just before AD 900, except for the limited period of approximately 1935 to 1980. Around 1935 landings by small boats on the sandy beach stopped almost completely, but around 1980 flights to the islands increased from the small Bakki airfield close to the shore. In 2009/2010 the first sandy beach harbour in Iceland, Landeyjar harbour, was built just 2 km west of the Markarfljot river outlet, opposite the Westman Islands, shortening the sailing time to Heimaey from 3 hours to 30 minutes. However, the operation of the new harbour has been interupted because of greatly increased littoral drift of ash carried by longshore current to the entrance of the harbour. The net average littoral drift for the past decades has been approximately 0.3 M tonnes/y, east or west. In the beginning of the 2010 Eyjafjallajökull eruption, two glacial floods during the first two days, carried nearly 30 million tonnes of ash down the Markarfljot river to the shore just 2 km east of the harbour entrance. Unusually persistent SE-waves have transported a large part of these ash sediments westwards partly blocking the harbour entrance, so constant dredging has been needed whenever weather permits.

GA 2 – Risk assessment and management of geohazards

GA2-1

The SafeLand project; Impacts of global change on landslide hazard and risk in Europe in 21st century

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SafeLand is a Large-scale integrating Collaborative research project funded by the FP7 of the European Commission (www.safeland-fp7.eu). The project team composed of 27 institutions from 13 European countries is coordinated by Norwegian Geotechnical Institute (NGI). SafeLand will develop generic quantitative risk assessment and management tools and strategies for landslides at local, regional, European and societal scales and establish the baseline for the risk associated with landslides in Europe, to improve our ability to forecast landslide hazard and detect hazard and risk zones. The scientific work packages in SafeLand are organized in five Areas:

- Area 1 focuses on improving the knowledge on triggering mechanisms, processes and thresholds, including climate-related and anthropogenic triggers, and on run-out models in landslide hazard assessment;
- Area 2 harmonizes quantitative risk assessment methodologies for different spatial scales, looking into uncertainties, vulnerability, landslide susceptibility, landslide frequency, and identifying hotspots in Europe with higher landslide hazard and risk;
- Area 3 focuses on future climate change scenarios and changes in demography and infrastructure, resulting in the evolution of hazard and risk in Europe at selected hotspots;
- Area 4 addresses the technical and practical issues related to monitoring and early warning for landslides, and identifies the best technologies available both in the context of hazard assessment and in the context of design of early warning systems;
- Area 5 provides a toolbox of risk mitigation strategies and guidelines for choosing the most appropriate risk management strategy.

Identification of landslide hazard and risk hotspots was one of the major tasks in the beginning of the project. For that purpose three different models were developed, all of them using the same input data for entire Europe. Common for the three models was the identification of Italy as the country with the highest exposure to landslide risk. However, the small alpine countries had the highest relative exposure compared to their total land area and population. Overall, 4 to 7 million people in Europe, as well as significant amount of infrastructure are exposed to landslide threat.

In the expectation of a changing climate, the question arises on how the level and spatial pattern of landslide hazard and risk in Europe will develop in the 21st century. To answer this question, several factors must be considered. Not only will the climate change in the next 90 years, but also the demography and land cover in Europe will change significantly. The main objective of the present study was therefore to quantify the landslide hazard and risk in Europe now and in the future and see if there will be significant changes. Changing precipitation pattern, land cover and population were used as input to assess the landslide hazard and risk in the years 2030, 2050, 2070 and 2090. The results were then compared to the present situation in 2010. The effect of climate change varies depending on the type of landslide. In this study the focus was on precipitation-induced landslides, which are a direct consequence of the extreme precipitation events and therefore closely coupled to a change in the frequency of extreme events.

The study showed that climate change and changes in land cover will only cause minor variations in landslide hazard. The risk associated with landslides, however, is expected to change significantly due to changing patterns of population in Europe.

GA2-2

Landslide hazard mapping in Bergen, Norway

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During the fall of 2005, two shallow landslides caused a total of four people to perish in Norway's second largest city, Bergen. Both accidents were triggered by extreme rainfall events, with a diurnal maximum of 156 mm precipitation on September 14th 2005. A rockslide accident in Ålesund in 2008 also contributed to the understanding that landslides may pose a serious hazard in urban areas in Norway.

The Geological Survey of Norway, in cooperation with the municipality of Bergen, started investigations in 2005 to systematically map the landslide hazard in the whole municipality. Many areas have already been mapped by various consultant companies, and the author's currently ongoing master thesis will be a contribution in line with these works in the areas Haukeland and Løvstakken close to Bergen city center. However, this thesis will also focus on testing and implementing methodology that has not been commonly used in the Nordic countries before, but that is regularly being used in e.g. the European Alps.

As in most hazard mapping projects done on a local scale, fieldwork will be the primary method. The focus of the fieldwork will be 1) to identify and characterize the source areas, perhaps using a rock mass classification system and 2) to study geomorphological evidence in the run-out areas with the purpose of creating a landslide inventory and estimating event frequency and run-out lengths.

Vegetation in the study areas will also be investigated. The type and density of the vegetation determines the level of protection it offers against rock falls. Traces of previous rock falls might be recorded in vegetation in the run-out areas, which helps determining the frequency of rock falls in the past. Also, the vegetation cover is an important factor for the stability of soils regarding shallow landslides and debris flows.

A structural analysis might be carried out to determine the kinematics of potential failures in the source areas, using field measurements of discontinuities and a high resolution Digital Elevation Model (DEM).

This DEM will also be used together with field data to model rock fall using the software RockyFor3D. The data from the fieldwork and the modeling will be compiled to make landslide hazard zones for annual event probabilities of 1/100, 1/1000 and 1/5000, according to Norwegian regulations. This map, along with considerations regarding methodology, will be the main product of the master thesis. In addition, a brief risk analysis might also be carried out.

GA2-3

Assessing and managing the risk from landslides in a loess plateau, Heifangtai, Gansu Province, NW China.

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In a joint project between NGI and China Geological Survey (CGS), funded by the Norwegian Ministry of Foreign Affairs, we assess landslide problems in the NW China loess region. The Heifangtai area consists of villages along the Yellow River, and a farming community on a plateau 100m above the river level. The farmers were moved here in the late 1960'ies and a large irrigation project was initiated, pumping water from the river to the plateau. 12-15 years later, the area started to experience significant landslide problems, with many fatalities and large economic losses. The project aims at understanding the landslide processes and suggesting robust mitigation measures.

Managing the water balance in the area is the key problem. However, the local stratigraphy allows different solutions for drainage, being most important near the steep slopes of the plateau. The project includes significant data acquisition over several years, including laser scanning of the whole area, infiltration tests, pumping tests and other in-situ tests in boreholes, in-situ and laboratory geotechnical testing, chemical analyses, hazard and risk mapping, tsunami analyses (from landslides into the Yellow River), etc. The project poses cultural and socio-economic challenges. This is a poor region, and the costs of any large scale mitigation measures to be suggested must be acceptable to both the local and central authorities.

We will present preliminary results of landslide hazard assessment, including stability calculations for the Heifangtai slopes, as well as suggested solutions for mitigation measures to reduce the risk for the villages along the Yellow River.