UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ
FACULTAD DE INGENIERÍA
ÁREA CURRICULAR DE INGENIERÍA CIVIL Y AGRÍCOLA
DOCTORADO EN INGENIERÍA - INGENIERÍA CIVIL

Línea de investigación

Grupo de investigación:
Suelos Residuales y Parcialmente Saturados

Topic:
Landslide,
Mass movement
Slope failure

Seminario Doctoral de Ingeniería Civil - SEDIC 2015

Programa de Doctorado en Ingeniería – Ingeniería Civil

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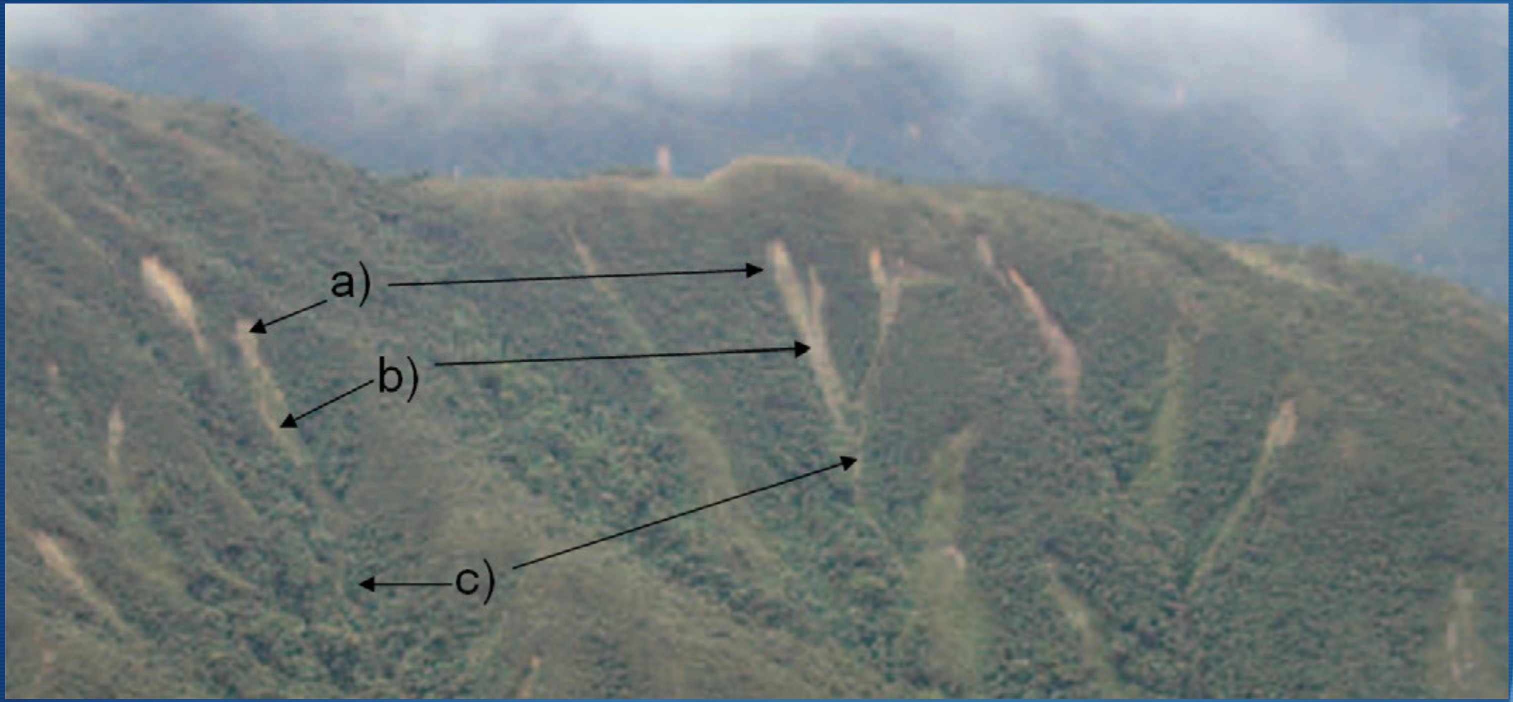
Method for preparing inventories of terrestrial landslides with semi-automatic procedures



Student: Nixon Alexander Correa Muñoz, MSc

Director: Carol Andrea Murillo Feo, PhD

Doctorado en Ingeniería
Ingeniería Civil

Introduction [1]

Landslide hazard determination process

Susceptibility analysis

- Deterministic models (GI)
- Heuristic models (SME)
- **Statistical models** (LR, ANN, FEP)

