Hazard mapping of rockfalls and rock avalanches in Norway

How to prioritise areas?

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Goals

Plan for national landslide hazard mapping in Norway:

- Overview of the most common types of landslides in rock slopes
- Current state of investigations and available data
- Evaluation of needs for future hazard mapping and risk assessment
- Priority lists for further investigations

Define priorities for:

- Rockfall hazard mapping at site-specific scale
- Investigations of potential rock avalanches at county-scale

Types of landslides in rocks

Rockfalls

- Single or multiple blocks
- Volumes ranging from few to ~100’000 m^3
- Deposition on the talus slope or at foot of slope
- Important destruction in the run-out area (landslide dams or tsunamis possible for large rockfalls)


Jaedicke et al., 2009


Photo: NGI


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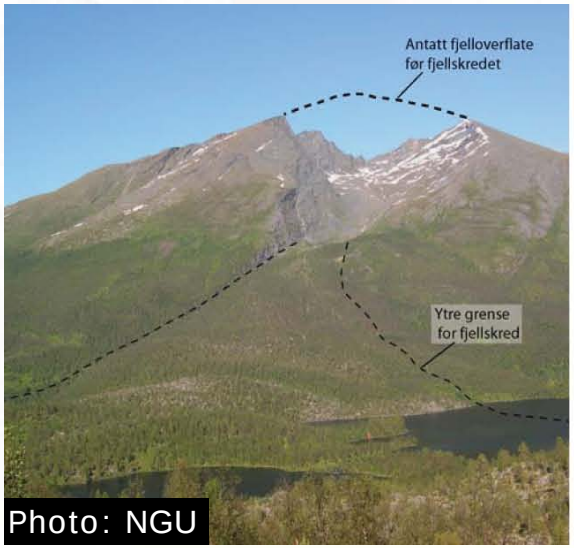
Types of landslides in rocks

Rock avalanche

- Large volumes ranging from ~100’000 to millions m^3
- Excessive run-out distance due to a flow-like behaviour of the avalanche
- Very destructive with heavy consequences (incl. landslide dams or tsunamis)



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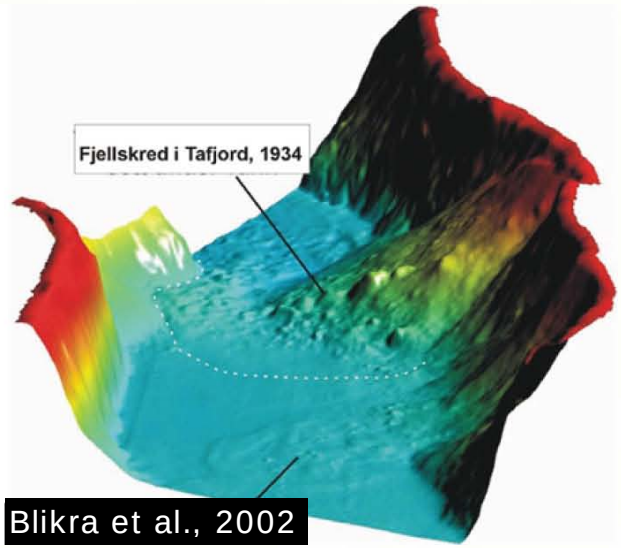


