Masterproefonderwerpen

FYSISCHE GEOFRAFIE
1. Topographic rain zones and regional rain shadows related to mountain massifs in the Ethiopian highlands

Promoter: Prof. Jan Nyssen
Co-Promoter: Prof. Piet Termonia
Advisors: Dr. Miro Jacob (UGent Department of Geography)
Note: Fieldwork in Ethiopia is not required for this master thesis.

In mountainous countries mapping of annual rainfall depth often done using interpolations that involve longitude, latitude and possibly elevation of meteorological stations. Such an approach does not allow to account for dominant wind directions and rain shadow. For instance, in Ethiopia, slope aspect has been demonstrated to be an important explanatory factor of rainfall depth (Nyssen et al., 2005). On rainfall maps at different scales, the major massifs appear to induce topographic rain on the windward side, and rain shadow on the leeward side. For instance, it has been demonstrated that the Semien mountains (4560 m) throw a rain shadow on its northern slopes (Puff & Nemomissa, 2001, Fig. 3B) that is believed to extend hundreds of km further to the NNW (Feoli et al., 2002; Deyassa et al. 2014).

Also at local scale relatively minor massifs generate a similar effect. The Dogu’a Tembien massif (photo), under conditions of dominant southwesterlies in the rainy season, generates a topographic rain zone near Abi Adi and Hagere Selam, and less rain (including frequent catastrophic droughts) in the Wukro-Senkata area.

The Dogu’a Tembien massif, seen from the West. Difference in elevation between the lowlands in front and the crestlines is 1200-1400 m.
Topography (left) and annual rainfall (right) in Geba catchment. Wind direction during the rainy season is from the SW. The high rainfall around Abi Adi is thought to be largely of orographic nature, induced by the Dogu’a Tembien massif around Hagere Selam. A rain shadow occurs then in the Senkata-Wukro area (Etefa et al., 2016). Dots are monitoring sites for land cover since the 1930s.

Using station data and the state-of-the-art ALADIN climate model, as well as the expertise available at the RMI, the student will study the annual rainfall distribution in northern Ethiopia in relation to global circulation, orographic forcing, and föhn effects. Inputs will also be provided through an ongoing MSc research on “Rainfall and drought modelling in Ethiopia using the ALADIN model” (Sander Van Vooren, Dept. Geography, UGent).

References


2. River channel response to land cover changes in the Ethiopian Highlands since the 1930s

Promoter: Prof. dr. J. Nyssen
Co-promoter: Dr. Tesfaalem Gebreyohannes (Mekelle University)
Supervisor: PhD student Sofie Annys

Context
The dynamics of streams, and related flooding, are strongly governed by the characteristics of discharge and sediment supply to their channels which in turn are controlled by the geological, geomorphological, hydrological, climatic and vegetal characteristics of their catchments. In contrast to the geological and geomorphological factors, climatic variability and land cover changes were shown to induce changes in stream channels over short timescales in northern Ethiopia. Eleven small streams on the western Rift Valley escarpment of Ethiopia have already been studied to understand how mountain streams have reacted to land cover changes over the last eight decades. In the 1970s and 1980s, peak discharge and the size of bed load supply increased. Consequently, stream channels increased in width, straightened and braided. After reforestation starting from 1986, the channels have narrowed, the braided pattern was abandoned in favour of a single thread, and boulder bars and channels were stabilized by vegetation. Hence, it was demonstrated that reforestation of steep mountain catchments can give quick response in reducing discharge and sediment supply to the streams and thereby curb associated flooding calamities. This study by Tesfaalem Ghebreyohannes at Ghent University was the first to use the aerial photographs (APs) of Ethiopia realised in the 1930s.

The Italian Military Geographical Institute has photographed large parts of Ethiopia in the 1930s, to prepare and sustain its war activities, and to establish infrastructure in that country. The nearly complete archive of this aerial photography was re-discovered by the promoters in the Ethiopian Mapping Agency (EMA) building in Addis Ababa and is at hand. More recent aerial photographs (1964 and 1994) as well as Google Earth imagery are also at hand.

The pre-eminent evidence of geomorphic activity in a mountainous landscape that can be retrieved from APs is river morphology. Several researches have shown the strong relationship between changes in vegetation cover of catchments and stream geomorphology. Deforestation-induced increase in sediment supply causes channel widening, bank erosion and increase in flood risk whereas reforestation is associated with reduction in runoff and sediment supply and thereby narrowing channels, stabilization of bars, incision, changes from braided to meandering patterns and new terrace levels. The MSc thesis student will study the changes at a regional scale and in the long term, in contrast to earlier studies that were limited in time or spatial extent.
Fig. 1. Suluh River near May Tiwaru (13.7524°N, 39.5065°E), in 1936 (Italian aerial photograph) and 2014 (Google Earth). The river channel has widened and gravel bars appeared. Such changes will be quantified along several rivers draining the Ethiopian highlands and correlated to land cover changes. Width of scene: approx. 650 m.

Fig. 2. Confluence of May Zegzeg river (at left) that drains a protected catchment and Tsigaba river (at right) from a catchment with less vegetation cover. The sediment deposits at the confluence (13.6141°N, 39.2263°E) can be clearly linked to the river that drains the unprotected Tsigaba catchment. Image: Google Earth; width of scene: approx. 500 m.

Study methodology
1. Selection of suitable rivers. River channels over the whole study area will be systematically screened for the occurrence of gravel bars, both in the 1930s and currently (Fig. 1; Fig. 2). To be done during the preliminary study, based on screening of the already relocated APs.

2. Mapping changes to river channels. For selected subsets, the current spatial extent will be measured in the field and on APs; similarly, channel width will be measured at regular intervals (100 m) using APs. In floodplains, the sinuosity will also be measured for both periods. Temporal changes to these parameters will allow characterising and mapping the changes to stream channel morphology.

3. Interpretation of landscape dynamics. Changes in channel characteristics will be correlated to changes in land use and cover in the upper catchments.

