Hazard Maps in Switzerland

State-of-the-Art and Potential Improvements

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Abstract

As an alpine country Switzerland has always been threatened by natural hazards. Our ancestors respected nature and used to build their houses in safe places where the risk was naturally low. As the settlements expanded and space got limited people started to inhabit more exposed areas. In order to protect housing and personal belongings protective structures against floods, mass movements and snow avalanches have been built.

However, after the experience of massive floods and other extreme weather events during the last decades we know that nature cannot be controlled and this selective approach does not sufficiently protect us and our property. The solution to decrease the damage potential and to satisfy the call for protection of property is the alignment of land-use with the natural conditions.

Hazard maps are fundamental for land-use planning and hazard prevention and serve to determine endangered areas and as a base to formulate conditions of building. Although their benefit is not challenged anymore and the Swiss hazard maps are of high quality some improvements might be of value. Especially the visualisation of synoptic hazard maps is a challenge and new digital ways of displaying these complex maps could facilitate their reading.

The visualisation of uncertainty is a relevant issue whenever spatial data is concerned. Since the implementation of hazard maps can bear huge consequences for property owners and municipalities the data quality is very important and it would be interesting to know how (if at all) the visualisation of uncertainty alters the process of decision making. However, suitable methods for the assessment and presentation of those uncertainties will have to be found.

1. Introduction

Hazard mapping has a long history in Switzerland. The first attempt to create a hazard map was made after several snow avalanches had been responsible for the loss of life of 54 people and the destruction of 656 buildings during the winter 1951. The publication of federal guidelines helped to standardise the designs and in the meantime hazard maps have been produced for numerous municipalities.

The damage costs of more than 3 billion Swiss Francs caused by the inundations in 2005 were a result of the consistently increasing damage potential and emphasised the importance of hazard maps. The Swiss government reacted and has subsidised the cantons with money and relevant knowledge with the aim to complete hazard maps for every municipality by 2011. After this deadline federal subsidies for protection measures will only be granted for areas with existing hazard maps.

However, hazard maps only serve their purpose if they are properly interpreted. This paper will give an overview on Swiss hazard maps and introduce the challenges of the visualisation of synoptic hazard maps and their uncertainty.

2. Hazard Maps in Switzerland

2.1. General Overview

The goal of hazard maps is to protect people and buildings by indicating dangerous areas. By aligning land-use with the natural conditions risk as well as damage potential can be decreased. Hazard maps provide a basis for regional and land-use planning, national concepts and plans, the planning and construction of buildings, grants of buildings and concessions, and the granting of subsidies.

In 1965 the first legal foundations for the production of hazard maps were set in the regulation concerning the federal superintendence on the forestry police[1]. In 1979 the federal law on spatial planning[2] laid stress on the importance of considering natural hazards for local and regional planning. The federal laws on water constructions[3] and forestry[4] were revised in 1991 and together with the according regulations they oblige all Swiss cantons to create hazard maps for their municipalities. This legal foundation is very important

[1] Vollziehungsverordnung vom 1. Oktober 1965 zum Bundesgesetz betreffend die eidgenössische Oberaufsicht über die Forstpolizei (FPoIV, SR 921.01)

[2] Bundesgesetz vom 22. Juni 1979 über die Raumplanung (RPG, SR 700)

[3] Bundesgesetz vom 21. Juni 1991 über den Wasserbau (WBG, SR 721.100)

[4] Bundesgesetz vom 4. Oktober 1991 über den Wald (WaG, SR 921.0)