Blikra et al., 2002

Existing data: landslide inventory

Systematic registration of historical landslides

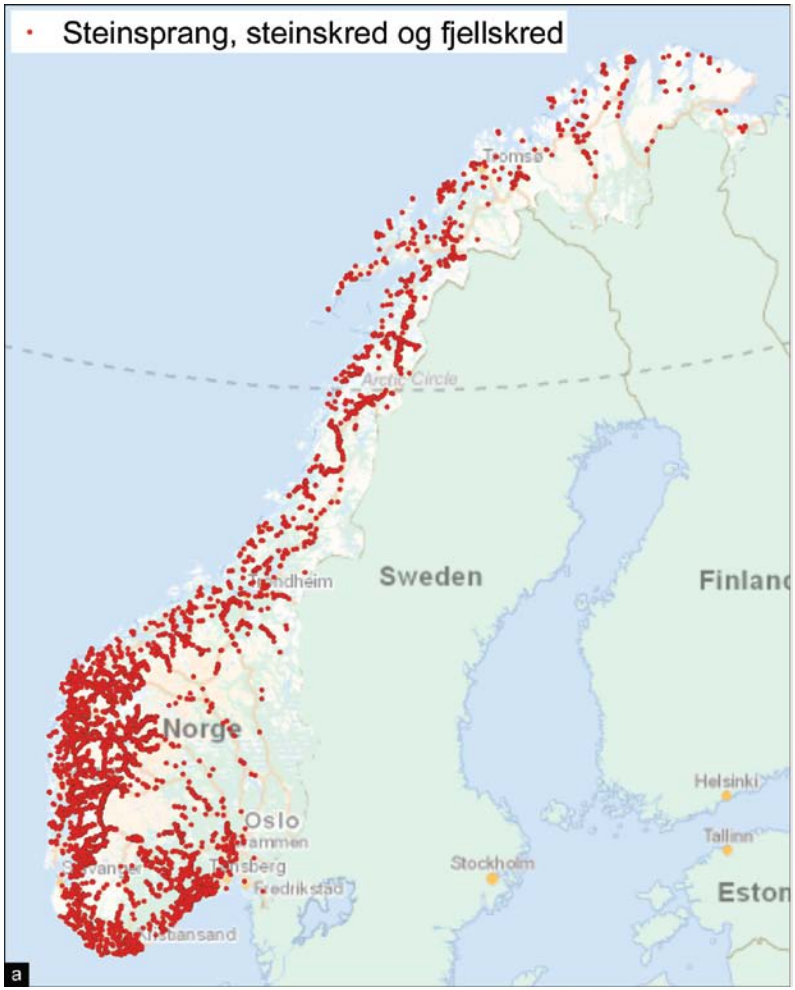
- Data from road and railroad authorities, technical reports, old chronicals, news-papers, church registers etc.

Event description

- Location and date of landslide
- Volume
- Consequences

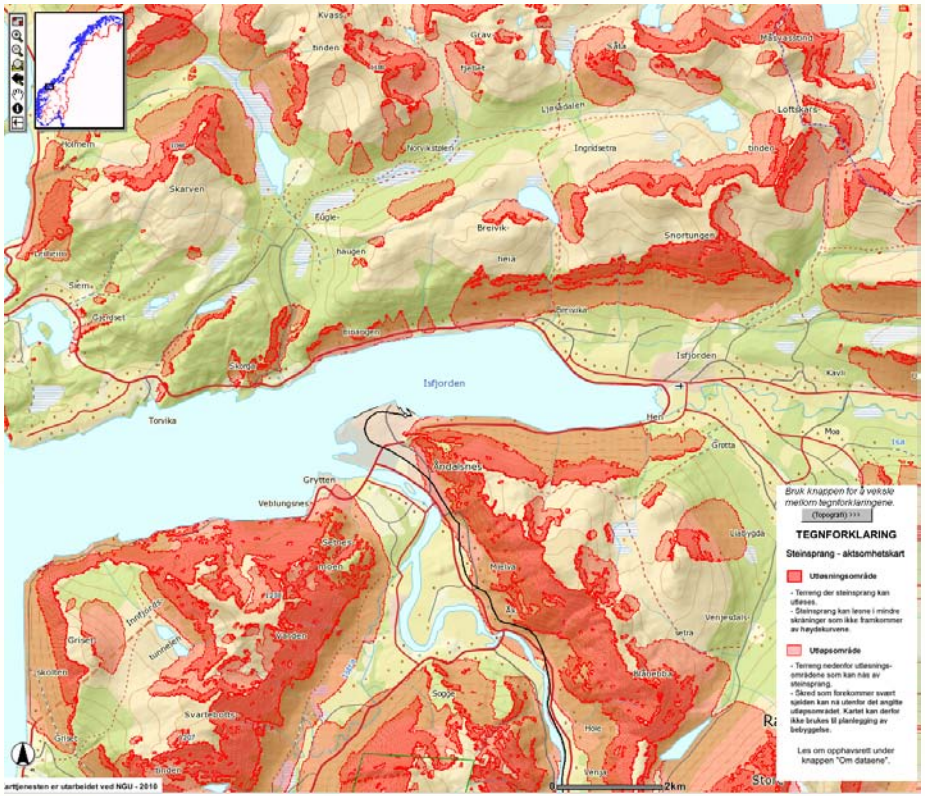
Valuable information source, but:

- Incomplete inventory
- Variable quality of information



Existing data: susceptibility map

- The rockfall susceptibility maps shows potential source areas and their maximum run-out area
- Nationwide map based on DEM analysis
- No temporal or magni-tude considerations
- Does not exist for rock avalanches