4. Detailed case studies to be carried out for rivers with contrasted bed load (Fig. 2).

References


Tesfaalem Gebreyohannes, Mountain stream dynamics as impacted by rainfall variability and land cover change in the western Rift Valley escarpment of northern Ethiopia. PhD thesis. 2015, Ghent: Department of Geography, Ghent University.

3. A 3D representation of the late Tertiary clay-with-flint peneplains of E Belgium and N France/SE England: what does it learn us about neotectonics and current valley asymmetries?

*Driedimensionele voorstelling van schiervlaktes op vuursteeneluvium in Oost-België, Noord-Frankrijk en Zuidoost Engeland; wat leert het ons over neotektoniek en asymmetrische valleien?*

Promoter: Prof. Jan Nyssen

Het voorkomen van vuursteeneluvium is een getuige van schiervlaktes die ontstonden tijdens het Tertiair op kalksteenafzettingen uit het Krijt. Ze komen voor in het Oosten van het land, maar ook in Noord Frankrijk en Zuidoost Engeland. Bij Valkenburg (NL) komt het vuursteeneluvium voor op een hoogte van 150 m, maar een honderdtal km ten Zuiden, zijn er resten van de formatie op de toppen van de Hoge Venen. De schiervlakte zit dus niet meer horizontaal. Aan de hand van geologische kaarten, ondersteund door terreinobservaties zal de student de afzettingen precies in kaart brengen, en daarna een driedimensionele voorstelling van de vlaktes met hun huidige hellingsgradient uitwerken. Dit wordt dan verder gelinkt aan de voorkomende neotektoniek van het Ardens massief. Ook zal de student onderzoeken of de huidige helling van het schiervlak een band vertoont met het mogelijke voorkomen van asymmetrische valleien.

Naar analogie, zie het voorkomen van “clay-with-flint” (in het donkerrood), in onderstaande 2D voorstelling:

![Fig. 2 WNW - ESE Section Across Hertfordshire](http://www.hertsgeolsoc.ology.org.uk/IntroToHertsGeology.htm)


4. Regional geomorphology of the Schophem valley (East Belgium)

Promoter: Prof. Dr. Jan Nyssen  
Co-promoter: Prof. Dr. Alain Demoulin (Université de Liège)  
Advisor: Hanne Hendrickx

The Schophem valley (approx. between 50.759472°N, 5.774985°E and 50.728976°N, 5.798444°E) in East Belgium is one of the areas where geomorphological mapping may contribute to the understanding of regional geomorphology. The catchment is located on the boundary of two geomorphological regions: the Pays de Herve and the Maas River Terraces. Main geological formations are Mesozoic chalk and Pleistocene river terrace deposits. Locally, aeolian silt has been preserved. An alluvial cone of the Voer R. mouth into the Pleistocene Maas is present, as well as mass wastings. The valley is largely under meadows with locally some forests and cropland. An estimated 50 households live in the valley, mainly in hamlets Schophem, Ketten, as well as Einde and La Heydt on the edges.

Approximate outline of the Schophem valley (in red), against a background of geological map (Felder & Bosch, 1989). Deep colours are Maas terraces, light colours are chalk (Gulpen Fm.). Barbed line is maximal extent of Pleistocene Maas terraces. Gridlines with 1 km interval.

In this MSc thesis, the different geomorphological features and processes need to be properly mapped, in line with earlier works of our research group (Annys et al., 2014; Hendrickx et al., 2015; Poppe et al., 2013). Attention needs to be given to features such as river terraces, clay-with-flint as hard protective layer, Voer R. palaeo alluvial cone, solifluction paths and lobes, occurrence of calcretes, dolines, lynchetts, transversal ridges.
Besides mapping of known features, through LIDAR imagery, fieldwork and aerial photo interpretation, attention needs to be given to the position and genesis of gelifluction lobes, as well as occurrence of calcretes. To locate precisely the solifluction lobes, using visual observations (small forests often correspond to high stone density), and augerings first, and then complement with electrical resistivity tomography (ETM) profiles (instrumentation through Université de Liège) to find thickness of overlying loam and löss; after precise location, the source area of such lobes needs to be investigated.

Analysis and genesis of the calcrete. Is it a cemented part of slope deposit (so-called croûte ondulée)? Or the bottom of the alluvial cone, at the contact to chalk? Under which environmental conditions could such cementation have taken place?

Escarment perpendicular to main valley; possibly the edge of a solifluction path. Behind the trees, a minor lynchet is also discernible

Calcrete formation at the edge of alluvial cone.
Attention is drawn to the existence of an Erasmus Belgica agreement with ULg, that can be used for a research and study stay at ULg.

As the research will be done in cooperation with our ULg colleagues, the thesis may possibly be written in Dutch, English or French.

References


5. Automated land-use/land-cover classification and change modelling using Markov chain geostatistics in Dogu’a Tembien (Ethiopia) over the period 1935-2035

Promoter: Prof. Dr. Jan Nyssen  
Co-promoter: Prof. Dr. Anton Van Rompaey

UGent’s Department of Geography is in possession of a unique dataset of aerial photographs covering the northern part of Ethiopia, which allows to do land use change studies for the Dogu’a Tembien district (between 13°47’N, 39°E, and 13°27’N, 39°24’E) the geography of which is best known by earlier research (numerous scientific publications summarised by Nyssen et al., 2018, and detailed mapping). Besides a good coverage for the period 1935-1936 (Nyssen et al., 2016; Forceville, 2018) (Figure 1), more recent aerial photographs with regular flight lines and full coverage (1964, 1994), as well as highly detailed recent Google Earth imagery are also at hand. These materials will be used for a state-of-the-art LU/LC change study involving automated land-cover classification and LU/LC modelling by Markov chain geostatistics.

![Figure 1: Overview of the centerpoints of localised APs situated in the study area for the period 1935-1936. Additional APs will be relocated in the coming months.](image)

1. Preparation of orthophotos
State-of-the-art technology has been developed for restitution of the imagery, particularly orthorectification. Using image-based modelling software with Structure from Motion and MultiView Stereo (SfM-MVS) procedures implemented, workflows for development of such ortho-mosaics have been developed (Frankl et al., 2014), and further work is ongoing in relation to automated pre-processing of the aerial photographs (Forceville; Kropacek; Frankl).

