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# Can a high-resolution Digital Elevation Model predict the thickness of the organic soil layer in the riparian soil?

## Kan en högupplöst höjdmodell förutsäga den organiska jordens mäktighet i bäcknära zonen?

Maria Blomberg

## Abstract

**Can a high-resolution digital elevation model predict the thickness of the organic soil layer in the riparian soil?**
*Maria Blomberg*

Topography is a fundamental factor for soil formation and a characteristic of the landscape that can be easily measured through remote sensing. Geomorphological and hydrological landscape analyses provide new ways to interpret and describe the landscape with high resolution digital maps. A Light Detection And Ranging (LiDAR) digital elevation map (DEM) was used to compute various terrain indices with the GIS (Geographical Information System) software SAGA. The terrain indices were then linked to three soil indices related to the organic horizon of riparian soils. The study was based on an extensive soil survey in the Krycklan catchment, a 66 $km^2$ boreal catchment area located near Vindeln in northern Sweden. Investigation of the soil indices gave valuable insights about the architecture of the riparian zone. Understanding riparian soil is of great interest because it is hypothesised to determine much of the variation in stream water chemistry (Bishop, 1991; Buffam, 2007). This study revealed clear structural patterns of organic soil distribution in the riparian zone. Aggregated organic soil horizon pattern for the profiles showed that organic horizons were clearly deeper near the stream than further away and that first-order headwater streams were bordered with soils having thicker organic horizons compared to third or forth-order streams. Organic horizons were considerably more abundant in the moraine part of the catchment than the sedimentary part. Of all the terrain indices, elevation above sea level showed the strongest correlation with all three organic soil indices, near stream organic soil depth, lateral extent of organic soils, and the cross sectional area of organic soil adjacent to the stream. Other terrain indices that were significantly correlated to the soil indices were slope, curvature, height above stream and the topographic wetness index (TWI). However, terrain indices and soil indices were not sufficiently well correlated to allow prediction of organic soil properties solely based on terrain indices.

**Key words:** Riparian soil, LiDAR, GIS, landscape analyses, topographical indices

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## Referat


**Kan en högupplöst höjdmodell förutsäga den organiska jordens mäktighet i bäcknära zonen?**
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Denna studie behandlar strukturen av organisk jord i den bäcknära zonen och förhållanden mellan tre framtagna jordindex och ett antal geografiska höjdindex beräknade från en högupplöst digitalhöjdmodell (DEM) framtagen från Light Detection And Ranging (LiDAR) data. Jordindexen är relaterade till den organiska jorden närmast bäcken. Topografin är en av fem huvudfaktorer som styr de jordmånsbildande processerna. Topografiska index är variabler som är relativt enkla att ta fram ur höjdmodeller samt att mäta i naturen. De digitala kartornas upplösning och användningsområden ökar i snabb takt, vilket genererar nya metoder för tolkning och beskrivning av naturen. Geografiska höjdindex beräknades från höjdmodellen med dataprogrammet SAGA. Till grund för studien låg ett omfattande fältarbete där markdata och geomorfologiska data insamlats längs bäckar i Krycklans avrinningsområde. Krycklan är ett 66 km$^2$ stort avrinningsområde beläget i Vindelns kommun i norra Sverige. Krycklans avrinningsområde hade en övre del som dominerades av moränmark och en nedre del som dominerades av sedimentära jordarter. Studien visade tydliga mönster hos den organiska jorden längs bäckarna. Generellt var den organiska jordens mäktighet större nära bäcken än längre bort och små bäckar kantades av djupare organiska horisonter än större bäckar av högre ordning. Jordprofilerna längs bäckarna i moränmarken hade en markant högre andel organisk jord än jordprofilerna i den sedimentära delen av avrinningsområdet. Höjd över havet gav bäst korrelationer vid jämförelser med alla tre jordindex. Andra geografiska index med signifikanta korrelationer var sluttning, kurvatur, höjd över bäcken och det topografiska fuktighetsindexet (TWI). Mellan de beräknade höjdindexen och jordindexen visades inte tillräckligt tydliga samband för att man ska kunna förutsäga den organiska jordens bäcknära utbredning genom enbart analys av den digitala höjdmodellen.



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# POPULÄRVETENSKAPLIG SAMMANFATTNING

**Kan en högupplöst höjdmodell förutsäga den organiska jordens mäktighet i bäcknära zonen?**
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Denna studie behandlar strukturen av organisk jord i den bäcknära zonen och förhållanden mellan tre framtagna jordindex och ett antal höjdindex beräknade från en högupplöst digital höjdmodell (DEM, Digital Elevation Model) vilken var framtagen ur data från flygburen laserscanning (LiDAR, Light Detection And Ranging). Hypotesen är att den lokala topografin påverkar vilken typ av jord som bildas nära bäcken.

Topografin är en av fem huvudfaktorer som styr de jordmånsbildande processerna. De andra är klimat, modermaterial (berggrund), organismer och tiden. Topografiska index såsom höjd och sluttning är variabler som är relativt enkla att mäta i naturen och beräkna ur digitala höjdmodeller. De digitala kartornas upplösning och användningsområden ökar i snabb takt vilket samtidigt genererar nya metoder för tolkning och beskrivning av landskapet. I studien beräknades geografiska höjdindex från rasterlager baserade på höjdmodellen med GIS, Geografiska Information System, programmet SAGA, System for Automated Geoscientific Analyses. Rasterlagren som användes i analysen var uppbyggda av pixlar som motsvarade 5x5 m i verkligheten. I studien användes 13 olika topografiska index beräknade från höjdmodellen. De topografiska indexen korrelerades sedan med de framtagna jordindexen: avstånd från bäcken där den organiska jorden understiger 30 cm, medeldjup av den organiska jorden de närmsta fyra metrarna från bäcken och tvärsnittsarean av organisk jord till ett maximalt avstånd på 25 m från bäcken. Studien baserades på insamlade data från ett omfattande fältarbete utfört längs bäckar i Krycklans avrinningsområde från år 2004 till år 2007.

Det studerade området är ett 66 $km^2$ stort avrinningsområde i Krycklans övre del. Krycklan är en biflod till Vindelälven beläget i Vindelns kommun i norra Sverige. Högsta kustlinjen går igenom avrinningsområdet och dess påverkan sågs genom att området hade en övre del som dominerades av moränmark och en nedre del som dominerades av sedimentära jordarter. De dominerande trädslagen var gran och tall med inslag av lövskog närmast bäcken. På grund av att avrinningsområdet uppvisade så stora geologiska skillnader indelades provtagningspunkterna i flera undergrupper för att se vilken betydelse de olika områdena samt bäckarnas olika storlek hade på de beräknade korrelationerna.

Studien av jordindexen gav en uppfattning om strukturen av den organiska jorden närmast bäcken. En förståelse av strukturen är viktig, då man tror att den organiska jorden påverkar mycket av kemiska variationer i bäckvattnet. Området närmast bäcken fungerar som en buffrande zon som bland annat kan fånga upp sediment, metaller och näringsämnen som annars skulle medfölja det rinnande vattnet rakt ner i bäcken. Data insamlades längs transekter tvärs bäckarna i avrinningsområdet. Bestämning av jordtyp och vegetationstyp gjordes vid 0,5, 2, 4, 8, 12 och 25 m avstånd från bäcken, på både höger och vänster sida om bäcken. Bäckpunktens läge, dvs. vid mitten av transekten, uppmättes i fält med en handhållen GPS, Global Positioning System. De erhållna koordinaterna användes till att placera bäckpunkten på den digitala kartan.

Markprovtagningen uppvisade en stor variation av andelen organisk jord inom ett relativt litet område längs bäcken, dock såg man tydliga storskaliga skillnader. Studien visade en markant högre andel organisk jord i moränmarken än i sedimentjorden. Moränmarken hade även djupare organiskt jordlager närmast bäcken än vad som ses i den sedimentära delen. Variationen kan dels vara naturlig, dels bero på mätfel. Källflöden, de minsta bäckarna av första ordningen, hade generellt högre värden för alla tre jordindex än de större bäckarna av högre ordning.

Topografin påverkar de jordmånsbildande processerna bland annat genom att den ofta styr grundvattenytans läge. Grundvattenytans läge har stor betydelse genom grundvattnets påverkan i marken på vittring, transport av näringsämnen och metaller samt tillgänglig mängd syre i jorden, vilket påverkar de biologiska processerna. Sluttningars längd och riktning i naturen påverkar vilken inverkan det lokala klimatet så som regn, sol och vind har på jorden och de jordmånsbildande processerna. Marken längst upp i sluttningar är oftast väldränerad medan mark i sänkor och dalar samlar upp vatten och ofta innehåller en större andel lera och organiskt material. De digitalt framtagna topografiska indexen som användes i korrelationsanalysen är ett beräknat medelvärde av det angränsande pixlarna till bäckpunkten. Det topografiska indexet baserat på höjd över havet gav bäst korrelationer vid jämförelser med alla jordindex. Andra topografiska index med god korrelation var sluttning, kurvatur (om topografin är konvex eller konkav, höjd eller sänka), topografiska fuktighetsindexet (TWI) och höjd över bäcken.

Skillnaden hos den organiska jordens mäktighet mellan de olika delarna av avrinningsområdet har även observerats i vattenkemin i bäckarna, såsom pH och löst organiskt kol. För att få full förståelse och kunna dra säkra slutsatser om vilken påverkan som den organiska jorden har på vattenkemin behöver man dock även förstå och göra analyser av områdets hydrologi.

Korrelationerna mellan de beräknade höjdindexen och jordindexen visade inga tydliga samband som kan användas för att förutsäga den bäcknära organiska jordens utbredning genom att endast analysera en digital höjdkarta.

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## Preface

This master thesis was made at the Department of Environmental Assessment, Swedish University of Agricultural Sciences. The thesis covers 30 credits and was a part of the Master of Science programme in Aquatic and Environmental Engineering at Uppsala University. The thesis was a part of the Krycklan Catchment Survey.

Subject reviewer: Prof. Kevin Bishop, Department of Environmental Assessment, Swedish University of Agricultural Sciences.
Supervisors: Ph.D. candidate Thomas Grabs and Associated professor Jan Seibert, Department of Physical Geography and Quaternary Geology, Stockholm University.

Thank you Kevin for all support, all your enthusiasm and belief in the progress of this thesis. Special thanks to Thomas for support, invaluable help with comments, processing of the terrain indices, fieldwork and help with the statistics. I would like to thank Jan for support and giving me the chance to come to the workshop in Manchester. Thanks to Hjalmar, Ishi, and Annelie and to all of you who helped answering my Krycklan questions. Special thanks to Kjell Larsson at the Department of Forest ecology, SLU, Uppsala for support and help with field equipment and thank you Eva for helping me with the fieldwork. I give my warmest thanks to all personal at the Department of Environmental Assessment, IMA for the friendly atmosphere you bring to the department and all your support. A special thanks to Martin who always lighted up my working days and helped me with the statistics. And a special thanks to Maria I. for her happy smile, her cheering and encouraging so I finally reached the end of this thesis.

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*Maria Blomberg*


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# ABBREVIATIONS

| | |
|---|---|
| A | Mineral soil horizon at or near the surface. |
| B | Mineral soil horizon |
| C | Carbon |
| CCREW | Cold Climate Research |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| -COOH | Carboxyl group, functional group |
| CA | Catchment area |
| DOC | Dissolved Organic Carbon |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| HC | Highest coastline |
| INS | Internal Navigation System |
| IMA | Institutionen för MiljöAnalys, Department of environmental assessment |
| IUSS | International Union of Soil Sciences |
| JMP | Statistical programme developed by SAS Institute Inc. |
| LASER | Light Amplification by Stimulated Emission of Radiation |
| LiDAR | Light Detection And Ranging |
| -OH | Hydroxyl group, functional group |
| RIS | Riks Inventeringen av skog, The Swedish National Inventory of Forests |
| SAGA | System for Automated Geoscientific Analyses |
| SGU | Sveriges Geologiska Undersökning, Swedish Geological Survey |
| SLU | Sveriges Lantbruksuniversitet, Swedish university of Agriculture Sciences |
| GUI | Graphical User Interface |
| WRB | World Reference Base for soils |

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# 1. INTRODUCTION

## 1.1. Aim

A large amount of data was collected to describe the riparian zone in the Krycklan catchment during several field campaigns in the years 2004 to 2007. The aim of this study was to examine these data further, describe the architecture of the near stream soil and compare and correlate the results with topographic indices from a Light Detection And Ranging (LiDAR) digital elevation model (DEM) to see if the extension of organic riparian soil could be predicted by terrain indices derived from the DEM. The hypothesis was that the local topography has a major influence on the soils in the riparian zone, especially concerning organic soil horizons. Understanding the landscape architecture of riparian zones is of great interest because the riparian zone plays an important role for the stream water quality. The riparian zone acts as a buffer zone that traps sediment, metals and nutrients in the runoff water and controls their entry into the stream water (Parklyn, 2004).

Data was sampled along transects perpendicular to the streams in the whole catchment. In this study, the sampled soil dataset was related to topography after aggregating it to soil indices that consisted of more homogenous data subsets. The soil indices were comparable with topographic indices derived from the DEM as raster cell values using the GIS programme SAGA (System for Automated Geoscientific Analyses). Soil indices and correlation data were examined in the statistic programme JMP.

## 1.2. Background

There are many different definitions of the riparian zone. Parklyn (2004) describes the riparian zone as the strip of land next to a water body (stream, river, lake) that interacts with runoff from hill slopes and water from flooding. The riparian area is the interface between terrestrial and aquatic systems and plays an important role for the water quality. The zone can sometimes be identified by eye when there is a clear change in topography or vegetation cover, with more water demanding plants growing in the riparian zone. In the Krycklan catchment, however, no clear topographic changes were apparent which would have allowed simple determination of the riparian zone. Instead, the presence of organic soil horizons was used to delimit the extent of the riparian zone.

The five major soil forming factors are climate, topography, parent material, biota and time. All these soil forming processes require the presence of water since most chemical and physical processes cannot happen without it. Water is also necessary for life, dissolves rock and it is an important transport medium. In the riparian zone, updwelling groundwater has a direct effect on the water processes. The organic content of soil often increases towards the stream at sites where the water table is shallow (Mikkelsen and Vesho, 2000). Organic soil in the riparian zone is hypothesised to control much of the variation in stream water chemistry, both as a sink for nutrients and metals and as a source for carbon (Bishop, 1991; Buffam, 2007). The surface of clays and organic matter is where most of the chemical reactions take place in soils. Main components of soil organic matter are organic macromolecules consisting of long carbon chains combined with hydrogen, oxygen, phosphorus, nitrogen and sulphur, forming the organic material like humus. Humus contains a variety of functional groups such as carboxyl (COOH) and hydroxyl (OH), which often changes with pH. The charges on the particles depend on interaction with ions present in the soil solution by losses or addition of hydrogen cations in the functional groups. Clays have a built-in negative electrical charge. At the crystal surface, the negative charges interact with cations from the surrounding soil solution. The negative charge depends on the type of clay and varies with the pH of the surrounding solution (Singer and Munns, 1999). Presence of organic material in the riparian zone can have important effects on the environment. Environmental toxic substances like the heavy metals cadmium, mercury, lead, aluminium and copper bind to the charged surfaces and can be released if the local environment changes.

The locations of the soil in the landscape, slope angle and slope length determine how climate processes such as rain, wind and sunshine affect the soil. Soil profiles are built up of different layers called horizons, named with capital letters. The amount of water that enters the soil influences the soil formation and development of soil horizons, differing from each other through their chemical composition, colour, texture and structure. The upper soil layers often contain organic material and little or no mineral soil while the lower layers mostly consist of mineral soil originating from the parent bedrock. Figure 1 shows the names and sequence of different soil horizons that can occur in a soil profile. The top soil consists of an organic H or O layer, containing more or less decomposed organic material. An H horizon is saturated with water for prolonged periods (or has been and afterwards it has been artificially drained) whereas an O horizon has not been saturated for prolonged periods. Soil horizon A is the uppermost mineral soil horizon formed at the surface or below an organic horizon. The A horizon consists of humified organic matter mixed with mineral material where the mineral content of the soil horizon is larger than 10%. An E horizon is often lighter in colour than the underlying horizons. This is due to decomposition and leaching of the mineral soil, developing an eluviation layer. The B-horizons in Swedish soils are often illuviation horizons where iron, aluminium and/or humus are accumulated (RIS, 2007; WRB, 1998). Podzols often consist of all horizons while Histosols lack E and B horizons. The local moisture regime, for example the drainage abilities and water table depths, influence soil formation. For soils that are poorly drained, free water in a profile is more important for soil than the regional climate. Slope and distance to the streams have impact on hydrological pathways. They often follow the topographic gradient which leads to well drained soils at the top of the slope while soils in depressions are poorly drained and often contain more clay and organic soil material. Type of vegetation and vegetation cover which also influence the formation of organic soils are also affected by the topography. Partly as an effect of prolonged wetness, hydrophilic plants, for example grass and mosses, grow at the bottom of the slope. These plants add more humus to the soil than the trees growing at the slope and summit.

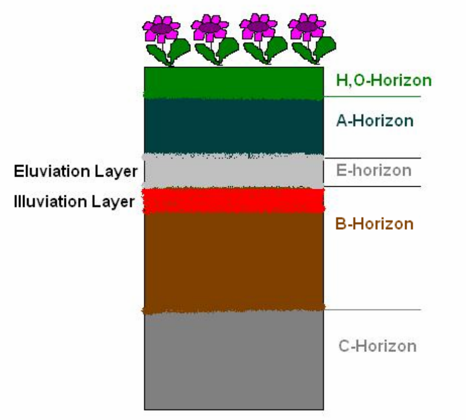



Figure 1. *Names and sequence of different soil horizons that can occur in a soil profile*

This topographically driven gradient of soils and vegetation can be seen in hollows in boreal forests and close to streams where it forms riparian peat soil that influences the stream chemistry. The aspect is equivalent to the direction to which a slope is oriented. In the northern hemisphere, northern oriented hillslopes tend to be generally cooler than south-facing ones because they receive less direct solar radiation. Because of the cooler slopes and temperature limits of development, soils are generally shallower on the north-facing slopes than on the south-facing ones (Singer and Munns, 1999).

The resolution of the standard Swedish DEM that was 50x50 m was too coarse to reflect the local topography of the riparian zone. In the end of 2006 the Krycklan catchment area was surveyed with an airborne LiDAR system. The LiDAR system consisted of three technologies: Inertial Navigation System (INS), LASER and GPS .The technique gives a digital map with very high resolution and high levels of accuracy. After filtering and reduction of noise, LiDAR can give horizontal and vertical accuracy at decimetre levels (Vallet, 2007). From the LiDAR data a pre-processed DEM was calculated which was used in this thesis. The pre-processing included aggregation of the original 1x1 m DEM to a 5x5 m resolution, noise reduction, removal of sinks and manual correction to reproduce the observed stream network. Coordinates were given in the Swedish system RT 90. The software used was the open-sourse programme SAGA version 2.0.01.

