Automatic generation of shallow ditch network in forest using LiDAR data and multispectral satellite imagery

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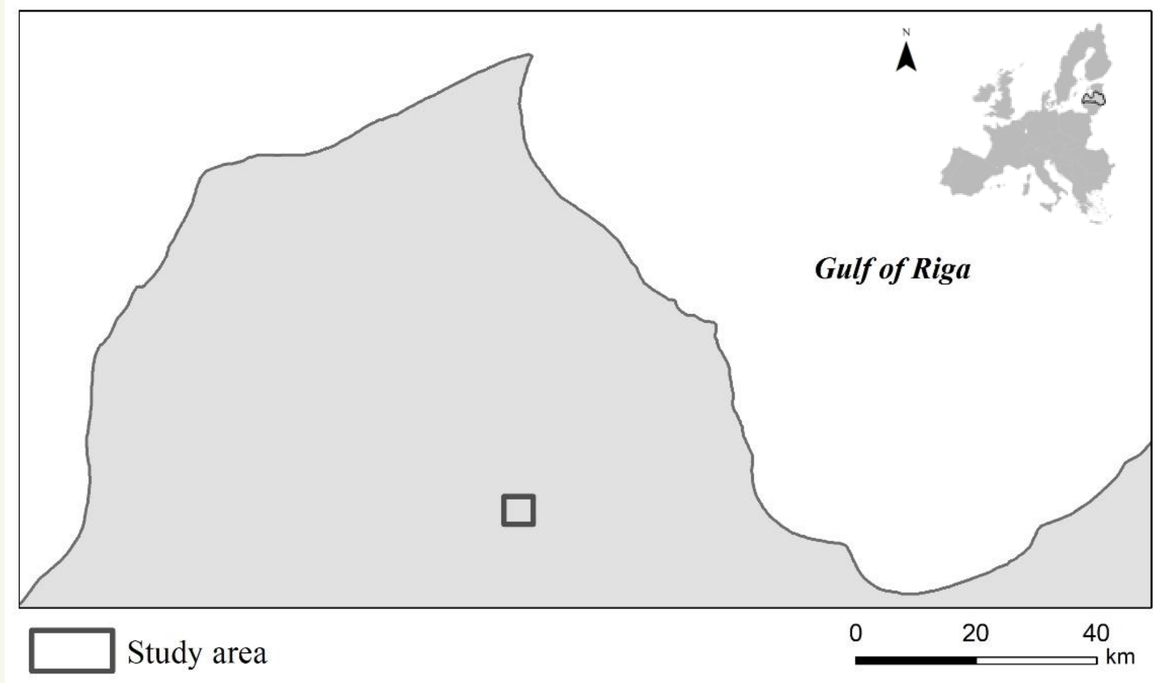
Aim of this study is to develop methods for automatic surface drainage system generation using LiDAR (Light detecting and ranging) data and Sentinel-2 multispectral satellite imagery. LiDAR data is used for mapping of depressions in DEM (digital elevation model), for generation of surface water runoff and CHM (canopy height model) raster maps. Multispectral satellite imagery is used for detecting and separating coniferous forest stands, deciduous forest stands and other land cover types. Study area is more than 25 km^2 large and consists of areas on various quaternary sediment types. Three factor cost surface which includes previously mentioned data layers has been made and it is used to calculate least cost surface raster. Least cost surface connects DEM depressions and already existing drainage ditches. Least cost paths then represents best areas for shallow ditch network creation. Results show that using this method in forest average reduction of depression area is 79% generating average 370 m of shallow ditches on each drained depression hectare.

Study area



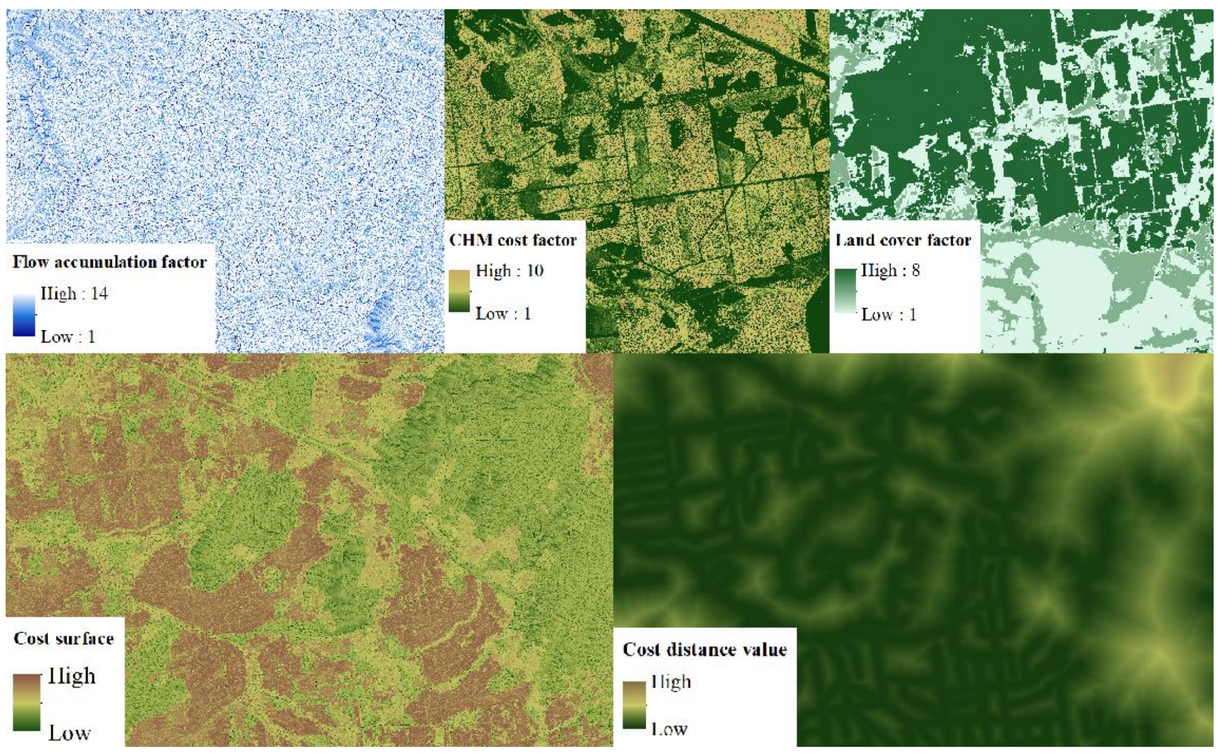
Materials and methods:

Method is developed on various DEM (Digital elevation model) and CHM (Canopy height model) transformations as well as multispectral satellite imagery classification basis which are used to make three factor cost surface. Canopy height model was created in 1 m resolution using DEM and digital surface model (DSM) in same 1 m resolution. Whitebox was used to smooth out road artifacts over stream crossings using ditch and culvert vector data to make possible water flow modelling on DEM.

SAGA GIS algorithm Fill Sinks (Wang&Liu) is used to generate raster map of surface depressions. It is done by extracting original DEM from filled DEM. Resulting raster map contains information about spatial distribution and depth of depressions in given area. According to previous studies in Latvia, soil wetness is more likely to increase in depressions which are at least 4 cm deep (Ivanovs, Lupikis 2018).

Least-cost surface is made using three raster maps as cost factors – flow accumulation raster, canopy height model and land cover raster map. Flow accumulation raster is recalculated using function *logX*, where X is flow accumulation raster. Cost factor contains values from 1-14. CHM raster map are smoothed using sliding window principle, to obtain more homogenous raster, which later is divided by 4 to obtain cost values from 1-10. Land cover raster, which is made classifying NDVI and NIR raster map combination, dividing coniferous and deciduous forest stands, but other land cover types are set in one category. Land cover cost values – 8 for coniferous stands, 5 for deciduous and 1 for other land cover type. Least-cost surface is made mathematically counting those three factors together. Obtained raster is attached to existing ditch network using ArcGIS *Cost distance* tool.

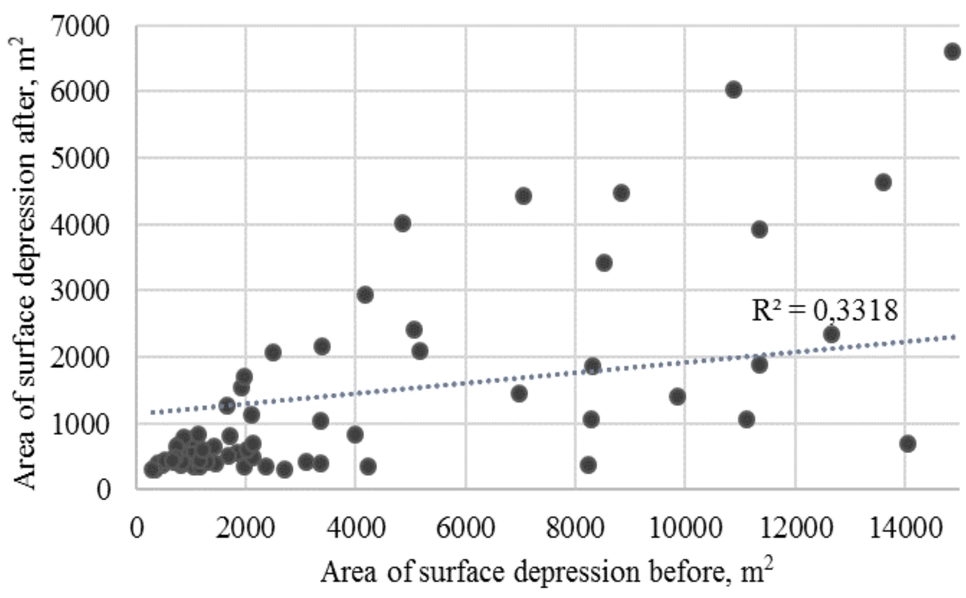
Cost distance raster map is used to find most appropriate paths for shallow drainage ditch network creation, starting from centre of each depression and leading to existing ditch. It is done using GRASS GIS tool *r.drain.*

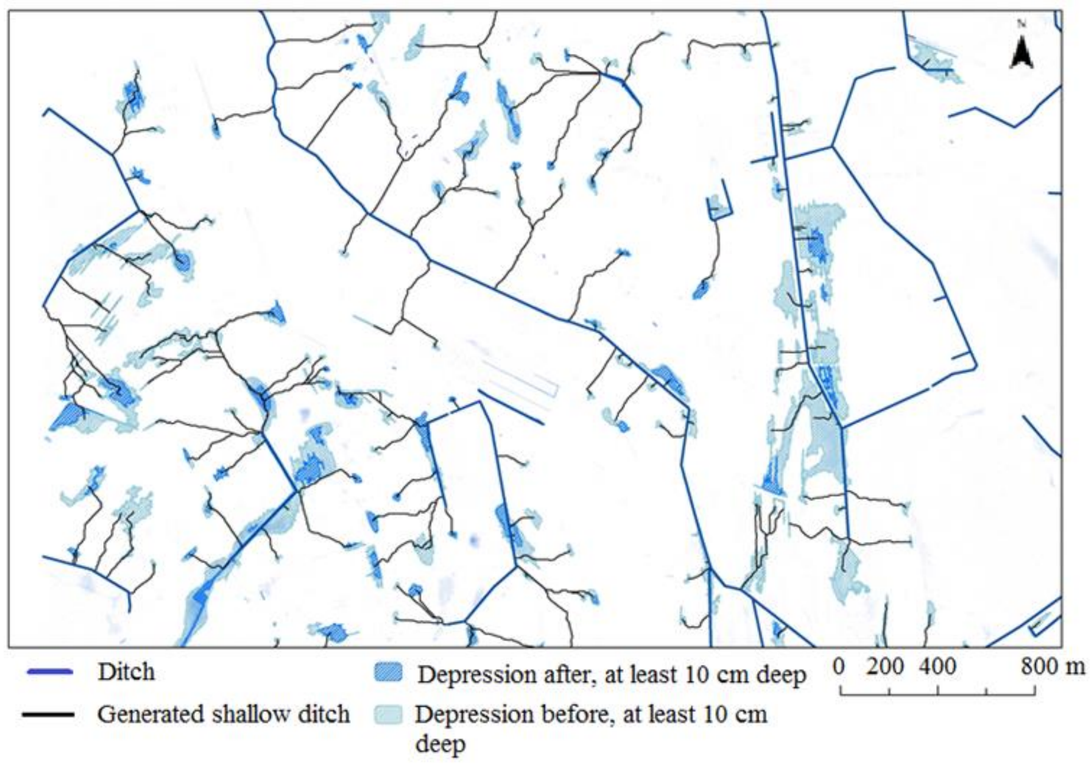


Results:

To analyze obtained results, we use filled surface depression area and depth before any manipulations and compare them with area after burning shallow ditches. The length of generated ditches is used as well, to estimate approximate carving efficiency on affected area.

Area of depressions moderately decreases for 79%, using 265 depressions from our study area. Total area of all depressions is 108 ha and after processing total area decreases for 85,32 ha reaching 22,68 ha of remaining area of undrained surface depressions. From total count of depressions, 97 was fully drained or there was left only insignificant area less than 30 m2 large. This result is obtained generating 35,26 km of shallow ditches in total, regarding each depression average 133 m and regarding each drained hectare – 370 meters of ditches.





Conclusions:

- Using this method, it is possible to plan forest depression drainage. In our case average reduction of depression area was 79% which is promising number for further studies improving our method;
- Usage of this method may be limited in fragmented terrain with different types of relief shapes which have larger elevation difference than shallow ditch can cross;
- Method requires complete and correct existing drainage system data, which is not currently available in Latvia and we need to continue studies to develop methods for automatic identification of drainage ditches and culverts in Latvia.