Analyzing Digital Elevation Models using Relief Analysis within ArcInfo

The following manual is given to the reader to allow easy computations of relief parameters based on Digital Elevation Models (DEM). The sections are parts of my thesis, some AML codes and additional explaining commands. For the execution of the different Arc Marco Language (AML) – scripts the reader should have access to ArcInfo with a GRID license. Secondly, he/she should be able to understand how to type command line macros in ArcInfo. For further questions please contact the author at gisxperts add web point de.

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1 Background of relief analysis

Primary topographic attributes are calculated from directional derivatives of a topographic surface. They include for example slope, aspect, profile and plan curvature, flow path length and are computed using a second-order finite difference scheme or by fitting a bivariate interpolation function (Wilson and Gallant, 2001).
Secondary topographic attributes (i.e., sediment transport capacity, topographic wetness index) are computed from two or more primary attributes and offer an opportunity to describe patterns as a function of processes. An example may be the Topographic Wetness Index, which quantifies the role of topography for redistributing water in the landscape. The TWI assumes steady-state conditions and spatially invariant conditions for infiltration and transmissivity as well as that sub surface flow follows surface morphology.
Primary and secondary topographic attributes were computed for the DEM's using the Arc Info GRID module. All primary and secondary variables, which can be computed with the developed tools provided in Appendix AML, are summarized in Table 1. The parameters 1-15, based on available ArcInfo commands, were grouped into the *topo* AML-script, which allows to compute a comprehensive relief analysis with one model call (i.e. &r topo <INPUTDEM> {streamflow threshold} {streamcover}).
The secondary relief parameters (Number 13-15) are computed according to Moore et al. (1993):

$$TWI = \ln\left(\frac{A_S}{\tan\beta}\right) \qquad [1]$$

for topographic wetness index (TWI) with A_S the specific catchment area and β the slope angle in degrees. The stream power index (SPI) was computed:

$$SPI = AS * \tan\beta \qquad [2]$$

and the sediment transport capacity (STC):

$$STC = \left(\frac{A_S}{22.13}\right)^{0.6}\left(\frac{\sin\beta}{0.0896}\right)^{1.3} \qquad [3]$$

For the computations of secondary relief parameter A_S was set to half the cell size, if a Nodata value was observed, β was set to 0.001 if a zero value was observed.
The parameter 16 - 19 in Table 1 are described in more detail latter. The parameter 20-26 (Wilson and Gallant, 2001) were implemented in the *elevres.aml* AML-script to compute relief analysis for a given window size. The command call is: &r elevres <INPUTDEM> {cell size}.
The slope in ° was computed using the steepest downhill slope method (D8), aspect in ° as line of steepest descent, and curvature values as the second derivative of the slope. For profile curvature this is the direction of the flowline of a cell, whereas plan curvature is the direction perpendicular to that direction. The values are given as 1/100 meter.
The parameter 27 in Table 1 is based on a simple Monte-Carlo simulation approach to account for uncertainties/inaccuracies of the DEM. It computes the TWI n times by adding a given probability distribution (STD) to the original DEM, and delivers the mean TWI of all model runs. The AML will stop if (I) the number of iterations (N) is reached or (II) the difference between two iterations gets smaller than a threshold value. The threshold is computed by dividing the STD by N. The command call is: &r montewi <INPUTDEM> <OUTPUTDEM> <standard deviation> <number of iterations> {break}.

Table 1 A list of relief parameters computed using self developed AML-Scripts and the SRAD-Program

