

Vulnerability highlights how much the man and his assets are exposed to the various hazards, shows the damage that may occur to a certain phenomenon and is expressed on a scale between 0 and 1 figuring the total destruction of goods and total loss of life of the affected area. Environmental damage causes an increase in vulnerability. For example, deforestation causes an increase in erosion and landslides, floods that are producing faster, more powerful and increase the vulnerability of settlements and communication routes.

Risk is defined as the probability of human exposure and property caused by it to the action of a particular hazard of a certain size. The risk is probably the casualties, the number of injuries, property damage and economic activities of a natural phenomenon or group of phenomena, in a certain place and in a certain period. Elements like people, properties, communication ways, economic activities etc. are values which are exposed at risk in a certain area.

Although measures to prevent adverse effects of extreme natural events were probably taken from the first contact between man and nature, concern for finding solutions like early warning systems to prevent or to provide comprehensive information related to production hazards continues.

Warning systems contain important information and can, by analyzing the events that took place with the implemented models, estimate the likelihood of a new event, while allowing a classification of areas according to their vulnerability.

Prediction is based on statistical theory and uses historical data of past events to estimate the likely future recurrence in similar events. Because the results are expressed in terms of average probabilities, there is no precise indication on when a particular event may occur. By definition, the predictions tend to be relatively long.

Forecast depends on the detection and evaluation of an individual event that is developed through a sequence of environmental processes that are well understood. The forecast is based on observable scientific facts; it tends to be short.

The warning is a message that informs and alerts the public about an event and shows the steps that must be followed in order to minimize loss. Always is based on predictions or forecasts. Their combination is necessary in the process of protection of human life in case of disasters with a very short action. The best results were obtained for hurricanes, floods and tornadoes. Drought is still difficult to predict.

2. Monitoring

In general, monitoring may be considered as a process of regular observation and recording of activities which are taking place in a certain structure.

Monitoring is the routine collection of information on all aspects of the studied object. Monitoring term is often confused with the tracking deformations term, because the latter is a systematic process for measuring and tracking the change in shape (position and elevation) and size of an object as a result of external forces.

Unlike deformation monitoring, if in the case of monitoring an important role is played by characteristics (parameters) like soil water content, vegetation, erosion, drainage, geomorphology and historical information. Deformation monitoring and data collection are two components with a major influence on soil and rock stability calculation, the deformation analysis, prediction and warning [Moore, 1992].

Since each monitoring project includes specific requirements, monitoring equipment of deformations are largely dependent by the chosen measurement method and the precision that is required. Therefore, landslides and diving monitoring should be seen as an interdisciplinary approach [Wunderlich, 2006]. A prerequisite is represented by the close cooperation between geologists, geophysicists, hydrologists, experts in the field of land measurement (geodesy, remote sensing) and other academic areas.

The ultimate goal of each monitoring project is the development and improvement of measurement and real time warning system for the direct transmission (online) of the physical parameters which are an imminent danger. Below i will present some considerations on monitoring systems and specially integrated monitoring systems.

2.1. Geodetic datum problems

Ground movements or rock mass movements monitoring is realised using geodetic and remote sensing methods only when we want to determine absolute displacements. Unlike other methods such as for example, geotechnical methods that provide relative information, the results provided by geodetic and remote sensing methods are defined in a coordinate system and referenced to a reference surface. Given this fact, geodetic datum, may be determined from an epoch to another, depending mutual position of each point or points [Wunderlich, 2004].

We should not forget that terrestrial and satellite methods are refering to different datum. Terrestrial measurements are related to gravity - the position of a point in space is given by latitude and longitude, respectively by the orthometric altitude defined as the height of point above sea level, measured from geoid along the line of force (the plumb line).

Distances obtained by GNSS measurements are unrelated to gravity. These are geometric referred to the international ellipsoid GRS80. The shift from GRS80 to the national system is based on the 7 parameters spatial transformation (3 translations, 3 rotations and a scale factor). These seven parameters are determined using the coordinate values of at least three known points in both systems.

2.2. Long-term monitoring

Regular monitoring and the time interval in which the measurements must be made are defined by the application and the studied subject. The objects can suffer: fast moves, high frequency moves, and slow moves or gradual moves. To cover permanently the mass range movements, the measuring intervals often vary from fractions of seconds to hours. Seasonal periods or long-term monitoring may be covered by regular measurement campaigns ranging from days or weeks to years and decades.

When starting a project monitoring an important role is played by history of the object or the history of the area. Normally, quantitative information regarding the production rate of movements is in the archives of national geodetic agencies or remote sensing. Existing archives (sometimes) can provide information on the frequency of movements and type of motions. These will influence the choice of monitoring method. Also, it must be taken into account the geological history, chemical and physical history which is providing information necessary for determining the age of sliding/diving and determination of its volume.

In developing and implementing a long-term monitoring system which should take into account several years of observation, the experts are facing with many problems. This is due to the monitoring constraints and technical capabilities which are developing in the same time with technological progress and will change over the years.