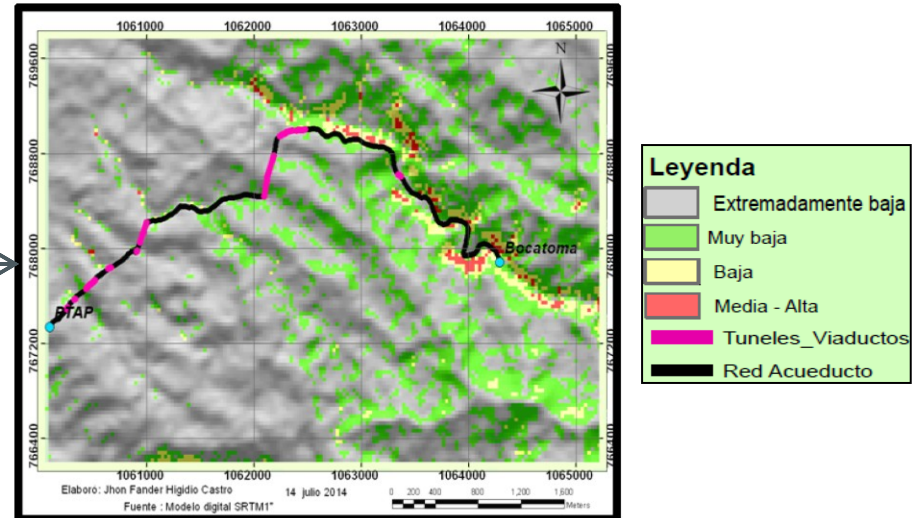
Susceptibility map

Hazard analysis

- Frecuency determination
- Intensity determination

Hazard map

Taken from Margottini et al. (2013), p477



Taken from Higidio y Correa (2014)

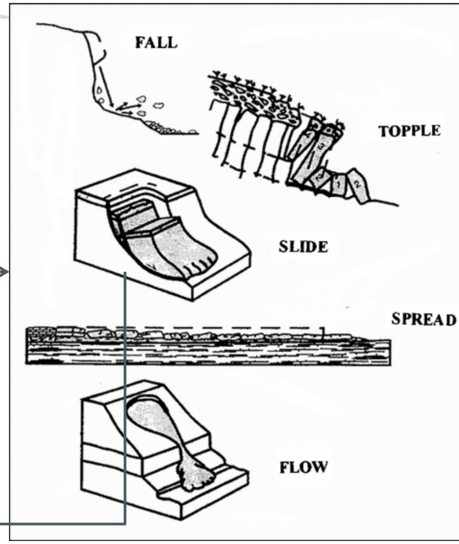
Landslide inventory= 0,28***Slope**+0,78***LengthSlope**+0,16***Wetness**-0,06***PathFlow**+7,3***SoilsMap**-0,21***ConvIndex**

Introduction [2]

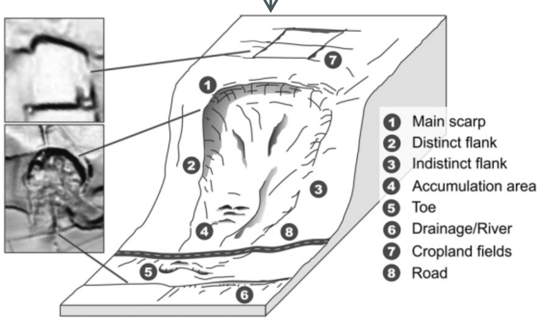
Movement type

Cruden and Varnes (1996):

Fall
Rotational sliding
Translational sliding
Lateral spreading
Flow
Complex

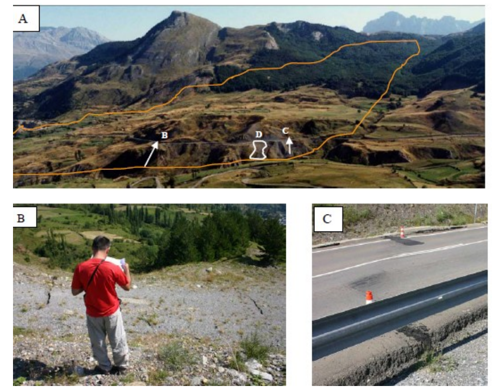


Taken from Hungr et al. (2014), p168

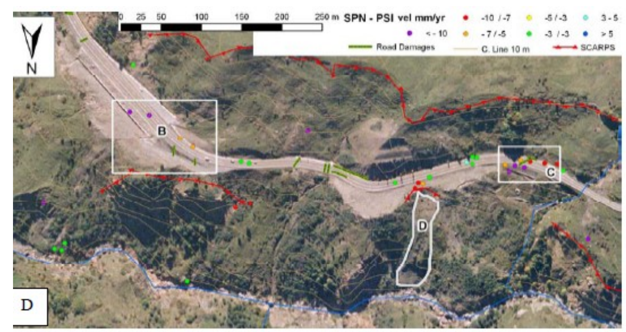


Taken from Van Den Eeckhaut et al. (2012), p32

Gemorphological field mapping
(Brunsden, 1985)