	Attribute	Unit	Values	Characterization Example	AML-Code
1	Height	M	NA	Height above a specific datum	Topo.aml
2	Slope	°	0..90	Gradient, Runoff Rate	Topo.aml
3	Plan curvature	1/100m	-30..30	Contour Curvature, Converging/Diverging flow	Topo.aml
4	Profile curvature	1/100m	-30..30	Slope Profile Curvature, Flow Acceleration	Topo.aml
5	Aspect	°	0..360	Slope azimuth, solar radiation	Topo.aml
6	Flowaccumulation	Cells	NA	Accumulated flow to each cell	Topo.aml
7	Flowdirection	ORDINAL	0-64	Direction of Flow	Topo.aml
8	Strnet	Boolean	0/1	Stream network	Topo.aml
9	Basin	No.	NA	Unique basin number	Topo.aml
10	Watershed	No.	NA	Unique watershed	Topo.aml
11	RDG	Boolean	0/1	Ridges	Topo.aml
12	PCTG1	%	0..100	Position in landscape based on basin	Topo.aml
13	STC	Unitless	NA	Sediment Transport Capacity	Topo.aml
14	TWI	Unitless	NA	Topographic Wetness Index	Topo.aml
15	SPI	Unitless	NA	Stream power index	Topo.aml
16	SRAD	W/m^2	0..200	Characterize incoming long- and shortwave solar radiation at sloping surface	SRAD
17	LF	ORDINAL (11)	1-11	raw landforms	Landform.aml
18	LFR	ORDINAL (4)	1-4	aggregated raw landforms	Landform.aml
19	LFC	ORDINAL (11)	1-11	Filtered landforms	Landform.aml
20	MEAN	M	NA	Mean height for filter	Elevres.aml
21	SD	M	NA	SD for filter	Elevres.aml
22	DIFF	M	NA	Range for Filter	Elevres.aml
23	DEV	M	NA	Deviation for filter	Elevres.aml
24	PCTG	%	0..100	Position in landscape	Elevres.aml
25	MIN	M	NA	Min height for filter	Elevres.aml
26	MAX	M	NA	Max height for filter	Elevres.aml
27	MWI	Unitless	NA	Topographic Wetness Index using Monte Carlo Simulation	Montewi.aml