2.3. Integrated Monitoring Systems

The integrated term ideally describes a flexible monitoring system that combines geodetic, geotechnical and meteorological sensors in order to supply the monitoring requirements even if are about a small or large system, a temporary or permanent monitoring facility.

Thus, as it can be seen, from the above discussion, an integrated monitoring system involves the merger of sensors to obtain a homogeneous signal. It includes:

- Sensor Fusion – multi sensor system which is able to observe different types of parameters;

- Sensor control - a program / online application responsible for data collection;

- Data Communication - data transfer to processing centre via LAN, UMTS, etc.;

- Data processing - specific programs to transform data into results;

- Data Fusion - different data rates, types, dimensions, reference systems, mapping, precision

- Data management and quality: The registration and handling of large amounts of information;

- Data analysis: robust processing algorithms to obtain final results.

3. Early Warning Systems

All warning systems consist of three interdependent functional modules:

a. *Evaluation* - this includes several subcategories from the first observation of a change in the environment that may pose a threat, to the estimation of the nature and the dimension of the disaster, up to the final optimal solutions; the priority is to increase the accuracy of this module to prevent and increase the time period between when the warning was released and the actual production time of occurrence.

b. Spreading the message is the warning message of an event that will occur to the inhabitants of the area that is highly expected to be affected.

c. Answer: the two previous stages are designed to activate this module. Response subsystems are influenced by direct production of the event and feedback mechanisms to help improve the warning systems; the natural response is influenced by the warning message and the determinants.

An early warning system is a method of risk reduction. In most cases it was used with good results. Sometimes, simple alarm signals were declared early warning systems, for example, loud ads in the mountain, region Art-Goldau, Switzerland, before the fall of 1806 or the slope growth record of Monte Toc Vajont in 1963. In both cases, the threat was obvious, but the warning was not made correctly by the responsible people and because of this fact the protection proceedings were not initiated. Apparently, often is not understood what an early warning system is. Terms like monitoring and warning system are mistaken. It is therefore necessary to present the differences between these two.

In a monitoring system, data can be collected continuously or analysed at regular time intervals. It consists in a set of devices that allow:

- Determining the depth and shape of sliding mass;

- Determine the rate of the landslide movement;

- Monitoring the activity of stable sliding slopes;

- Monitoring of groundwater level and pore pressure.

A warning system is a monitoring system in which:

- Data are collected continuously;

- The data collected are analyzed continuously;

- If the threshold is exceeded the limit of civil protection are predefined procedures that are activated.

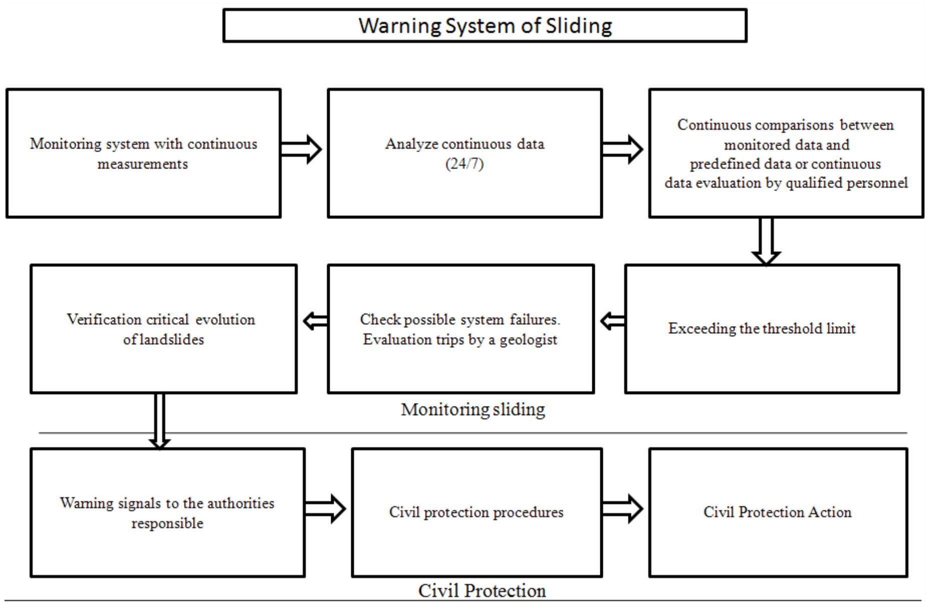

Figure 2.1 General scheme of an early warning system.

Warning systems landslides are often proposed for several reasons:
a) warning system with a strong technological impact,
b) companies that produce and/or install monitoring tools offer monitoring systems as current devices, in addition to technological application indicates that natural, obvious and simple monitoring landslides/dives
c) in complex crisis a warning system of field sliding/diving is considered as a cheap and temporary solution;

2.3.1. Warning system elements

According to a recommendation of the United Nations (2006) the effective early warning systems must be focus on people and should include four elements: knowledge of faced risks, warning and technical monitoring services, significant warnings dissemination, awareness campaigns and training of public opinion.