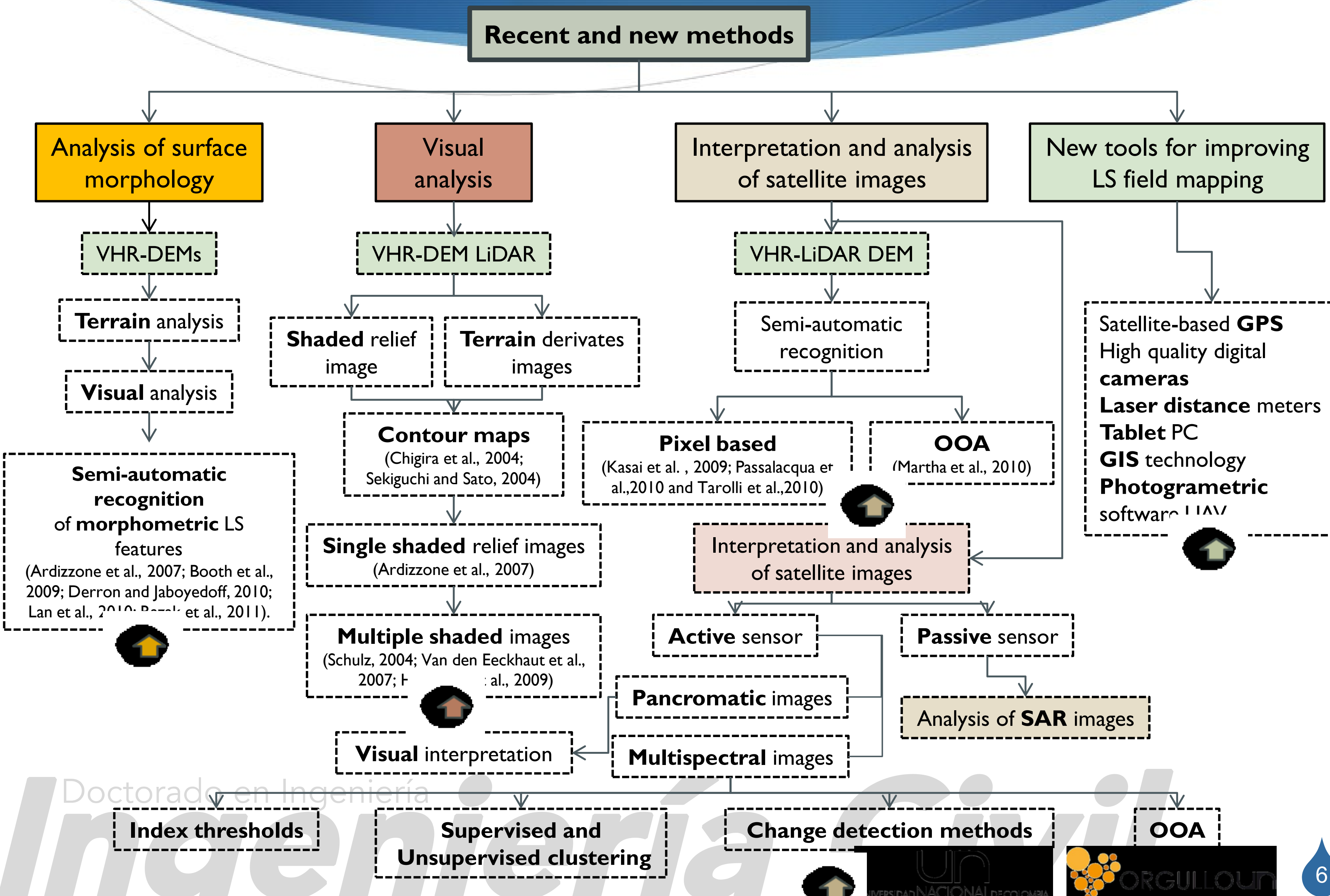


Visual interpretation of aerial photographs
(Rib and Liang, 1978; Turner and Schuster, 1996)



Taken from Notti et al. (2010), p1874

State of the art: Landslides recognition



Lack of research

- Inventory
- landslide map
- landslide inventory
- landslide inventory map

Modifications to the Varne's classification
(Hungr, Leroueil, & Picarelli, 2014)

There is lack of standards and accepted, properly defined best practices, or operational protocols, for the preparation and update of LS maps
(Fausto Guzzetti et al., 2012b).

The criteria for the production of LS maps and for the evaluation of their quality remain poorly defined
(Soeters and van Westen, 1996; Guzzetti et al., 2000; Guzzetti, 2006; van Westen et al., 2006, 2008)

The identification of old vegetated LS, has not been investigated so far
(Van Den Eeckhaut, Kerle, Hervás, & Supper, 2013)

Few studies have attempted to develop computer-aided methods for extracting LS from LiDAR data
(Lin et al., 2013)

To study deeply the choice of textural and topological features on Segmentation
(Hungr, Leroueil, & Picarelli, 2014)

To validate the methodologies by using other classification strategies
(Hungr, Leroueil, & Picarelli, 2014)

To study more formally the robustness of the learning transfer step to deal with different LS
(Hungr, Leroueil, & Picarelli, 2014)

To study the impact of potential image to image spatial registration issues
(Kurtz et al., 2014)

It should be subject of future research, an integrated approach that considers a combination fo different platforms (SI, SAR, LiDAR)
(Lin et al., 2013)

Problem

LS are one of the main natural threats in mountainous areas of the world; they cause significant damage to property, life and engineering projects. To comprehend the spatial and temporal occurrence of those, as well as the risk management, one must start by comprehending the detection methods and LS cartography (Martha, Kerle, Jetten, van Westen, & Kumar, 2010).

LS inventories are the most important source of information for the quantitative zoning of susceptibility, hazard and slide risk, for they gather data about position, date, type, size, activity and causal factors, as well as potential damage. The national landslide databases use harvesting methods for traditional data (field survey, historical data analysis, scientific literature inclusion, technical reports and aerial photo interpretation (Ventura, Vilardo, & Terranova, 2013).