## 1.3. Study area

Krycklan catchment is situated in the boreal northern part of Sweden, see Figure 2. Interest in understanding of what controls the temporal and spatial variability in water quality and how this affects the biodiversity initiated the Krycklan Catchment Survey (CCREW, 2007).


Figure 2. *Location of the Krycklan catchment.*

Krycklan is a tributary to Vindelälven. The upper catchment area used in this study is 66.2 $km^2$ (calculated from the DEM). Topographically the area has many small mountains and hills. Dominant tectonic direction goes from north-west to south-east. Other tectonic directions are also present for example a wide valley, Åheden, reaching in east-west direction across the catchment area. The highest coastline, HC, in the area is situated at 255-260 m.a.s.l. The upper part of the cathment are dominated by quaternary till deposits while the lower part below HC contained mostly consists of alluvial and glaciofluvial sediments remaining from an postglacial delta. Streams in the lower part have eroded the sediments and formed steep ravines up to 30 m deep. (Ivarsson and Johnsson, 1988). Dominant forest vegetation species in the upper part of the catchment area are spruce and pine, with elements of deciduous species, mainly birch, in wetter areas and near the streams. On the steep ravine slopes in the southern parts of the catchment area, mainly older forest is growing with a dominance of spruce and pine trees but sometimes with quite large elements of birch, alder, aspen, willow and sallow. On the flat valley bottoms, pure deciduous forest areas can be seen. The catchment is mostly covered by forests but there are some smaller areas of houses, roads and agriculture land in the catchment. Ditching of wetlands and streams took place in the 1930´s (Bishop, 1994).

# 2. METHODS

## 2.1. Sampling of field data

The field data was sampled in transects along the stream. The transect site consisted of 13 sampling points, six at each side perpendicular of the stream at distances of 0.5, 2, 4, 8, 12 and 25 m and one point within the stream referred to in this report as the stream point (Figure 3). Distances were measured with a measuring tape, attached to a wooden stick that marked the channel edge. In total there were 191 measured transects spread out in the catchment.

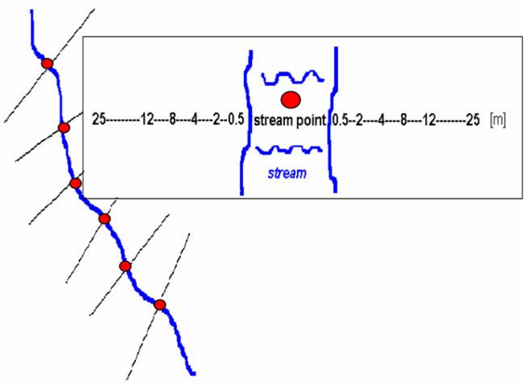



Figure 3. *Description of the location for the sampling points along a transect site.*

The data for each site was collected according to a field protocol, appendix A. Data of the channel properties was not used in this study. Right and left sides of the stream were in this study defined when looking in the upstream direction i.e. towards the direction of flow. This was opposite to the general definition of a streams right and left sides. Different intervals between transects were chosen for different stream reaches. In large streams the distances between two neighbouring transects was approximately 500 m while in smaller streams the distances were approximately 100 m. Distances between transects were estimated in field by counting steps. More precise positions of the stream points were measured with a hand held GPS. The orientation of the stream channel was measured with a compass looking in the upstream direction. Four pictures were taken with a digital camera in upstream, downstream and right and left direction at each stream point. The extent of the riparian zone were directly noted where it was possible to define the riparian zone by eye (i.e. by looking on signs of flooding sometimes seen as pronounced changes in topography or vegetation), for most transects this was not possible to see. Terrain morphology at the sites was determined using clinometer-measurements. Forest vegetation was described in percentage of the most dominant species at the sampling point looking approximately 10 m upstream and downstream in an imagined line parallel to the stream at each distance (0.5 m, 2 m...) from the stream. The ground vegetation was documented by writing down the species seen around the point in the same area as for the forest vegetation. Description of the soil horizons was made by using a soil coring tube (Figure 4). Along the transect different coring tubes and spots around the defined transect-points were tried out to get as deep soil profile as possible. When the soil coring tube hit a stone, root or compact mineral soil that prevented it from getting the whole core length of the soil profile this was noted in the field protocol. The soil was examined and named by looking in field at the colour and texture of the soil, estimation of soil organic matter and defining soil horizons. The thickness of each soil horizon was measured in centimetres with a folding rule.

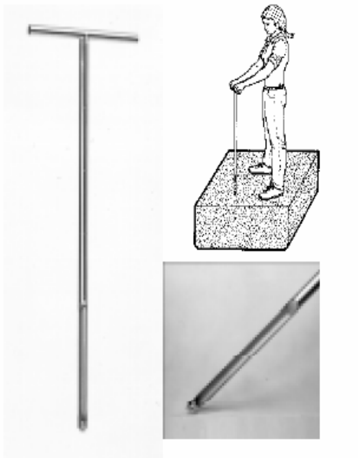


Figure 4. *Picture of a Soil coring tube. (Soilmoisture equipment corp., 2008)*

## 2.2. Processing of data

The terrain and topography sometimes differ between left and right side of the stream, because of that the indices were calculated and compared to soil indices for both sides separately.

### 2.2.1. Vegetation indices

Five tree species were noted; Pine, Spruce, Birch, Alder/Aspen and Willow. The deciduous species Alder and Aspen were put together since there was an uncertainty of which of the species that was noted in the original data. Eighteen different ground vegetation species were noted in the original field data, these were reduced to the seven most abundant species: Sphagnum, Vaccinium, Herbaceous, Grass, Fern, Lichen and Heather. The original species information noted in field was changed to a ranking scale. The rank for forest vegetation went from 5 to 0 where 5 was the most common specie at the sampling point, 4 equalled the second most common specie and so on. A rank value of 0 meant that the species was not found at the sampling point. For the ground vegetation the highest rank value was 7 and the lowest rank value was 0. A vegetation index based on the rank value for each vegetation specie at every transect point was made by calculating a mean rank value for the species in each soil type. The higher vegetation index value the more common was the specie for the soil type.

### 2.2.2. Soil horizons

Soil horizons were defined in field by looking at colour and texture. From the defined soil horizon data the soil was divided into soil groups by following the instructions in World Reference Base for soils (WRB) and the Swedish national inventory of forests (RIS). The found soil groups decided from the field data were: Histosol, Gleysol, Podzol, Umbrisol, Arenosol and Regosol.

<u>Histosol</u> had an organic soil horizon thicker than 10 cm.
<u>Gleysol</u> were soils that showed reducing or alternate reducing/oxidising conditions with a high ground water level within 50 cm from the surface. The colour was greyish in the register from white to black or blue-greenish. Red spots in the soils, mottled, were a sign of a fluctuating ground water surface.
<u>Podzol</u> was a soil with a diagnostic spodic-horizon, a subsurface illuvial horizon. The illuvial substances consist of organic material, aluminium or iron.

Umbrisol had an umbric-horizon, a mineral soil horizon rich in organic matter. Soils with a mineral B-horizon where it was noted high amount of organic matter was placed in this group.
Arenosol was sandy soil.
Regosol was soil where no clear horizons could be found, it was a common soil type with a texture that ranged from clay to coarse sand. (RIS, fältinstruktion, 2007), (IUSS Working Group WRB, 2006).

From the measured field data the organic soil was defined as the sum of the noted organic horizons O, histic (Mor), peat and peat with mineral content, i.e. all horizon-data that contained organic soil matter. The top layer O was dominated by partially decomposed organic material. Histic (Mor) horizon consisted of non humified dead organic matter. Peat had dark brown colour and was composed of humified organic matter. Peat that was mixed with small gravel, sand or till was defined as peat with mineral content. The colours for this peat class were often lighter than for peat.

To simplify the comparison of soil data with terrain indices, the soil samples from the transects were aggregated to single-value soil indices. Three soil indices related to the extension of organic soil were chosen: Distance30, Depth4 and CArea. All soil indices were calculated separately for both left and right side of the stream.

### 2.2.3 Soil index –Distance30

Distance30 index was measured from the stream until the thickness of the organic horizon was less than 30 cm, also seen as the boundary between riparian peat and upslope mineral soil. 30 cm of peat depth is a common boundary in connection with peat, in Scandinavia this is the depth limit for peat soil. In the calculations for finding the Distance30 index, linear interpolation was used to calculate the distance between the measured transect points (Figure 5).

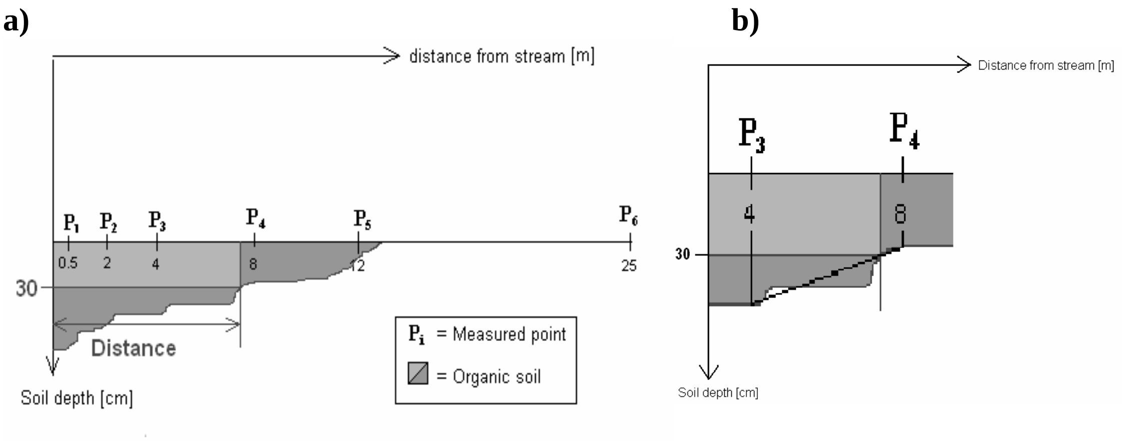



Figure 5. *Explanation of the Distance index. a) Whole transect. b) Linear interpolation between transect point 3 and 4 at a distance of 4 m respective 8 m from the stream.*

## 2.2.4. Soil index –Depth4

Depth4 index was the weighted mean depth of the organic soil horizon for the nearest three measuring points reaching four metres from the stream. Mean depth was calculated separately for both sides of the stream point. Equation (1) describes how the mean depth index, called Depth was calculated, explanation of the parameters are shown in Figure 6.

$$Depth = \frac{P_1 \cdot \Delta d_1 + P_2 \cdot \Delta d_2 + P_3 \cdot \Delta d_3}{\sum_{1}^{3} \Delta d_i} \qquad (1)$$

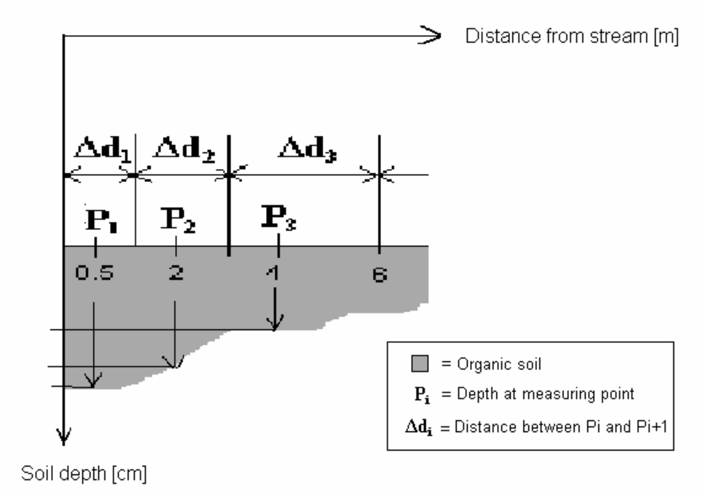



Figure 6. *Description of the soil index Depth4.*

## 2.2.5. Soil index –CArea

CArea index was the total cross-sectional area of organic soil along the transect. The area index was calculated by equation (2) and explanations of the parameters are shown in Figure 7.

$$Area = \sum_{1}^{6} P_i \cdot \Delta d_i \qquad (2)$$

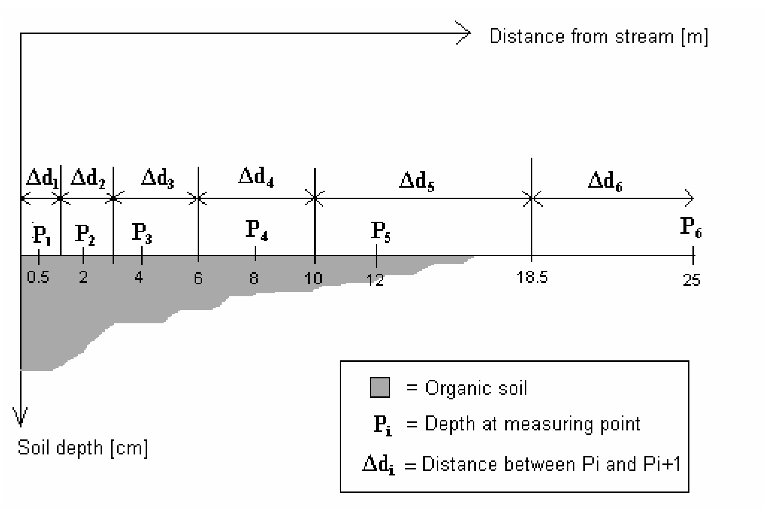



Figure 7. *Description of distance and points used for calculation of the CArea soil index.*

## 2.3. Terrain indices

The coordinates of the transect sites, measured with a handheld GPS, were imported into the SAGA-GIS software. In some cases the sites were manually moved to the closest stream channel pixel. Terrain indices were derived from the DEM using different terrain analyse modules in SAGA. The statistical analyses of the relation between soil and terrain indices were performed with the statistical programme JMP.

### 2.3.1. Calculated index grids in SAGA

Several indices were calculated based on the local incoming catchment area. For the indices with an ending of _Acc, the indices represented the total accumulated catchment area for the stream pixel (Figure 8a).

<u>CA_MTF (Catchmentarea, Multidirectional Triangular Flow)</u>
Catchment area created in SAGA with module "Parallel Processing" and method "Multiple Triangular Flow direction". The method was based on calculations using triangular facets between the grid cells allowing multi directional flow in any downslope direction (Seibert and McGlynn, 2007). Unit: [$m^2$]

<u>CA_MTF_Acc</u>
Created as the CA_MTF index. Represent the total accumulated area above the stream pixel. Unit: [$m^2$]

<u>Curvature</u>
The curvatures were calculated as the second derivate of elevation. Positive values equal a convex surface and negative values equal a concave surface topography. Unit: [1/m].

<u>HAStream (Height Above Stream)</u>
Difference in height between the streams and the surrounding landscape. The streams were set to zero in the digital map. Unit: [m].

<u>EASea (Elevation Above Sea level)</u>
Elevation above sea level, given in the pre-processed DEM. Unit: [m].

<u>MTF (Multidirectional Triangular Flow)</u>
Local catchment area entering the stream point from left respective right side. This index grid was calculated in a modified way by Grabs (personal communication). Method used in the calculations was "Multiple Triangular flow direction" (Seibert and McGlynn, 2007). Unit: [$m^2$].

<u>PIndex (Prescott Index)</u>
The Prescott Index characterizes vertical water fluxes by comparing potential evaporation and precipitation (McKenzie and Ryan, 1999). Unit: dimensionless.

<u>SAGA_CA (Saga calculated catchment area)</u>
Local incoming catchment area. Calculated by SAGA in a modified way that uses the discharge in dependence of the slope as a hyperbolic function projected onto the adjacent grid cells (Boehner et al., 2002). Unit: Unit: [$m^2$].

SAGA_CA_Acc
Created as the SAGA_CA index. Represent the total accumulated area above the stream pixel. Unit: [$m^2$].

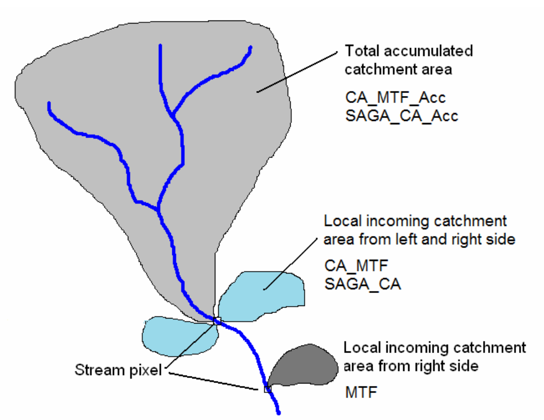
SAGA_WI (Saga Wetness Index)
Wetness index calculated by SAGA and based on the catchmentarea calculated by SAGA. SAGA_WI gives a higher potential soil moisture value to valley floor sites compared to the standard TWI calculation method described below (Boehner et al., 2002). Unit: dimensionless.

Slope
Slope was calculated as the first derivate of elevation. In SAGA the module "Local Morphometry" was used with the method "Fit 3.Degree Polynom" (Haralick, 1983). Unit: [m/m].

SolR (Solar Radiation)
Sum of incoming solar radiation calculated as average daily radiation for each month. The radiation settings were set as the default values given by SAGA in the used module "Incoming Solar Radiation" (Wilson and Gallant, 2000). Unit: [$kWhm^{-2}day^{-1}$].

TWI (Topographic Wetness index)
The index describes the moisture conditions of a given site in the terrain. TWI was calculated as ln (a/tan β), where a is the specific upslope area calculated as upslope area, A divided by unit contour length L (Figure 8b), tan β is the local slope were β is the angle in degrees. Unit: dimensionless.

a)




b)

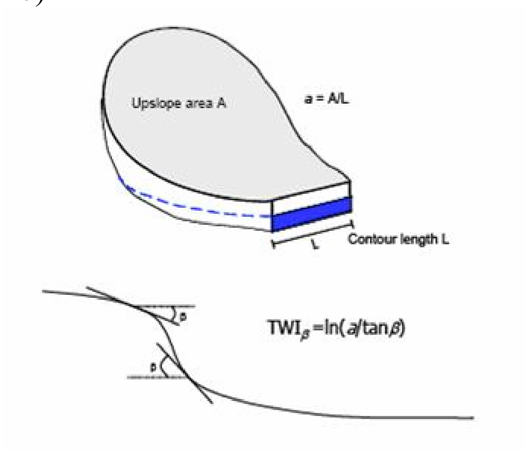



Figure 8. *a) Description of catchment areas and related indices. b) Variables in the TWI index (Sørensen R., 2006).*

Each index has one value per pixel in the DEM, except for the indices CA_MTF_Acc and SAGA_CA_Acc which have values only in the stream pixels. Figure 9 shows some of the terrain indices over the same area. The difference between the calculation methods for the wetness in the indices, SAGA_WI and TWI is clearly seen in picture A and C. Picture B shows the slope and picture D the flow pattern over the same area.