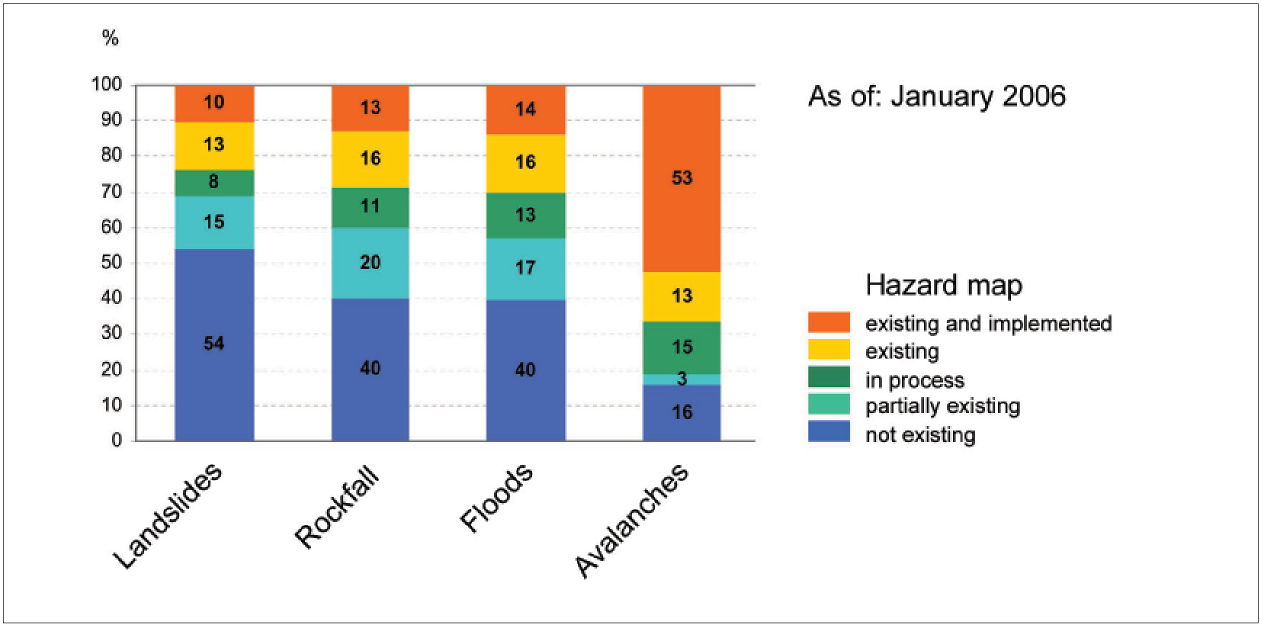

Fig. 1: Percentages of existing hazard maps in Switzerland (BAFU, 2007)

because only after their implementation in regional and land-use planning hazard maps become legally binding.

Due to the federalist structure of Switzerland, the current situation of mapped areas varies from canton to canton; some have already finished most of the mapping, others are still working on their concepts. Fig. 1 shows the percentage of the area which has been mapped until January 2006.

2.2. Content of Swiss Hazard Maps

Natural hazards in Switzerland comprise a lot of different processes, including earthquakes and gale-force winds. Since hazard maps are maps of suitability (they indicate areas which are not suitable for a certain land use due to the presence of natural hazards) they aim to relate hazards to specific areas. Therefore, the natural hazards which are considered have to exhibit clearly definable spatial impacts.

For Swiss hazard maps the following processes are taken into account:

- **Floods** (inundations, debris flows, sediment deposition, bank erosion)
- **Mass Movements** (rock-, block-, and ice fall, rock- and block avalanches, spontaneous and continuous landslides, unconfined debris flows, subsidence, sinkholes)
- **Snow Avalanches** (powder and dense flow avalanches, now slabs)

For each of these processes a separate hazard map is produced which always includes a technical report. The assessed perimeters have to be clearly identified and are usually limited to populated and developed areas as well as transportation routes.

2.3. Production and Design

The intensities of possible hazardous events are assessed by the consultation of past events, current conditions, numerical and physical models and expert judgment. These results are transferred into a number of classes (e.g. 10 in Switzerland) according to the intensity and the probability of occurrence of an event. These classes are applied to the study area which is divided into discrete zones. The Swiss system works with four hazard zones coloured as follows:

- **Red** (high hazard)
- **Blue** (moderate hazard)
- **Yellow** (low hazard)
- **White/yellow-hatched** (residual danger, high intensity but very unlikely)

Fig. 2 shows how these colours are linked to the intensity and the probability of an event.