LS cartography is carried out through photo geological interpretation from images. This manual method is slow and requires professional working; besides, the high cost limits the number of places that can be studied with detail. The application of automatic cartographic techniques increases the process speed, reduces the cost (Bue & Stepinski, 2006) and uses spectral, spatial morphometric and contextual properties (Martha et al., 2010).

The visual, automatic and semiautomatic analysis of satellite images of VHR has been considered a promising way to identifying and mapping landslides both in local and regional scale. However, the state of the art of the image analysis tools used in landslide cartography deals with the homogenous radiometry hypothesis, which can't manipulate the new spatial detail levels of VHR images. Therefore, new methodologies for image analysis have to be proposed for landslide cartography from optical satellite images VHR (Kurtz et al., 2014).

There is not a single or unique method for landslide identification through stereo-pair images; recognition of landslides through imagery may be affected by land-use cover and by height, type, and density of vegetation. Additionally, landslide boundaries could also be difficult to delineate, even in the case of recent or very small landslides (Murillo-García et al., 2014).

Hyphotesis

LS discernible signs, most of which can be recognized, classified, and mapped in the field, through the interpretation of (stereoscopic) aerial photographs, satellite images, or digital representations of the topographic surface (*Rin and Liang, 1978; Hansen, 1984 a, 1984 b, Hutchinson, 1988; Turner and Schuster, 1996; Guzzetti et al., 2000*).

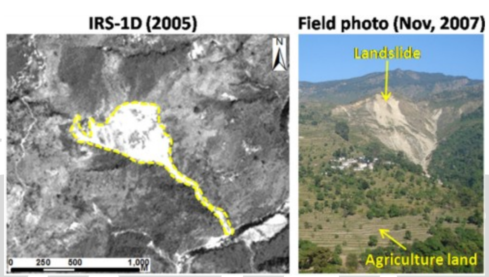
The morphological signature of a LS depends on the type and the rate of motion of the mass movement (*Cruden & Varnes, 1996; Dikau et al. 1996*).

LS do not occur randomly, or by chance (*Guzzetti et al., 2002; Turcotte et al., 2002*). Slope failures are the result of the interplay of physical processes, and mechanical laws controling the stability or failure of a slope.

For landslide, geomorphologists adopt the principle that "the past and present are keys to the future" (*D. J. Varnes, 1984*; *Carrara et al., 1991; Hutchinson, 1995; Aleotti and Chowdhury, 1999; Guzzetti et al., 1999, 2000*), a consequence of uniformitariasnism..

The satellite images of Very High Resolution contain enough spatial data for deploying attributes of the geomorphological surface and can, in principle, carry out an analysis in the sub-part level that integrate a LS (Kurtz, Passat, Gançarski, & Puissant, 2012).

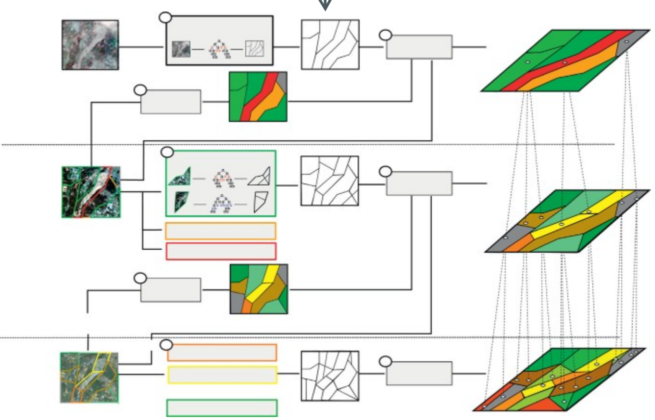
The high resolution topographical data (LiDAR) has the potential to distinguish the morphological components inside a landslide and showing signals of material type and landslides activities (Glenn, Streutker, Chadwick, Thackray, & Dorsch, 2006).



Taken from (Tapas et al., 2012)

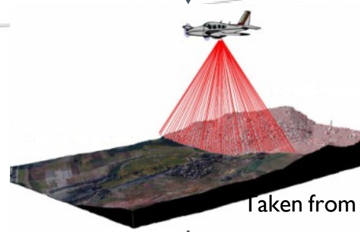
Summary of approaches

Top-Down Hierarchical Approach (TDHA)

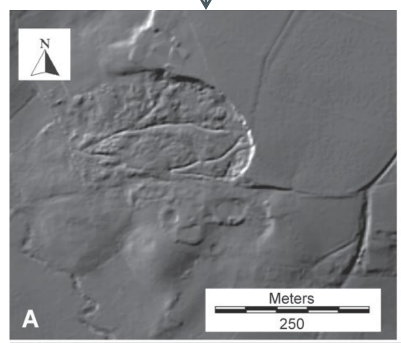


Taken from (Ardizzone et al., 2007)