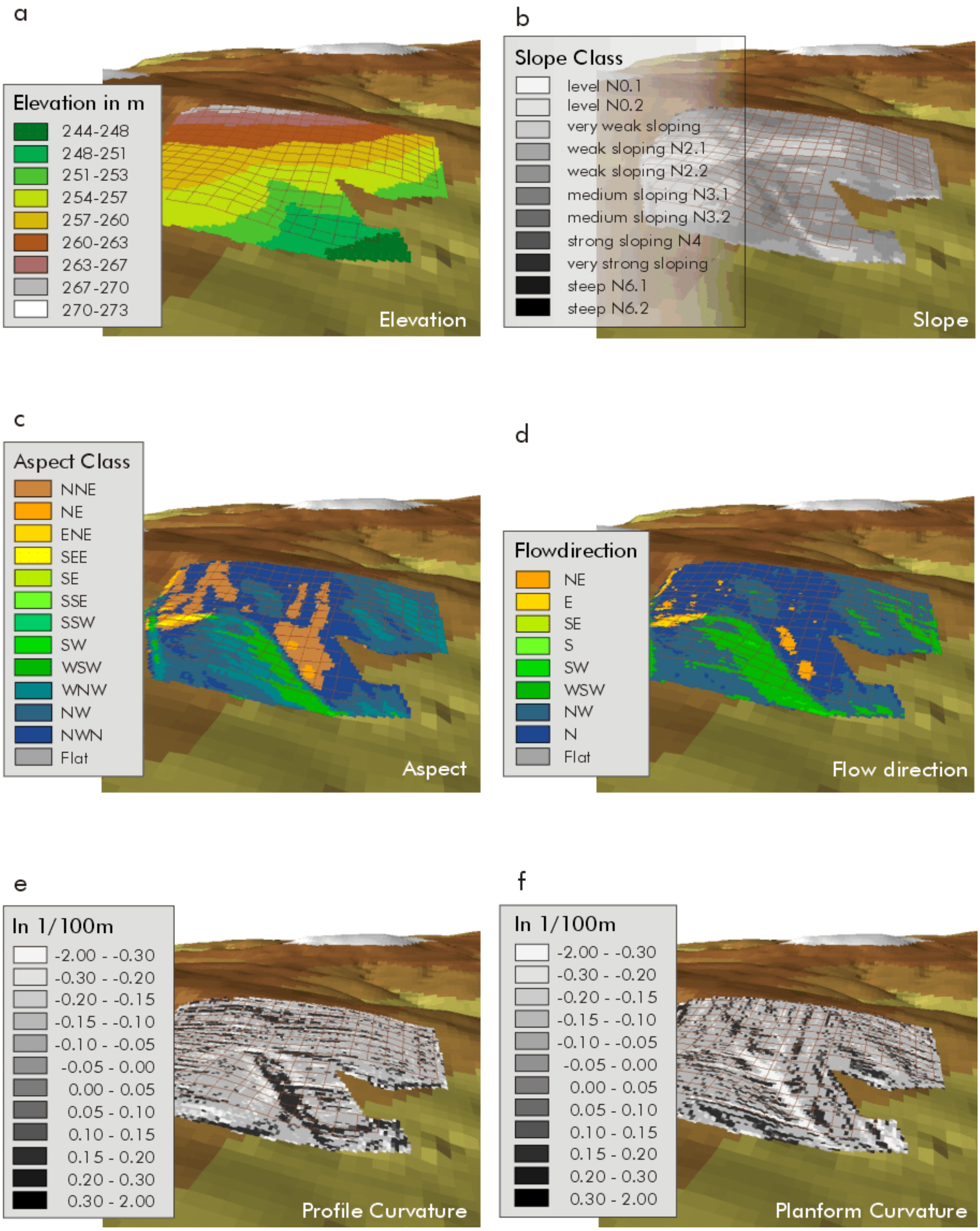

Figure 1 Examples of relief parameters for the field site "Bei Lotte" computed from the Laserscan-DEM using the topo.aml and draped onto the DEM generated from topographic map sheets. View to the south.