2. Fieldwork
- Ground truthing of current land uses
- Ground truthing of ancient land uses, using the few terrestrial photographs available, evidence of previous land uses on the ground, and particularly interviews with elders
- Field observations and interviews allowing to understand and map drivers of the changes
3. **(Semi-)Automated AP interpretation**

As the study area covers some 1000 km², manual land cover mapping will be substituted by automated recognition of vegetation cover and land cover on aerial photos using greytones and texture (Erener & Düzgün, 2009), supervised maximum likelihood classification and shape indices. This methodology is currently under development internationally, including by our research group (Jacob et al., 2015; Frankl et al., in progress), and needs to be further elaborated for tropical mountain regions.

4. **Markov chain geostatistics for land cover change analysis and prediction**

Once land cover has been mapped for 1935, 1964, 1994 and 2018, this series of maps with regular interval will be used to analyse land cover change using Markov chain geostatistics. Markov-type models are common methods of predicting change among various categorical states. The mathematics of Markov chains were first used in non-geographic change models, but since the middle of 20th century, the Markov model has been used to analyse changes in spatial distribution (Baltzer et al. 1998; and many other more recent publications).

Transition analysis in Dogu’a Tembien will be done using the Cellular Automata and Markov Chain routine (CA_Markov) in IDRISI. For this, fuzzy set membership will be evaluated for various terrain, biophysical, population and proximity classes (generally obtained from existing gridded datasets). The fuzzy set membership will be refined through expert rating (large number of experts available for this district, see Nyssen et al., 2018).

First a model will be developed to predict the 2017 situation based on the changes monitored over the period (1935-1994). After verification of the model output against the observed situation for 2017 and re-calibration, the model will be used to predict the 2035 land cover, using the land cover maps over the period (1935-2017).

Besides the delivery of high resolution land cover maps that will be very useful for regional planners, the thesis will result in important advances in research methods related to land cover changes and its prediction.

**References**


Frankl et al., 2018. A century of changes at the source of the Blue Nile as studied from historical aerial photographs in GIS, in preparation.


Kropacek, J. et al. (in prep). Four-coupled historical aerial photographs: semi-automated preprocessing and orthorectification.


6. Geomorphological mapping with focus on glacial and periglacial landforms on Mt. Guna (4200 m, NW Ethiopia), and their impact on the current hydrological response

Promoter: Prof. J. Nyssen
Copromoter: Dr. Enyew Adgo (Bahir Dar University)
Advisors: Hanne Hendrickx and Adugnaw Birhanu

1. Introduction
A regional geomorphological map of the tropical extinct shield volcano Mt. Guna must allow to understand the genesis of landforms on the upper slopes of the mountain, and their impact on hydrological response.
Although no glaciers are present nowadays and no glacier seems to have existed in historical times, block streams and potentially a cirque lake evidence the possible existence of glaciers during glacial periods. The block streams were first observed by Hurni (1982) and the periglacial lake by the promoters in 2017. Neither of these features has been investigated or mapped so far. Periglacial morphologies (gelifluction lobes) have also been observed.

![Fig. 1: General view of Mt Guna’s summital part.](image)

2. Objective
The study will include detailed geomorphological mapping: morphography, morphometry, genesis, processes, structures, (relative) chronology, lithology, hydrography of the study area. The research will include the following:
   a. To investigate the geomorphology of Mt. Guna with focus on glacial and periglacial deposits and landforms
   b. To establish a geomorphological map with appropriate legend
   c. To define the relation between runoff response and landforms and their properties.
3. **Background of Mt Guna’s (peri-)glacial geomorphology**

a. **Mt Guna setting**

Mt. Guna (11.7033°N, 38.234°E) is a distinct Miocene shield volcano that stands some 1000 m high above the Ethiopian plateau. Its surface waters drain into four river systems (Tekeze, Rib, Gumara, Blue Nile), whereas deep percolated water feeds a series of springs at the interface between Mt. Guna’s volcanic tuffs and the underlying Ashangi trap basalt of the Ethiopian plateau. This mountain forms the divide between the drainage basins of Blue Nile and Tekeze Rivers. There are some 15 more similar shield volcanoes on the Ethiopian plateau, the most known of which is Simien Mts.

b. **Glacial geomorphology**

Four regions of Africa, of which the high volcanic plateau of Ethiopia, bear evidence of former glaciations of LGM age. Glacial geomorphology in Ethiopia has been studied in the Semien Mountains by Hurni (1982) and in Abune Yosef massif by Hendrickx et al. (2015). Hurni (1982) concluded that the Semien glaciation was primarily restricted to NW and NE exposures above 4000 m a.s.l. However, the lower end of the glaciers extended down to 3760 m a.s.l., corresponding to the lowest mapped moraines. By analogy to Bale Mts. (Williams, 2016), a possible cirque lake has been identified near the top of Mt. Guna, as well as, on its slopes, clast-supported block streams without colluvial fill over metres thickness, have been observed. Other indicators of glacial activity that have been observed and mapped in Semien are:

- **Striations**, that were formed as ice dragged smaller, angular pieces of rock across rock formations
- **Perched boulders**, that were carried by the ice and dropped as it melted
- **Glacial till**, a mixture of fine clay and angular boulders of mixed sizes deposited by a glacier, having no distinct morphology
- **Roches moutonneé**, smoothed asymmetric rock outcrops
Fig. 3. Bahr Shish, a possible cirque lake: its name in Amharic means shrinking lake. The shallow lake is hidden by large grasses on its shores (centre left of the photo)

c. Periglacial geomorphology at lower elevations (based on Hurni (1982), and Hendrickx et al. (2015))
   - Freeze-thaw activity in the periglacial environment caused frost-weathering of the bedrock (angular rock fragments) and solifluction.
   - ‘Solifluvial’ mantles, large vegetated lower valley-side debris mantles (4–7 m high) which extend down to about 3000 m a.s.l. (Hastenrath, 1974).
   - Thufur (polygon pattern on soil surface) along lower valley side wetlands suggests the occurrence of localized seasonal freeze down to 3600 m a.s.l.
   - Diurnal freeze-thaw pattern during the colder months above 3600 m a.s.l. Needle ice develops towards the end of the rain season (October to December) and produces a variety of small-scale periglacial phenomena.
   It will be part of this study to identify to what extent the glacial features listed above and other glacial activity can be observed in the study areas.