Airborne laser scanning

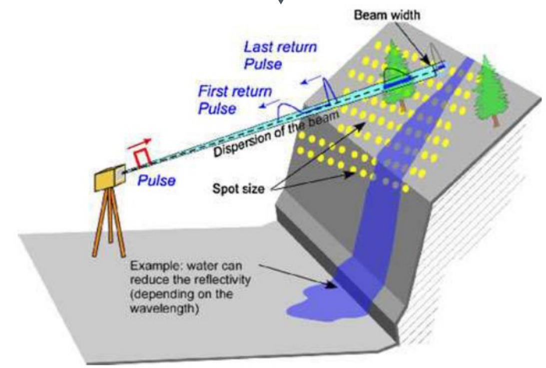


Taken from (Albacete, 2011)



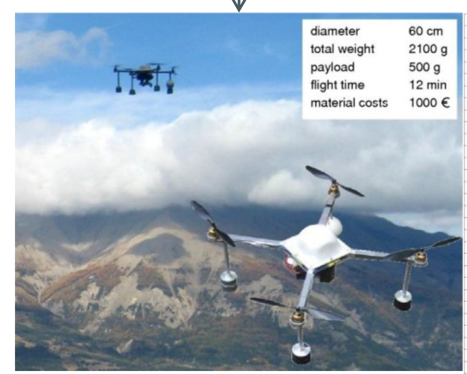
Taken from (Van Den Eeckhaut et al., 2007

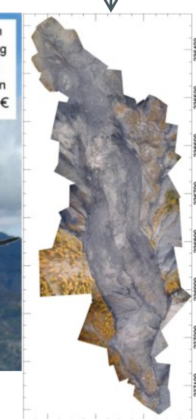
Terrestrial laser scanning



Taken from (Jaboyedoff et al., 2012)

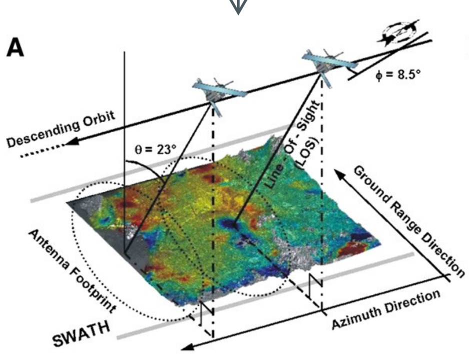
UAV-based remote sensing

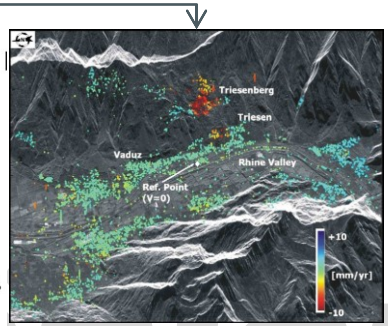




Taken from (Niethammer et al., 2010)

Space borne Synthetic Aperture Radar Interferometry





Taken from (Colesanti and Wasowski, 2006)

Systematic literature review

Evidence-based process

438 papers
- 97 Very high
- 228 High

Year
- 2010 – 2015: 132
- 2005 – 2010: 137

Topic
- Susceptibility LS: 52
- Monitoring LS: 51
- Extraction LS: 46
- Inventory LS: 19
- Accuracy LS: 5
- State of the art LS: 3

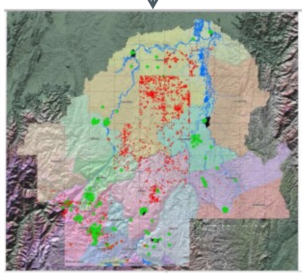
Country
- Italy: 49
- USA: 21
- France: 14
- Indian: 13

Journal
- Geomorphology: 51
- Remote Sensing: 16
- ISPRS: 15
- Engineering Geology: 14
- Landside Science and Practice: 12
- Landslides: 10

Study area

Criterion

Previous studies of LS geomorphology



CORANTIOQUIA-IGAC (Karin, 2013)

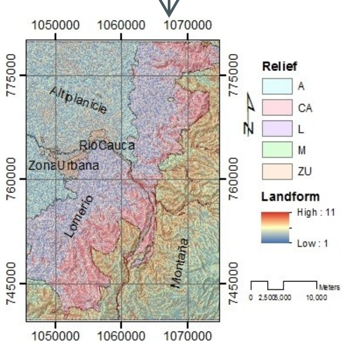
Roads affected during period 2010-2011 winter

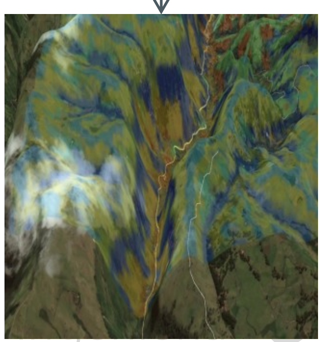
Tramo	Departamento	Eventos de cierre total
Honda – Alto de la Mona – Villeta	Cundinamarca	111
Puente La Libertad – Fresno – Honda	Caldas – Tolima	41
San Roque – Bosconia	Cesar	36
Chigorodó – Dabeiba	Antioquia	34
Barbosa – Cisneros – Puerto Berrío	Antioquia	33

Tramo	Departamento	Eventos de cierre parcial
Barbosa – Cisneros – Puerto Berrío	Antioquia	312
Honda – Alto de la Mona – Villeta	Cundinamarca	299
San Roque – Bosconia	Cesar	214
Pasto – Popayán	Cauca	175
Bucaramanga – San Alberto	Santander	102