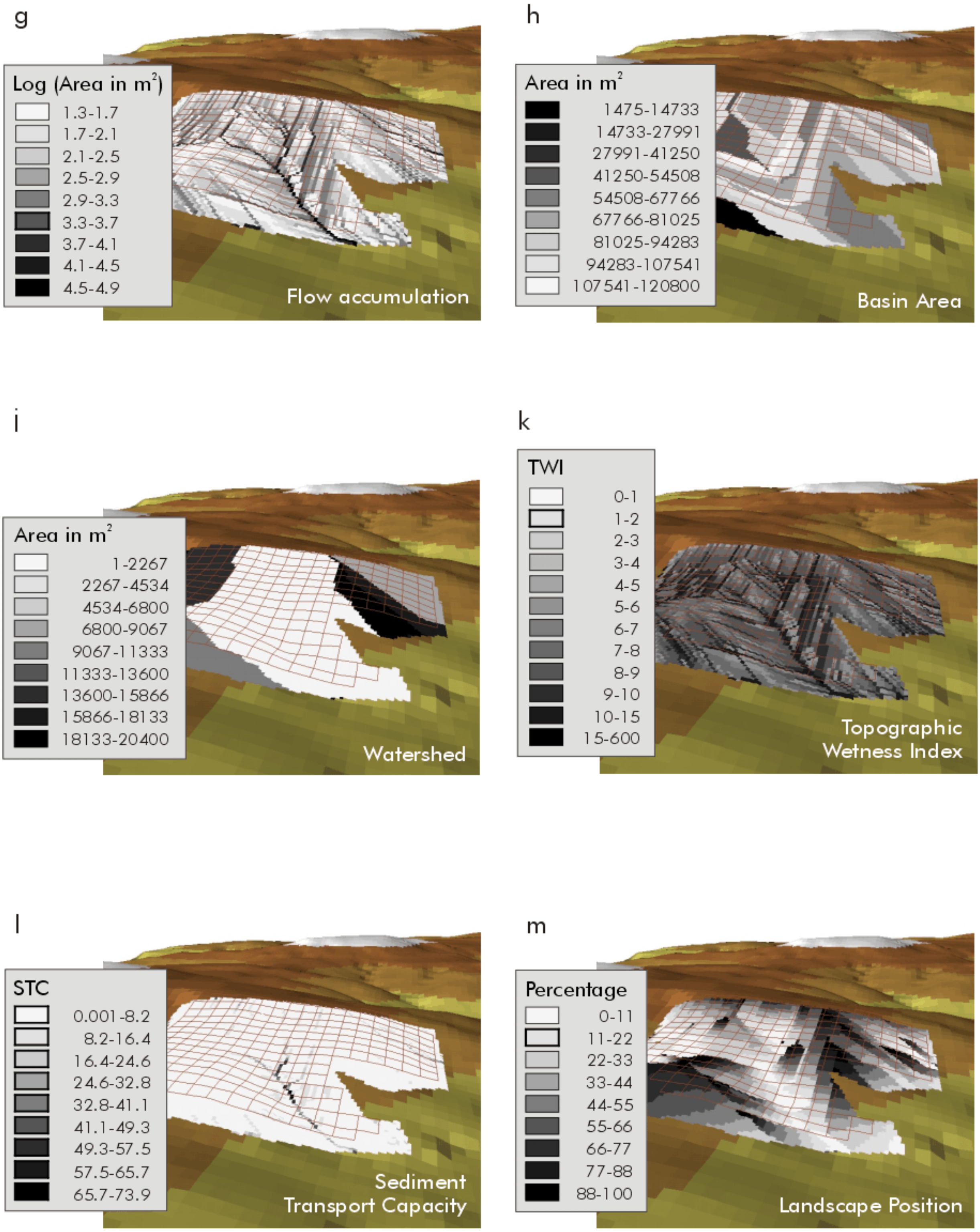

Figure 2 Examples of relief parameters for the field site "Bei Lotte" computed from the Laserscan-DEM using the topo.aml and draped onto the DEM generated from topographic map sheets. View to the south.

2 Landform classification process

Primary and secondary attributes were used to classify the DEM's into different landforms. A method by Pennock et al. (1987) and Pennock et al. (1994) were implemented to allow an automatic classification. For a distribution of landform elements see Figure 3.