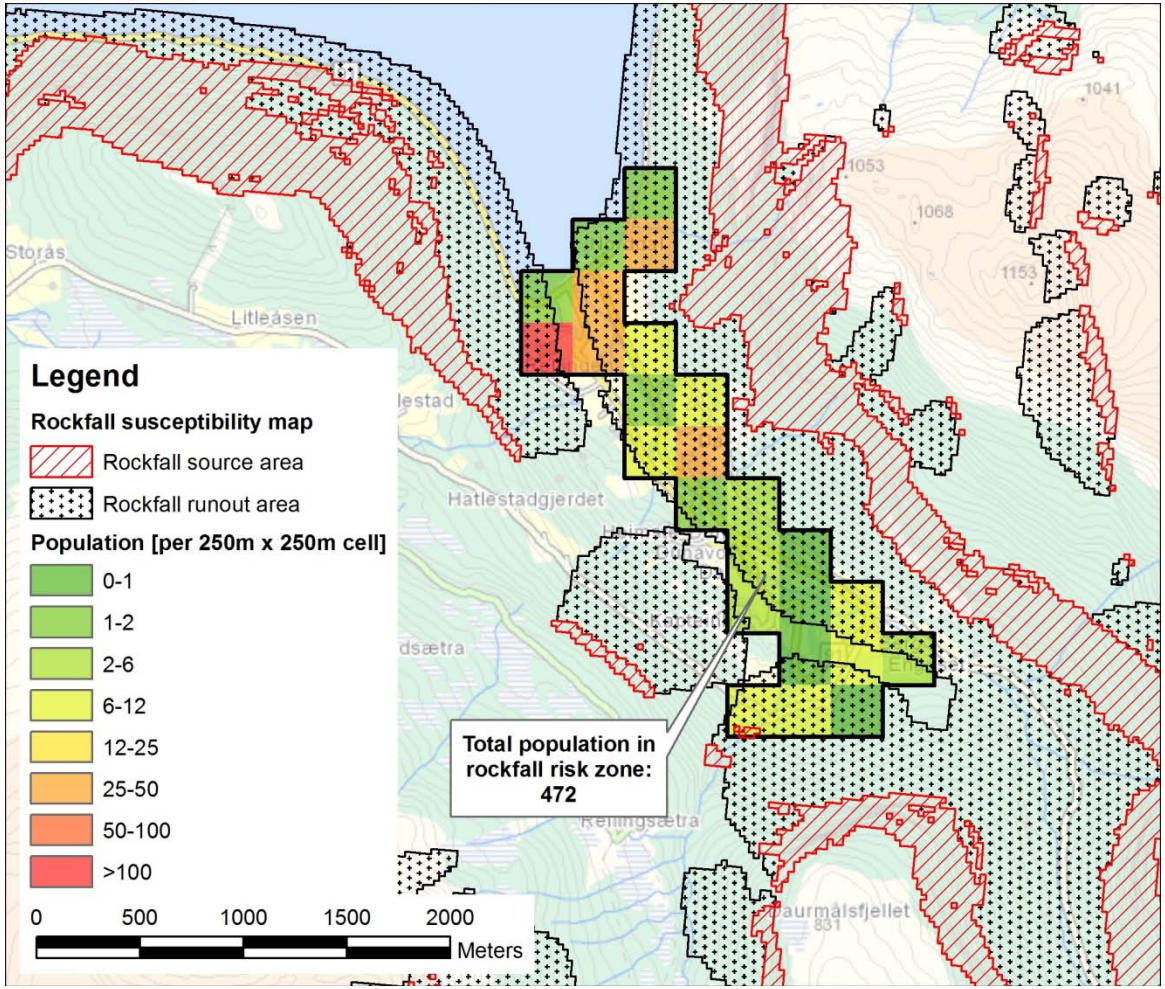
1. Priority list for rockfalls

Methodology

- Combination of two criteria
  1. Total number of persons living or present in a potential rockfall run-out area (conflict zone)
  2. Presence of potential rockfall sources along with signs of rockfall activity (scree slopes, historical events)
- Used data
  - Population data from Statistics Norway
  - Rockfall susceptibility map
  - Orthophoto analysis
  - Historical rockfalls from the national landslide database

