

From landslide susceptibility to risk mapping for France: improvement and application at 1:500,000 scale of work

Yannick Thiery, Gilles Grandjean, Yann Cottereau, Bastien Colas, Olivier Maquaire, M Fressard, Melody Premaillon, Séverine Bernardie, Sébastien Gourdier

▶ **To cite this version:**

Yannick Thiery, Gilles Grandjean, Yann Cottereau, Bastien Colas, Olivier Maquaire, et al.. From landslide susceptibility to risk mapping for France: improvement and application at 1:500,000 scale of work. Journées Aléas Gravitaires - 2022, May 2022, Montpellier, France. hal-03653686

HAL Id: hal-03653686
https://hal.science/hal-03653686

Submitted on 28 Apr 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

From landslide susceptibility to risk mapping for France: improvement and application at 1:500,000 scale of work

Thiery, Y[1].; Grandjean, G[1] ; Cottereau, Y[1].; Colas, B[1].; Maquaire, O.[3] ; Fressard, M.[4] ; Premaillon, M[1].; Bernardie, S. [1] ; Gourdier, S. [1]

[1] BRGM, Directions Risques et Prévention, 45 000 Orléans France
[2] BRGM, Direction des Actions territoriales, 34 000 Montpellier, France
[3] Normandie Univ, UNICAEN, CNRS, IDEES, 14 000 CAEN, France
[4] CNRS UMR 5600, Environnement, ville et société (EVS) ,69676 BRON, France

Keywords : landslide susceptibility, landslide risk, national scale, mapping, quantitative method

Introduction

Assessing landslide risk at national scale has become a major issue for countries, as these maps provide a first overview and qualitative information of the areas potentially susceptible to landslides. In Europe, for more than ten years, several maps have been proposed at the initiative of the JRC (https://esdac.jrc.ec.europa.eu/themes/european-landslide-expert-group). Thus, several maps were produced whether at supranational scale (Gunther et al., 2013; Wide et al., 2018) or at national scale (e.g. for Italy, Triglia et al., 2013; Romania, Bălteanu et al., 2020; Austria, Lima et al., 2021). In France, some tests for metropolitan territory and Corsica were proposed based on expert knowledge as in 1984 (Delauney, 1984) and later on the basis of the approach proposed by Hervás et al. (2007, 2010; Tier 1 approach; Malet et al., 2009). The first results of the Tier 1 approach at the million scale were improved in 2013 (Malet et al., 2013). However, while this map presents a first result for landslide susceptibility assessment, limitations can be highlighted. These limitations are:

i. Methodological, for instance lithology reclassification and weightings are subjective and based on the expertise of the person in charge of the map. At this scale of work, it is complex to know the influence of each class of variables on the susceptibility to landslides; this is why Hervàs et al. (2010) also proposes a Tier 2 approach based on a more objective calculation and quantification of the susceptibility or hazard.
ii. Geographical, with areas underestimated in term of susceptibility class in particular slopes of plateau areas knowing landslides.
iii. Linked to the improvement of some spatial variables in term of resolution and nomenclature such as the DTM, the national landslide database (BD-MVT), or lithological map.

Thus, this work proposes a new approach for national landslide susceptibility mapping (NLSM) for France. Furthermore, it is proposed to go further and realize landslide risk maps at the national scale. The principles are based on the guidance given by Hervás et al. (2010), Günther et al. (2010, 2014), Sedan et al. (2012), and Wide et al. (2018), which are:

i. The computations are performed using a data driven method (quantitative method) and not a heuristic method limiting the subjectivity of the weightings.
ii. New spatial variables are tested in order to spatially improve the unidentified areas.

Finally, the risk is assessed on the principles of Sedan et al (2012) for each municipality with a selection of the stakes based on land use. These issues at this scale are the built-up area and the linear roads of each municipality.