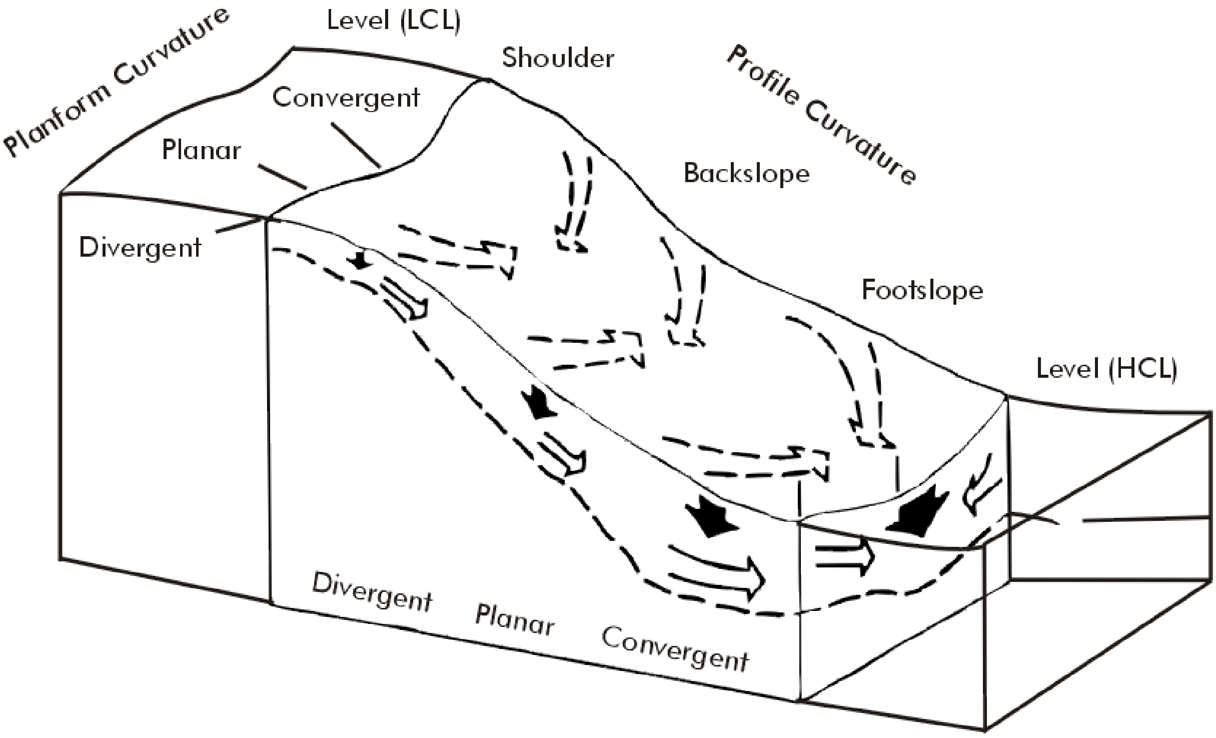

Figure 3 Different landform elements and their probable water movement and concentrations adapted from Pennock et al. (1987). Black arrows indicate vertical infiltration, empty arrows throughflow of water and dotted arrows surface flow of water and sediments.

Table 2 Classification table for different landform elements for a DEM resolution of 10 x 10 m

Landform Elements		*Slope in°*	*Profile Curvature in 1 / 100 m*		*Plan Curvature in 1 / 100 m*		*Watershed area in m^2*
Divergent Shoulder	DSH	>0	>0.1		>0.1		NA
Planar Shoulder	PSH	>0	>0.1		<0.1	>-0.1	NA
Convergent Shoulder	CSH	>0	>0.1		<-0.1		NA
Divergent BackSlope	DBS	>3.0	>-0.1	<0.1	>0.1		NA
Planar BackSlope	PBS	>3.0	>-0.1	<0.1	<0.1	>-0.1	NA
Convergent BackSlope	CBS	>3.0	>-0.1	<0.1	<-0.1		NA
Divergent FootSlope	DFS	>0	<-0.1		>0.1		NA
Planar FootSlope	PFS	>0	<-0.1		<0.1	>-0.1	NA
Convergent FootSlope	CFS	>0	<-0.1		<-0.1		NA
Low Catchment Level	LCL	<3.0	>-0.1	<0.1	NA		<500
High Catchment Level	HCL	<3.0	>-0.1	<0.1	NA		>500

In the original papers by Pennock et al. (1987) and Pennock et al. (1994), the slope, profile curvature, plan curvature and the watershed size were used to classify eight different landforms. A limitation existed in this classification, due to the fact that only convex or concave landforms are classified. However, in Pennock et al. (1987) the recommendation is

given to use a criterion of +/- 0.116 1/100m of profile curvature (Young, 1972) to separate planar areas from convex/concave areas. This criterion was added and used to identify three additional relief units (planar landforms) – yielding a total of 11 units (Table 2). The criterion of +/-0.1 1/100m profile curvature was taken as granted for a DEM resolution of 10 by 10 meters. Preliminary results for the field site “Bei Lotte” showed, that certain relief units were biased after the original (without planar) classification, i.e. for the shoulder positions 16 positions were classified as convex and only 2 for divergent, compared to a distribution of 2 for CSH and 15 for PSH positions for the extended (including planar) classification.
DEM provided by different sources may contain certain errors from different origin – in maps due to cartographic errors or generalization, in a laser scan DEM due to positioning errors or false values due to backscattering (Huising and Gomes Pereira, 1998)). In a terrain analysis as described above, errors become accentuated, mainly because the planform and profile curvature is the second derivative of the slope. As a result, “misclassified” areas can appear in the results. “Misclassified” pixels represent either (I) true micro-topographic landform elements that differ strongly from their surrounding positions, or (II) “misclassified” landforms due to errors in the DEM. Both results increase the difficulties to understand landform relationships connected to other processes. A classification, which minimizes “misclassified” areas was implemented in ArcInfo based on the work of Pennock et al. (1994) and extended. Five steps were implemented:

1. Performing a preliminary landform classification
2. Group the classification results into the main relief positions (Shoulder, Backslope, Footslope, Level)
3. Check if four adjacent cells are in the same relief position. If this is the case, no further classification occurs. Otherwise steps 4 and 5 are performed.
4. First, a clustering is performed to aggregate areas of similar relief positions. Secondly, if one of the adjacent cells of a given cell meets the minimum size criterion (5 cells), the value of that cell is used for the cell in question. Multiple iterations of that step are performed until no further reclassification is necessary. However, if all four cells meet that criterion, the question remains open, which value will be assigned.
5. The last step classifies cells, which did not meet the size criterion, and did not get a value assigned. Thereby the modal class of the eight cells surrounding it was assigned. However, the question remains open, which value might be assigned, if a tie between 2 classes occurs.