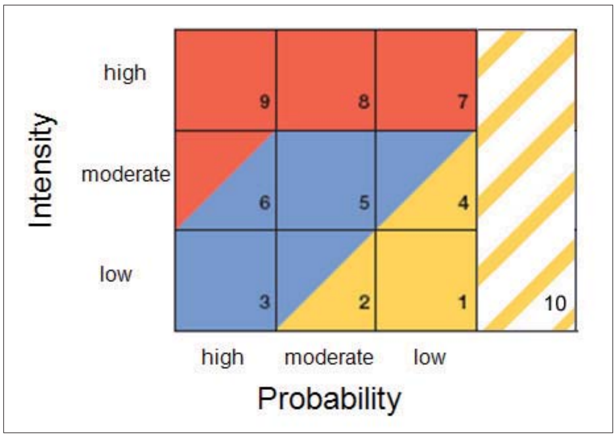

Fig. 2: Magnitude-Frequency Diagram

In the red zone people are at risk both inside and outside of buildings. A rapid destruction of buildings is possible. This zone designates a prohibition domain where development is banned. Existing buildings can be maintained but no enlargements are allowed.

The blue zone indicates an area where people are at risk outside of buildings. It is a regulation domain and damage to the building structure should be expected but no rapid destruction should occur as long as the restrictive regulations have been followed and the construction type has been adapted to the present conditions.

There are no restrictive regulations in the yellow zone and people are only at low risk even outside of buildings. Damage inside of buildings might occur but not at the structure. People living in this alerting domain have to be notified of possible hazards.

If an area is threatened by an event of high intensity but very low probability, this area can be hatched in yellow and white which represents a residual danger. In these zones no public buildings (like hospitals, etc.) should be built.

Zones which are not affected by any natural hazard or the danger is negligible according to present information are kept in white.

The cantons delegate the creation of hazard maps to private engineering companies and working groups. Experts are free in the choice of method as long as it meets the current scientific requirements.

In order to provide for a consistent and equal assessment of the different processes of natural hazards, the magnitude-frequency diagrams as well as the visualisation have been standardised in Switzerland and are presented in federal guidelines. To date each canton might use a slightly different colouring, but the use of red, blue and yellow for the designation of hazardous areas is the rule. The Swiss maps with a scale of 1:2,000 to 1:10,000 allow analyses for each lot of land and are easy to understand by experts and novices.

3. Synoptic Hazard Maps

3.1. The Situation of Synoptic Hazard Maps in Switzerland

After the consultation of the separate hazard maps we know by which processes an area is endangered, however, also the total risk is of interest. This sum is assessed by the overlay of the hazard maps, merging the information of three different maps in one. To date this aggregation only happens on a visual basis, which means that the interactions between the different processes are not taken into account. The national guidelines only state that if an area is threatened by different hazards this has to be displayed in an adequate form and the highest hazard class is authoritative. Therefore different techniques have been applied trying to present this flood of information comprehensibly. Due to the fact that most of the hazard maps are presented as static maps in printed form (although they were mostly made with the aid of a GIS) this task became even more complicated.

Some cantons (e.g. Canton of Berne) label each area with an abbreviation of the underlying hazard and the index of the magnitude-frequency diagram (Fig. 3a).

The Canton of Zug chose a differing way of visualisation and marks the borders of the areas affected by different hazards with coloured lines (Fig. 3b).