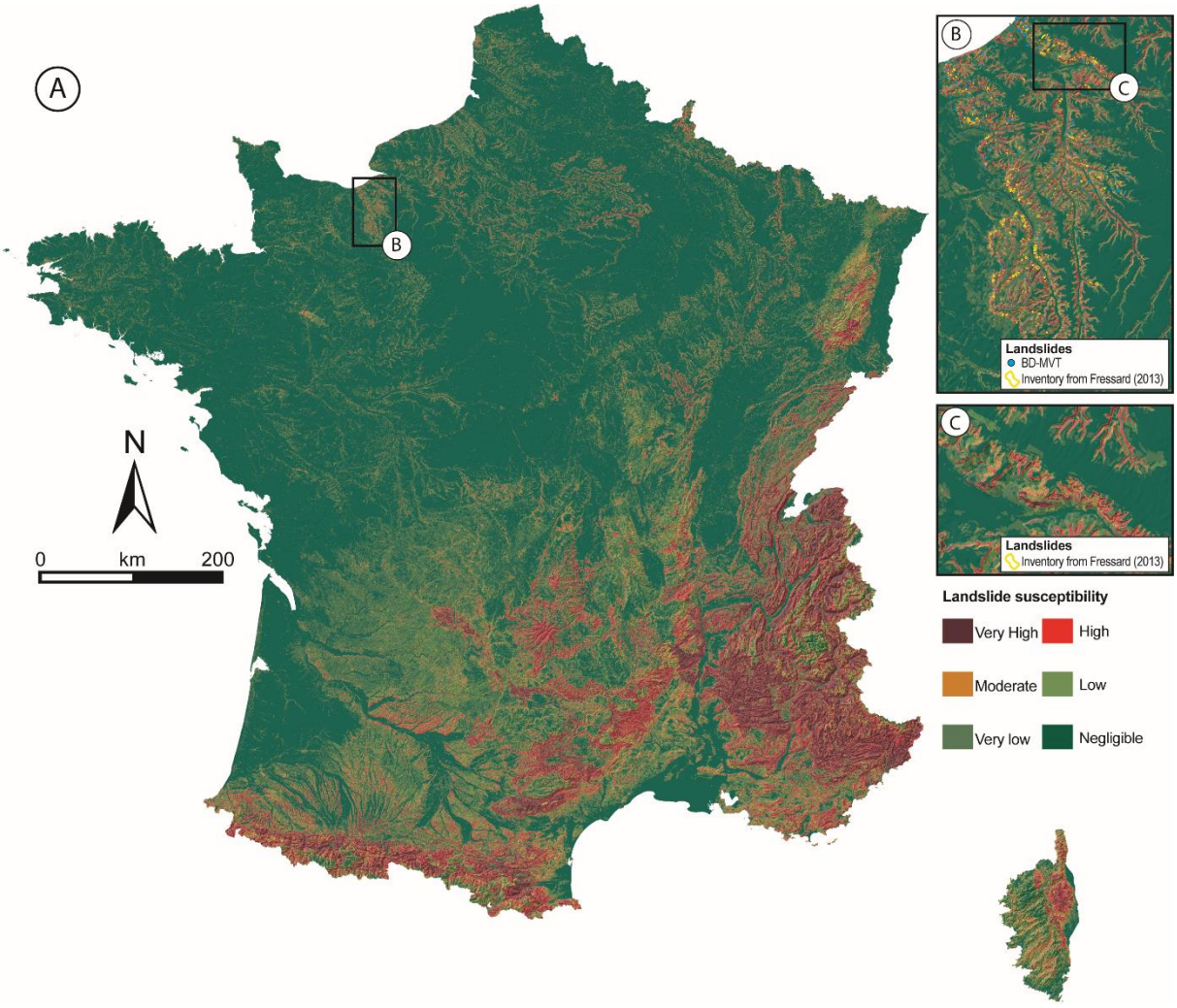


Figure 1. *National landslide susceptibility map (NLSM) obtained with quantitative method (WoE method). A. LSM for metropolitan territory and Corsica. B Zoom of the NLSM for the Pays de Caux (with BD-Mvt and independent landslide inventory; Fressard, 2013). C. Zoom for the Touques area (with independent landslide inventory; Fressard, 2013).*