d. Potential impacts on hydrological response.
   - What is the role of the cirque lake in the water balance? Can it contribute to infiltration? Has its storage capacity decreased over time (seasonally and/or over decades) as its name in local language “shrinking lake” suggests?
   - Do the block stream deposits enhance rapid infiltration, or is there rather dominance of subsurface drainage across the large voids?
   - Does the presence of large voids in the block streams enhance build-up of cold and hence permafrost or seasonal soil frost, that could prevent infiltration?
   - Runoff could be monitored in a valley with many block streams and another of similar size without block streams.
   - Did the existence of permafrost in the Pleistocene affect soil properties of the slope deposits, and does this affect current infiltration rates?

e. Scope for geotourism
   The link with geoconservation, geotourism, geomorphosites, geoheritage could be made in the geomorphological map, in line with recent work in Simien Mts (Mauerhofer et al., 2017)
4. **Instrumentation**

Two temperature loggers have been installed in a block stream to monitor full year of temperature conditions.

Thermometers, rain gauges, runoff and spring monitoring installations will be installed in spring 2018 and the data will be availed to the MSc student. Suggestions for runoff measurement locations can be done in the MSc research proposal.

Relevant samples (e.g. peat from closed depressions) can be $^{14}$C dated.

![Fig. 4. Temperature logger installation](image)

**References**


**Specific profile of the candidate**

The student is to work at high-altitude (sub)alpine environment (3500-4200 m a.s.l.) and a good physical condition is required for the fieldwork. Experience in mountains is a plus.
FOR FIELDWORK IN ETHIOPIA

Topics 2, 5 and 6 concern MSc theses with fieldwork in Ethiopia. This note gives some more details about the organization of the fieldwork.
The MSc students will generally stay in small towns; one translator/field assistant will work permanently with him/her.

Some important points for students to consider before declaring an interest:

- The thesis will have to be written in English.
- Fieldwork period: 2 months between early July and late September 2017. This implies that the student needs to make sure he/she will not have to take exams in August/September!
- Environment for the fieldwork: cool tropical climate (June/September is the rainy season), keep in mind that you will work in the mountains; other culture, totally different food, other norms for comfort; often no electricity; telecommunication is difficult; only a few busses per day; the student will often move on foot (mountains; heavy rains possible in the afternoon). But also: friendly, dynamic people and breathtaking landscapes, and a unique experience.
- Before departure, practical guidelines and information sessions will be provided, both by UGent and by the research group Physical Geography.
- Assistance by promoter(s) during start-up of fieldwork; possibly other UGent Master students will be in the region or in the country.
- Profile of the student: should be prepared to live and work with local farmers, technicians and authorities; strong sense of autonomy and adaptability; conversational English.
- Partial funding for the travel costs can possibly be obtained through a “reisbeurs naar ontwikkelingslanden” (deadline 8 January), see https://www.ugent.be/nl/onderzoek/financiering/ontwikkelingssamenwerking/beursmogelijkhedenvlaamsestudenten

If you have practical queries about living and doing research in Ethiopia, you may want to get in touch with students or researchers who recently did their thesis in Northern Ethiopia:
- Dr. Sil Lanckriet (sil.lanckriet@ugent.be)
- Dr. Amaury Frnakl (amaury.frankl@ugent.be)
- Hanne Hendrickx (hanne.hendrickx@ugent.be)
- Sofie Annys (Sofie.Annys@ugent.be)
- Dr. Miro Jacob (miro.jacob@ugent.be)

As indicated on the topical presentation, you will also have a local advisor.
1. Understanding the impact of soil management and properties on erosion, runoff and sediment yield from very-high resolution 4D proximate soil sensing (East-Flanders, Belgium)

2. Understanding the impact of fascines as sediment buffers on a supra-regional scale (N. France, Flanders, Wallonia)

3. Understanding talus slope geomorphology from permafrost distribution and degradation using geophysical methods and detailed geomorphological mapping (Col du Sanetsch, Switzerland).

4. Geomorphological mapping of ‘Creux de la Lé’ glacier forefield: glacier evolution and the debris covered glacier complex (Col du Sanetsch, Switzerland)

5. Understanding and quantifying sediment redistribution at catchment scales from very-high resolution proximate soil sensing (Ethiopia)
1. Understanding the impact of soil management and properties on erosion, runoff and sediment yield from very-high resolution 4D proximate soil sensing (East-Flanders, Belgium)

Promoter: Dr. Amaury Frankl (UGent)
Co-promoter: Prof. Dr. Kristof Van Oost (UCL)
Advisor: Dr. Maarten De Boever (PCG)

Context
This thesis topic frames within the Interreg 2 Seas project Triple C (www.triple-c-water.eu). Triple C stands for "Climate resilient Community-based Catchment planning and management". Flooding is a costly natural hazard and is expected to increase further under future climate change scenarios. The coming decades are likely to see a higher flood risk in Europe and greater economic damage. New cost-effective solutions for improving environmental and economic resilience are therefore needed. Due to erosion and sedimentation, the buffering and discharge capacity of waterways and fields are being lost, resulting in an increased flooding risk. There is a need to implement techniques that reduce flooding by reducing water runoff and soil erosion. The main objective of Triple C is, therefore, to reduce flooding in the participating catchment areas by demonstrating and validating, through a series of pilot projects, how farmers can create cost-saving water retention and erosion control measures upstream. Co-developed by networks of farmers and water managers, these will take better control of additional rainfall at the source and result in wide ranging benefits to both the farmers and local communities and other stakeholders.