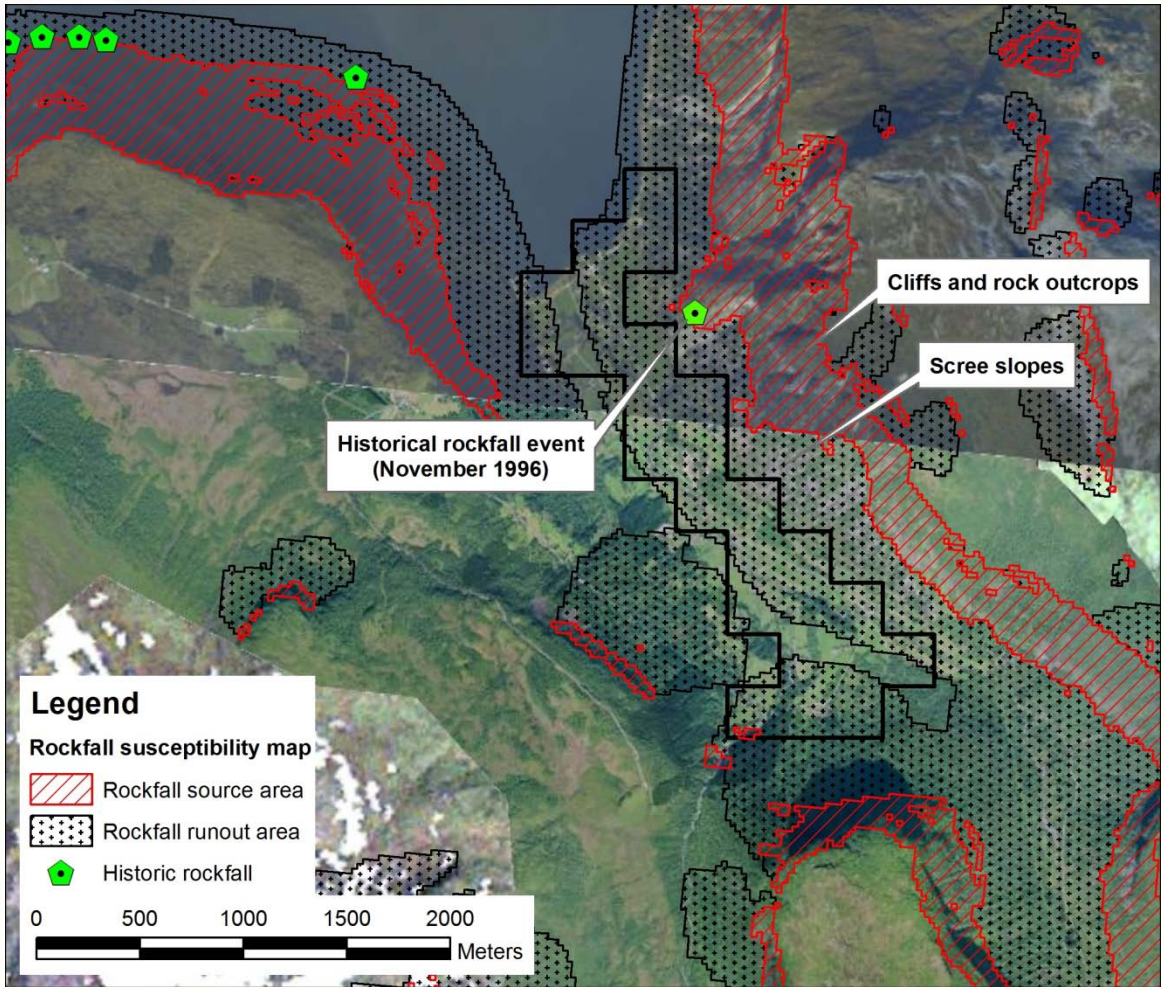
1. Exposed population

- Combination of population data and the rockfall run-out areas (conflict zone)
- Total number of persons being potentially exposed



2. Rockfall activity

- Orthophoto analysis and national land-slide inventory
- Signs of activity:
  - Visible cliffs
  - Scree deposits
  - Historical events
- Hazard-reducing factors:
  - Forest cover in run-out area



Rockfall priority classification

1. Exposed population

Total population	Weighting	Count
≤ 10	1	224
11 – 100	2	609
101 – 1000	3	275
> 1000	4	15

2. Rockfall activity

Presence of rockfall sources & signs of rockfall activity	Weighting (with forested run-out area)	Count (with forested run-out area)
No cliffs or rock outcrops	0	178
Cliffs or rock outcrops	1	551
Cliffs + historical events	3 (2)	134 (31)
Cliffs + scree slopes	3 (2)	188 (17)
Cliffs + hist. events + scree slopes	4 (3)	72 (39)