The procedure described above was used as a basis to develop an AML-script (landform.aml). The major difference between the published work by Pennock et al. (1994) and the program presented here is, that in all steps instead of the relief positions (SH, BS, FS, LE) the classified landforms were used. Additionally, step four and five used multiple iterations with step five using increasing window sizes to classify cells. Specific cells exist where the modal class of a 3 by 3 window does not allow to determine a landform unit. In this case, an iterative process with increasing window sizes is started until a modal value can be determined or a certain threshold due to computing efficiency (window size is 11 by 11) is met. The arbitrary threshold of 11 was set to the number of multiple iterations in step 5, because no performance gain in classification results could be observed. Figure 4 shows the results of relief classification before and after the iterative process.

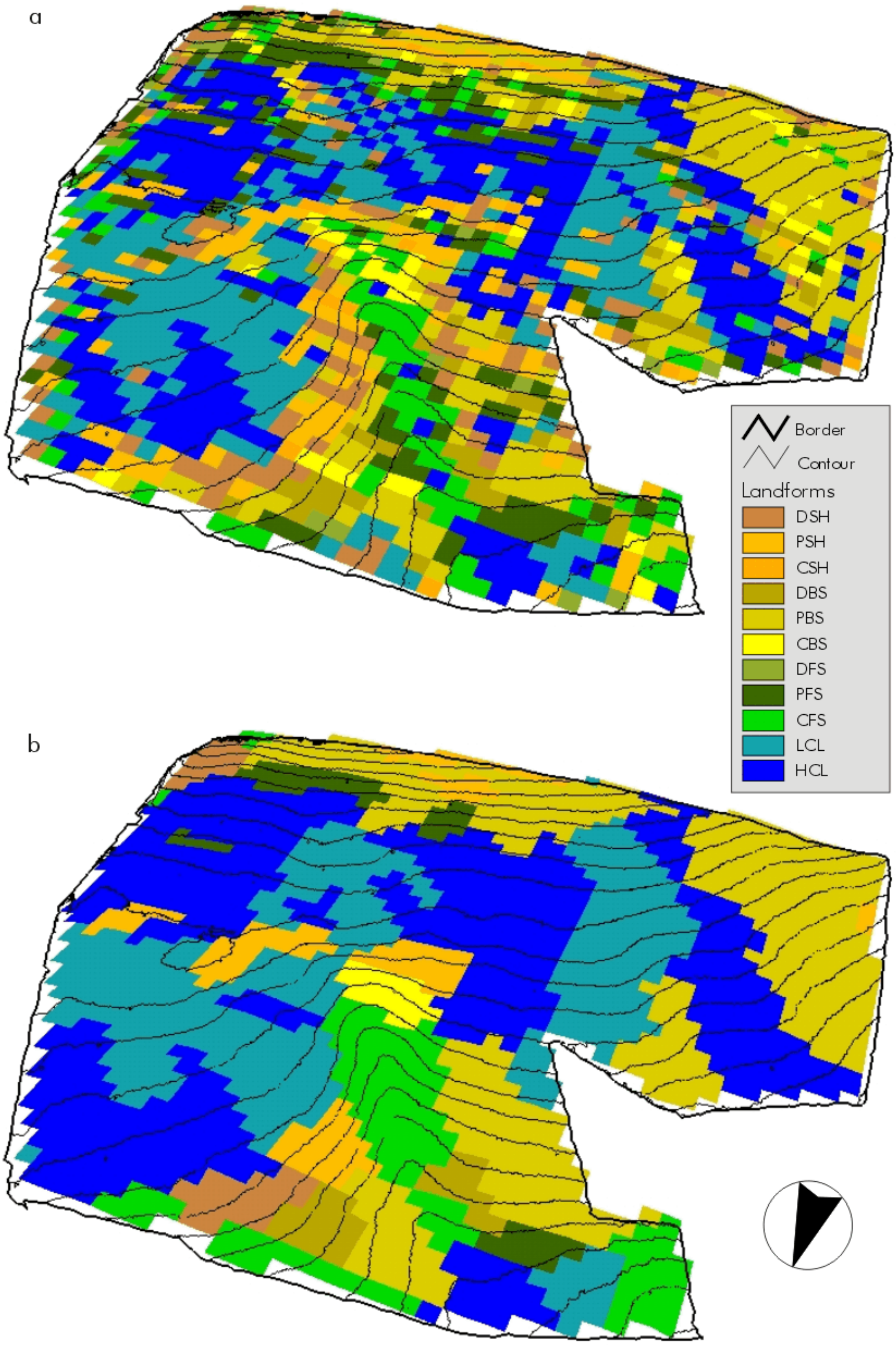

Figure 4 Example of a landform classification for the field site "Bei Lotte". (A) shows the result of an unfiltered landform classification, whereas (B) shows the same area after the area filtering approach (Threshold was set to 5 cells). The base dataset was a 10 x 10 m aggregated Laser Scan DEM.