Vulnerabilty terms, MinTransporte (2012)

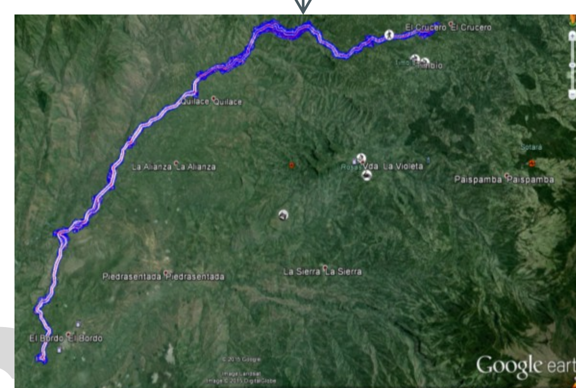
Geomorphometry study





Master´s thesis (Correa, 2012)

Data availability

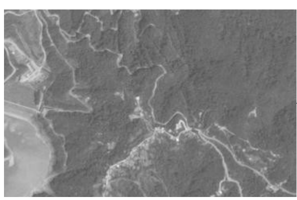


(SIG de Latinoamérica, S.A.S.

Materials

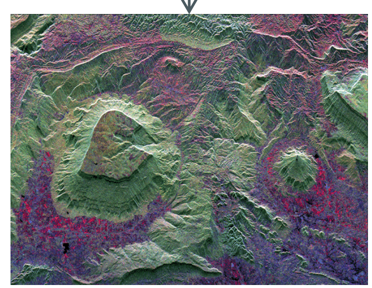
Satellite images → **Active images**

- **Medium Resolution 15 a 30 m** → LANDSAT, ASTER, SPOT5
- **High Resolution 5 m** → RAPID-EYE
- **Very high resolution**
  - **Panchromatic 0.5-1.5 m**
  - **Multispectral 1.8-4.0 m**
  - → Quickbird, Worldview, GeoEye-1, IKONOS, EROS-B, SPOT-6, PLEIADES-1 A y 1B



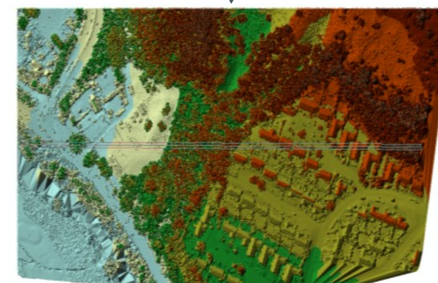
Taken from (Jacobsen, 2011)

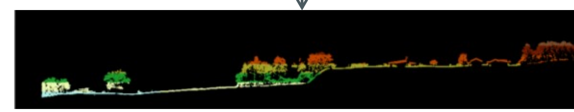
Satellite images → **Pasive images** → **Radar images** → ERS-1 and ERS-2, RadarSAT, JERS-1, SRTM, ENVISAT, PALSAR/ALOS, TERRA-SAR, E-SAR



Taken from (Tansey, 2013)