Σ

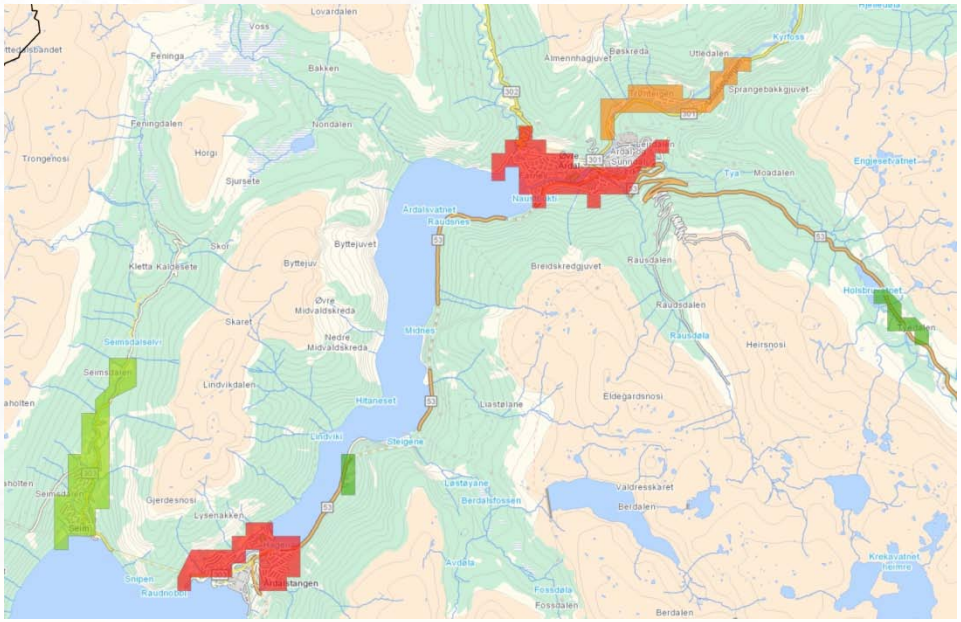
Conflict zone priority

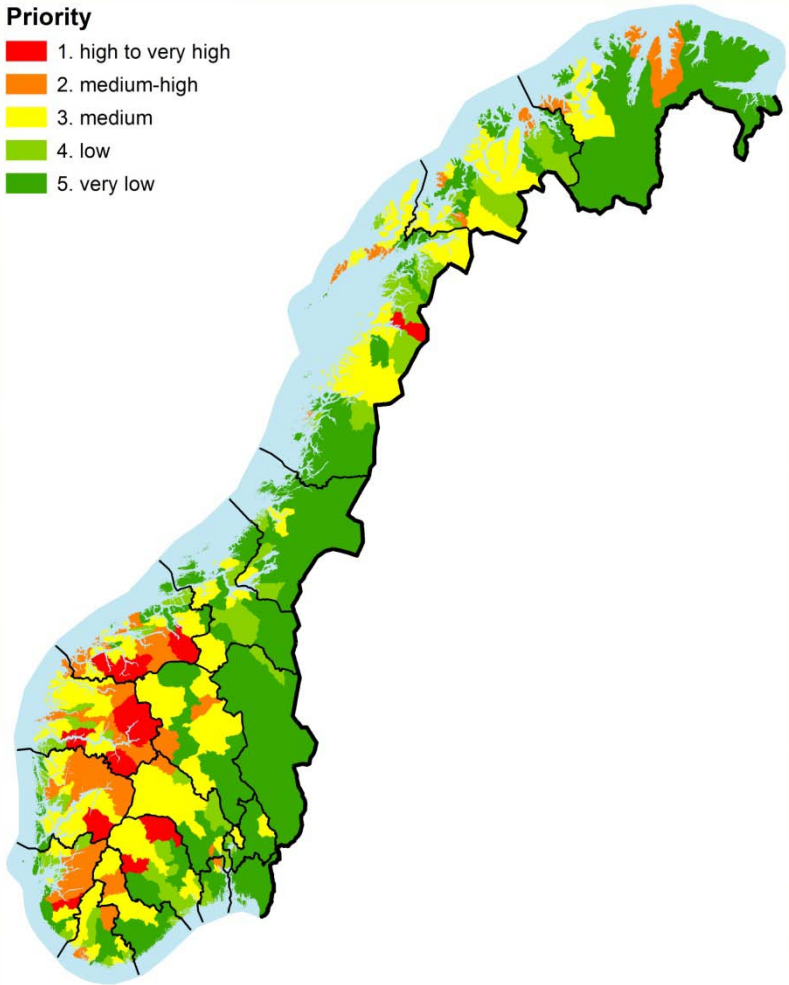
Score	Priority	Count
7 – 8	1. High to very high	21
6	2. Medium-high	94
4 – 5	3. Medium	393
2 – 3	4. Low	437
0 – 1	5. Very low	178

