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Methods for detecting channel bed surface changes in a mountain torrent – experiences from the Dorfbach torrent

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S 1 Guideline for choosing the appropriated method according to the aims of application and analysis

Research question: **Methods to localise and quantify erosion and deposition in torrent channels**		**Requirements**	**In-situ methods**	**Cross sections**	**Terrain models**		**Qualitative methods**
			Erosion sensors	TruPulse and dGPS	Terrestrial Laser Scanning	LiDAR	Geomorphological mapping
			Berger et al. (2010; 2011a); McArdell (2012, personale communication) Fritschi (2012, personale communication)	Own application	Own application	Scheidl et al. (2008); Scheidl (2012, personale communication)	Own application
Location and process	**Process and process characteristics**	Channel changes caused by debris-flows: dimension and position of extensive structures should be measureable	**Time, duration and extent (max. Δz)** of erosion caused by debris-flows. Detection of deposition is not provided.	**Extent (net Δz and ΔF)** of erosion and deposition caused by debris-flows in a certain cross section.	**Extent (net Δz and ΔV)** of erosion and deposition caused by debris-flows for a confined torrent area. Pattern are detectable.	**Extent (net Δz and ΔV)** of erosion and deposition caused by debris-flows for a confined torrent area. Pattern are detectable.	**Tendencies of changes (Δz)** area-wide for the whole torrent channel. Pattern are detectable, no quantitative (only estimated) results.
	Channel properties and conditions	8-3 m wide channel with a channel bed consisting of coarse debris and levees up to 4 m high	Application only in torrent channels with fine grained bed (d 90 < 0.3- 0.5 m) possible.	Application difficult with steep or instable bank and missing slopes, measurement sites preferable outside the channel.	Application difficult if banks are steep or unstable. High banks and narrow channels are also inappropriate. Measurement sites preferable outside the channel.	Application is hindered if the channel is strongly vegetated or hardly visible or if banks are steep. Inaccuracies and errors increase.	Application independent of the channel properties possible.
	Access to the torrent channel	The torrent channel is accessible on hiking trails. The channel itself is walkable with mountaineering boots.	Punctual access to the channel by a roadway, accessibility of the channel necessary.	Access to the channel by walkable banks is sufficient, accessibility of banks and channel necessary.	Access to the channel by a roadway or path, good accessibility of the channel necessary.	No access to the torrent channel necessary.	Access to the channel by walkable banks is sufficient, accessibility of banks and channel necessary.
	Application during/ after massive channel changes	Channel changes up to 10 m difference are realistic.	Sensors no more applicable after a major event; sensors would erode completely or would be massively covered - no data.	Method not applicable anymore due to reduced view, eroded/ covered marks, unstable banks, missing accessibility to the channel.	Method may not be applicable anymore due to reduced view, missing GPS signal for georeferencing, missing accessibility to the channel.	Method applicable, reduced view and data accuracy with steepened channel and banks.	Method applicable, as long as the channel is accessible or at least visible, varieties in the amount of changes hardly differentiable.
Quality criteria	**Scope of application** (investigation during only one day)	Continuous, extensive detection of the analysed channel section or entire channel as far as possible.	**Point-based detection** in a small space inside the analysed channel section.	Point-based **cross sectional detection** spread over the entire channel (interpolation between single cross sections feasible).	**Confined area(s)** of the analysed channel section.	**Total area** of the analysed channel section.	**Total area** of the analysed channel section.
	Accuracy of the raw data	10^{-2} m-range up to m-range, depending on the intended use of the data.	0.05 m resolution in correspondence to a single sensor element	dGPS: horizontal and vertical precision +/- 0.1 m TruPulse: Distance +/- 0.3 m Inclination: +/- 0.25° Azimuth: +/- 1° (LTI, 2009:52; Trimble, 2011)	Modelled surface: 0.002 m (Leica 2012)	Location: +/- 0.1 m Height: +/- 0.5 m (Standard accuracy according to Vosselman and Maas, 2010:21)	Location: multiple meters Height: not observable Mapping accuracy varies depending on the mapping base and scope for interpretation.
	Accuracy of the final data	10^{-1} m-range up to m-range, depending on the intended use of the data.	0.05 m resolution in correspondence to a single sensor element and inaccuracies in 10^{-1} m-range due to deposition on the sensor and measurement device.	Location: in the range of 0.5 m Height: in the range of 0.5 m	Location: < 0.3 m Height: in the range of 0.3 m	Location: 0.3-0.5 m Height: 0.1-0.3 m (data for CH mountain torrents, also realistic in the Dorfbach torrent).	Location: multiple meters (strongly influenced by the interpretation of mapping person). Height: Changes only detectable as tendencies.
	Spatial resolution	2-3 m or < 0.5 m, depending on the intended use of the data	5 measurements on 20 m^2, remaining channel not covered	Cross sectional resolution in 10^{-2} m-range Distance between cross sections: 50-150 m	Enables 10^{-1} m-raster	Raster resolution 0.5-5 m (Oguchi et al. 2011)	In the range of 5-30 m, depending on the mapping base and scope for interpretation.
	Temporal resolution	Measurements during or after each event or at least once a month (to eliminate continuous changes).	**Permanently installed and ready for measurements**, time limits of erosion during an event are exactly detectable.	**Data collection few days up to max. one month before and after an event,** at any time possible if the channel is accessible.	**Data collection few days up to max. one month before and after an event,** at any time possible if the channel is accessible.	**Data collection few weeks up to several months before and after an event,** lack of temporal resolution due to financial reasons.	**Data collection few days up to max. one month before and after an event,** at any time possible if the channel is accessible.
	Repeatability	Necessary	**Possible,** due to permanent installation.	**Possible,** as long as measurements sites are outside the torrent channel.	**Possible,** fixed targets or georeferencing necessary.	**Possible**	**Possible,** it should be noted that every mapping leaves scope for interpretation.