Three pilot project sites have been selected in the region of East-Flanders, in Kluisbergen, Zwalm and Wortegem-Petegem. A pilot project site consists of an agricultural plot which has been identified as being very vulnerable to water erosion; plots with red colors on Fig. 1. For each plot, the impact of agricultural practices on runoff and sediment yield are being studied, in relationship to soil compaction, soil quality, soil life, crop development and yield.

Fig. 1. Pilot site in Zwalm. Pilot sites have been identified from the DOV ‘Potentiële bodemerosiekaart per perceel (2017)’, which gives the erosion vulnerability according to the WATEM-SEDEM soil erosion model (Van Rompeay et al., 2001).
Objective of the MSc thesis

The objective of this MSc thesis is to understand the impact of agricultural practices and soil properties on soil surface characteristics (surface sealing) and erosion patterns (rill development) at the plot scale (sites in Kluisbergen, Zwalm and Wortegem-Petegem). From this, catchment runoff response and sediment yield will be understood.

Research Methods

Soil surface characterisation and erosion quantification

Central to the research methods is to produce very-high resolution 3D representations of agricultural plots at the time-interval of major precipitation events (Fig. 2, Fig. 3). Data acquisition will occur from SfM-MVS photogrammetry from both unmanned aerial vehicles (UAVs) and terrestrial approaches (Frankl et al., 2015). Fixed ground control points will be used to optimize accuracies of resulting Digital Elevation Models (DEMs). When wind speeds are too high during data acquisition, a telescopic pole with camera mounted at the top (12 m high) will be used for data collection. For the resulting DEMs, we will aim at cm resolutions. Surveys at finer accuracies (mm-level) will be done for small sample areas (1 m²) using a fixed frame on which ground control points (GCPs) have been materialized and calibrated at <mm level.

Maps of soil crusts will be produced when physical soil crusts are fully developed in the field, typically in early spring. The volume of erosion processes (mainly rill development) will be calculated at the time-step of major precipitation events. Based on the volume of erosion features, soil mass redistribution will be quantified by also considering the soil bulk density.

Fig. 2: Experimental site in Zwalm where runoff and sediment yield are being monitored (copyright Triple C Project)
Soil organic carbon mapping
A key soil surface process in understanding runoff generation, erosion and sediment yield is the development of soil crusts (typically on loamy soils), given that there is a strong relationship, between soil organic carbon (SOC), aggregate stability and soil erodibility. Aggregate stability is indeed a very pertinent indicator of the propensity of a given soil to generate runoff and erosion (Bryan, 1968). Numerous studies have shown that aggregate stability increases with increases in organic carbon (Chenu et al., 2000). A UAV carrying a hyperspectral sensor will be used to map SOC (Aldana-Jague et al., 2016). Calibration of the hyperspectral signals will be done from a PLSR (Partial Least Squares Regression) using the LUCAS database and in a first instance will need some ground truthing to correct for the atmospheric conditions. SOC maps for the pilot areas will be produced at 2.5 m resolution.

Interrelating soil crust development, erosion patterns and plot runoff and sediment yield
The development of soil crusts and their typology will be related to soil management (tillage techniques applied) and soil characteristics (SOC). These relationships will allow to understand the development of erosion features in the plots. Runoff and sediment yield at the plot scale (data from the Interreg 2 Seas project Triple C) will be understood from both the importance of soil crusts and the quantification of diffuse and concentrated erosion processes.

References
2. Understanding the impact of fascines as sediment buffers on a supra-regional scale (N. France, Flanders, Wallonia)
Promoter: Dr. Amaury Frankl (UGent)
Co-promoter: Prof. Dr. Charles Bielders (UCL)

Context
This thesis topic frames within FASCINation project which aims at understanding the impact of recent innovations in the combat against aggravated soil erosion in farmland. This especially includes the recent implementation of vegetation barriers (Fr. fascines) in Nord-Pas-De-Calais, Flanders and Wallonia. See www.geoweb.ugent.be/projects/59f17ccfc5d12c02d2cb0ad8
Fascines are any type of linear vegetation barrier consisting of live and/or dead vegetation (Evette et al., 2009; Richet et al., 2016). They differ from hedges in the sense that they were especially conceived to reduce runoff velocities and trigger sedimentation. Many types can be found, including double-rowed willow posts with in-between staples of bundled willow branch cuttings, woven branches along poles, wood chips, straw, or any other organic residue inserted in-between rows of mesh fences. Such barriers are typically implemented on plot boundaries across thalwegs or along topographic contours (Figs. 1C and 1D). As biophysical buffers oriented perpendicular to the flow, the hydrological effect of fascines is to reduce flow velocities (by increasing the hydraulic roughness); up to a factor of three (Ouvry, 2012; Richet et al., 2016). This causes water to pond behind them, creating a backwater effect that encourages infiltration and sedimentation (Fig. 1C). Sediment trapping efficiencies of 16-99% are reported in literature, and consist especially of coarse particles (Ouvry, 2012; Degré et al., 2013; Bielders et al., 2016; Richet et al., 2016). Downslope of fascines, runoff (with fine suspended sediment) is released in a diffuse way (Fig. 1D), and concentrates again in the thalweg only a few metres below the vegetation barrier.

Fig. 1: Open-field agricultural landscapes, being highly vulnerable to hydrogeomorphic hazards. A: Ephemeral gully erosion, B: Road cleaning subsequent to a mudflow hazard, C: Fascine as control measure viewed from the top while buffering runoff and sediment, and D: Viewed from downslope indicating the diffuse release of runoff and sediment. (photograph B by www.smageaa.fr)
Objective of the MSc thesis
The objective of this MSc thesis is to assess the importance of fascines as sediment buffers by considering their sediment trapping effect and impact of gully morphology.

Research Methods
Characterizing fascines and controls of sediment production in their catchments
A quality assessment of the fascines will be done based on a semi-quantitative assessment of the condition of the posts or poles, the condition of vegetative filters (willow bunches mainly), the ground contact, presence of gaps in the structure, and the positioning of the fascine relative to the thalweg, etc. Factors controlling sediment production are mainly catchment characteristics such as the catchment area and slope, the land use and cover (resulting from the crop calendar) and precipitation.