Usually a landslide warning system involves several elements:
- Geological analysis in order to define development scenarios;
- Pre-alarm weather;
- A monitoring system to measure and data transmission;
- Continuous analysis of data;
- Civil protection procedures;
- Procedures for communication between the disciplines involved.

2.3.1.1. Geological defining scenarios

The first necessary element of a warning system is to define the spatial and temporal evolution scenarios.

Scenarios are:
- Evaluation of different possible evolutions of the volume displaced
- Assessment of endangered areas
- Evaluation of magnitude order of the time in which landslides may evolve.

Definition of a scenario is based on a general mode ling takes into account the entire landslide (historical records, hydraulic records, hydrogeological and climatic, geological data, geometric and geostructural etc.). Scenarios should be tailored to the input data. Following the precautionary principle, scenarios must be related to those developments that can create major damage on the environment and people and must be based on the results of the critical areas of erosion.

Regarding warning systems, the presence of scenarios is required to:
- Definition of pre-alarm thresholds for precipitation;
- Definition of displacements;
- Defining critical slip sectors in order to choose the tools to be used;
- Defining precise area to be used in emergency procedure.

2.3.1.2. Pre-alarm thresholds for precipitation

In most part of Europe, meteorological analyzes are able to produce alarm codes based on expected rainfall. These codes can be used as landslide pre-alarm warning systems in order to enlist the attention to critical situations. This type of pre-alarm can be related only to those phenomena that are closely related to rainfalls.

2.3.1.3. Continuously measurements of displacement, data recording and processing

The system can be fully automated or manual handling. In a fully automatic system, a warning is issued automatically (through fixed telephony, GSM / GPRS / UMTS, etc.) In other cases, some of the interpretation and transmission signal is made by operators.

2.3.1.4. Tools, data recording and processing

Data recording from measuring instruments must be made continuously. Several types of tools that can be used for warning purposes and allow the registration of such movements are the inclinometers, extensometers etc. Also, there are used the uncommon geophysical devices like geo-specific phones.

Records must be analysed continuously. This analyse can be really continuous (24/7) or limited to alert periods defined in terms of weather forecasting. Data processing consists in data validation and the comparison with predefined threshold values. In the automatic analysis, the warning signal is issued when one or more instruments simultaneously exceed the defined thresholds or indicate sudden acceleration. In the latter case, the warning signal is issued manually by staff.

When thresholds are exceeded or if the results indicate a critical evolution of landslides should be two possibilities to check:

- Check possible system failures;
- Geological verification, which consists in a study realised by a geologist who knows the sliding/diving, thus assessing whether proximal development is actually in progress or under the scenarios is valid.

2.3.1.5. Civil Protection

The system must alert the personnel responsible for civil protection in the commissioning of security measures (evacuation, road blocks etc.). All these measures should be built in order to achieve a civil protection plan. The plan must be updated with any change scenarios.

2.3.1.6. Procedures and communication protocols

Without going into details, for each system, it is necessary to emphasize how the number of subjects and their different levels of responsibility can easily create major problems concerning the procedures and communication protocols.

Example of a list of topics for a warning system already installed:

- Client (common, local authorities) acting as authorizing officer;
- Professionals (geologists and/or engineers) who manage the system;
- Companies which manage the system;
- A person in charge of receiving the warning signal and forward it to concerned authorities;
- Civil protection authorities are responsible for civil protection measures.

2.4. Issues on warning systems

2.4.1. General

a. Costs and the sustainability: warning systems are usually installed after the activation of landslides, which often involves the opening of preferential funding channels and widespread demand for action by local communities.

b. False Alarms: Repeated false alarms are usually not tolerated by local government and population. Finally, they choose to abandon the warning system.

c. Theft and vandalism: There are frequent cases of theft or vandalism of monitoring devices. If the devices are located in remote, mountainous, they are rarely subjected to such problems. Otherwise, the problem is serious and real, because it is almost impossible to provide total protection devices. In addition, the presence of a warning system may be undesirable for a number of people who perceive it as unnecessary and unjustified.

2.4.2. Technical Issues

a. System Vulnerability: thermal shock and humidity can cause problems, but due to lightning and power overstressing.

b. Data transmission: data transmission can be achieved between the different components of radio systems and GSM. Bandwidth is often adopted for small systems or to connect sensors to the recording unit or transmission. GSM transmission may be used only in areas where coverage exists. Data transmission via radio frequencies is the best solution. The future should consider using communication satellites and WLAN communications.

c. Longevity and maintenance of devices: warning systems should operate on a very long time. One obstacle is the rapid development of systems and related programs that cause obsolescence of system components that need changes and updates continue. Maintain a warning system is difficult, complex, expensive and demanding.

3. Conclusions

Landslides warning systems may help reduce risk remarkable. In case of an imminent event these can help in data occurrence collapse determination. Thus, they are an important part of civil protection procedures. Clear definition of a protection plan as mentioned above is a prerequisite.

4. References

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