Methodology

To achieve these objectives, the strategy was divided into two phases with phase 1 focusing on susceptibility analysis, and phase 2 performing risk computations. The first phase was carried out in four steps:

i. Selection of the best spatial variables (i.e. topography, geomorphology, geology, land use, physio-geographic area ...) according to the aptitude to spatial variables to build landslide susceptibility maps recommended by Thiery et al. (2007), the computations were performed with a cell size of 250 m in order to optimize the calculation time.

ii. Once the best set of spatial variables were defined, in order to meet the objectives set for the working scale, the calculations were carried out with a cell size of 50m and on a partition of the country in 18 physio-geographical units based on topographic and climatic units.

iii. Each unit was subjected to a statistical validation procedure with four tests before reclassification into 6 classes following the limits given by the JTC-1. The limits are given for guidance purposes. The reclassified maps are then merged to obtain a single national landslide susceptibility map.

iv. Finally, the final landslide susceptibility map (Fig. 1) was compared to different local landslide databases not implemented in the national landslide database (BD-MVT) and to different national, regional, and local landslide susceptibility maps for different areas.

The second steps consisted in crossing the national landslide susceptibility map with a map of the stakes represented by the built-up areas and the roads for each commune (Sedan et al., 2012). Four types of maps were obtained with:

i. Absolute risk maps representing the surface (in m²) of built areas or road length (in m) affected by moderate, high and very high susceptibility by municipality

ii. Relative risk maps representing dimensionless maps. These maps are the result of a ratio between the built-up surfaces or the road surfaces and the total surface of the municipality.

Results

The results show that the national landslide susceptibility map (NLSM, Fig. 1) obtaining by the procedure based on the principle of selection of the best variables and computation by physio-geographical units significantly improves the map. For the whole territory, the relative error is 0.27, the success rate is 72.8% and the prediction rate is 73.7%. The non-recognition rate is low, meaning that few phenomena are in the negligible class (9%). If we retain the edge areas (e.g. plateau edges) known to produce landslides, they are very well identified with recognition rates higher than 80% (Fig. 1B & 1C).

We can add that 80-97%of the landslides from local databases not introduced in the computation process are well identified in, very high, high and moderate susceptibility. There are strong similarities between the landslides susceptibility maps obtained at other scales and by other techniques, and despite a different number of classes, the very high, high and moderate classes retained for the NLSM overlap well with the high and moderate classes of the other maps without large overlapping.

Finally, the cross-referencing with simplified maps of the stakes (built-up areas and linear roads) makes it possible to identify the communes that potentially have the highest landslide risks.

Discussion - conclusion

If the results of the NLSM are very satisfactory from a statistical and expert point of view, the results for the risk maps are less conclusive. Indeed, the treatment of simplified issues for the built-up environment was carried out from the Corine Land Cover database. Even though it was improved over time, its resolution does not allow obtaining all built-up areas, especially when the habitat is loose. Thus, some municipalities appear without buildings and consequently are not integrated in the maps of absolute and relative risks. It is therefore necessary to re-process the numerical computations by municipality with a more spatially precise database such as the landuse database from THEIA (https://www.theia-land.fr/product/carte-doccupation-des-sols-de-la-france-metropolitaine/).

Finally, the landslide susceptibility and risk maps for a scale of 1:500,000 is a new spatialization tool that can be integrated into the global assessment scheme of landslide hazard in France with a nested scale approach proposed by Thiery et al (2020). These two tools could allow to better target the municipalities not yet been integrated in the global scheme of PPRs elaboration or that are not a priority although they could have landsliding probability. Thus, it would be

necessary, after reprocessing the risk maps, to compare the results with the GeoHazards database (http://www.georisques.gouv.fr/), which provides information on the PPRs planned, in progress or approved.