Organisational aspects	**Suitability of the material for field investigations**	Material must be portable in difficult terrain.	Single use of an excavator necessary; durability of the sensors lowered in a humid channel bed.	Measurement devices and tripod are handy and transportable by one person.	Measurement device is heavy, multi-pieced and only transportable by multiple people.	-	Necessary material transportable without problems.
	Total expenditure (for preparation, data collection, processing and analysis to gain data from one event)	-	**Approx. 13 person-days,** however decreasing with every further event (> 1 week for development and manufacturing).	**Approx. 8-9 person-days** caused by time-consuming data correction.	**Approx. 14-15 person-days** mainly due to diverse work steps and data correction.	**9-10 person-days** if data collection and preparation is carried out by a professional company (Helimap 2011).	**Approx. 2-3 work-days,** expenditure depending on level of detail.
	Expenditure for field work (for the collection of the data of one event)	Maximum one day of field investigation for each measuring period.	**6 person-days** for installation (additional field work for detecting the height of sediment cover over the erosion sensors)	**2 x 2 person-days** for 6-7 cross sections spread over 260 m altitude	**2 x 3 person-days** for 2 areas of 70 m x 20 m with 5 scans each	**No field work** necessary (only for plausibility check) (data collection **2 x 2 person-days** (Helimap 2011))	**2 x < 1/2 person-day** for detailed mapping of studied channel reach
	Post-processing expenditure (for the processing of the data of one event)	-	**< 30 minutes**	**Approx. 3-4 days** depending on the data quality.	**Approx. 5-7 days,** mainly due to manual data correction.	**2 days work** by a professional company for a 250 ha area (Helimap 2011)	**Approx. 1 day,** mainly for digitizing and dGPS data preparation.
	Assistant needs for the field investigation	-	**2 people,** including an excavator driver	**1 person**	**Minimum 2 people**	-	**No need,** except for safety reasons.
	Further aspects	-	Distinctive **intervention** in the channel bed necessary to install the sensors.	Accuracy of georeferencing depends on the **satellite availability.**	Lower resolution and quality requirements massively lower **work expenditure.**	LiDAR data collection expensive in comparison to other methods.	**Mapping base**: 1:5'000 to 1:25'000 maps.
			Described sensor conforms to a top-end version and could be produced simpler and cheaper: as an alternative to the aluminium case a PVC case could be used.	**Atmospheric conditions** influence the measurements.	**Atmospheric conditions** influence the measurements.	Data collection only if weather conditions are good, **atmospheric conditions** influence the measurements.	
			Excavator necessary, increases costs.			**Helicopter** needed for data collection.	