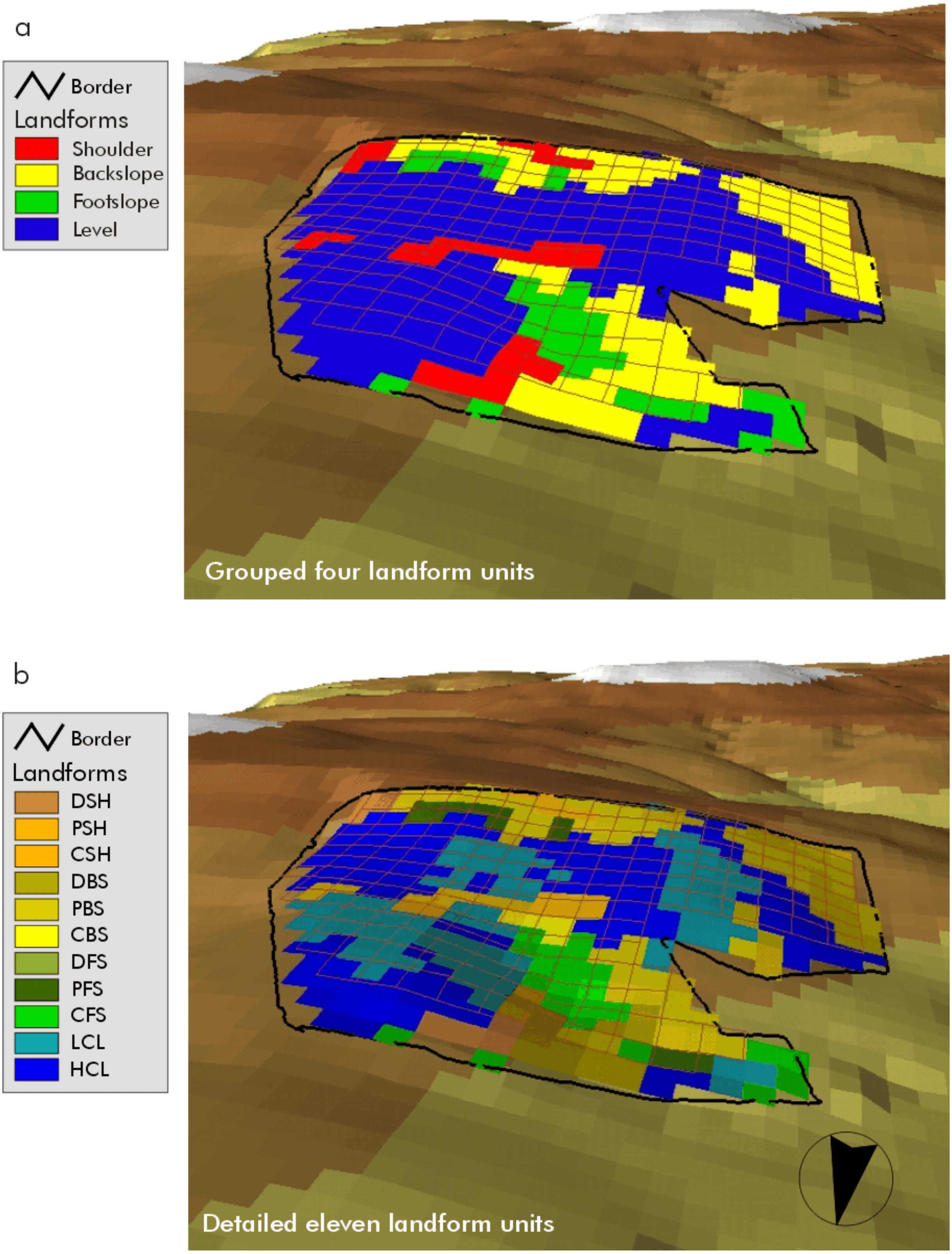

Figure 5 Landform classification for the field site “Bei Lotte” using the landform.aml. The top graph shows aggregated landform units grouped for landform positions (SH, BS, FS, LE). The bottom graph shows a detailed landform classification with all possible landforms (Notice that the CSH and the DFS do not occur at that field) . View to the south.

3 Comparison Original / Extended LF algorithm

The landform classification algorithm presented extends the original approach (Pennock et al., 1987, Pennock et al., 1994)) by adding planar LF classes. Additionally, the shape of the LF (e.g. Convergent FS instead of FS) is conserved in the classification process. The change in the methodology is evaluated against the results of the original coding in the following part.
This evaluation is shown as an example in Figure 6 for the field sites “Bei Lotte” (left) and “Sportkomplex” (right). The 400 ha 10 m x 10 m DEM, including the investigated sites, was classified using the landform.aml with an area threshold of 5 pixel, a value of 0.1 for planform curvature and profile curvature, a value of 3.0 for slope and a threshold of 500 m^2 to differentiate Level Landforms. The original classification results in so called Landform Element Complexes (LEC, Pennock and Corre, 2001), which include only Shoulder, Backslope, Footslope and Level. To compare both methods, the extended data sets were reclassified from the extended (including planar landforms) 11 LF’s to the four LECs. Part A in Figure 6 represents the original classification, whereas part B is the reclassified extended classification, and part C shows the differences between both classification approaches.
For the field site “Bei Lotte” a larger zone of SH positions are found in the northern part of the field, surrounding the depressional area running SW-NE. Additional FS and SH positions are classified at the southern end of this depression, which are not visible in the extended classification (Part B-left). These differences are visible in Part C, representing an area of 280 m^2 for the SH and LF positions and an area of 250 m^2 at the southern end of the field. Several