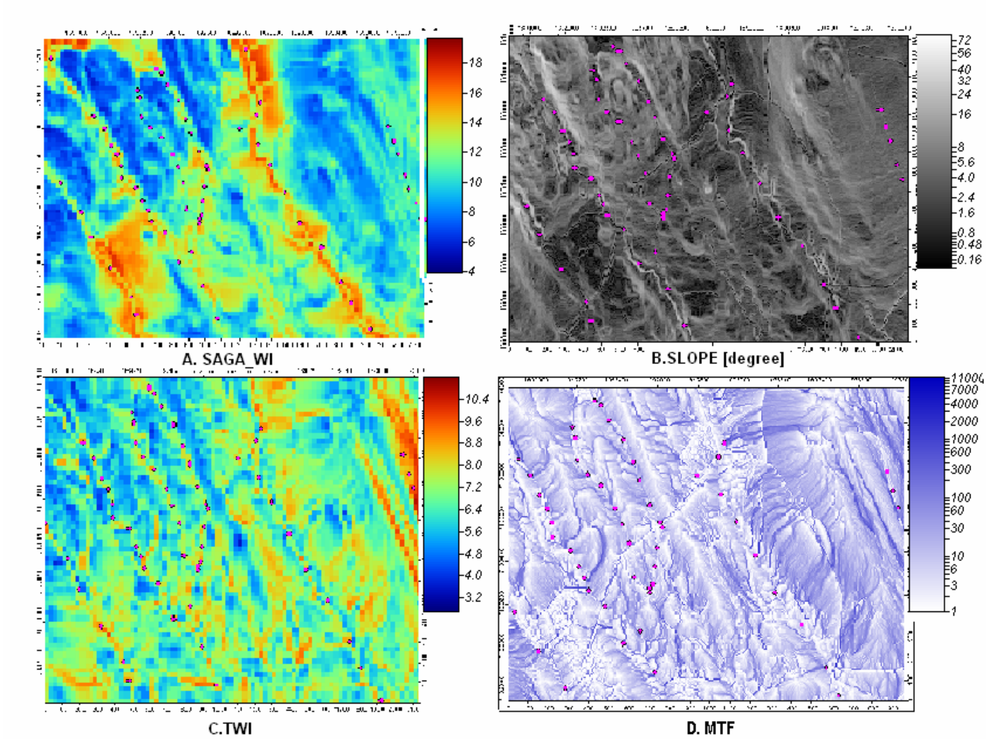



Figure 9. *Pictures of some terrain indices, A. SAGA_WI, B. Slope, C. TWI and D. MTF.*

For comparison of GIS data with the produced soil indices a 3x3 window was used with centre in a transect stream point. Around the centre the pixels were numbered from 0 to 8, figure 10 illustrates the naming and numeration of the pixels. The middle picture was cut out from the DEM were the blue pixels were the stream. The stream pixels were named S1, S2 and S3. S2 was always the middle stream point and S1 the first stream point in the flow direction. L=left side pixels and R=right side pixels of the stream.

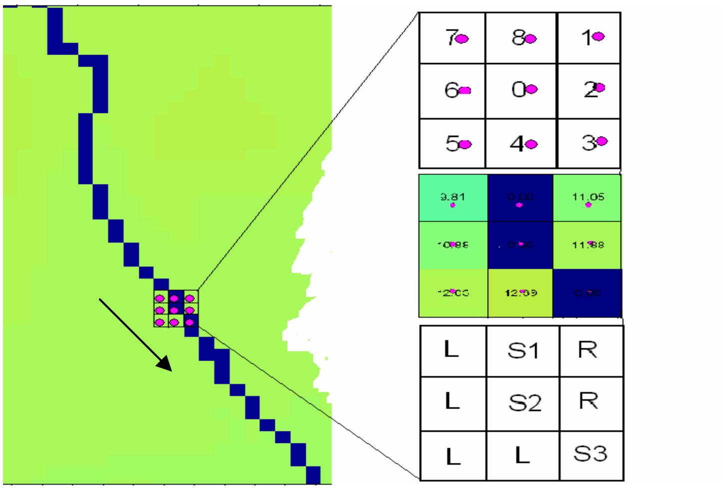



Figure 10. *Number and names in the3x3 stream point window. The middle picture was from a DEM were the blue pixels were the stream. Naming: S1, S2, S3=Stream pixels, L=left side pixels and R=right side pixels. The arrow shows the direction of the flow.*

In total 25 different stream combinations around the transect stream points existed, the combinations could be found in appendix B. Mean values from the pixels on the left and right side of the stream, L and R, were used to calculate the terrain index values for the statistical correlations. When assigning grid values to the 3x3 points window the nearest neighbourhood interpolation method was used. For the indices with ending _Acc (CA_MTF_Acc and SAGA_CA_Acc) values were calculated as the mean of the three stream pixel values, i.e. (S1+S2+S3)/3. These values represent the total accumulated catchment area for each stream pixel.

## 2.4. Group classification

Since the transect sites were spread in the catchment the sites were divided into more homogeneous subgroups to see if differences in the correlations occurred. The sites were divided into three main groups named Stream group, Soil group and Stream Order group. Each main group contained several subgroups.

### 2.4.1. Stream group

The Stream group contained 16 subgroups named with capital letters from A to P. The subgroups were defined by looking at the location of the sites on the map. Sites belonging to a certain stream branch were directed into the same subgroup. In areas with sparse sampling several branches were consolidated since the stream branches alone had too few sites along them to be able to perform statistical analyses on. Site distributions in the subgroups are shown in Figure 11 and the location of the 16 subgroup areas are illustrated in Figure 12.

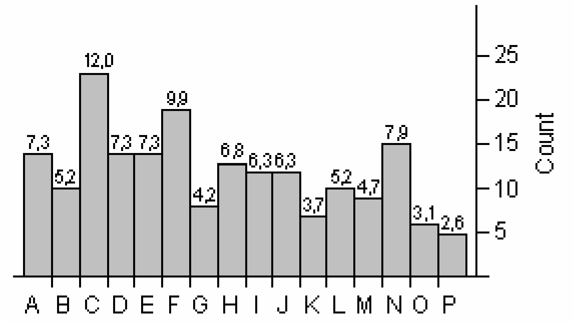



Figure 11. *Site distribution for respective Stream subgroup. Numbers on the bars were percentage share for the subgroups.*

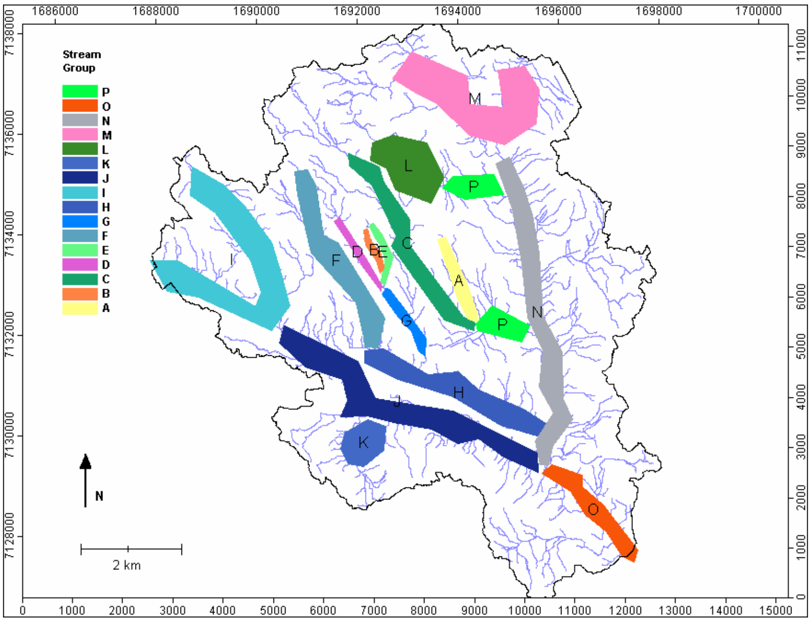



Figure 12. *Location of the Stream subgroups.*

## 2.4.2. Soil group

In the Soil group the sites were grouped into sedimentary or non-sedimentary sites. This was done in the GIS programme by overlaying the position layer of the stream points with a simplified soil map (1:100 000) (Swedish Geological Survey, SGU, Uppsala, Sweden). A clear separation of moraine and glaciofluvial material caused by the location of the highest coastline can be seen in Figure 13. The corresponding soil id name from the SGU soilmap to the transect sites is seen in the legend. Sites with soil identification silt or alluvium/glaciofluvial deposits were defined as sedimentary sites. The sedimentary subgroup was named Sed and the non-sedimentary subgroup, also referred to as the moraine part of the catchment, was named Till. Distribution of the sites in the sediment subgroups is seen in Figure 14.

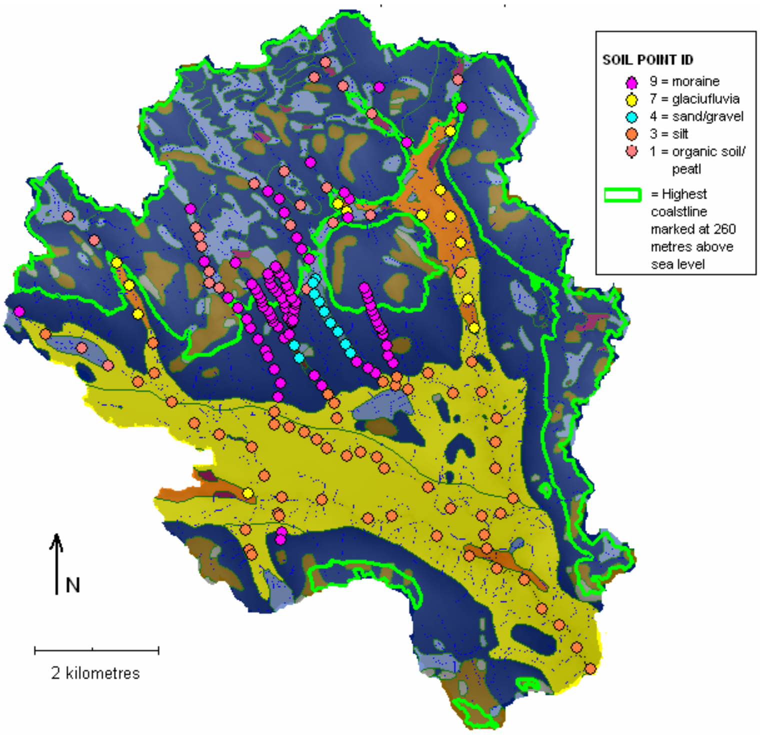



Figure 13. *Highest coastline and soil definition for the transect sites.*

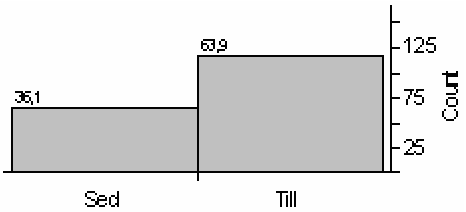



Figure 14. *Site distribution for the Soil subgroups. Numbers on the bars were percentage share for the subgroups.*

## 2.4.3. Stream Order group

Stream order divides the small headwater streams from the larger streams further down in the system, headwater streams were of first order. When two headwater streams meet they form a second order stream, when two second order streams meet they form a stream of third order and so on (Figure 15). The hydrological algorithm is often referred to as Strahler Stream order, named after Arthur Strahler who introduced the concept in 1952 (Strahler 1952).

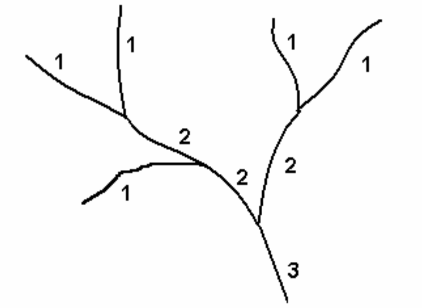



Figure 15. *Strahler Stream order relationship.*

The stream order definition for Krycklan catchment area was made by looking at the DEM, the topographic map (21J Vindeln NO) and interpretations of the stream order done by Ågren 2007. Only taking the order values from the GIS programme would give too high values for the stream order because of a high amount of small streams derived from the DEM. There were uncertain if these smaller streams were filled with water and had flow all the time. Stream points in the sedimentary part were of order 1 to 4, and were named S1 to S4. Stream points in the moraine part were of order 1 and 2 and were named T1 and T2. Distribution of the sites in the Stream order subgroups is seen in Figure 16 and location for the sites of different stream order is seen in Figure 17.

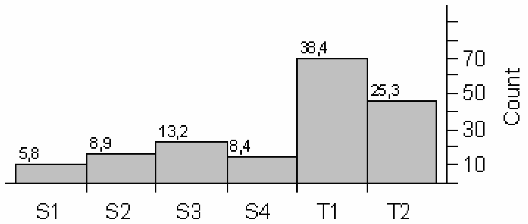



Figure 16. *Distribution of the sites in the stream order subgroups. Numbers on the bars were percentage share for the subgroups.*

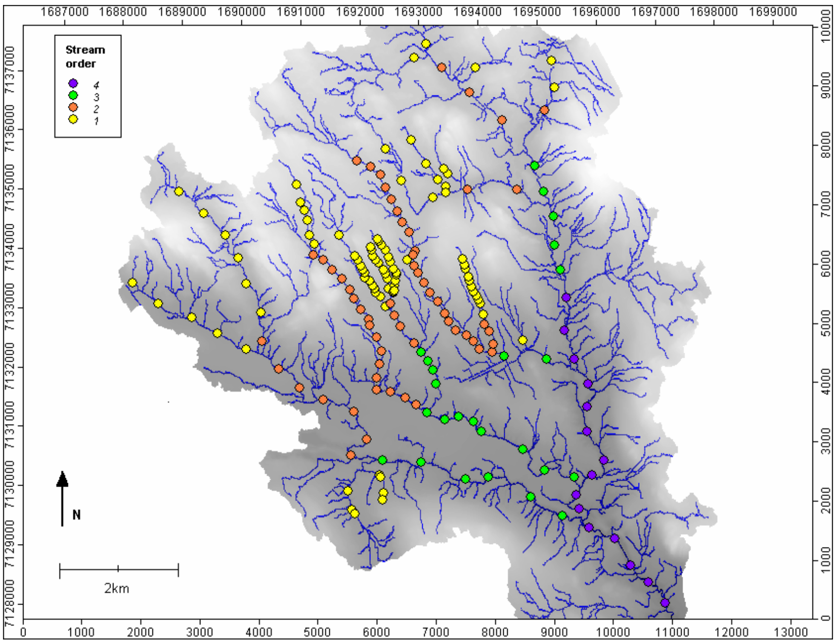



Figure 17. *Stream order for the transect sites in Kryklan catchment area.*

## 2.5. Statistical analyses

The statistical analyses were done in EXCEL and JMP. Mean and median values of the soil indices were displayed with box plot diagrams. Figure 18 shows an explanation of the box plot diagrams.

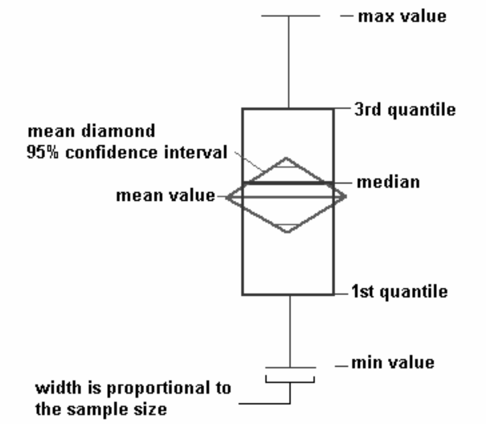



Figure 18. *Explanation of the box plot diagrams.*

Often the median value gives a more true vision of the actual middle point among values since outliers have less weight compared to their weight when calculating mean values. The significances calculated for the soil indices were tested in JMP with the nonparametric Wilcoxon rank test. If not specifically noted the significance level was set to a 95% confidence interval. Wilcoxon was used since the distributions for the soil indices were not normal distributed in most of the cases.

The terrain indices were calculated as mean values of the pixels at left respective right side of the stream, as mentioned previously. Pairwise Pearson product-moment correlations of the soil indices and terrain indices were computed in JMP. The correlation coefficient, r in Pearson product-moment correlation measures the strength of the linear relationship between two variables, x and y, formula 3. Perfectly linear relationships have r-values of -1 or 1.

*Pearson Product-Moment Correlation coefficient*:

$$r = \frac{\sum(x-\bar{x})\cdot(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2}\cdot\sqrt{\sum(y-\bar{y})^2}} \quad (3)$$

For all subgroups and indices the number of significant positive or negative r-values was counted. Maximum significance score for the soil subgroups were 13, since there were 13 different terrain indices and maximum significance score for the terrain indices were 25 since there exists 24 soil subgroups plus one group with all sites included, the All point group.

# 3. RESULTS

## 3.1. Vegetation Index

The distribution of forest vegetation among the soil are shown in Figure 19, a short bar means a small share of the tree specie.

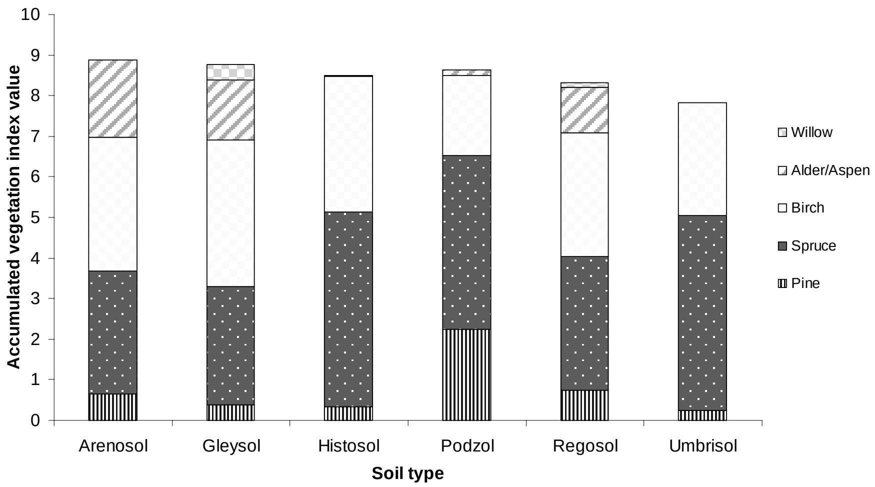



Figure 19. *Forest vegetation index for the different soils.*

Arenosol, gleysol and regosol were similar in tree specie composition. Histosol and umbrisol had the highest forest vegetation index of spruce while podzol had the highest value of pine trees.