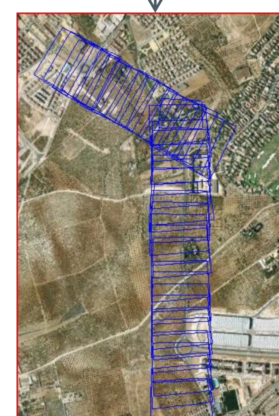
LiDAR





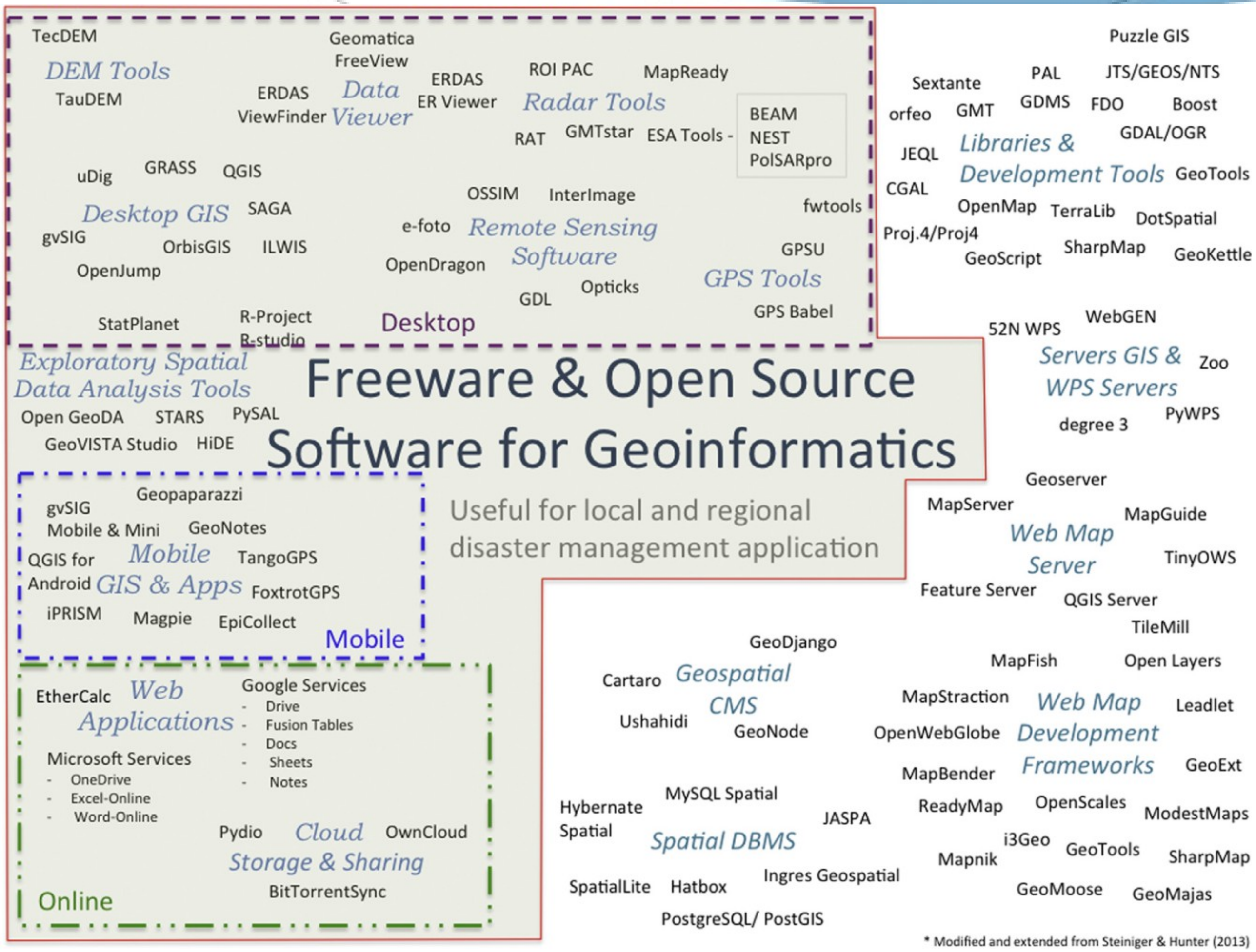
Taken from (Tansey, 2013)

UAV



Taken from (Meroño et al., 2013

Software



Taken from (Leidig and Teeuw, 2015)

-**Visual_Data** (Carr, 2002)

-**SOM-PAK** (kohonen et al., 1996)

-**ImageStation Automatic Elevation** (Prokesova et al., 2010)

-**JAVA-MUSTIC and ORFERO TOOLBOX** (de Lussy et al., 2005)

-Algorithms in **eCognition**: Mean Shift and **Region Merging** (Baatz and Schape, 2000)

-**Leica Photogrammetry Suite** de ERDAS IMAGINE and **Stereo Analyst** de ArcGIS (Margottini et al., 2013)

-Algoritmo **Gram-Schmidt Spectral Sharpening** de ENVI (Guzzetti et al., 2012)

References [1]

Ardizzone, F., Cardinali, M., Galli, M., Guzzetti, F., & Reichenbach, P. (2007). **Identification and mapping of recent rainfall-induced landslides using elevation data collected by airborne Lidar**. *Natural Hazards and Earth System Science*. http://doi.org/10.5194/nhess-7-637-2007

Colesanti, C., & Wasowski, J. (2006). **Investigating landslides with space-borne Synthetic Aperture Radar (SAR) interferometry**. *Engineering Geology*, *88*(3-4), 173–199. http://doi.org/10.1016/j.enggeo.2006.09.013

Cruden, D. M., & Varnes, D. J. (1996). *Landslides: Investigation & Mitigation*. (A. K. Turner & R. L. Shuster, Eds.)***Landslides*** (Vol. 6). Transp Res Board, Spec Rep 247. Retrieved from http://www.springerlink.com/index/10.1007/s10346-009-0175-2

Glenn, N. F., Streutker, D. R., Chadwick, D. J., Thackray, G. D., & Dorsch, S. J. (2006). **Analysis of LiDAR-derived topographic information for characterizing and differentiating landslide morphology and activity.** *Geomorphology*, *73*(1-2), 131–148. http://doi.org/10.1016/j.geomorph.2005.07.006

Guzzetti, F., Mondini, A. C., Cardinali, M., Fiorucci, F., Santangelo, M., & Chang, K. T. (2012). **Landslide inventory maps: New tools for an old problem**. *Earth-Science Reviews*, *112*(1-2), 42–66. http://doi.org/10.1016/j.earscirev.2012.02.001

Hungr, O., Leroueil, S., & Picarelli, L. (2014). **The Varnes classification of landslide types, an update**. *Landslides*. http://doi.org/10.1007/s10346-013-0436-y

Jaboyedoff, M., Oppikofer, T., Abellán, A., Derron, M. H., Loye, A., Metzger, R., & Pedrazzini, A. (2012). **Use of LIDAR in landslide investigations: A review**. *Natural Hazards*.

Kurtz, C., Passat, N., Gançarski, P., & Puissant, A. (2012). **Extraction of complex patterns from multiresolution remote sensing images: A hierarchical top-down methodology**. *Pattern Recognition*, *45*(2), 685–706.