3.2. Weaknesses of Synoptic Hazard Maps

Synoptic hazard maps contain an enormous amount of information. The two examples shown below illustrate that the visualisation of such a flood of data is a challenge: too many labels lead to a concealment of the background, the whole picture gets confusing and even experts fail to get a clear picture of the situation. The use of coloured lines

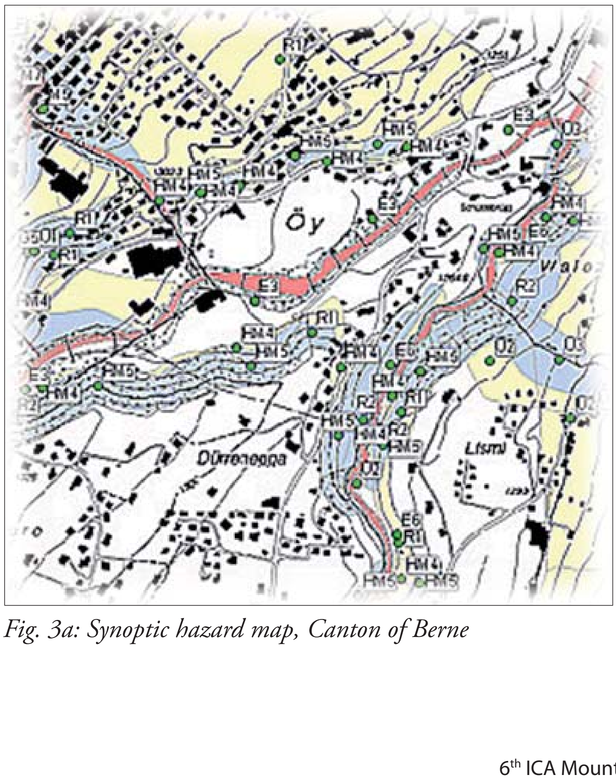

Fig. 3a: Synoptic hazard map, Canton of Berne

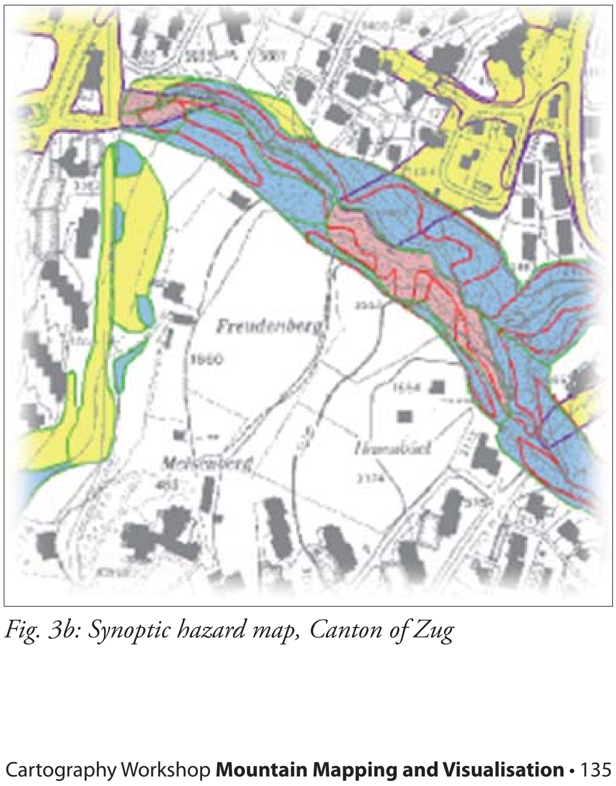

Fig. 3b: Synoptic hazard map, Canton of Zug

might visually be more appealing but the interpretation remains difficult.

Experts having worked with hazard maps for some time are familiar with the content and the appearance of hazard maps. However, novices have to cope with a lot of information. Hence, a decrease of the level of complexity would lead to a better understanding. The disentanglement of intensity and probability organised in a layer structure as it is used in GIS is a plausible idea and will be inquired.

Another point of discussion is the current definition of colours. The choice of blue for the moderate hazard zone has been criticised because there is no logical transition between yellow and red and the blue areas are often misinterpreted as inundations (Zimmermann et al., 2005). However, Swiss experts seem to be used to this colouring and do not consider changing it.