Quantifying sediment storage behind fascines
Sediment storage behind fascines will be quantified by multiplying the volume of the sediment cones (surface area x average depth determined by augering) with the bulk density (using one 100 cm² Kopecky ring sample per site; weighted after oven-drying). This will be done before new farming operations (excavating and tillage) erases the sediment accumulation behind fascines, which mainly occurs in in autumn.

Quantifying gully morphological change due to fascine implementation
At sites where ephemeral gullies occur, the morphology of the erosion channels before and after the fascines will be quantified. This will be done from defining gully cross-sectional characteristics at regular intervals. Multiplying the average gully cross-section with gully length will allow to quantify gully volumes.

Understanding the impact of fascines on sediment storage and ephemeral gully erosion
Given the variability in controls of sediment production in the fascine catchments, and the characterization of fascines, the functioning of fascines as sediment sinks will be studied from a statistical analysis. Where ephemeral gullies occur at the fascine locations, the effect of the fascines on gully morphology will also be quantified. This will allow to understand the net importance of fascines as sediment buffers in small agricultural catchments where gullying occurs and to assess the importance of the clear water effect below fascines. In N. France, Flanders and Wallonia, we aim at 50-100 sites.

References

Richet, J.-B., Ouvry, J.-F., Saunier, M., 2016. The role of vegetative barriers such as fascines and dense shrub hedges in catchment management to reduce runoff and erosion effects: Experimental evidence of efficiency, and conditions of use. Ecol. Eng. doi:10.1016/j.ecoleng.2016.08.008
3. Understanding talus slope geomorphology from permafrost distribution and degradation using geophysical methods and detailed geomorphological mapping (Col du Sanetsch, Switzerland).
Promoter: Dr. Amaury Frankl (UGent)
Co-promoter: Prof. Dr. Reynald Delaloye (UniFr)
Advisor: Drs. Hanne Hendrickx (UGent)

Context
This thesis topic frames in Hanne Hendrickx’s PhD on ‘Talus slope geomorphology as impacted by permafrost thaw.’ Since 1900, atmospheric temperatures have risen twice as fast as the global average in the European Alps, and precipitation regimes are changing as well. Moreover, future projections predict a continuation of these trends. Spatial distribution and thermal properties of permafrost are highly influenced by ground surface conditions (snow and vegetation) and air temperature. Climate induced permafrost degradation is therefore expected. Talus slopes, steep debris accumulations underneath rock faces, are one of the most common landforms in high mountain environments and an important debris storage. Therefore, they are often subjected to mass wasting processes. The study area in Col du Sanetsch (Fig. 1) has a variety of geomorphological landforms, such as debris flow channels, small rock glaciers, solifluction lobes, and evidence of rock fall and landslide activity. In order to study permafrost conditions in this area, temperature and geophysical data are used. Repeated measurements of this data over a timeframe of 20 years will reveal permafrost evolution in the area. Moreover, permafrost conditions can be linked to surface geomorphology. Geomorphological dynamics of a rock glacier and a landslide in the area will need to be investigated in more detail. The study area is located in Col du Sanetsch, Switzerland (Fig. 1). In 2000, geophysical measurements where performed, indicating the presence of permafrost. Starting from 2011, a network of measurement points has been installed, in order to determine displacement velocities, and to specify the deformation mechanisms involved. Continuous temperature data is available since 2014.

Fig. 1: The Study area ‘Arpille’ in Col du Sanetsch, featuring a small rock glacier and landslide. (http://www.unifr.ch/geoscience/geographie/en/research/physical-geography/geomorphologie-groupe-delaloye/sites-detudes/arpille)
Objective of the Msc thesis
The objective of this Msc thesis is to understand and define the intensity of geomorphological processes in the context of permafrost degradation on high Alpine slopes.

Research methods
Using geophysical methods to detect permafrost
Geophysical methods are non-invasive methods, used to understand subsurface conditions. With the Electrical Resistivity Tomography method (ERT), electrical resistivity of the subsurface material will be measured. A marked increase in electrical resistivity when ice is present makes this method suitable for detecting, mapping and characterizing permafrost. An array of electrodes connected to cables is used to pulse an electrical current within the subsurface, while the device is measuring its resistivity (Fig. 2). The spacing of the electrodes will change the resolution and the penetration depth of the survey and needs to be adjusted to get the desired results. Because these measurements are repeat measurements, exactly the same settings and locations will be used as the measurements done in 2000 by Russil. This will make a comparison with their results possible, allowing to understand permafrost evolution in the area. Note that there is a possibility to enrol for an applied geophysical methods course that will be organised during the first week of August.

Detailed geomorphological mapping based on drone survey data
A detailed geomorphological mapping of the study area will be performed using very high resolution Digital Elevation Models (DEMs). Data acquisition will be done with SfM - photogrammetry from unmanned aerial vehicles (UAVs). Fixed ground control points will be used to optimize accuracies of the resulting DEMs. Surface geomorphology will then be linked to permafrost distribution.

Using existing datasets of temperature and displacement
Beside geophysical data of the year 2000, existing data consists of temperature and displacement measurements on the landslide-like feature in the study area. These data will be analysed to link the occurrence of permafrost with temperature evolution. Displacement data gives information about the geomorphological dynamics of the area. Explaining these dynamics by using both geophysical data
and temperature data will improve the understanding of the effect of climate change on geomorphological processes on high alpine talus slopes.

References
4. Geomorphological mapping of ‘Creux de la Lé’ glacier forefield: glacier evolution and the debris covered glacier complex (Col du Sanetsch, Switzerland)

Promoter: Dr. Amaury Frankl (UGent)
Co-promoter: Prof. Dr. Reynald Delaloye (UniFr)
Advisor: Drs. Hanne Hendrickx (UGent)

Context

This thesis topic frames in Hanne Hendrickx’s PhD on ‘Talus slope geomorphology as impacted by permafrost thaw.’ In the Swiss Alps, historical glaciations left their imprint on the landscape. The current glacier retreat is also clearly visible. A detailed geomorphological mapping will be used in order to reconstruct the landscape evolution. The current state of a marginal debris covered glacier will be investigated using a Ground Penetrating Radar (GPR), detecting buried ice.