Kurtz, C., Stumpf, A., Malet, J. P., Gançarski, P., Puissant, A., & Passat, N. (2014). **Hierarchical extraction of landslides from multiresolution remotely sensed optical images**. *ISPRS Journal of Photogrammetry and Remote Sensing*, *87*, 122–136. http://doi.org/10.1016/j.isprsjprs.2013.11.003

Lin, C. W., Tseng, C. M., Tseng, Y. H., Fei, L. Y., Hsieh, Y. C., & Tarolli, P. (2013). **Recognition of large scale deep-seated landslides in forest areas of Taiwan using high resolution topography**. *Journal of Asian Earth Sciences*, *62*, 389–400. http://doi.org/10.1016/j.jseaes.2012.10.022

References [2]

Martha, T. R., Kerle, N., Jetten, V., van Westen, C. J., & Kumar, K. V. (2010). **Characterising spectral, spatial and morphometric properties of landslides for semi-automatic detection using object-oriented methods**. *Geomorphology*, *116*(1-2), 24–36. http://doi.org/10.1016/j.geomorph.2009.10.004.

Murillo-García, F. G., Alcántara-Ayala, I., Ardizzone, F., Cardinali, M., Fiourucci, F., & Guzzetti, F. (2014). **Satellite stereoscopic pair images of very high resolution: a step forward for the development of landslide inventories. *Landslides*. http://doi.org/10.1007/s10346-014-0473-1**

Niethammer, U., Rothmund, S., James, M. R., Travelletti, J., & Joswig, M. (2010). **UAV - BASED REMOTE SENSING OF LANDSLIDES**. In *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVIII, Part 5. Commission V Symposium* (pp. 496–501).

Notti, D., Davalillo, J. C., Herrera, G., & Mora, O. (2010). **Assessment of the performance of X-band satellite radar data for landslide mapping and monitoring: Upper Tena Valley case stu**dy. *Natural Hazards and Earth System Science*, *10*(9), 1865–1875. http://doi.org/10.5194/nhess-10-1865-2010.

Passalacqua, P., Tarolli, P., & Foufoula-Georgiou, E. (2010). **Testing space-scale methodologies for automatic geomorphic feature extraction from lidar in a complex mountainous landscape**. *Water Resources Research*, *46*(11).

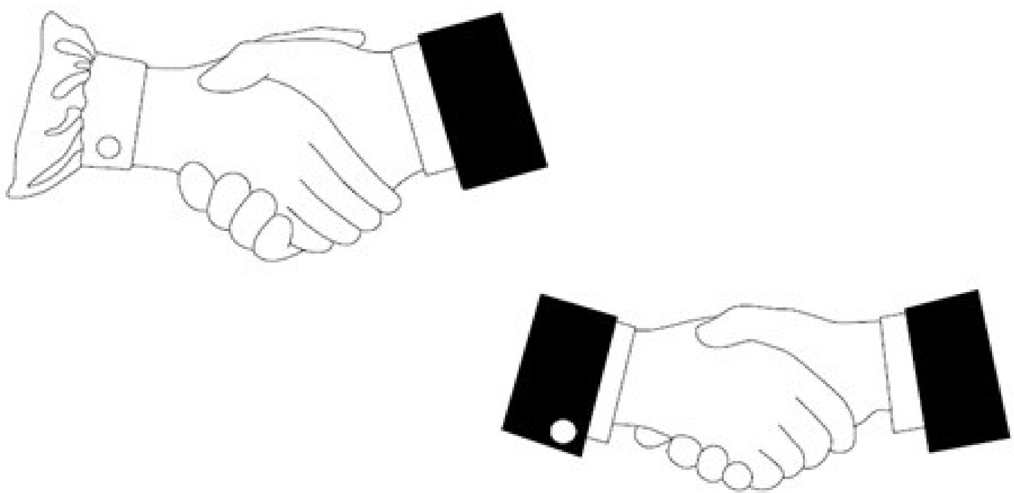
Van Den Eeckhaut, M., Kerle, N., Poesen, J., & Hervás, J. (2012). **Object-oriented identification of forested landslides with derivatives of single pulse LiDAR data**. *Geomorphology*, *173-174*, 30–42. http://doi.org/10.1016/j.geomorph.2012.05.024

Van Den Eeckhaut, M., Poesen, J., Verstraeten, G., Vanacker, V., Nyssen, J., Moeyersons, J., … Vandekerckhove, L. (2007). **Use of LIDAR-derived images for mapping old landslides under forest**. *Earth Surface Processes and Landforms*, *32*(5), 754–769. http://doi.org/10.1002/esp.1417

Van Westen, C. J., van Asch, T. W. J., & Soeters, R. (2006). **Landslide hazard and risk zonation - Why is it still so difficult**? *Bulletin of Engineering Geology and the Environment*, *65*(2), 167–184. http://doi.org/10.1007/s10064-005-0023-0

Ventura, G., Vilardo, G., Terranova, C., & Sessa, E. B. (2013). **4D monitoring of active landslides by multi-temporal airborne LiDAR data**. In *Landslide Science and Practice: Early Warning, Instrumentation and Monitoring* (Vol. 2, pp. 147–151).

!Thank you!



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