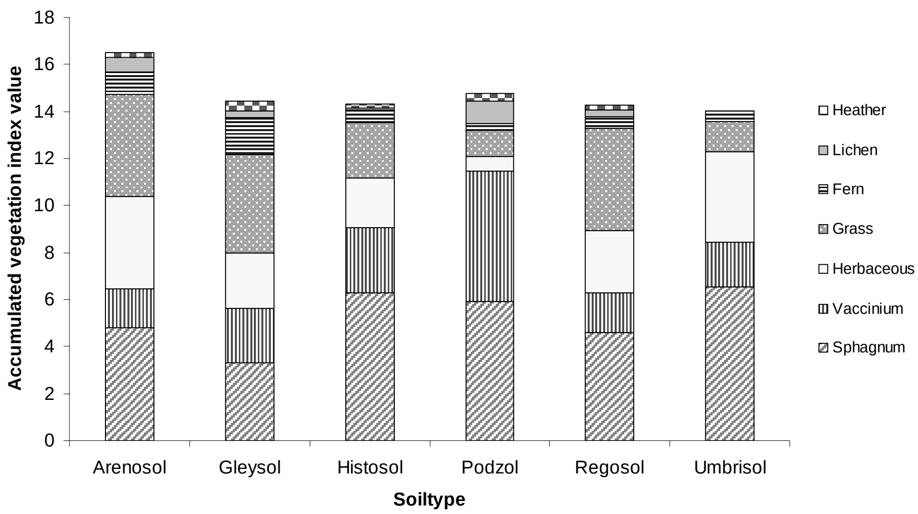



Figure 20. *Ground vegetation index for the different soils.*

Podzol had the highest ground vegetation index value of vaccinium and lichen and gleysol had the highest value of fern. Umbrisol and arenosol had similar vegetation index of herbaceous and arenosol, gleysol and regosol had similar index values of grass. Sphagnum existed in all soils with highest ranks for the organic soils histosol and umbrisol (Figure 20).

## 3.2. Soil index

Organic soil measurement reached the maximum soil core length for 5% of all investigated points. The dominant soil type for all sampling points in the catchment was histosol (62%) followed by regosol (18%) and podzol (15%), (Figure 21).

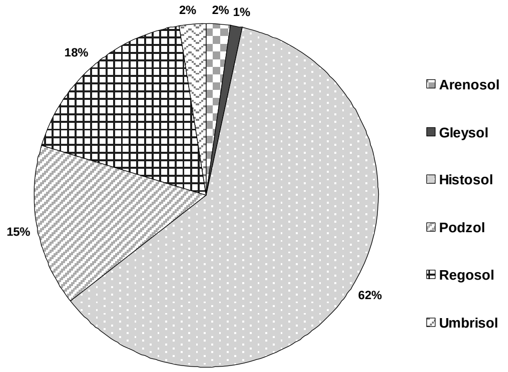



Figure 21. *Classification of the soils calculated as a percentage, based on all sampling points.*

Dominant soils along the transects and its respective distance from stream showed a clear trend of high percentage of the organic soils near the stream and less more distant to the stream (Figure 22 and 23). The opposite case applies for podzol with small percentage share closer to the stream and larger share further away from the stream.

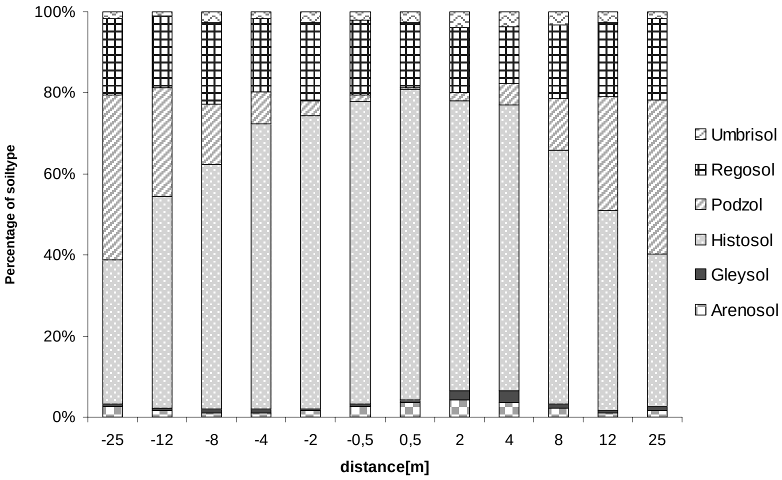



Figure 22. *Average percentage of the specified soils at the different sampling distances along all transects.*

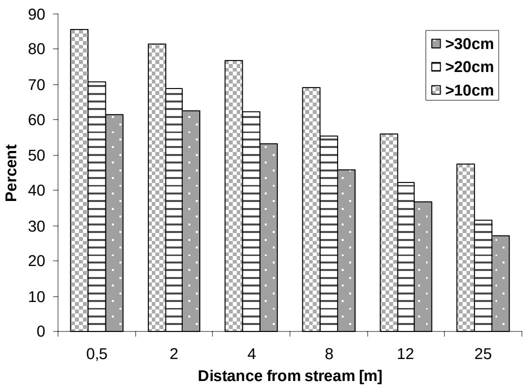



Figure 23. *Percentages of Organic soil horizons, deeper than 10 cm, 20 cm and 30 cm, at different distances from the stream.*

Stream groups A, B, D and E were relatively close and similar in size to each other (Figure 24), but the variation among the groups were considerable (Figure 25). Even along one stream reach there were large variations among transects (Figure 26).

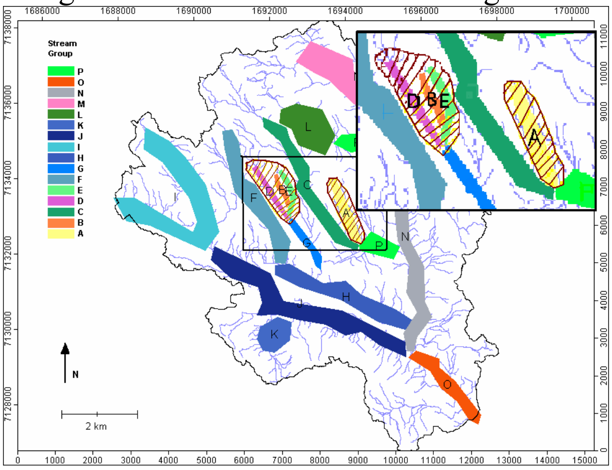



Figure 24. *Location in the catchment of the four stream groups A, B, D and E.*

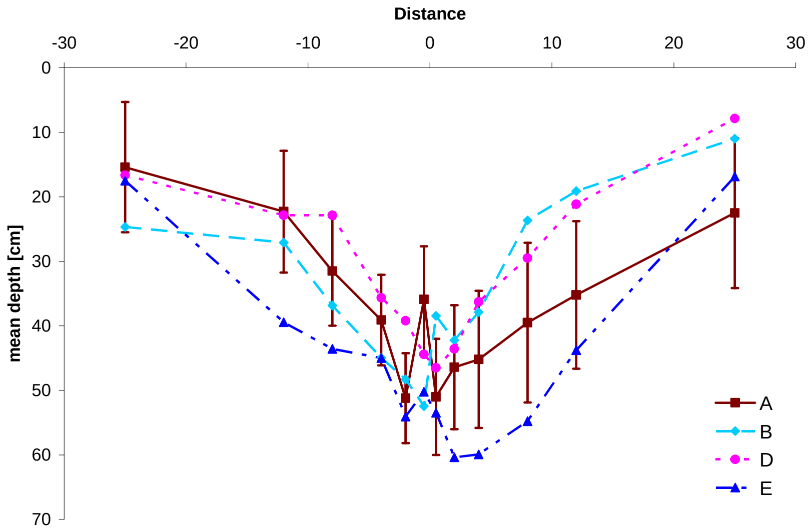



Figure 25. *Mean organic soil horizon depth for the stream groups A, B, D and E.*

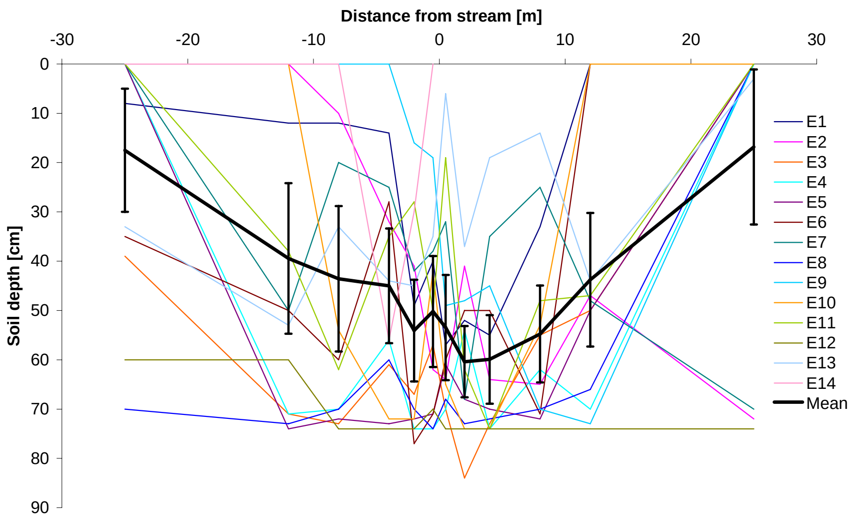



Figure 26. *Organic soil horizon depths along the transects in one stream reach, stream group E. The black line shows the mean value for the group with standard deviation bars.*

Figures 27-28 show the organic soil horizon depth along transects in the Till and Sed groups, data for the figures are found in appendix C. For both mean and median values, the trend was a lower organic depth further away from the stream. Mean and median depths were much smaller in the Sed group than in the Till group, in the Till group the values range from zero to 100 cm depth at almost all the distances from the stream, while in the Sed group the values were more gathered. The distribution was skewed i.e. the median and mean value differs, mostly towards lower depth values for the medians than for the mean values. This was clearly seen for the 25 m distances in the Till group and for all distances in the Sed group.

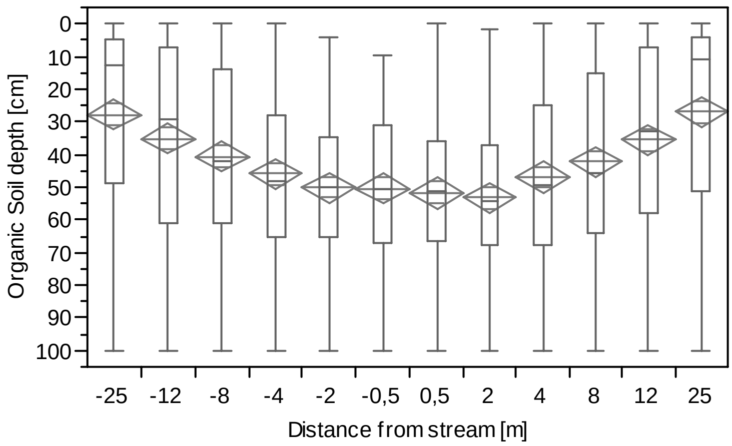



Figure 27. *Analysis of organic soil horizon depth along the transects in Till group.*

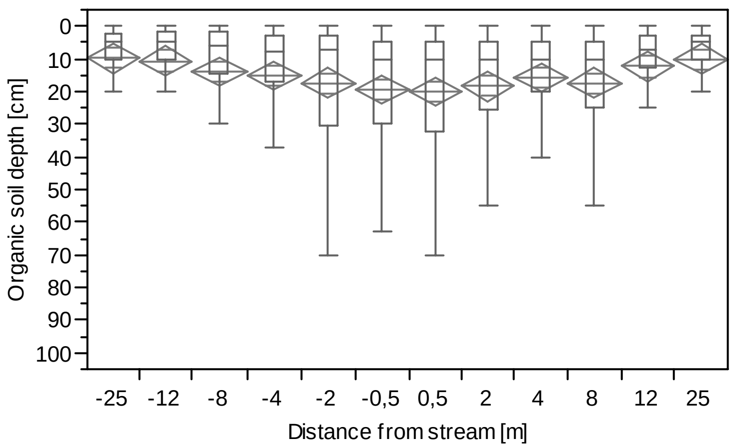



Figure 28. *Analysis of organic soil horizon depth along the transects in the Sed group.*

The data was tested for normality which gave that only the distances 2 m from the stream was normal distributed. Mean values for each sampling distance from the stream point, i.e. 0.5 m, 2 m, 4 m etc. in the Till and Sed group was individually compared for each pair using the nonparametric Wilcoxon rank-sum test in JMP (Table 1 and 2). The shaded squares show which sampling distances that were significantly different from each other at a 95% confidence interval. Distances on the left side from the stream point were marked with a minus (–) sign. Confidence intervals for the means for the distances were illustrated by the mean diamonds in Figure 27 and 28.

Table1. Comparisons of the mean depth of organic soil horizons between the sampling distances along the transects in the sediment subgroup Till.

| | -25 | -12 | -8 | -4 | -2 | -0.5 | 0.5 | 2 | 4 | 8 | 12 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -25 | | x | x | x | x | x | x | x | x | x | x | |
| -12 | | | | x | x | x | x | x | x | | | |
| -8 | | | | | x | x | x | x | | | | |
| -4 | | | | | | | | x | | | x | x |
| -2 | | | | | | | | | | x | x | x |
| -0.5 | | | | | | | | | | x | x | x |
| 0.5 | | | | | | | | | | x | x | x |
| 2 | | | | | | | | | | x | x | x |
| 4 | | | | | | | | | | | x | x |
| 8 | | | | | | | | | | | x | x |
| 12 | | | | | | | | | | | | x |
| 25 | | | | | | | | | | | | |

x = Significantly different at 95% confidence interval

Table 2. Comparisons of the mean depth of organic soil horizons between the sampling distances along the transects in the sediment subgroup Sed.

| | -25 | -12 | -8 | -4 | -2 | -0.5 | 0.5 | 2 | 4 | 8 | 12 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -25 | | | | | x | x | x | x | x | x | | |
| -12 | | | | | x | x | x | x | x | x | | |
| -8 | | | | | | | | x | | | | |
| -4 | | | | | | | | | | | | |
| -2 | | | | | | | | | | | | x |
| -0.5 | | | | | | | | | | | | x |
| 0.5 | | | | | | | | | | | | x |
| 2 | | | | | | | | | | | x | x |
| 4 | | | | | | | | | | | | x |
| 8 | | | | | | | | | | | | x |
| 12 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |

x = Significantly different at 95% confidence interval

### 3.2.1. Soil index correlations

Correlations between the soil indices Distance30, Depth4 and CArea are shown in Table 3. Strong correlations between the Depth4 indices and CArea indices were apparent for all subgroups except for the stream subgroups N and O. For Distance30 indices versus Depth4 indices, significances were found in all subgroups except for subgroups J, L, N, O and S4. Correlations between Distance30 indices and CArea indices were significantly for all subgroups except for the subgroups H, J, N, O, S2 and S4.

Table 3. r-values from pair-wise Pearson product-moment correlations between soil indices.

| subgroup | Depth4/CArea | Distance30/Depth4 | Distance30/CArea |
|---|---|---|---|
| All points | 0.85* | 0.80* | 0.92* |
| Sed | 0.82* | 0.85* | 0.90* |
| Till | 0.79* | 0.66* | 0.89* |
| A | 0.56* | 0.43* | 0.81* |
| B | 0.73* | 0.65* | 0.97* |
| C | 0.68* | 0.60* | 0.94* |
| D | 0.61* | 0.56* | 0.95* |
| E | 0.68* | 0.49* | 0.92* |
| F | 0.80* | 0.75* | 0.95* |
| G | 0.88* | 0.91* | 0.97* |
| H | 0.66* | 0.83* | 0.35* |
| I | 0.88* | 0.92* | 0.95* |
| J | 0.53* | . | . |
| K | 0.89* | 0.90* | 0.97* |
| L | 0.65* | 0.26* | 0.85* |
| M | 0.85* | 0.81* | 0.84* |
| N | 0.27 | . | . |
| O | 0.36 | . | . |
| P | 0.95* | 0.97* | 0.97* |
| S1 | 0.86* | 0.90* | 0.94* |
| S2 | 0.63* | 0.86* | 0.34* |
| S3 | 0.50* | 0.78* | 0.31* |
| S4 | 0.36* | . | . |
| T1 | 0.76* | 0.59* | 0.90* |
| T2 | 0.83* | 0.75* | 0.87* |

* = Values correlated at 95% confidence level.

For all created soil indices (Distance30, Depth4 and CArea) significant differences could be seen between points in the sedimentary (Sed) part and moraine (Till) part of the catchment. Since there were so large differences between sites belonging to the moraine or sedimentary part the sampling points in each area were analysed separately and the stream groups were divided into two subgroups called StreamSed group (stream subgroups G, H, J, K, N, O and P) and StreamTill group (stream subgroups A, B, C, D, E, F, I, L and M). The results of the soil indices are shown as box plot diagrams for the different subgroups; Distance30 can be seen in Figure 29-30, Depth4 results Figure 31-32 and CArea results in figure 33-34. Statistic numbers to the figures (median, 1$^{st}$ and 3$^{rd}$ quartiles, max value, min value, mean, standard deviation, upper and lower 95% confidence interval of the mean and number of records (i.e. transects) in respective sub group) are tabulated in appendix D.

## 3.2.2. Distance30 index results

Distance30 was the index defining the distance from the stream point where the organic soil depth became less than 30 cm deep.

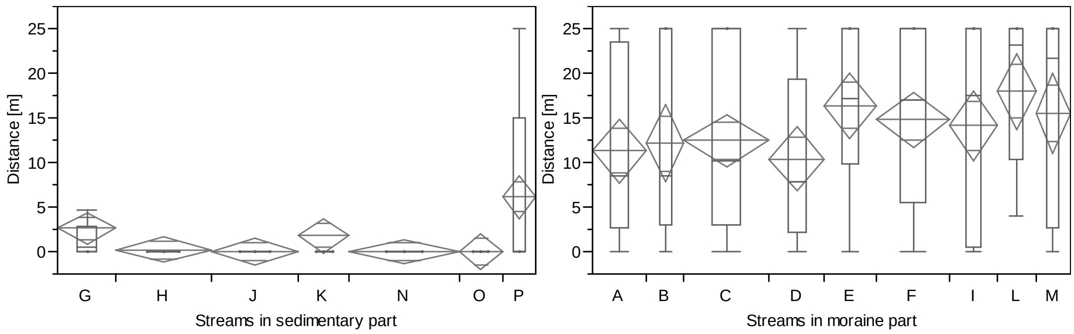



Figure 29. *Box plot diagram of Distance30 soil index, distance from the stream with an organic depth less than 30 cm. Results by stream subgroups in the sedimentary and moraine part of the catchment.*

In the StreamSed group mean Distance30 value for subgroups G(2.6 m) and P(6.1 m) was significantly different from H, J, N and O(0-0.2 m) but not from each other. The mean value for subgroup K was significantly different from N. All Stream subgroups in the sedimentary part except G which had the median 0.5m had a zero median. In the StreamTill group the subgroups had more organic soil close to the stream points and a higher variability of the Distance30 index values. Mean values were quite similar in the StreamTill group, only the subgroups E and L have significantly different mean values, E was significantly different from D. Subgroup L differed significantly from A, C and D. The mean values in the StreamTill group ranged from 10 m in stream subgroup D to 18 m in subgroup L and the median from 8.5 m for stream subgroup A and B to 23 m for subgroup M.