Creux de la Lé is a small glacier forefield (< 2 km²) with a variety of geomorphological landforms (Fig. 1). Continuous temperature data is available and last summer geophysical measurements were repeated in order to investigate the permafrost state around the push moraine. The existence of a debris covered glacier is known. However, its extent is unclear.

Fig. 1: Study area ‘Creux de la Lé’ in Col du Sanetsch. A variety of glacial and periglacial landforms are present, such as morainic material, a push moraine, eskers, neo-permafrost, ice caves, hummocky moraines and a small marginal glacier, mostly debris covered. (http://www.unifr.ch/geoscience/geographie/en/research/physical-geography/geomorphologie-groupe-delaloye/sites-detudes/creux-de-la-le)

Objective of the Msc. Thesis

The objective of this Msc thesis is to map the Creux de la Lé glacier forefield in very high detail using UAV imagery and fieldwork data in order to reconstruct the glacial history. The current extent of a
marginal debris covered glacier will be investigated using GPR. In addition, temperature and geophysical data is available to support the geomorphological mapping.

**Research methods**

**Detailed geomorphological mapping using UAV and the SfM-method**

A detailed geomorphological mapping of the study area will be performed using very high resolution Digital Elevation Models (DEMs). Data acquisition will be done with SfM - photogrammetry from unmanned aerial vehicles (UAVs). Fixed ground control points will be used to optimize accuracies of resulting DEMs (Fig. 2). This DEM can then be used to perform a detailed mapping in ArcGIS. Besides this, mappings will also be carried out in the field. Detailed analyses of certain geomorphological features (grain size distribution, texture analyses) need to be performed as well.

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**Using Ground Penetrating Radar (GPR) to map the extent of the marginal glacier present**

A GPR-device consists of a transmitter, which transmits microwaves, and a receiver that receives the refracted signal. Clear changes in subsurface layers (e.g. ice and rock) can be detected this way. GPR is therefore often applied in glaciology, determining glacier thicknesses and thicknesses of the debris covers (Fig. 3). GPR transects will be performed on the debris covered glacier in Creux de la Lé in order to determine the thickness of the glacier and the debris cover and the extent of the current glacier. Note that there is a possibility in following an applied geophysical methods course that will be organised during one week in August.
Fig. 3: Ground Penetrating Radar in action

References


5. Understanding and quantifying sediment redistribution at catchment scales from very-high resolution proximate soil sensing (Ethiopia)

Promoter: Dr. Amaury Frankl (UGent)
Co-promoter: Prof. Dr. Aurore Degré (ULiège)
Advisor: Drs. Habtamu Assaye (UGent)

Context
This thesis topic frames within the Land Resilience project (http://www.geoweb.ugent.be/projects/59f17fd9c5d12c02d2cb0adf). The Land Resilience project is part of the larger VLIR IUC institutional cooperation with Bahir Dar University in Ethiopia, and aims at improving the resilience of the land in the framework of building a climate resilient green economy in NW Ethiopia. With the Land Resilience project, we aim at strengthening knowledge on present and past land degradation processes and ecosystem functioning, focussing on the importance of ecologically connected forests in agricultural landscapes. Through capacity building and the involvement of stakeholders, we ultimately aim at improving food security and ecosystems functioning for better livelihoods. Four PhD students are currently involved in this project.

Fig. 1: Study area with centrally a gully in the thalweg. Location (11.632242°N, 37.802605°E)
Objective of the MSc thesis
The objective of this thesis proposal is to understand the interrelations between sediment and vegetation connectivity in the highly degraded highlands of NW Ethiopia. Six catchments (50-200 ha) with various degrees of vegetation will be studied.

Methods
Data acquisition will occur from SfM-MVS photogrammetry from both UAVs and terrestrial approaches (Frankl et al., 2015). For the former, a DEM and orthophotographs will be produced in March 2017 by the promoters during their fieldwork in Ethiopia. Therefore, a hexacopter drone with Sony EOS 20 Megapixel camera will be used. Optimizing accuracies (to cm-level) of the produced DEMs will be achieved by using a Real-Time Kinematic Global Navigation Satellite System.

Mapping and quantifying sediment redistribution in relationship to vegetation
From the DEMs, erosion sources and sinks will be mapped and quantified. The same will be done from a fieldwork campaign allowing to assess the accuracy of the sediment redistribution maps produced from the DEMs. The role and effectiveness of vegetation as a sink will be studied.

Defining sediment connectivity and the impact of vegetation
Sediment connectivity maps will be derived from the high-resolution DEMs after Borselli et al. (2008), using ArcGIS Software and dedicated toolboxes. Connectivity index (CI) ranges between $-\infty$ and $+\infty$ with increasing connectivity for higher CI values. The upslope component is the potential for downward routing of the sediment produced upslope and the downslope component takes into account the flow path length that a particle has to travel to arrive to the nearest target or sink. The comparison of DEMs and CI maps will be used to characterize erosion and deposition patterns (Pineux et al., 2017), the sediment journey across the watershed and budgets of sediment redistribution and loss at catchment scales. For the latter, the sediment yield measurements by Habtamu Assaye will be used to close the sediment budget.