Rockfall priority map

Zones with 1st priority:

- Sogn og Fjordane (9)
- Møre og Romsdal (5)
- Hordaland (3), Telemark (2)
- Rogaland (1), Nordland (1)



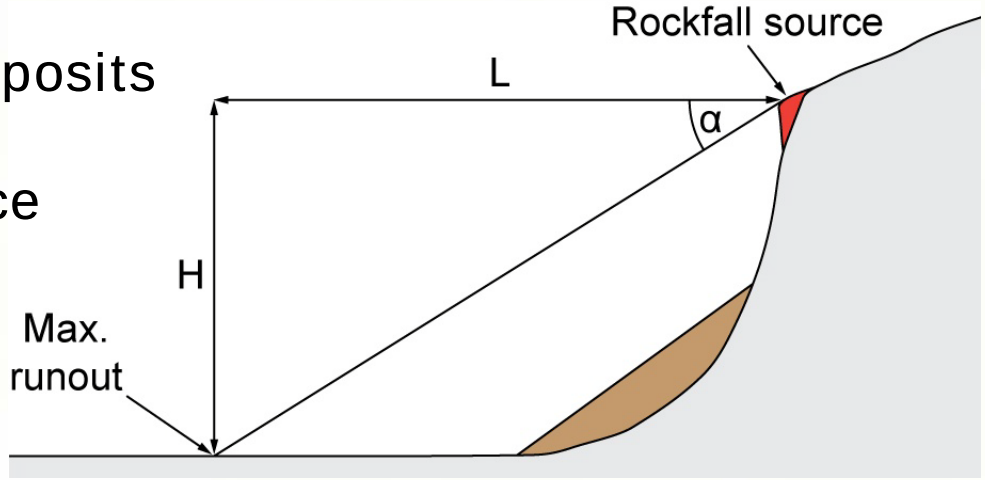


2. Priority list for rock avalanches

Methodology

Based on the historic large rockfall and rock avalanche events in the national landslide database:

1. Landslide type based on event description and orthophoto analysis:
   - Visible rock avalanche deposits
   - Visible rock slide scars
   - Excessive run-out distance (low angle of reach)
     - 15° – 32°
     - Rockfalls >32°