4. Possible Improvements

4.1. Interactive Visualisation Solutions for Synoptic Hazard Maps

A possible approach to solve the problem of the visual overload of synoptic hazard maps is the use of digital and interactive solutions. The idea is to help the map reader to understand the map by splitting up the complex information and letting him "draw" the map himself. Numerous interactive operations allow the user to choose the displayed layers, to create new layers by blending, to have the processes labelled by mouse-over, to zoom in and out, to choose a specific region, to use animations, etc.

Although interactive tools can lead to a better understanding of maps and can support decision making processes, novice users could perform actions and create maps which do not follow the cartographic standards and lead to misinterpretation, confusion and missing readability. This can be prevented by an appropriate graphic user interface (GUI) which helps to guide and/or to restrict the available interactivity (only predefined actions can be performed).

The aim of the new techniques is not only to facilitate the reading and understanding of the map for decision makers but also to support the communication between experts and lay persons which will lead to a better acceptance of hazard maps.

A digital, interactive visualisation solution could be extended to offer additional value to users outside the field of land-use planning. Fire brigades or insurance companies could be interested in certain information which are contained in the reports accompanying hazard maps but have not yet been visualised. An example would be the fact that synoptic hazard maps only show the highest occurring hazard classes but for insurance companies it makes a difference if a property is "only" situated in a blue zone threatened by snow avalanches or also affected by low intensity floods.

Possible extra features would be the import of extra files containing transportation routes, information of sensitive areas, or other relevant data which could then be compared with the hazard zones.

4.2. Visualisation of Uncertainty

"Once a map is drawn people tend to accept it as reality."

Bert Friesen

The issue of spatial data quality in general has attracted attention during the last decade, especially when associated with GIS. A lot of research has been done on classifying uncertainties and also on finding new methods to visualise them but there is little consensus about the best way of visualisation. Furthermore, little effort has been made to assess the use and usability of the different methods (MacEachren et al. 2005).

The production of hazard maps is an interdisciplinary task which depends on a lot of expertise and knowledge. Uncertainties arise from different actions during different stages and are divided into acquisition uncertainties, transformation uncertainties and visualisation uncertainties. Among those categories uncertainty comprises statistical variation, errors and differences, min-max range values, noisy data, or missing data (Pang et al. 1997). Taylor and Kuyatt (1994) added scientific judgment as criterion which is very important in the context of natural hazards. Some of those uncertainties can be assessed quantitatively. However, ordinal or even nominal scales will usually be used.

To date hazard mapping does not yet include the visualisation of uncertainty because it is not clear if and how this can support decision makers. Experts often argue that it would only make concerned people insecure and lead to a discredit of the hazard maps. Another argument is that the approach of applying the magnitude-frequency matrix to the natural hazard analysis output data acts as a classification. It already accounts for the uncertainties as the output is presented in ranges and not in absolute values.

However, data uncertainty is not created by its visualisation. The accuracy of hazard maps has been the topic of many discussions among experts during the last years. Landowners and municipalities are directly affected by the implementation of hazard maps and would be interested to know how reliable the boundaries between the hazard zones are. In the conventional way of representation they suggest a sharp and sudden change in magnitude-frequency although the transition might be rather continuous. Furthermore, areas inside a hazard class are not homogeneous as the colouring might imply (Trau and Hurni 2007).

Decision making in land-use planning is a very complex task and can induce severe consequences for different parties. Poor decisions can be very expensive and even put lives in danger. Therefore, it is very important that the decision making process remains transparent and traceable for everyone. Uncertainties will always be present due to the characteristics of natural hazards and their visualisation could provide a means to draw attention to them, to support the decision making process or even to reassure people because the uncertainty becomes tangible.

In order to assess all the uncertainties occurring during the production process of hazard maps an analysis of every single step is required. Even if this process varies between the cantons and the different engineering companies it would be interesting to give some examples and to point out the sensitive phases to raise awareness.