![Connectivity fluxes index](image)

**Fig. 4.** a: Site 1—Area close to a local sink at the bottom of a field: direct connection of ill system without detectable sedimentation. b: Site 1—Area close to a local sink at the bottom of a field: direct connection of ill system and intense sedimentation. c: IC map of Site 1—Deposition and connection areas are evidenced inside the circular areas.
Fig. 2: Example of sediment connectivity map (Borselli et al. (2008))

References
The potential benefits of reforestation on groundwater recharge and carbon storage in the context of climate mitigation in North Ethiopia

Promoters: Dr. S. Lanckriet, Dr. M. Jacob

Context

Climatic variability is recurrently threatening water supplies across the globe. Future climate change can put further pressure on water supplies and land resources. This will most likely be the case in the world’s drylands, where the magnitude and effects of drought are likely to persist or even increase over the twenty-first century (Sheffield & Wood, 2011). Drylands suffer from processes of desertification, which can be defined as ‘the temporary or permanent lowering of the productive capacity of drylands’ (UNEP, 1992) and includes deforestation, expansion of cultivation, increasing water runoff and erosion, and soil degradation. (Dry) land degradation is, together with climate change, named as the biggest global threat to sustainable development (UNEP, 1992). Land degradation is, amongst others, such a serious issue because (i) lands and soils are important buffers that regulate the resilience of ecosystems as a whole (Roberts, 2006) and (ii) soil losses have a significant impact on plant and crop productivity (Lal, 1995). Studies across Africa for instance show that crop yield reductions due to land degradation are considerable (Lal, 1995).

Yet, forest cover is key to tackle land degradation in relation to climate change. Firstly, forest cover slows down rainfall erosivity, runoff, sheet erosion, rill erosion and gullyling; and is thus crucial to fight land degradation in dryland areas (Descheemaeker et al., 2006). Secondly, through reduction of runoff, forest cover allows an in-crease of green groundwater availability in dryland watersheds, which could offset the climatic effects of recurrent drought (Sheil & Murdiyarso, 2009; Bargués Tobella et al., 2014; Muys et al., 2014). Thirdly, non-timber forest products (NTFPs, such as honey and frankincense resins from the Boswellia papyrifera) can foster the development of local micro-economies, thus reducing human pressure on the land (Tilahun et al., 2007; Babulo et al., 2009). Finally, and importantly, forest cover is not only key to climate change adaptation (through the positive hydrological impacts of forest cover and the micro-economies of forest resources) (Bruijnzeel & van Noordwijk, 2008; Ghimire et al., 2014), but also to climate change mitigation through increased carbon storage. Carbon storage in dryland areas accounts for a very significant part (over one third) of the total global carbon storage.

Research questions

(i) What is the potential carbon storage of the Ethiopian dryland environment (in particular the Tembien Highlands)?
(ii) How does reforestation influence groundwater recharge in a drought prone dryland area?
(iii) How can different land management scenarios make a difference on drought resistance and in mitigating climate change?
The degraded grazing lands, located between the upslope village Gednet Gestet and a hamlet more downslope, are regenerating under protected conditions. This area has quite steep and rocky slopes, and the bushland vegetation is clearly degraded. Under a gradual increase in soil- and groundwater, an increase of olive trees in this area is expected. Olive is an indicator species of improved water availability. The restoration activities will also induce increased water availability for the downslope population.

Access to drinking water is crucial for local communities in the drylands of North Ethiopia. Forest restoration on steep upslope parts of the catchment will increase rainfall infiltration to the groundwater and subsequently a rising water table.

**Objective**

Mapping the potential benefits of reforestation on carbon storage and groundwater recharge in Dogu’a Tembien
**Study methodology**

1. *Fieldwork (optional): collecting biomassa and carbon storage data and monitoring discharge in protected forest areas ('exclosures') of different ages.*

2. *Defining the relation between forest characteristics and (i) carbon storage, (ii) groundwater recharge*

3. *Quantifying potential carbon storage and groundwater recharge effects of different management scenarios*

**Key references:**


A GIS model of carbon storage potential to mitigate climate change in a dry African highland environment

Promoters: Dr. M. Jacob, Dr. S. Lanckriet

Context

Forest cover is key to mitigate and adapt to climate change. Through generation of large-scale flows in atmospheric water vapor, reduction of runoff and increase of soil infiltrability, forest cover allows an increase of green groundwater availability in dryland watersheds. This can offset the hydroclimatic effects of recurrent drought (Sheil & Murdiyarso, 2009; Bargués Tobella et al., 2014). Forest cover is thus important for effective climate change adaptation in dryland Africa, through its positive hydrological impacts (Bruijnzeel & van Noordwijk, 2008).

However, forest cover is also crucial for climate change mitigation, through increased soil and above-ground carbon storage. Carbon storage in dryland areas accounts for a very significant part (over one third) of the total global carbon storage. This is certainly the case in Africa, where ~59% of the carbon is stored in dryland ecosystems (Campbell et al., 2008; Mekuria et al., 2011). Land cover, but also land management, can positively impact carbon storage in tropical drylands (Lal, 2001; Lanckriet et al., 2012).

The aim of this thesis is to map and model carbon storage potential to mitigate climate change in a dry African highland environment (i.e. the Tembien Highlands of Ethiopia). The research will lead to recommendations for sustainable development projects in dry highland environments of Africa.

Research objectives

Objective 1. Mapping and modeling carbon evolution and baseline in the Tembien Highlands

In order to assess a baseline for forest cover evolution, the research will produce 4 forest cover maps of 1936, 1965, 1986 and 2015. This can be based on available datasets of aerial photography and satellite imagery. Based on existing datasets of above-ground and soil organic carbon in >20 study sites, the thesis will interpolate, quantify and model carbon storage in exclosures of different ages, lithologies, latitudes, slope (aspects) and altitudes.

Objective 2. Mapping and modeling future carbon storage potential

In order to estimate the future potential of reforestation, the research will produce a map of future potential of reforestation, based on historical forest cover maps and current human activities. Simultaneously, the thesis aims to estimate the total carbon storage for the forests in the study area. Further, the research will estimate the ‘potential future carbon storage’, based on the map of future potential of reforestation.

Overall, this research uses GIS to investigate whether the carbon storage potential in a dry African highland environment can contribute to climate change mitigation.
Field work in Ethiopia is possible but is not compulsory. Field work will be funded by a VLIR initiative.

Figure 1: Measurement of soil thickness in augering hole, in a 5x5m compartment.

Figure 2. Sampling height and crown diameter on the field.

Key references:


