Automatic identification of water-logged agricultural areas using LiDAR DEMs

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Introduction

Remote sensing is an important approach to control the implementation of the area-based subsidy system of the European Common Agricultural Policy (CAP) in Denmark. The control process aims at deriving limits of declared cultivated parcels and the identification of non-eligible areas (NEA) for farmland support. Until today, however, control with remote sensing (CwRS) has combined manual, visual interpretation of aerial ortho photos and field inspection, thus being labor intensive and limited to a small extent of the country-wide agricultural area.

Fig.: Study site for algorithm development and testing. Grey areas are field blocks and red areas refer to non-eligible areas for farmland support that are of limited agricultural use due to water logging.

The project REMOTE CONTROL

The project RemoteControl commissioned by the Danish agricultural ministry aims at the development of methods and techniques towards automatic mapping of non-eligible agricultural land and related mapping tasks such as the update of field-block polygons from high-resolution aerial ortho photos and LiDAR derived, high-resolution point clouds and digital elevation models (DEM). DEMs are particularly important within the CwRS approach since they contain structural, physically meaningful information that can be used to identify and delineate landscape features that are related to water redistribution, sediment flux and habitat characterization.

Aim of the study

The central aim of this study is to develop and test an approach towards the automatic identification of NEAs for farmland support. Our objectives are (1) to develop a conceptual model for the identification of agricultural areas prone to water logging, (2) to design a procedure combining geomorphometric analysis and digital image processing to extract these areas using LiDAR DEMs, (3) to train the procedure in an area where data on water logged areas is available, and (4) to validate it.

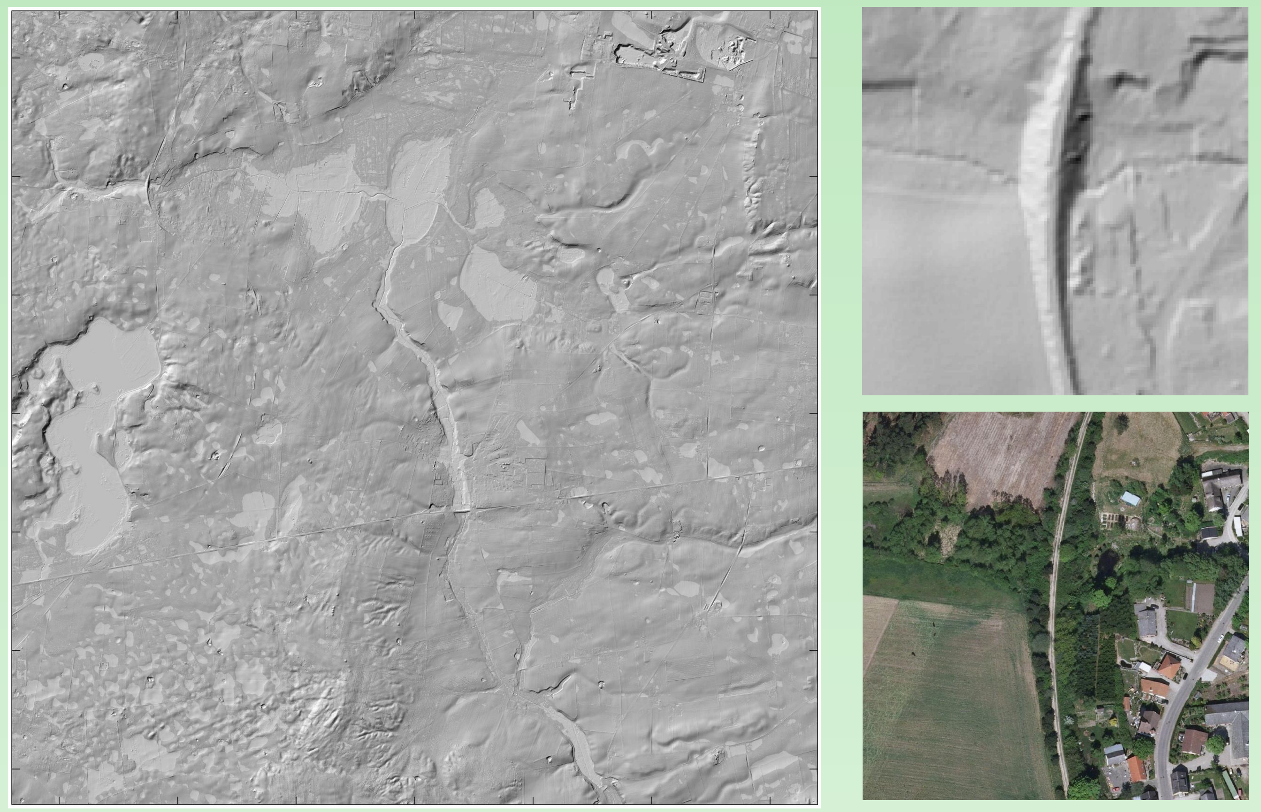

Fig. 2: Digital elevation model of the study site and examples of artificial features in Danish landscapes that cause a lack of hydrological connectivity in high resolution DEMs.

Study site

The DEM covers an area of 45.6 km2 at a pixel size of 1.6 m. There are numerous sinks (n = 167129), whereas the larger ones are generated by bridges across streams and tunneled sections of artificial drainage channels (see Fig. 2). Some of the sinks may also be due to measurement artifacts generated by dense vegetation cover alongside rivers. In addition, the young moraine landscape is characterized by several closed depressions with moors and lakes. The DEM features altitudes between 4 and 67 m a.s.l. and is thus representative for very flat terrain with a young and chaotic drainage system.

Hydrological connectivity in high-resolution DEMs

There are numerous sinks (n = 167129) and contiguous flat areas (n = 115232), whereas the larger sinks are generated by bridges across streams and tunneled sections of artificial drainage channels (see Fig. 2). Some of the sinks are likely due to measurement and filtering artefacts generated by dense vegetation cover alongside rivers.

Hydrological conditioning of the DEM follows a two step approach. First, we employ a constrained channel breaching algorithm to remove channel obstructions by small features such as bridges. In a second step, remaining sinks with depths below 1 m are processed using a geodesic channel carving algorithm (Schwanghart et al., 2011). All remaining sinks are treated as closed basins.

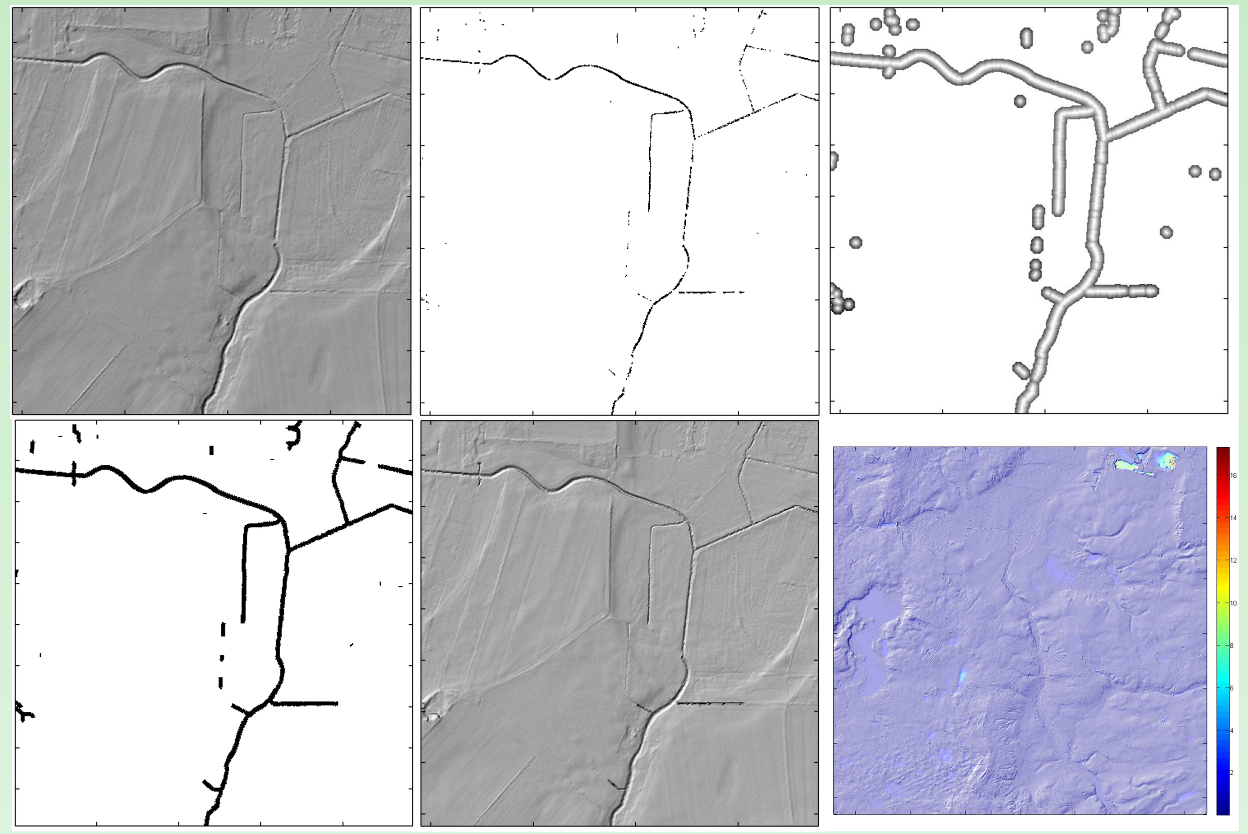

Fig. 3: Constrained stream carving procedure as applied to the DEM. Sink depth [m] after hydrological conditioning of the DEM.