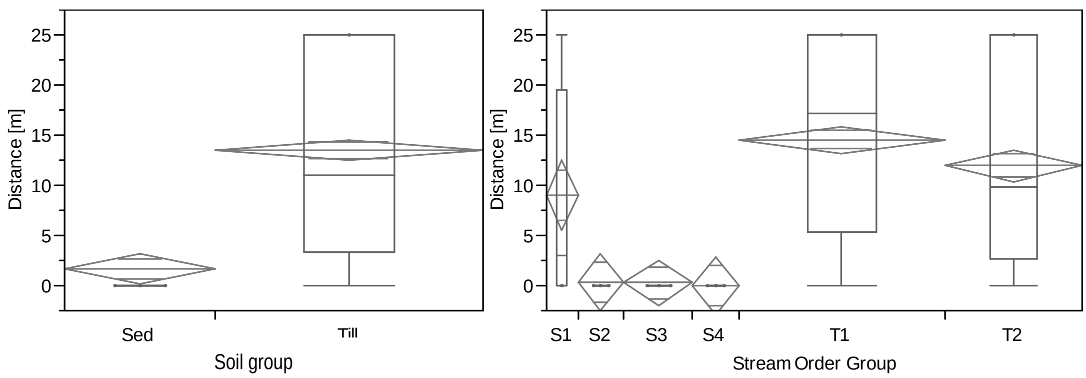



Figure 30. *Box plot diagram of Distance30 soil index, distance from the stream with an organic depth less than 30 cm. Results by Soil group and Stream Order group.*

There was a significant difference between points in the sedimentary (Sed) and moraine (Till) part of the catchment. There were also differences among the stream orders where the headwater streams had generally a greater extent of adjacent organic soils more than 30 cm deep than higher stream orders. For S1 (headwater stream in the sedimentary part) and T1 (headwater stream in the moraine part) the Distance30 index was significantly different at a 95% confidence level from all higher orders. Between S1 and T2 was the difference significant in a 90% confidence interval.

### 3.2.3. Depth4 index results

Depth4 index was the mean value of organic soil depth from the first three sampling points reaching four metres from the stream point.

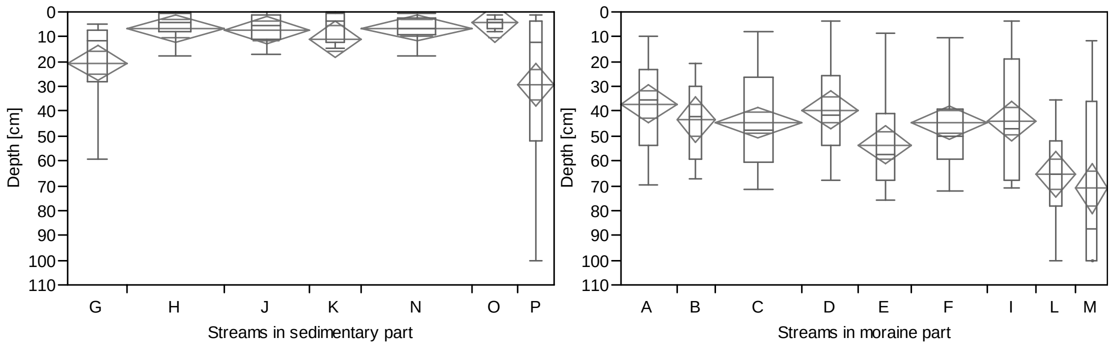



Figure 31. *Box plot diagram of Depth4 soil index, mean organic soil depth of the three sampling points nearest to the stream point. Results by stream subgroups in the sedimentary and moraine part of the catchment.*

Organic soil depths were generally shallow in the StreamSed group. Depth4 index mean values ranged from 5 cm in stream subgroup O to 31.5 cm in stream subgroup P and median from 2 cm for stream subgroup K to 29.5cm for subgroup P. Subgroups G and P were significantly different from the subgroups H, J, K, N and O. The differences between J, K, N and P were significant at a 90% confidence interval and the others at a 95% confidence interval. In StreamTill group mean values for the Depth4 index ranged from 37 cm in subgroup A to 81 cm in subgroup M, their respective median were 35 cm and 100 cm. Stream subgroups M and L had a significantly different mean values compared with the other stream subgroups but not between them. Mean value for subgroup E was significantly different to stream subgroups A, B, C and D.

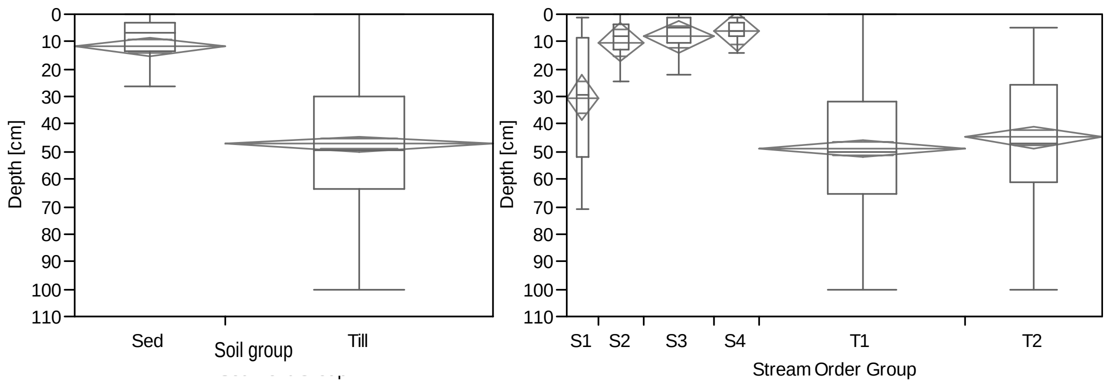



Figure 32. *Box plot diagram of Depth4 soil index, mean organic soil depth of the three sampling points nearest to the stream point. Results by Soil group and Stream Order group.*

The Depth4 indices were significantly different in the sedimentary area compared to the moraine area (Sed mean 11.8 cm and Till mean 47.2 cm). There were differences between the headwaters (T1 in the moraine part and S1 in the sedimentary part) and higher stream orders, these differences were significant for stream order subgroup S1 and higher orders but not for T1 compared with T2.

### 3.2.4. CArea index result

CArea soil index were defined as the total cross-sectional area of organic soil along the transect. The patterns for the CArea indices were similar to those of the soil index Depth4.

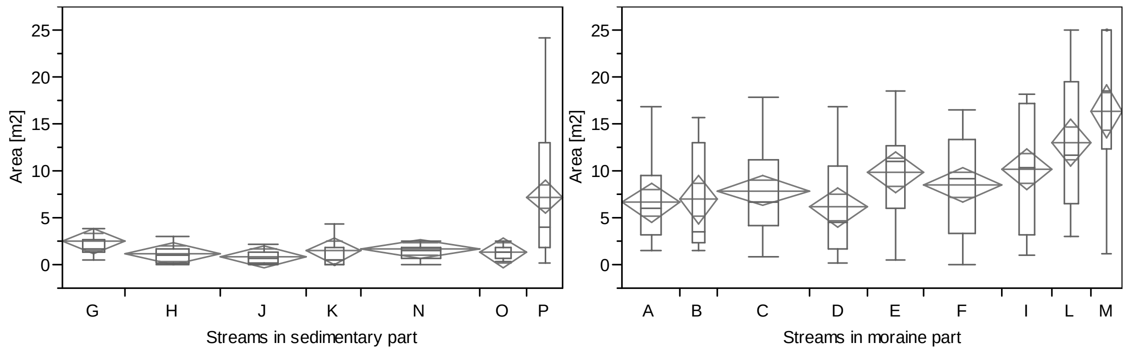



Figure 33. *Box plot diagram of CArea soil index, cross-sectional area of organic soil along the transects. Results by stream subgroups in the sedimentary and moraine part of the catchment.*

CArea indices of stream subgroup P were significantly different from the other subgroups in StreamSed group. (Between P and G at a 90% confidence interval, between P and the others at a 95% confidence interval). Subgroup G was significantly different from H, J and K at 95% and from N, O and P at 90% confidence interval. Mean CArea index in the StreamSed group varied between 1 $m^2$ in subgroup J to 6 $m^2$ in subgroup P and medians from 0.1 $m^2$ in subgroup K to 2.6 $m^2$ in subgroup P. In the StreamTill group CArea index for stream subgroup M was significantly different from the other subgroups except from subgroup L. Significant differences were also noted for L against B, C, D and F, I against D, F against A and E against D. The mean and median values in StreamTill group ranged from 6 $m^2$ (subgroup D) to 18 $m^2$ (subgroup M) respective 3.5 $m^2$ (subgroup B) to 18.5 $m^2$ (subgroup M).

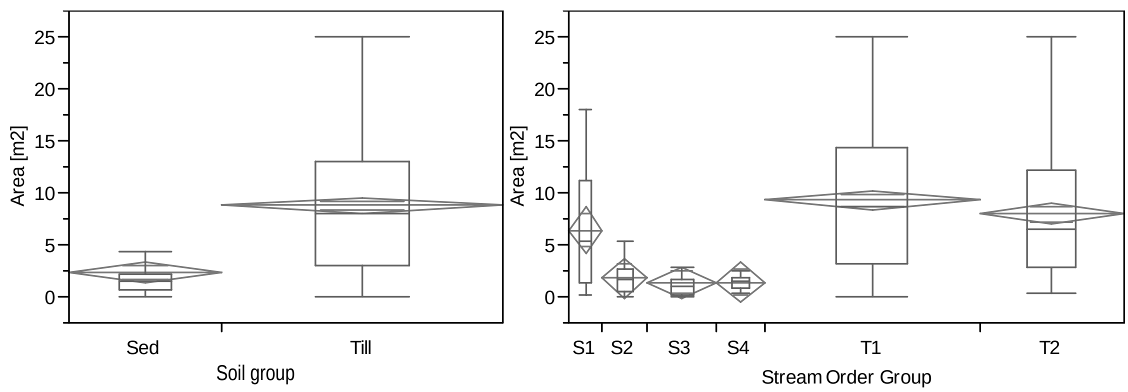



Figure 34. *Box plot diagram of CArea soil index, cross-sectional area of organic soil along the transects. Results by Soil group and Stream Order group.*

There were significant differences between sedimentary (8.8 $m^2$) and non-sedimentary (2.3 $m^2$) CArea indices. In the Stream Order group CArea index for subgroup S1 were significantly different from higher orders in the sedimentary area. Subgroup T1 in the moraine area was not significantly different from higher orders in the same area.

## 3.3. Terrain indices

After missing values were removed, correlations between the created soil indices (Distance30, Depth4 and CArea) and the terrain indices were calculated. A test on outliers showed that these not affected the result notably so all points were considered in the calculations. Correlation r-values and their level of significance for the three subgroups with highest number of points (i.e. All points, Sed and Till) and the Stream Order subgroups are shown in Figures 36-41. Corresponding correlation values to the bars and the r-values for all sub groups are shown in appendix E.

The maximum summarized significance score a soil index could get was 325 (13 terrain indices x 25 subgroups). The highest significance score 90 was found for the CArea followed by Depth4 with score 75 and Distance30 with a score of 70. For the terrain indices, shown in Figure 35, the maximum summarized score was 75 (3 soil indices x 25 subgroups). The terrain index with the highest summarized significance score were EASea (39), Slope (31), TWI (26) and Curvature (25). Maximum significance score for the subgroups were 39 (13 terrain indices x 3 soil indices). Stream group F was the subgroup with the highest summarized score of 21 followed by stream group C with 17 and stream Group M with a score of 13. Tables with the summarized significance scores are shown in appendix F.

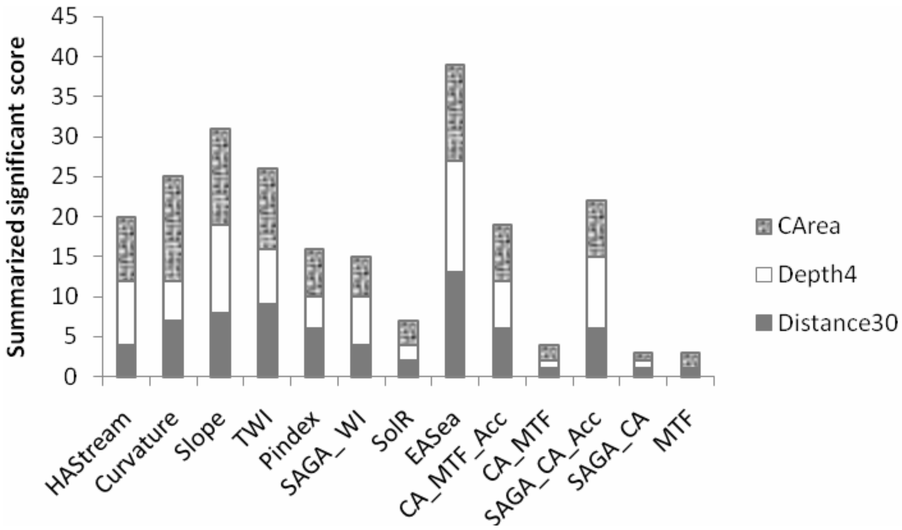



Figure 35. *Summarized significant scores for the terrain indices.*

### 3.3.1. Soil index Distance30 versus terrain indices

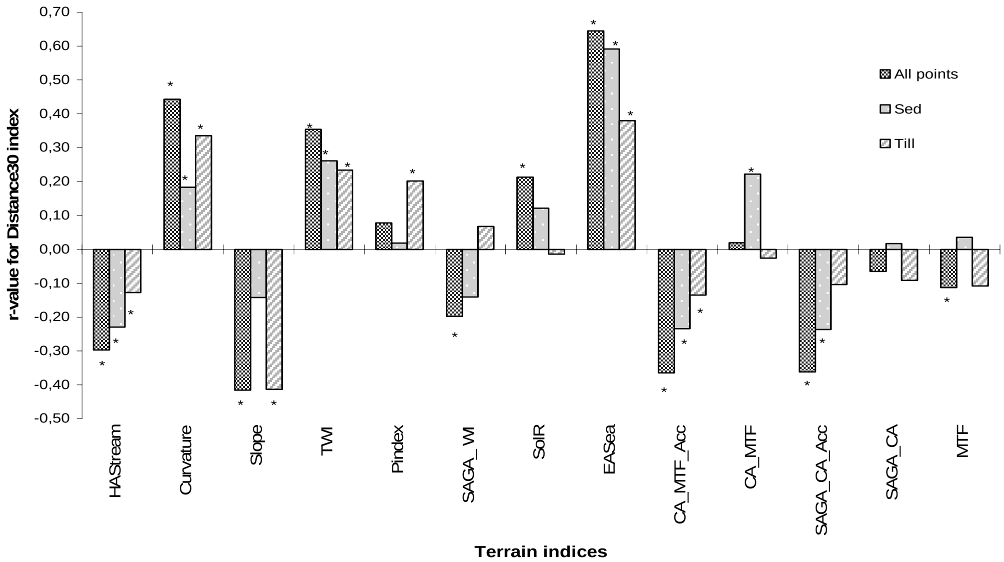



Figure 36. *R-values for correlations between the soil index Distance30 and the terrain indices by the subgroups All points, Sed and Till. Bars marked with a * was significant in a 90% confidence interval.*

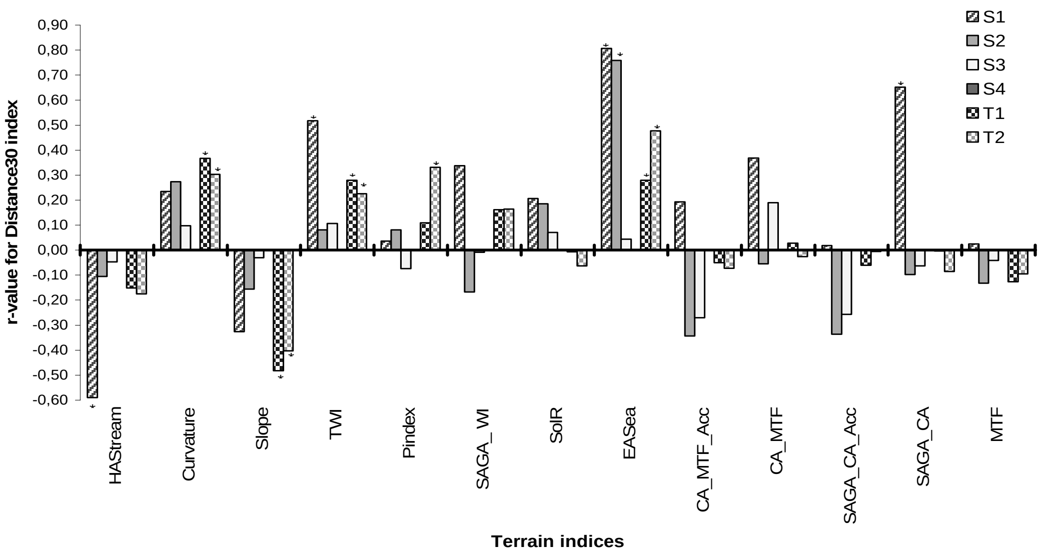



Figure 37. *R-values for correlations between the soil index Distance30 and the terrain indices by the Stream Order group. Bars marked with a * was significant in a 90% confidence interval.*

The highest r-value of 0.81 for the correlation between Distance30 index and the terrain indices was found for the correlation between stream order 1 (S1) in the sedimentary part and elevation above sea level (EASea) second highest correlation had subgroup K (r=0.80) and third r-value had S2 (r=0.76) both correlated with EASea. Highest significance score of 10 had the All point subgroup followed by Sed with a score of 8. The subgroups Till, C and F had all a significance score of 7. Highest scores among the terrain indices were counted for EASea, TWI and Slope.

## 3.3.2. Soil index Depth4 versus terrain indices

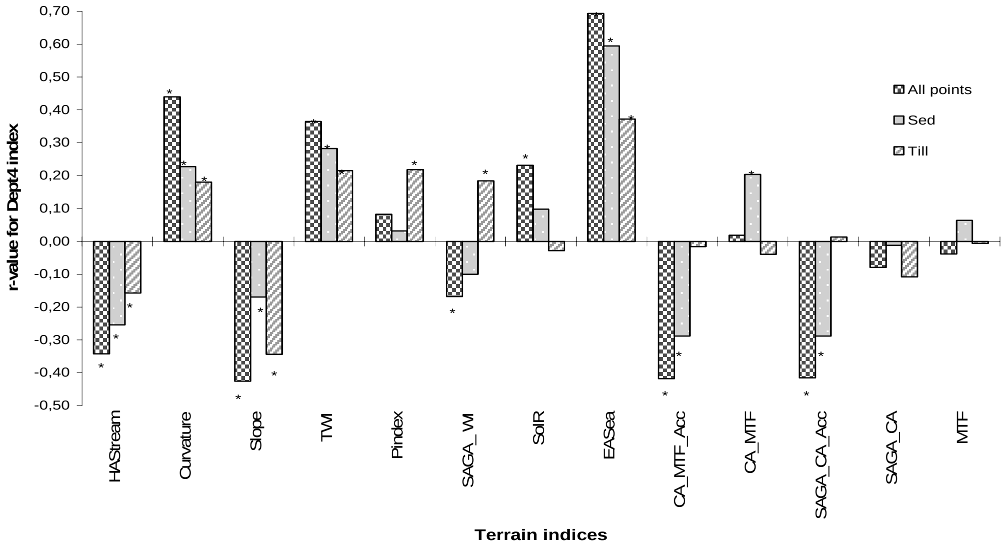



Figure 38. *R-values for correlations between the soil index Depth4 and the terrain indices by the subgroups All points, Sed and Till. Bars marked with a * was significant in a 90% confidence interval.*

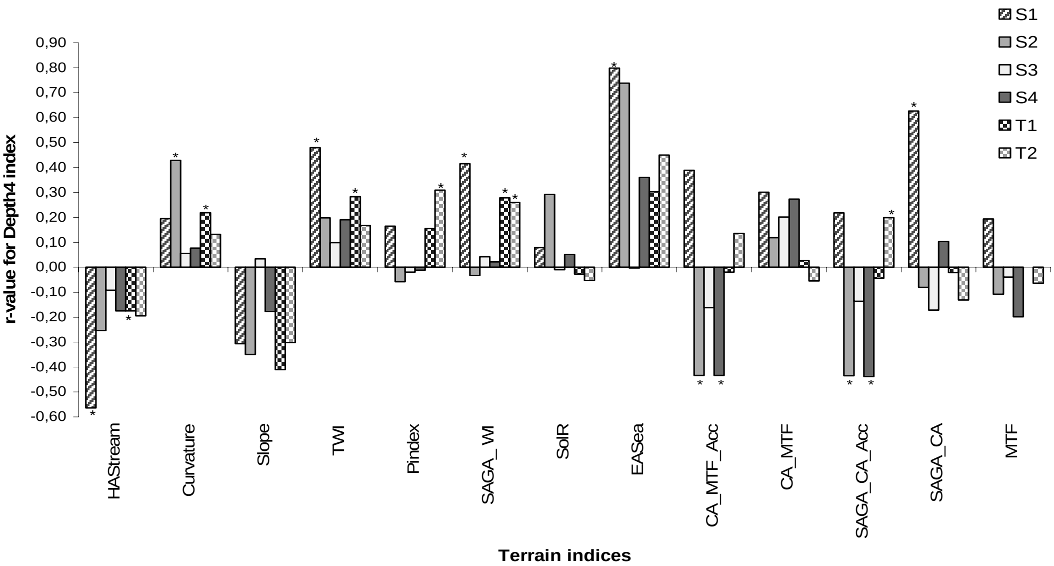



Figure 39. *R-values for correlations between the soil index Depth4 and the terrain indices by the Stream Order group. Bars marked with a * was significant in a 90% confidence interval.*

The highest r-values for the Depth4 index were found by correlation between the terrain index EASea and the subgroups K (r=0.84), S1 (r=0.80) and P (r=0.75). The subgroups with the highest significance scores were All points (9), Sed (9), Till (7) and F (6). The highest scores among the terrain indices were EASea (14), Slope (11) and SAGA_CA_Acc (9). EASea had the highest number of r-values larger than 0.5.

### 3.3.4. Soil index CArea versus terrain indices

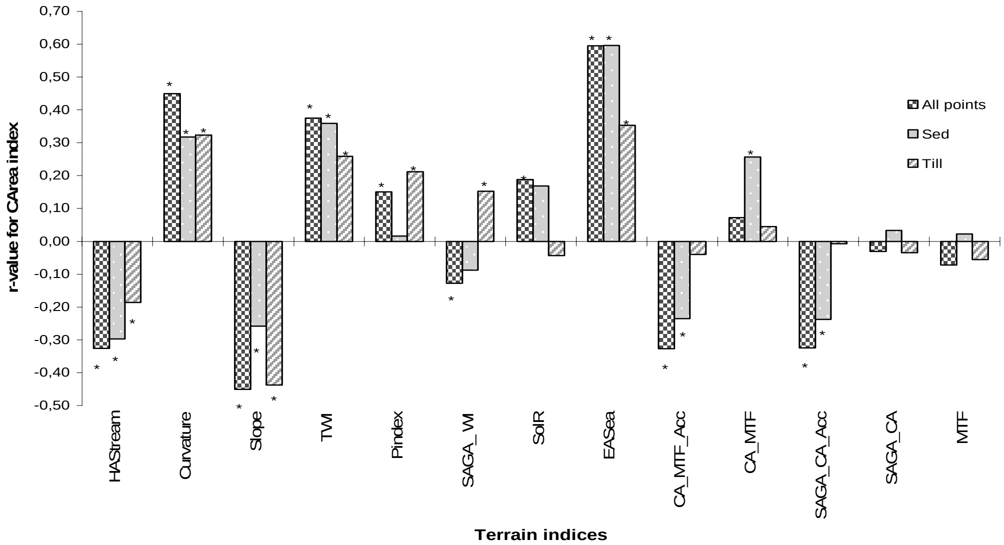



Figure 40. *R-values for correlations between the soil index CArea and the terrain indices by the subgroups All points, Sed and Till. Bars marked with a * was significant in a 90% confidence interval.*

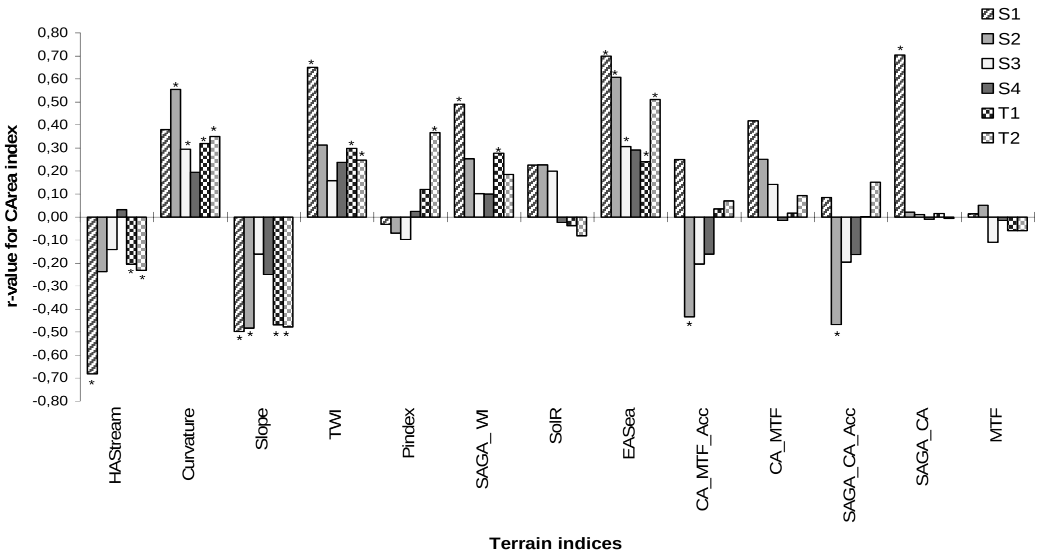



Figure 41. *R-values for correlations between the soil index CArea and the terrain indices by the Stream Order group. Bars marked with a * was significant in a 90% confidence interval.*

The highest r-values for CArea were found by correlation between EASea and K (r=0.81), F (r=0.77) and S1 by EASea and SAGA_CA (both index with r=0.70). The subgroups with highest scores were All points (10) and Sed (9) and F (8). The terrain indices with highest significance scores were Curvature (13), Slope and EASea (both with a score of 12). Although Curvature had the highest significance score EASea and Slope had the highest number of r-values above 0.5 (7 respective 4).

# 4. DISCUSSION

In this study the vegetation results showed that Pine and Vaccinium were species that had higher rank values for podzol than for the other soils. Vaccinium likes to grow on chalk deficient grounds, sandy soils and soils with low pH. Pine trees grow on dry sandy-soil, characteristics that fit in with podzols (Anderberg, 1998). Spruce was the dominant tree specie for the organic soil Histosol. Histosol was the most common soil type of all the measured points, dominating in 61% of the sampling sites, probably due to the location of the sampling sites with more dense sampling points closer to the stream where there was more organic soil. Another reason was that there were nearly twice as many points sampled in the moraine part than in the sedimentary part of the catchment. The Histosols were more abundant close to the streams than further away where Podzol was the most common soil type, probably due to the hydrological pathways that are important to soil formation. Significant differences between points in the sediment part and the moraine part of the catchment were probably due to the different water flow paths. Soils in the moraine part are shallower and more humid at the surfaces which are good conditions for developing organic soil. The number of soil profiles classified as Histosols might have been overestimated, while the depth limit used in this study for a soil profile to be classified as a Histosol, soils with an organic soil horizon thicker than 10cm, was set rather low. A great variability of organic soil depths was found in individual transects and when looking at transects in the same stream reach. This could be due to natural variability, and/or errors in measuring the organic soil depth. The general organic soil pattern for the profiles showed nevertheless that organic horizons were clearly thicker near the stream than further away. This pattern was more pronounced for the till soil that showed a sharper change in organic soil thickness than the sedimentary soil. There were a higher number of significantly differences of organic soil depth between the sampling distances in the Till group than in the Sedimentary group. The similarity in the Sedimentary group is due to the low amount of organic soil further away from the streams. Many points had no organic soil horizons at all.

Soil indices Depth4 and CArea were calculated in a similar way and showed strongest correlation between each other. The other indices had also rather strong correlations except for the larger streams N and O and the stream group J that had zero correlation. This could be due to few outspread sites in group J and differences in the channel morphology for N and O. Significant differences between Sed and Till group were found for all soil indices. Correlations between stream groups and soil indices gave similar patterns for all indices. Streams G and P were significantly different from streams H, J, N and O and clearly different from the other in the sedimentary part. One explanation is that stream G and P were situated higher up in the catchment than the other streams. For streams in the moraine part of the catchment stream group M and L were significantly different from most of the other groups. These were also situated higher up in the catchment with mostly small stream reaches, and smaller streams in this study had more organic soil in their transect. The data were most spread in the stream groups, with wide quartile boxes, for the Distance30 index. Index CArea had most variation between the stream groups. All soil indices showed differences with stream order where headwater streams had the highest values. The differences between the orders were more pronounced on the sedimentary soils than in the till soils. The stream order difference was significant for all soil indices in the sedimentary part of the catchment at a 95% confidence interval, while the only significant index for the moraine part was the Distance30 index at a 90% confidence interval. Why there is less organic soil in the sedimentary part than the moraine part is a combination of several factors. One is that the environment for developing organic soil is more favourable in the moraine part which contains more wetlands, mires and more mosses in the ground vegetation that keeps the soil humid. The slopes in the vicinity of the streams in the moraine part of the catchment are not so steep and the water table lies closer to the surface than it does in the sedimentary part. The streams in the sedimentary part are wider and deeper, many of them situated at the bottom of a steep ravine. The areas close to the streams in the sedimentary part are flooded periodically after the spring-flood and after heavy rains that raises the water level and periodically the soil is very dry when there is low flow in the streams and the ground water table is low. These flood plain areas are covered by more grassy vegetation compared to mosses in the moraine part.

In the subgroups that contained most points (i.e. All point group, Soil group and Till group) for all three soil indices correlation with the terrain index EASea gave the highest r-values followed by the terrain indices Curvature and Slope. The correlation patterns for the largest subgroups seen in the column diagrams, Figure 36, 38 and 40, were similar for all three soil indices. The patterns for the diagrams of the Stream Order subgroups, Figure 37, 39 and 41, were more complex, for example subgroup S2s correlation with SAGA_WI index was positively correlated with the CArea index but negatively correlated with Depth4 and Distance30 indices. Sites in the sedimentary part generally had stronger correlations (higher r-values) than points in the moraine part. Stream order 1 in the sedimentary part was the subgroup with the strongest correlations for all compared soil indices. The correlations between the terrain indices derived from the DEM and the organic soil indices were not strong enough to predict the organic soil. The sedimentary part contained fewer points than the till part and the terrain indices were correlated more strongly in the sedimentary part suggesting that the local terrain seemed to have stronger influences on the organic soil in the sedimentary area than in the till area.

The transect coordinates were measured with a GPS in field, with an accuracy ranging from 2 to 19 metres. When locating the stream sites in the GIS program, the study transects had to be moved from their GPS coordinates to the nearest stream pixel. The inbuilt uncertainty of the GPS coordinates and moving of the points leads to uncertainties if the terrain indices were linked to the right sampling site in nature. The GIS programme gave several choices of methods for calculation of the terrain indices which could affect the correlation results. In this study only one method was tested for each terrain index.

Uncertainties exist in the field data. The measurements and definitions of the soil type might sometimes be uncertain since not all field assistants had prior experience with soil classification methods. Different soil coring tubes were used during different field seasons. The soil coring tube reached 74 cm for the survey year 2004 and 2005, 100 cm for year 2006 and 65 and 95 cm for year 2007. These end values just represent the depth of the organic soil as deep as the soil probe could enter. The real depth could be considerably deeper in some cases. This could influence the correlation although the number of transect points that reached maximum soil core length was only five percent. The differences in core length did not affect the soil index of distance from stream until a depth of the organic soil less than 30 cm (Distance30), since the organic soil was generally the uppermost soil layer in the profiles.

Further investigations of the data set can be done with more calculations and correlations for the relation between soil formation and the terrain indices in the landscape. Another project has started where soil and stream chemistry is going to be correlated with the local slope. The Riparian Survey data suggests that organic soils were almost always present in the direct vicinity of streams in moraine soil areas but much less along streams in sedimentary soil areas. Differences in the water chemistry have also been seen between the upper moraine part and lower sedimentary part of the catchment (Buffam, 2007; Ågren, 2007). One likely explanation for this was the difference in organic soil cover although it is important to examine the hydrology in the area as well as the extension of organic soil to fully understand differences in the stream chemistry.

# 5. CONCLUDING REMARKS

This study found clear patterns in the structure of organic soil in the near stream zone. In Krycklan the organic soils are significantly more abundant, thicker and have a greater extend in the moraine part compared to the sedimentary part. The organic soils were deeper and more abundant near the streams than further away. More organic soil could be seen in headwater streams than in streams of higher orders. For all soil indices higher values of organic soil were found in the till soil than in the sediment soil. Elevation above sea level (EASea) generally gave the highest correlations for all soil indices and groups. The DEM can not alone be used for prediction of the organic riparian soil.

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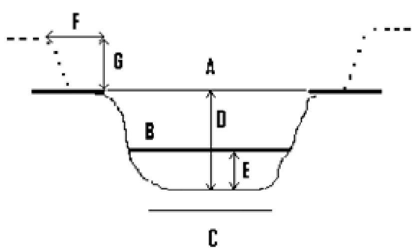
# Appendix A Standard protocol

SITE NUMBER: ____________________ DATE: ___ ___ ___ ___
INVESTIGATOR: ______________________________ _________
GPS COORDINATES [m]: X _______ ___ Y __________ Acc. ____
COMPASS BEARING (UPSTREAM): ________________________
DISTANCE FROM LAST SITE [m]: _________________________
PICTURES: Number: ____ ______Time: __________________

| RIPARIAN VEGETATION | |
|---|---|
| Width of Riparian Buffer Zone<br>_______ m Left<br>_______ m Right | Riparian Vegetation Age<br>□ Clear cut<br>□ Young<br>□ Mature/Old Growth |

| CHANNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WOOD DEBRIS | □ Not present □ Present in bank □ Present in Channel | | | | | | | | | | |
| AQUATIC VEGETATION | Indicate the dominant types<br>□ Not present □ Rooted emergent □ Rooted submergent<br>□ Rooted floating □ Free floating □ Floating Algae<br>□ Attached Algae | | | | | | | | | | |
| MORPHOLOGY [cm] | A | B | C | D | | E | F | | G | | |
| | | | | Left | Right | | Left | Right | Left | Right | |
| | | | | | | | | | | | |
| BED MATERIAL | Indicate %<br>_____ Sand ______ Pebbles ______Cobbles _______Boulders<br>□ Organic material □ Not visible | | | | | | | | | | |

CHANNEL MORPHOLOGY: NOTES:




SITE NUMBER: ______________________ LEFT □ RIGHT □

0,5 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

8 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

2 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
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| | | | |

12 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

4 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
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| | | | |

25 meters Dominant Veg:
Ground Veg:

| Layers | Depth | Texture | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| SLOPE | Distance [m] | Measurement |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

DESCRIPTION OF FIELD MEASUREMENTS OF CHANNEL PROPERTIES

- measured in the Standard Protocol

At the stream point four channel properties were documented looking a few metres upstream and down stream of the channel point. The properties were: presence of wood debris, dominant aquatic vegetation, channel morphology and bed material. Presence of wood debris, i.e. needles and dead wooden parts like small branches, was noted as not present, present in bank or present in channel. The dominant aquatic vegetation was noted as not present, rooted emergent, rooted submerge, rooted floating, free floating, floating algae or attached algae.
Description of the channel morphology was made by measuring different heights and distances with a folding rule and sometimes with the measuring tape, se figure A1. The measured section was chosen in a couple of metres where it seems to be as representative to the channel near upstream and downstream the channel point. Width and height for the second inflection point could only be measured in those cases where it was a clear second inflection point.

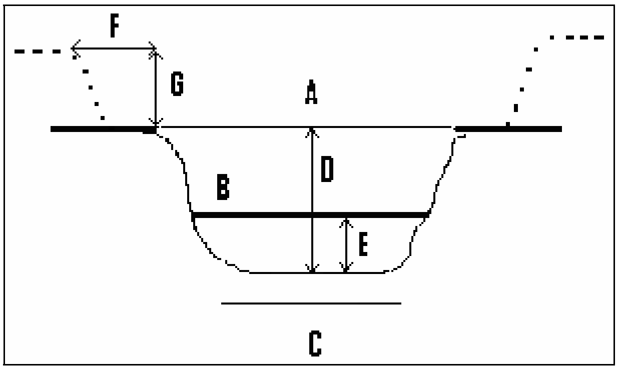


Figure A1. *Description of measured channel morphology. A: Width of stream channel, B: Width of water surface, C: Width of channel bottom, D: Depth of stream channel, E: Depth of water. F: Distance between first and second inflection point, G: Height between first and second inflection point. (Picture taken from the field report from Jaremalm and Nolin, 2006.)*

The percentage of different bed material was estimated by eye in an approximately 1 metre wide cross section of the channel. The bed material were divided into sand (0.5-2mm), pebbles (2-20mm), cobbles (20mm-10cm) or boulders (>10cm). The presence of organic bed material in the channel bed was noted as organic material or not visible.

# APPENDIX B Stream combination picture

**1**

| | | |
|---|---|---|
| l | s1 | r |
| L | s2 | R |
| l | s3 | r |

**2**

| | | |
|---|---|---|
| r | R | r |
| s1 | s2 | s3 |
| l | L | l |

**3**

| | | |
|---|---|---|
| s1 | r | r |
| L | s2 | R |
| l | s3 | r |

**4**

| | | |
|---|---|---|
| s1 | r | R |
| l | s2 | r |
| L | l | s3 |

**5**

| | | |
|---|---|---|
| s1 | R | r |
| l | s2 | s3 |
| l | L | l |

**6**

| | | |
|---|---|---|
| s1 | R | s3 |
| l | s2 | l |
| l | L | l |

**7**

| | | |
|---|---|---|
| s1 | r | r |
| L | s2 | R |
| s3 | r | r |

**8**

| | | |
|---|---|---|
| l | s1 | r |
| L | s2 | R |
| s3 | r | r |

**9**

| | | |
|---|---|---|
| l | s1 | r |
| L | s2 | R |
| l | l | s3 |

**10**

| | | |
|---|---|---|
| l | l | s1 |
| L | s2 | R |
| l | s3 | r |

**11**

| | | |
|---|---|---|
| L | l | s1 |
| l | s2 | r |
| s3 | r | R |

**12**

| | | |
|---|---|---|
| l | L | s1 |
| s3 | s2 | r |
| r | R | r |

**13**

| | | |
|---|---|---|
| l | l | s1 |
| L | s2 | R |
| l | l | s3 |

**14**

| | | |
|---|---|---|
| r | R | r |
| s1 | s2 | r |
| l | L | s3 |

**15**

| | | |
|---|---|---|
| r | R | r |
| r | s2 | s3 |
| s1 | L | l |

**16**

| | | |
|---|---|---|
| R | s3 | l |
| s1 | s2 | l |
| l | l | L |

**17**

| | | |
|---|---|---|
| l | s1 | R |
| l | s2 | s3 |
| L | l | l |

**18**

| | | |
|---|---|---|
| r | r | R |
| s1 | s2 | r |
| L | s3 | r |

**19**

| | | |
|---|---|---|
| r | R | s3 |
| s1 | s2 | l |
| l | L | l |

**20**

| | | |
|---|---|---|
| R | r | s3 |
| r | s2 | l |
| s1 | l | L |

**21**

| | | |
|---|---|---|
| r | R | r |
| r | s2 | r |
| s1 | L | s3 |

**22**

| | | |
|---|---|---|
| s1 | r | R |
| s2 | s3 | r |
| L | l | s4 |

**23**

| | | |
|---|---|---|
| s1 | r | R |
| l | s2 | r |
| L | s3 | s4 |

**24** *

| | | |
|---|---|---|
| r | R | s3 |
| s1 | s2 | r |
| l | L | s3 |

**25** *

| | | |
|---|---|---|
| L | s1 | r |
| s3 | s2 | R |
| l | l | s3 |

* = Stream junction

L = Left pixel closest to the transect stream point.
R = Right pixel closest to the transect stream point.
l = Pixels on the left hand side from the transect stream point.
r = Pixels on the right hand side from the transect stream point.
S1,S2,S3 = Stream points in order S1 to S3 from the flow direction.

| | | |
|---|---|---|
| 7 | 8 | 1 |
| 6 | 0 | 2 |
| 5 | 4 | 3 |

# APPENDIX C Statistics for the organic soil depth

**Till group**
Unit: cm

| Level | Quartiles | | | Mean value | |
|---|---|---|---|---|---|
| | 1st quartile | Median | 3rd quartile | Mean | Std Dev |
| -25 | 5 | 13 | 48.5 | 27.78 | 28.69 |
| -12 | 7 | 29 | 60.75 | 35.18 | 29.22 |
| -8 | 13.75 | 42 | 61.25 | 40.58 | 26.38 |
| -4 | 28 | 48 | 65 | 45.87 | 24.19 |
| -2 | 35 | 50 | 65 | 50.08 | 21.89 |
| -0.5 | 31 | 50.5 | 67.25 | 50.33 | 21.87 |
| 0.5 | 36 | 51.5 | 66.5 | 51.77 | 22.82 |
| 2 | 37.25 | 54.5 | 68 | 53.28 | 22.79 |
| 4 | 25 | 49.5 | 68 | 46.90 | 25.76 |
| 8 | 15.25 | 46 | 64 | 42.20 | 28.54 |
| 12 | 7 | 33 | 58 | 35.52 | 30.26 |
| 25 | 4 | 11 | 51 | 27.01 | 28.92 |

**Sed group**
Unit: cm

| Level | Quartiles | | | Mean value | |
|---|---|---|---|---|---|
| | 1st quartile | Median | 3rd quartile | Mean | Std Dev |
| -25 | 2.5 | 5 | 10 | 9.72 | 14.89 |
| -12 | 2 | 5 | 10 | 10.67 | 17.43 |
| -8 | 2 | 6 | 14.5 | 14.07 | 20.47 |
| -4 | 3 | 8 | 17.25 | 15.22 | 18.82 |
| -2 | 3.25 | 7 | 30.5 | 17.43 | 19.74 |
| -0.5 | 5 | 10 | 30 | 19.51 | 21.14 |
| 0.5 | 5 | 10 | 32 | 20.13 | 23.30 |
| 2 | 5 | 10 | 25.75 | 18.33 | 19.08 |
| 4 | 5 | 10 | 20 | 15.78 | 15.84 |
| 8 | 5 | 10 | 25 | 17.45 | 19.69 |
| 12 | 3 | 7 | 13 | 12.40 | 14.00 |
| 25 | 3 | 5 | 10 | 10.14 | 15.28 |

# APPENDIX D Statistics for the soil indices

N = Number of records (i.e. transects) in respective stream subgroup.

**Statistics for the distance where the organic soil was less than 30 cm deep, Distance30 index.**
Unit: Metres from the stream

**Distance30 index**

| Stream Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 8,52 | 2,71 | 23,50 | 25,00 | 0,00 | 11,32 | 9,75 | 15,10 | 7,54 | 28 |
| B | 8,47 | 3,00 | 25,00 | 25,00 | 0,00 | 12,16 | 9,83 | 16,90 | 7,42 | 19 |
| C | 10,16 | 3,04 | 25,00 | 25,00 | 0,00 | 12,42 | 9,16 | 15,21 | 9,64 | 44 |
| D | 7,88 | 2,16 | 19,33 | 25,00 | 0,00 | 10,35 | 9,07 | 13,87 | 6,83 | 28 |
| E | 17,20 | 9,78 | 25,00 | 25,00 | 0,00 | 16,38 | 8,09 | 19,58 | 13,17 | 27 |
| F | 16,96 | 5,55 | 25,00 | 25,00 | 0,00 | 14,76 | 10,14 | 18,09 | 11,43 | 38 |
| G | 0,55 | 0,00 | 2,82 | 17,04 | 0,00 | 2,59 | 4,64 | 5,06 | 0,11 | 16 |
| H | 0,00 | 0,00 | 0,00 | 5,67 | 0,00 | 0,22 | 1,11 | 0,67 | -0,23 | 26 |
| I | 17,57 | 0,43 | 25,00 | 25,00 | 0,00 | 14,12 | 11,34 | 18,91 | 9,34 | 24 |
| J | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 24 |
| K | 0,00 | 0,00 | 0,00 | 17,06 | 0,00 | 1,82 | 4,92 | 4,66 | -1,03 | 14 |
| L | 23,10 | 10,40 | 25,00 | 25,00 | 4,00 | 17,95 | 8,42 | 21,89 | 14,01 | 20 |
| M | 21,75 | 2,60 | 25,00 | 25,00 | 0,00 | 15,51 | 10,97 | 20,96 | 10,06 | 18 |
| N | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 30 |
| O | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 12 |
| P | 0,00 | 0,00 | 15,00 | 25,00 | 0,00 | 6,11 | 10,83 | 14,44 | -2,22 | 9 |

| Stream Order Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 2,99 | 0,00 | 19,49 | 25,00 | 0,00 | 9,01 | 10,31 | 13,58 | 4,44 | 22 |
| S2 | 0,00 | 0,00 | 0,00 | 5,00 | 0,00 | 0,39 | 1,10 | 0,79 | 0,00 | 32 |
| S3 | 0,00 | 0,00 | 0,00 | 5,67 | 0,00 | 0,27 | 1,10 | 0,58 | -0,05 | 49 |
| S4 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 32 |
| T1 | 17,20 | 5,27 | 25,00 | 25,00 | 0,00 | 14,56 | 9,81 | 16,17 | 12,95 | 145 |
| T2 | 10,07 | 2,80 | 25,00 | 25,00 | 0,00 | 12,15 | 9,58 | 14,10 | 10,20 | 95 |

| Soil group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Till | 10,93 | 3,30 | 25,00 | 25,00 | 0,00 | 13,50 | 9,79 | 14,74 | 12,26 | 242 |
| Sed | 0,00 | 0,00 | 0,00 | 25,00 | 0,00 | 1,66 | 5,29 | 2,56 | 0,76 | 135 |

**Statistics for average depth of organic soil the first four metres, Depth4 index.**
Unit: Depth in cm

## Depth4 index

| Stream Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 35,33 | 23,03 | 53,73 | 69,96 | 9,79 | 37,13 | 17,77 | 44,02 | 30,25 | 28 |
| B | 42,00 | 29,88 | 59,54 | 67,42 | 20,67 | 43,60 | 14,65 | 50,66 | 36,54 | 19 |
| C | 47,81 | 26,43 | 60,35 | 71,38 | 8,21 | 44,49 | 18,18 | 50,02 | 38,96 | 44 |
| D | 41,29 | 25,39 | 53,52 | 67,63 | 3,96 | 39,53 | 18,84 | 46,83 | 32,22 | 28 |
| E | 57,29 | 40,88 | 67,54 | 75,58 | 8,63 | 53,54 | 17,87 | 60,61 | 46,47 | 27 |
| F | 50,33 | 39,22 | 59,33 | 72,38 | 0,00 | 44,60 | 20,69 | 51,40 | 37,80 | 38 |
| G | 11,83 | 7,31 | 28,23 | 59,38 | 4,71 | 20,51 | 17,31 | 29,73 | 11,28 | 16 |
| H | 4,25 | 0,80 | 8,13 | 44,58 | 0,00 | 6,60 | 9,39 | 10,39 | 2,81 | 26 |
| I | 47,04 | 19,19 | 67,94 | 70,83 | 3,50 | 43,98 | 23,83 | 54,04 | 33,92 | 24 |
| J | 5,79 | 1,00 | 11,21 | 34,58 | 0,00 | 7,44 | 7,82 | 10,82 | 4,05 | 23 |
| K | 3,92 | 0,90 | 12,29 | 49,13 | 0,00 | 10,81 | 16,79 | 20,51 | 1,11 | 14 |
| L | 65,10 | 51,69 | 78,19 | 100,0 | 35,42 | 65,35 | 18,92 | 74,20 | 56,50 | 20 |
| M | 87,50 | 35,83 | 100,00 | 100,0 | 11,46 | 71,18 | 33,56 | 89,07 | 53,30 | 16 |
| N | 6,67 | 2,45 | 9,14 | 17,96 | 0,42 | 6,44 | 4,26 | 8,03 | 4,84 | 30 |
| O | 4,38 | 3,28 | 6,44 | 7,96 | 1,29 | 4,57 | 2,14 | 5,93 | 3,22 | 12 |
| P | 11,94 | 3,88 | 52,19 | 100,0 | 1,17 | 29,19 | 34,94 | 54,19 | 4,20 | 10 |

| Stream Order Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 29,35 | 8,31 | 51,93 | 70,83 | 1,00 | 30,26 | 24,32 | 41,04 | 19,48 | 22 |
| S2 | 8,06 | 3,76 | 13,06 | 42,92 | 0,00 | 10,19 | 9,54 | 13,63 | 6,75 | 32 |
| S3 | 4,88 | 1,16 | 10,46 | 44,71 | 0,00 | 8,22 | 10,71 | 11,30 | 5,14 | 49 |
| S4 | 6,42 | 3,28 | 7,88 | 17,96 | 1,29 | 6,36 | 3,98 | 7,79 | 4,92 | 32 |
| T1 | 50,33 | 31,70 | 65,31 | 100,0 | 0,00 | 48,88 | 23,22 | 52,71 | 45,06 | 144 |
| T2 | 48,33 | 25,48 | 61,52 | 100,0 | 4,71 | 45,29 | 22,78 | 49,96 | 40,63 | 94 |

| Soil group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Till | 49,25 | 29,68 | 63,42 | 100,0 | 0,00 | 47,24 | 23,11 | 50,18 | 44,3 | 240 |
| Sed | 6,83 | 2,92 | 13,25 | 70,83 | 0,00 | 11,84 | 15,06 | 14,40 | 9,273 | 135 |

**Statistics for the area of organic soil in the transects, CArea index.**
Unit: Area in $m^2$

## CArea index

| Stream Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 5,94 | 3,09 | 9,46 | 16,81 | 1,53 | 6,60 | 3,74 | 8,04 | 5,15 | 28 |
| B | 3,53 | 2,34 | 12,93 | 15,70 | 1,47 | 6,92 | 5,40 | 9,61 | 4,23 | 18 |
| C | 6,59 | 4,22 | 11,22 | 17,77 | 0,85 | 7,90 | 4,88 | 9,38 | 6,42 | 44 |
| D | 4,43 | 1,70 | 10,52 | 16,84 | 0,24 | 6,09 | 5,15 | 8,08 | 4,09 | 28 |
| E | 10,98 | 5,97 | 12,73 | 18,50 | 0,52 | 9,82 | 4,85 | 11,73 | 7,90 | 27 |
| F | 9,23 | 3,31 | 13,35 | 16,58 | 0,00 | 8,50 | 5,31 | 10,24 | 6,75 | 38 |
| G | 1,72 | 1,28 | 2,65 | 9,49 | 0,44 | 2,46 | 2,21 | 3,64 | 1,29 | 16 |
| H | 1,03 | 0,21 | 1,62 | 3,78 | 0,00 | 1,16 | 1,06 | 1,61 | 0,72 | 24 |
| I | 10,35 | 3,22 | 17,13 | 18,12 | 0,93 | 10,18 | 6,59 | 12,97 | 7,40 | 24 |
| J | 0,70 | 0,17 | 1,29 | 2,17 | 0,00 | 0,83 | 0,72 | 1,15 | 0,51 | 22 |
| K | 0,47 | 0,07 | 1,79 | 9,36 | 0,00 | 1,47 | 2,55 | 2,94 | 0,00 | 14 |
| L | 11,73 | 6,51 | 19,56 | 25,00 | 2,92 | 12,95 | 7,40 | 16,52 | 9,38 | 19 |
| M | 18,50 | 12,38 | 25,00 | 25,00 | 1,09 | 16,29 | 7,97 | 20,71 | 11,88 | 15 |
| N | 1,45 | 0,72 | 1,78 | 8,05 | 0,03 | 1,67 | 1,66 | 2,29 | 1,05 | 30 |
| O | 1,35 | 0,67 | 1,76 | 2,45 | 0,27 | 1,29 | 0,65 | 1,70 | 0,88 | 12 |
| P | 3,95 | 1,83 | 13,07 | 24,15 | 0,19 | 7,22 | 8,65 | 13,87 | 0,58 | 9 |

| Stream Order Group | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 5,38 | 1,41 | 11,13 | 17,98 | 0,12 | 6,37 | 5,82 | 8,95 | 3,79 | 22 |
| S2 | 1,60 | 0,55 | 2,63 | 5,26 | 0,00 | 1,77 | 1,43 | 2,31 | 1,24 | 30 |
| S3 | 0,97 | 0,17 | 1,63 | 8,05 | 0,00 | 1,38 | 1,76 | 1,90 | 0,86 | 46 |
| S4 | 1,43 | 0,83 | 1,79 | 3,82 | 0,27 | 1,41 | 0,71 | 1,67 | 1,16 | 32 |
| T1 | 8,71 | 3,20 | 14,28 | 25,00 | 0,00 | 9,28 | 6,50 | 10,36 | 8,20 | 142 |
| T2 | 6,55 | 3,09 | 12,41 | 25,00 | 0,41 | 8,12 | 5,85 | 9,32 | 6,92 | 94 |

| Sediment | median | 1st quartile | 3rd quartile | Max value | Min value | Mean | Std Dev | upper 95% Mean | lower 95% Mean | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Till | 7,94 | 3,08 | 13,05 | 25 | 0 | 8,76 | 6,27 | 9,56 | 8 | 238 |
| Sed | 1,42 | 0,64 | 2,20 | 17,98 | 0 | 2,32 | 3,25 | 2,89 | 2 | 130 |