Once the uncertainties have been assessed the best way of visualisation has to be found. A lot of different techniques have been presented in numerous research papers and the suggested methods include adding interactive capabilities, additional visual variables, or supplementing maps with added geometry (Deitrick 2007). Interactive capabilities include blinking areas, toggling between data and uncertainty visualisation, animated pictures, etc. The variables used to visualise uncertainty are among others: saturation, crispness, resolution, transparency (fog), colour, and texture. Geometry can be added by arrows, bars, dials or glyphs which are compound point symbols used to summarise a wide array of data aspects simultaneously (Pang 2001).

Those techniques can either be applied on separate maps (maps compared approach; Fig. 4a) or on a single map where data and uncertainty are combined (maps combined approach; Fig. 4b). A third way would be the use of an interactive computer environment where users are able to manipulate the display of the data and the uncertainty (Howard and MacEachren 1996).

Despite all this research analyses showed that there is no global solution and it seems that every specific problem has to be visualised differently in order to get the best results.

The use of digital interactive methods provides a lot of advantages. A prototype offering different approaches could be a way to find the best visualisation.

In the context of land-use planning it is not only interesting to quantify uncertainties and visualise them but also to know how the presence of uncertainty visualisation influences information analysis, decision making, and finally the decision outcome. According to MacEachren et al. (2005) the impact of visual depictions of uncertainty has not yet been sufficiently assessed. They suggest the development of formal and testable models of the role of visual and external display of uncertainty in the decision-making process. The design and implementation of such models into the survey would help to verify (or to invalidate the claim) that the inclusion of uncertainty visualisation improves the decision making in land-use planning.

5. Conclusions and Outlook

Although the first Swiss hazard maps were created over 50 years ago they are still mostly static representations of hazard zones and especially the derived synoptic map is hard to interpret. The use of an interactive computer environment for the visualisation of synoptic hazard maps could help to enhance the understanding of such complex representations and also the communication between decision makers and other parties. The usability and the efficiency of the different visualisation methods will have to be assessed in a survey (possibly internet-based). The implementation of extra features (e.g. import and visualisation of additional data) could provide an added value for specific users such as fire brigades or insurance companies.

Since experts are still debating whether or not the visualisation of uncertainties positively influences decision making processes more research has to be done. The feasibility of the assessment of the uncertainties inherent to hazard maps, their accuracy and finally the methods of their visual presentation will have to be investigated.

Different approaches to visualise the different detected uncertainties will have to be presented and the most effective design for this specific purpose will be identified by a survey collecting the opinions of both experts and lay persons.

Thus the following tasks will have to be completed:

- Investigation of the production process of hazard maps
- Disentanglement of the different levels of information included in a synoptic hazard map
- Creating a new design for synoptic hazard maps
- Implementation of the new design in an interactive computer environment
- Identification of uncertainty sources
- Classification and assessment of uncertainties (if possible quantitatively)

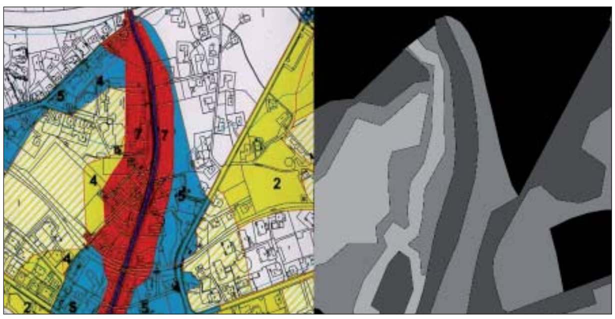

Fig. 4a: Maps compared approach

Fig. 4b: Maps combined approach

- Creating of different uncertainty visualisation methods
- Determination and implementation of the best method
- Assessment of user needs (e.g. of fire brigades, insurance companies, etc.)
- Implementation of extra features (e.g. import of additional data)

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