Water logged areas – a conceptual model

Visual interpretation of settings of water-logged areas reveals that their location is associated rather with marshes than with young morainic ridges and hillslopes. Their preferable location along surface waters such as lakes, streams and artificial drainage pathways suggests that their occurrence can be attributed to high, temporary water levels associated with high groundwater levels and inundation by surface waters. Water logged areas adjacent to steeper slopes hint at local accumulations of slope water generated on moraine hills.

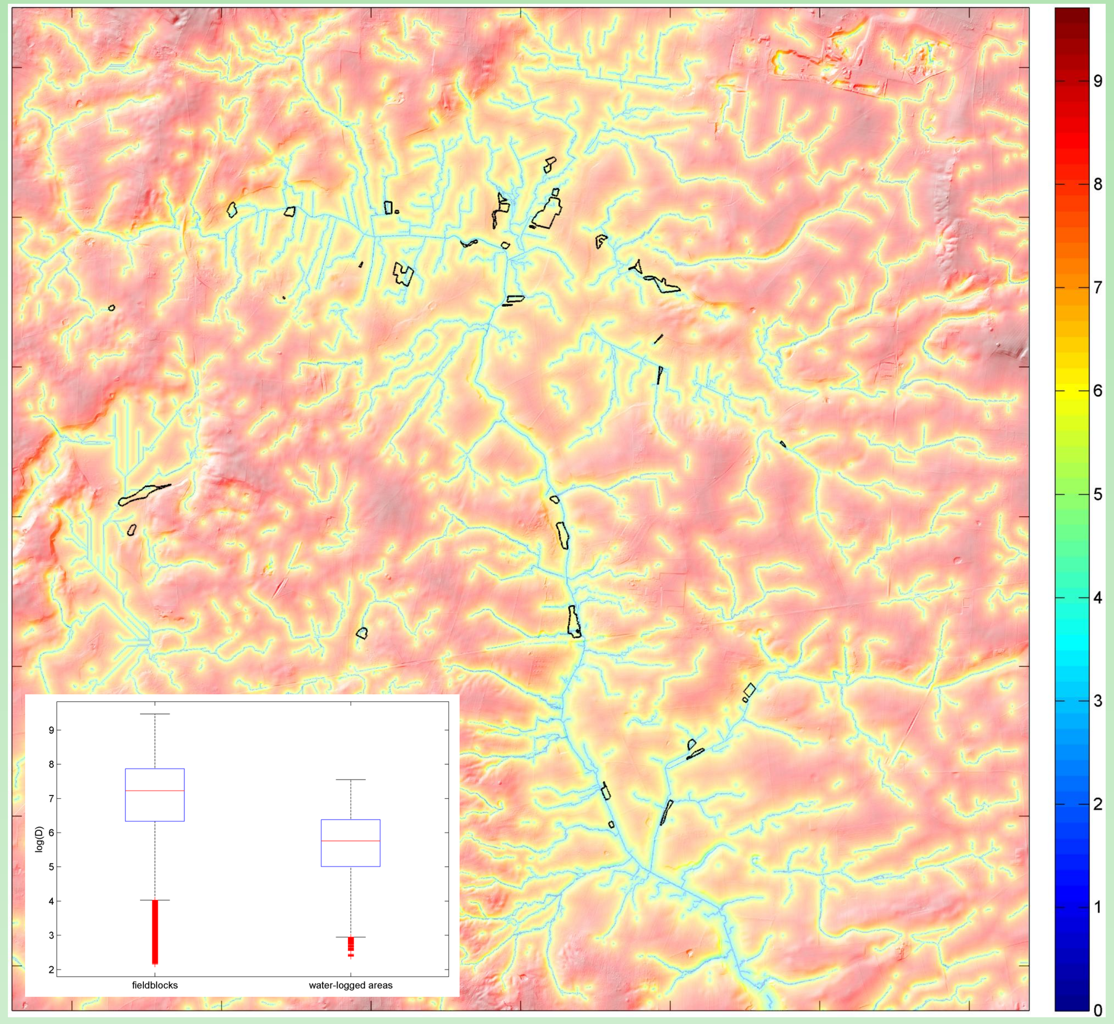

Fig. 4: Grey-weighted geodesic distance (log(D)) from water courses (map) with NEAs highlighted with black outlines. The inlet figure depicts significantly different distributions of distance values in fieldblocks and NEAs.

Identification of water logged areas

The conceptual model outlined below is partly formalized by a static, numerical model. The model uses grey-weighted geodesic distance transforms, where channels are markers and elevation is weight. It accounts for the "costs" for water to move through the landscape. Lower terrain around channels is associated thereby with higher propensity for flooding and low groundwater tables. Applying the model to the DEM shows that there is a good agreement between NEAs and low distance values. However, the model strongly overestimates the occurrence of water-logging since the extent of NEAs is most likely not congruent with a threshold of soil moisture. Moreover, water logged areas may exist outside NEAs, but were not declared as such.

References

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