# APPENDIX E Soil and terrain indices correlations

| **Distance30** | HAStream | Curvature | Slope | TWI | Pindexex | SAGA_WI | SolR | EASea | CA_MTF_Acc | CA_MTF | SAGA_CA_Acc | SAGA_CA | MTF | No sign.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All points | -0.30 | 0.44 | -0.42 | 0.35 | 0.08 | -0.20 | 0.21 | 0.64 | -0.37 | 0.02 | -0.36 | -0.07 | -0.11 | 10 |
| sed | -0.23 | 0.18 | -0.14 | 0.26 | 0.02 | -0.14 | 0.12 | 0.59 | -0.23 | 0.22 | -0.24 | 0.02 | 0.04 | 8 |
| Till | -0.13 | 0.34 | -0.41 | 0.23 | 0.20 | 0.07 | -0.01 | 0.38 | -0.14 | -0.03 | -0.10 | -0.09 | -0.11 | 7 |
| A | -0.07 | 0.18 | 0.08 | 0.13 | 0.39 | -0.44 | 0.26 | 0.64 | -0.54 | -0.20 | -0.50 | -0.36 | -0.17 | 5 |
| B | -0.33 | 0.05 | -0.29 | 0.32 | 0.09 | -0.12 | -0.31 | -0.15 | 0.28 | 0.22 | 0.25 | 0.09 | -0,34# | 0 |
| C | -0.21 | 0.44 | -0.58 | 0.45 | 0.33 | -0.24 | -0.01 | 0.45 | -0.51 | 0.21 | -0.48 | 0.12 | -0.19 | 7 |
| D | -0.05 | 0.08 | -0.29 | -0.09 | -0.12 | -0.01 | 0.12 | 0.11 | -0.04 | 0.21 | 0.20 | 0.13 | 0.29 | 0 |
| E | 0.25 | 0.34 | -0.50 | 0.03 | 0.32 | 0.46 | -0.33 | 0.13 | -0.09 | 0.13 | 0.14 | -0.18 | -0.05 | 2 |
| F | -0.31 | 0.35 | -0.65 | 0.36 | 0.72 | 0.03 | -0.20 | 0.73 | -0.65 | -0.05 | -0.56 | -0.24 | -0.24 | 7 |
| G | -0.16 | 0.06 | -0.11 | -0.03 | 0.06 | 0.21 | 0.07 | 0.51 | -0.35 | -0.04 | -0.09 | -0.11 | 0.26 | 1 |
| H | 0.04 | -0.09 | 0.16 | 0.01 | -0.03 | -0.09 | 0.01 | 0.14 | 0.06 | 0.06 | 0.06 | -0.07 | -0.10 | 0 |
| I | -0.39 | 0.19 | -0.31 | 0.58 | -0.23 | -0.05 | 0.33 | 0.25 | -0.40 | 0.40 | -0.47 | 0.18 | 0.19 | 3 |
| J | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| K | 0.16 | 0.50 | -0.23 | 0.15 | 0.09 | -0.35 | -0.06 | 0.80 | -0.36 | -0.11 | -0.36 | 0.13 | -0.13 | 1 |
| L | 0.00 | 0.37 | -0.15 | 0.24 | 0.14 | 0.35 | -0.21 | -0.27 | 0.34 | -0.03 | 0.15 | 0.34 | -0.26 | 0 |
| M | -0.32 | 0.45 | -0.54 | 0.41 | 0.52 | 0.66 | -0.47 | 0.26 | 0.18 | -0.31 | 0.17 | -0.33 | -0.04 | 4 |
| N | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| O | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| P | -0.6 | -0.33 | -0.31 | 0.19 | 0.48 | 0.20 | -0.05 | 0.72 | -0.23 | -0.22 | -0.13 | -0.32 | 0.15 | 1 |
| S1 | -0.59 | 0.23 | -0.33 | 0.52 | 0.04 | 0.34 | 0.21 | 0.81 | 0.19 | 0.37 | 0.02 | 0.65 | 0.03 | 4 |
| S2 | -0.10 | 0.27 | -0.16 | 0.08 | 0.08 | -0.17 | 0.19 | 0.76 | -0.34 | -0.05 | -0.34 | -0.10 | -0.13 | 1 |
| S3 | -0.05 | 0.10 | -0.03 | 0.11 | -0.07 | -0.01 | 0.07 | 0.04 | -0.27 | 0.19 | -0.26 | -0.06 | -0.04 | 0 |
| S4 | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| T1 | -0.15 | 0.37 | -0.48 | 0.28 | 0.11 | 0.16 | -0.01 | 0.28 | -0.05 | 0.03 | -0.06 | 0.00 | -0.13 | 4 |
| T2 | -0.17 | 0.30 | -0.40 | 0.23 | 0.33 | 0.16 | -0.06 | 0.48 | -0.07 | -0.03 | -0.01 | -0.09 | -0.09 | 5 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAX | 0.25 | 0.50 | 0.16 | 0.58 | 0.72 | 0.66 | 0.33 | 0.81 | 0.34 | 0.40 | 0.25 | 0.65 | 0.29 |
| MIN | -0.64 | -0.33 | -0.65 | -0.09 | -0.23 | -0.44 | -0.47 | -0.27 | -0.65 | -0.31 | -0.56 | -0.36 | -0.34 |
| No Sign.* | 4 | 7 | 8 | 9 | 6 | 4 | 2 | 13 | 6 | 1 | 6 | 1 | 1 |

(grey) = Significant for a 95% confidence interval

(yellow) = Significant for a 90% confidence interval

(pink) # = The value are not in the significance area. (B-MTF p= 0,16)

* No sign. = Number of significant values at a significance level of 90%.

| Depth4 | HAStream | Curvature | Slope | TWI | Pindex | SAGA_WI | SolR | EASea | CA_MTF_Acc | CA_MTF | SAGA_CA_Acc | SAGA_CA | MTF | No sign.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All points | -0.34 | 0.44 | -0.43 | 0.36 | 0.08 | -0.17 | 0.23 | 0.69 | -0.42 | 0.02 | -0.42 | -0.08 | -0.04 | 9 |
| Sed | -0.25 | 0.23 | -0.17 | 0.28 | 0.03 | -0.10 | 0.10 | 0.59 | -0.29 | 0.20 | -0.29 | -0.01 | 0.06 | 9 |
| Till | -0.16 | 0.18 | -0.34 | 0.22 | 0.22 | 0.18 | -0.03 | 0.37 | -0.02 | -0.04 | 0.01 | -0.11 | -0.01 | 7 |
| A | -0.09 | -0.32 | 0.24 | 0.20 | 0.00 | -0.10 | 0.22 | 0.18 | -0.17 | -0.05 | -0.17 | -0.08 | -0.01 | 0 |
| B | -0.27 | 0.21 | -0.22 | 0.22 | -0.13 | 0.01 | -0.23 | -0.47 | 0.23 | 0.22 | 0.14 | 0.38 | -0.07 | 1 |
| C | -0.35 | 0.18 | -0.36 | 0.28 | 0.20 | 0.13 | 0.02 | 0.30 | -0.17 | 0.07 | -0.21 | 0.11 | -0.23 | 3 |
| D | -0.17 | -0.03 | -0.44 | 0.17 | -0.11 | 0.08 | 0.00 | -0.25 | 0.25 | 0.23 | 0.55 | 0.03 | 0.33 | 2 |
| E | 0.12 | -0.03 | -0.39 | 0.14 | 0.28 | 0.20 | -0.19 | 0.30 | -0.34 | 0.16 | 0.11 | -0.28 | 0.29 | 1 |
| F | -0.23 | 0.06 | -0.47 | 0.32 | 0.56 | 0.05 | -0.02 | 0.69 | -0.53 | -0.03 | -0.46 | -0.23 | -0.05 | 6 |
| G | -0.09 | 0.00 | -0.05 | -0.07 | -0.01 | 0.23 | 0.12 | 0.43 | -0.22 | -0.03 | 0.02 | -0.12 | 0,35# | 0 |
| H | -0.19 | 0.12 | -0.01 | 0.30 | -0.16 | 0.08 | 0.17 | 0.21 | -0.18 | 0.30 | -0.18 | 0.06 | -0.11 | 0 |
| I | -0.38 | 0.00 | -0.13 | 0.49 | -0.03 | -0.15 | 0.18 | 0.46 | -0.39 | 0.22 | -0.49 | 0.26 | 0.17 | 3 |
| J | 0.00 | -0.09 | 0.15 | 0.11 | 0.25 | 0.05 | -0.31 | 0.06 | 0.04 | 0.26 | 0.09 | -0.09 | 0.33 | 0 |
| K | 0.18 | 0.50 | -0.22 | 0.22 | 0.22 | -0.44 | -0.17 | 0.84 | -0.48 | -0.16 | -0.48 | 0.23 | -0.18 | 1 |
| L | 0.20 | 0.03 | -0.11 | 0.15 | 0.24 | 0.09 | -0.14 | 0.37 | -0.06 | 0.11 | 0.19 | -0.38 | -0.16 | 0 |
| M | -0.45 | 0.17 | -0.54 | 0.36 | 0.70 | 0.61 | -0.60 | 0.42 | 0.15 | -0,34# | 0.13 | -0.37 | 0.34 | 4 |
| N | -0.05 | -0.02 | -0.02 | 0.13 | -0.08 | 0.11 | -0.06 | -0.28 | 0.19 | 0.26 | 0.18 | -0.13 | -0.20 | 0 |
| O | -0.65 | -0.11 | -0.13 | 0.22 | -0.09 | -0.10 | 0.10 | 0.18 | -0.59 | 0.08 | -0.59 | 0.50 | 0.06 | 3 |
| P | -0.63 | -0.36 | -0.34 | 0.29 | 0.54 | 0.23 | -0.10 | 0.75 | -0.24 | -0.06 | -0.09 | -0.40 | 0.03 | 2 |
| S1 | -0.56 | 0.19 | -0.31 | 0.48 | 0.16 | 0.42 | 0.08 | 0.80 | 0.39 | 0.30 | 0.22 | 0.63 | 0.19 | 5 |
| S2 | -0.25 | 0.43 | -0.35 | 0.20 | -0.06 | -0.03 | 0.29 | 0.74 | -0.43 | 0.12 | -0.43 | -0.08 | -0.11 | 5 |
| S3 | -0.09 | 0.06 | 0.03 | 0.10 | -0.02 | 0.04 | -0.01 | 0.00 | -0.16 | 0.20 | -0.14 | -0.17 | -0.04 | 0 |
| S4 | -0.17 | 0.08 | -0.18 | 0.19 | -0.01 | 0.02 | 0.05 | 0.36 | -0.43 | 0.27 | -0.44 | 0.10 | -0.20 | 3 |
| T1 | -0.17 | 0.22 | -0.41 | 0.28 | 0.16 | 0.28 | -0.03 | 0.30 | -0.02 | 0.03 | -0.04 | -0.02 | 0.00 | 6 |
| T2 | -0.20 | 0.13 | -0.30 | 0.17 | 0.31 | 0.26 | -0.05 | 0.45 | 0.14 | -0.05 | 0.20 | -0.13 | -0.06 | 5 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAX | 0.20 | 0.50 | 0.24 | 0.49 | 0.70 | 0.61 | 0.29 | 0.84 | 0.39 | 0.30 | 0.55 | 0.63 | 0.34 |
| MIN | -0.65 | -0.36 | -0.54 | -0.07 | -0.16 | -0.44 | -0.60 | -0.47 | -0.59 | -0.16 | -0.59 | -0.40 | -0.23 |
| No sign* | 8 | 5 | 11 | 7 | 4 | 6 | 2 | 14 | 6 | 1 | 9 | 1 | 0 |

(grey) = 95% Significance level

(yellow) = 90% Significance level

(pink) # =The value are not in the significance area (G-MTF: p=0,178; M-CA_MTF: p=0,193)

* No sign. = Number of significant values at a significance level of 90%.

| CArea | HAStream | Curvature | Slope | TWI | Pindex | SAGA_ WI | SolR | EASea | CA_MTF_Acc | CA_MTF | SAGA_CA_Acc | SAGA_CA | MTF | No sign.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All points | -0.33 | 0.45 | -0.45 | 0.38 | 0.15 | -0.13 | 0.19 | 0.60 | -0.33 | 0.07 | -0.32 | -0.03 | -0.07 | 10 |
| Sed | -0.30 | 0.32 | -0.26 | 0.36 | 0.02 | -0.09 | 0.17 | 0.60 | -0.24 | 0.26 | -0.24 | 0.03 | 0.02 | 9 |
| Till | -0.19 | 0.32 | -0.44 | 0.26 | 0.21 | 0.15 | -0.04 | 0.35 | -0.04 | 0.05 | -0.01 | -0.03 | -0.06 | 7 |
| A | -0.07 | 0.25 | 0.04 | 0.01 | 0.10 | -0.35 | 0.41 | 0.44 | -0.34 | 0.02 | -0.35 | -0.24 | -0.12 | 2 |
| B | -0.35 | 0.08 | -0.29 | 0.36 | 0.04 | -0.13 | -0.30 | -0.26 | 0.30 | 0.25 | 0.25 | 0.17 | -0.37 | 0 |
| C | -0.19 | 0.46 | -0.57 | 0.43 | 0.36 | -0.17 | -0.04 | 0.46 | -0.51 | 0.16 | -0.48 | 0.09 | -0.19 | 7 |
| D | -0.20 | 0.06 | -0.27 | -0.02 | -0.18 | -0.05 | 0.15 | -0.02 | 0.02 | 0.23 | 0.14 | 0.23 | 0.40 | 1 |
| E | 0.31 | 0.20 | -0.49 | 0.00 | 0.38 | 0.38 | -0.33 | 0.27 | -0.26 | 0.15 | 0.11 | -0.30 | -0.01 | 1 |
| F | -0.32 | 0.41 | -0.70 | 0.36 | 0.72 | 0.03 | -0.16 | 0.77 | -0.69 | -0.06 | -0.61 | -0.24 | -0.18 | 8 |
| G | -0.30 | 0.21 | -0.25 | 0.00 | -0.08 | 0.36 | 0.20 | 0.44 | -0.27 | -0.09 | -0.06 | -0.03 | 0.23 | 0 |
| H | -0.32 | 0.41 | -0.23 | 0.59 | -0.14 | 0.22 | 0.20 | 0.37 | -0.58 | 0.59 | -0.59 | 0.22 | 0.02 | 5 |
| I | -0.47 | 0.29 | -0.44 | 0.59 | -0.29 | 0.04 | 0.39 | 0.24 | -0.43 | 0.30 | -0.49 | 0.18 | 0.16 | 5 |
| J | 0.07 | 0.43 | -0.09 | 0.34 | 0.13 | 0.09 | 0.00 | 0.38 | -0.32 | 0.31 | -0.35 | 0.22 | 0.20 | 1 |
| K | 0.16 | 0.54 | -0.23 | 0.06 | 0.07 | -0.35 | -0.03 | 0.81 | -0.39 | -0.16 | -0.39 | 0.13 | -0.18 | 2 |
| L | 0.00 | 0.30 | -0.29 | 0.35 | 0.20 | 0.35 | -0.20 | 0.16 | 0.08 | 0.25 | 0.13 | 0.00 | -0.19 | 0 |
| M | -0.41 | 0.66 | -0.55 | 0.43 | 0.71 | 0.51 | -0.66 | 0.08 | 0.33 | -0.14 | 0.31 | -0.15 | 0.46 | 5 |
| N | -0.12 | 0.13 | -0.17 | 0.29 | -0.14 | 0.07 | 0.19 | 0.13 | -0.13 | -0.04 | -0.13 | 0.08 | -0.09 | 0 |
| O | -0.09 | 0.23 | -0.56 | 0.28 | 0.23 | 0.49 | -0.26 | 0.19 | 0.00 | 0.19 | 0.00 | 0.10 | 0.84 | 2 |
| P | -0.63 | -0.37 | -0.32 | 0.14 | 0.50 | 0.24 | -0.15 | 0.66 | -0.16 | -0.20 | -0.05 | -0.30 | 0.06 | 0 |
| S1 | -0.68 | 0.38 | -0.50 | 0.65 | -0.03 | 0.49 | 0.23 | 0.70 | 0.25 | 0.42 | 0.08 | 0.70 | 0.01 | 6 |
| S2 | -0.24 | 0.55 | -0.48 | 0.31 | -0.07 | 0.25 | 0.23 | 0.61 | -0.43 | 0.25 | -0.47 | 0.02 | 0.05 | 5 |
| S3 | -0.14 | 0.30 | -0.16 | 0.16 | -0.10 | 0.10 | 0.20 | 0.31 | -0.20 | 0.14 | -0.20 | 0.01 | -0.11 | 2 |
| S4 | 0.03 | 0.19 | -0.25 | 0.24 | 0.03 | 0.10 | -0.02 | 0.29 | -0.16 | -0.02 | -0.16 | -0.01 | -0.01 | 0 |
| T1 | -0.20 | 0.32 | -0.47 | 0.30 | 0.12 | 0.28 | -0.04 | 0.24 | 0.03 | 0.02 | 0.00 | 0.02 | -0.06 | 6 |
| T2 | -0.23 | 0.35 | -0.48 | 0.25 | 0.37 | 0.19 | -0.08 | 0.51 | 0.07 | 0.09 | 0.15 | -0.01 | -0.06 | 6 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAX | 0.31 | 0.66 | 0.04 | 0.65 | 0.72 | 0.51 | 0.41 | 0.81 | 0.33 | 0.59 | 0.31 | 0.70 | 0.84 |
| MIN | -0.68 | -0.37 | -0.70 | -0.02 | -0.29 | -0.35 | -0.66 | -0.26 | -0.69 | -0.20 | -0.61 | -0.30 | -0.37 |
| No sign.* | 8 | 13 | 12 | 10 | 6 | 5 | 3 | 12 | 7 | 2 | 7 | 1 | 2 |

(grey) = 95% Significance level
(yellow) = 90% Significance level
* No sign. = Number of significant values at a significance level of 90%.

# APPENDIX F Summarized significant scores

| | Distance30 | Depth4 | CArea | **Sum** |
|---|---|---|---|---|
| All points | 10 | 9 | 10 | **29** |
| Sed | 8 | 9 | 9 | **26** |
| Till | 7 | 7 | 7 | **21** |
| A | 5 | 0 | 2 | **7** |
| B | 0 | 1 | 0 | **1** |
| C | 7 | 3 | 7 | **17** |
| D | 0 | 2 | 1 | **3** |
| E | 2 | 1 | 1 | **4** |
| F | 7 | 6 | 8 | **21** |
| G | 1 | 0 | 0 | **1** |
| H | 0 | 0 | 5 | **5** |
| I | 3 | 3 | 5 | **11** |
| J | 0 | 0 | 1 | **1** |
| K | 1 | 1 | 2 | **4** |
| L | 0 | 0 | 0 | **0** |
| M | 4 | 4 | 5 | **13** |
| N | 0 | 0 | 0 | **0** |
| O | 0 | 3 | 2 | **5** |
| P | 1 | 2 | 0 | **3** |
| S1 | 4 | 5 | 6 | **15** |
| S2 | 1 | 5 | 5 | **11** |
| S3 | 0 | 0 | 2 | **2** |
| S4 | 0 | 3 | 0 | **3** |
| T1 | 4 | 6 | 6 | **16** |
| T2 | 5 | 5 | 6 | **16** |
| **Sum** | **70** | **75** | **90** | |

| | HAStream | Curvature | Slope | TWI | Pindex | SAGA_WI | SoIR | EASea | CA_MTF_Acc | CA_MTF | SAGA_CA_Acc | SAGA_CA | MTF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance30 | 4 | 7 | 8 | 9 | 6 | 4 | 2 | 13 | 6 | 1 | 6 | 1 | 1 |
| Depth4 | 8 | 5 | 11 | 7 | 4 | 6 | 2 | 14 | 6 | 1 | 9 | 1 | 0 |
| CArea | 8 | 13 | 12 | 10 | 6 | 5 | 3 | 12 | 7 | 2 | 7 | 1 | 2 |
| **Sum** | **20** | **25** | **31** | **26** | **16** | **15** | **7** | **39** | **19** | **4** | **22** | **3** | **3** |