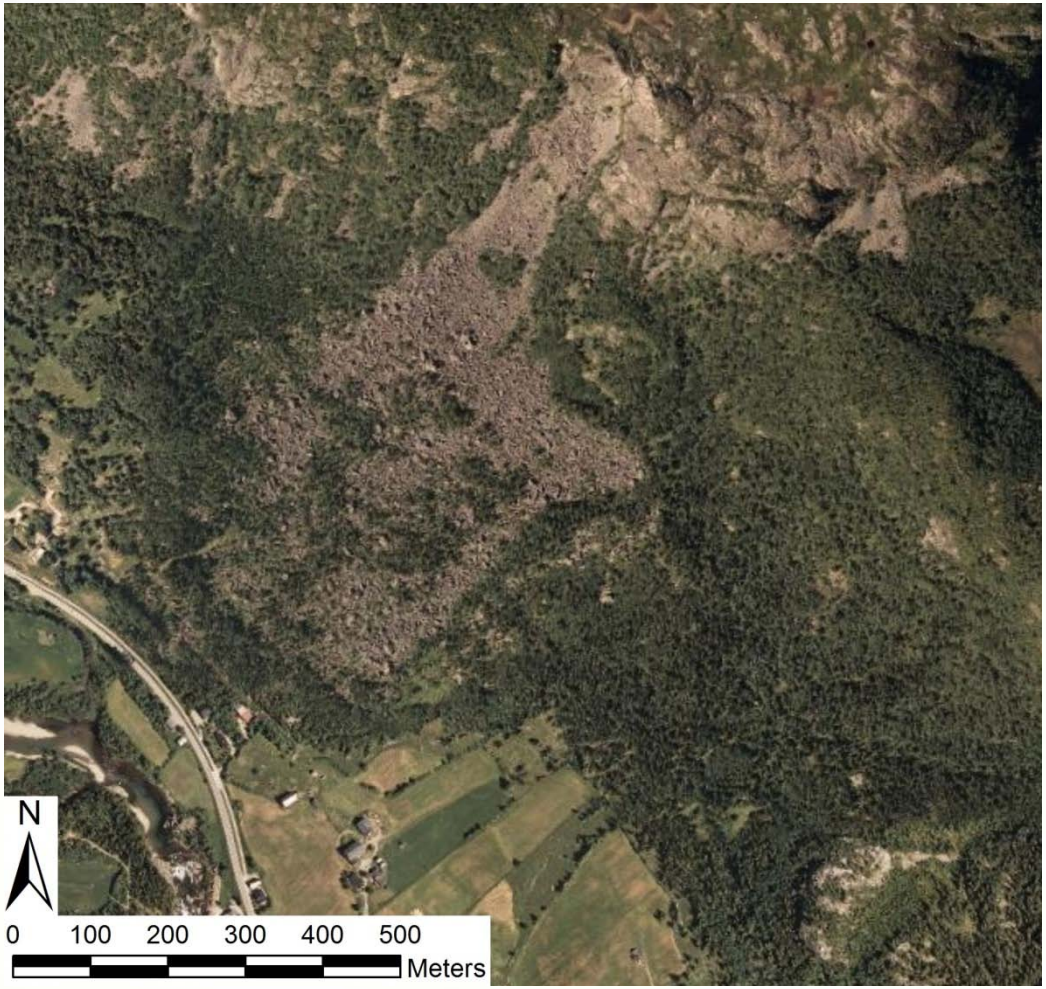


2. Assessment of consequences
   - Damages recorded in the landslide database
   - Casualties, landslide dams, tsunamis

Grøtura (Buskerud)

- Rock avalanche in 17th century
- Damages to buildings, forest & arable land
- No casualties
- Excessive run-out distance (low angle of reach)
  - 26°

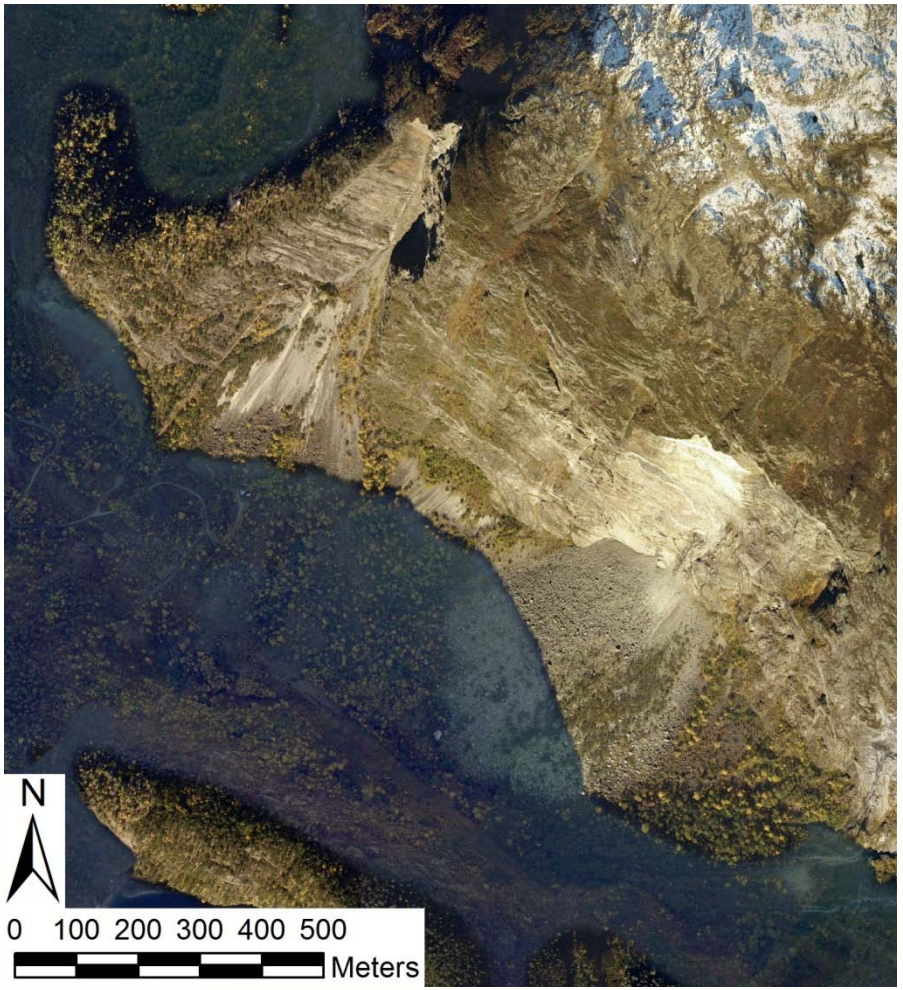
→ Rock avalanche



Jimdalen (Møre & Romsdalen)