References

Bălteanu et al., 2020. National-scale landslide susceptibility map of Romania in a European methodological framework. Geomorphology, 371. https://doi.org/10.1016/j.geomorph.2020.107432

Fressard Mathieu, 2013. Les glissements de terrain du Pays d'Auge continental (Normandie, France) Caractérisation, cartographie, analyse spatiale et modélisation. Géographie. Université de Caen. ⟨tel-00968473⟩

Günther, A., Reichenbach, P., Malet, J.-P., Van Den Eeckhaut, M., Hervás, J., Dashwood, C., Guzzetti, F., 2013. Tier-based approaches for landslide susceptibility assessment in Europe. Landslides 10: 529-546.

Günther, A., Van Den Eeckhaut, M., Malet, J.-P., Reichenbach, P., Hervás, J., 2014. Climate-physiographically differentiated Pan-European landslide susceptibility assessment using spatial multi-criteria evaluation and transnational landslide information. Geomorphology, 224: 69-85

Hervás, J. (Ed.), 2007. Guidelines for Mapping Areas at Risk of Landslides in Europe. Proc. Experts Meeting, JRC, Ispra, Italy, 23-24 October 2007. JRC Report EUR 23093 EN, Office for Official Publications of the European Communities, Luxembourg, 53 pp.

Hervás, J., Günther, A., Reichenbach, P., Malet, J.-P., Van Den Eeckhaut, M., 2010. Harmonised approaches for landslide susceptibility mapping in Europe. In: Malet, J.-P., Glade, T., Casagli, N. (Eds.), Proc. Int. Conference Mountain Risks: Bringing Science to Society, Florence, Italy, 24-26 November 2010. CERG Editions, Strasbourg, pp. 501-505.

Malet, J.-P., Thiery, Y., Puissant, A., Hervás, J., Günther, A., Grandjean, G., 2009. Landslide susceptibility mapping at 1:1M scale over France: exploratory results with a heuristic model. In: Malet, J.-P., Remaître, A., Boogard, T. (Eds), Proc. International Conference on Landslide Processes: from Geomorphologic Mapping to Dynamic Modelling, 6 -7 February 2009, Strasbourg, France. CERG Editions, Strasbourg, pp. 315-320.

Malet, J.-P., Puissant, A., Alexandre, M., Mathieu, A., Van Den Eeckhaut, M., Fressard, M., 2013. Integrating spatial multi-criteria evaluation and expert knowledge for national-scale landslide susceptibility analysis: application to France. In: Margottini, C., Canuti, P., Sassa, K. (Eds.), Landslide Science and Practice (Proc. Second World Landslide Forum, 3-7 October 2011, Rome), Springer, Heidelberg, Vol. 1, pp. 303-311.

Lima, P., Steger, S. & Glade, T. Counteracting flawed landslide data in statistically based landslide susceptibility modelling for very large areas: a national-scale assessment for Austria. Landslides 18, 3531–3546 (2021). https://doi.org/10.1007/s10346-021-01693-7

Sedan, O., Terrier, M., Hohmann, A., Kobayashi, H., Mathon, C., Rohmer, J. 2011 Scenario départemental de risque mouvements de terrain, méthodologie et processus de réalisation. Rapport final. BRGM/RP-9065. 291 p. https://infoterre.brgm.fr/rapports/RP-59065-FR.pdf

Thiery, Y., Malet, J.-P., Sterlacchini, S., Puissant, A., Maquaire, O., 2007. Landslide susceptibility assessment by bivariate methods at large scales: Application to a complex mountainous environment, Geomorphology, 92, 1–2, 38-59

Trigila, A. et al. (2013). Landslide Susceptibility Mapping at National Scale: The Italian Case Study. In: Margottini, C., Canuti, P., Sassa, K. (eds) Landslide Science and Practice. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-31325-7_38

Wilde, M., Günther, A., Reichenbach, P., Malet, J.-P., Hervás, J., 2018. Pan-European landslide susceptibility mapping: ELSUS Version 2. Journal of Maps, 14(2), 97-104 and supplemental map.