- Large rockfall in 1992: ~100000 m^3
- Large rockfall in ~1400: 5 casualties and building damages
- Low run-out distance (high angles of reach)
  - 45° in 1992
  - 34° in 1400

→ Large rockfalls, but not rock avalanches



Rock avalanche weighting

1. Landslide type

Landslide type	Weighting
Large rockfall	1
Uncertain rock avalanche	6
Certain rock avalanche	12

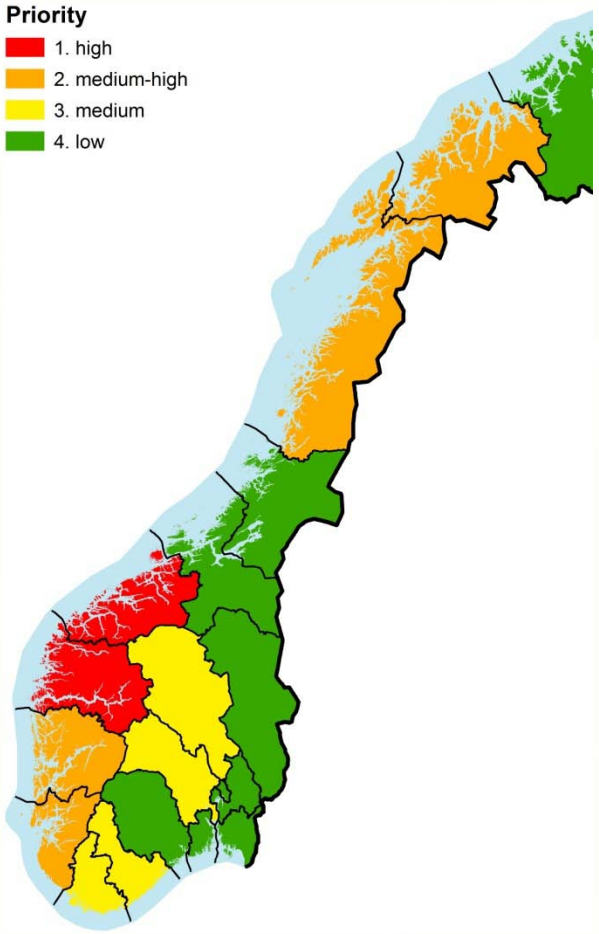
2. Consequences

Consequences	Weighting
No damages	0
Damages to forest, arable land or cattle	0.5
Damages to buildings	1
Landslide dam	3
Tsunami	4
Casualties	2

Σ Π → Total score of event

Rock avalanche priority map

County	Rock avalanches		Large rockfalls		Score
	Total	Certain	Total	with casualties	
Møre og Romsdal	9	4	114	35	640.5
Sogn og Fjordane	5	2	113	48	578.0
Hordaland	0	0	71	17	118.0
Troms	1	1	10	2	103.5
Rogaland	1	1	27	7	62.5
Nordland	0	0	31	8	44.5
Oppland	0	0	14	6	26.0
Buskerud	1	1	3	0	20.0
Vest-Agder	0	0	8	4	13.0
Aust-Agder	0	0	9	2	13.0
Finnmark	0	0	8	0	8.5
Telemark	0	0	4	2	6.5
Nord-Trøndelag	0	0	6	2	5.5
Vestfold	0	0	6	0	4.5
Sør-Trøndelag	0	0	4	1	2.5
Akershus	0	0	2	0	0.0
Hedmark	0	0	1	0	0.0
Oslo	0	0	0	0	0.0
Østfold	0	0	0	0	0.0



Conclusions & perspectives

- Priority lists will guide future mapping activities:
  - for rockfall hazard mapping
  - for detailed investigations of large rock slope instabilities
- Objective, with comprehensive expert judgement
- Main needs for future hazard and risk mapping:
  - Improvements in the national landslide database
  - Mapping of historic and pre-historic large rockfalls and rock avalanches
  - Methodology, tools and rules for rockfall hazard mapping in Norway need to be defined
  - Creation of a hazard and risk classification system for unstable rock slopes to prioritise sites for more detailed investigations and monitoring