extended structures in east-west direction are visible in the original classification (Part A), which are not represented by the extended classification. Finally, the differences between classifications are found at the field borders: It has to be noted, that classification was performed in each case for a larger area, therefore the clipped area contain only the boundary effects of the field site and no boundary effects of the DEM itself.
Similar results are obtained for the field site “Sportkomplex”. Again, the original classification resulted in an image with more pronounced heterogeneity. Especially the major west-east running depressional area (FS) is well represented. Certain structures (see the small SH-BS position visible at the northern side of the depressional area) are represented at the original classification more closely to reality (own investigations), than with the extended classification. Some linear east-west running LF’s are classified using the original classification, which are not visible in Part B, and could not be validated with the gained field experience. Similar to results for “Bei Lotte” differences are found at the field borders as well as single scattered LFs.
Generally, differences between different LF classifications can be shown for the original and the extended approach: (I) associated with the field border, (II) related to certain linear features, (III) around the borders of certain SH and FS positions and (IV) single LF elements distributed throughout the field sites. The original approach has the advantage of classifying more consistent areas for SH and FS positions (see SH and FS at field site “Bei Lotte”). One major disadvantage for the original procedure is the missing underlying shape of the landform, which is provided by the extended classification. Additionally, the linear shaped contours of landform features observed by the original classification disappear in the extended classification.
Another effect should be evaluated for the LF classification, which contributes considerably to the resulting landform classification process. As outlined above, an iterative classification process is applied based on an area threshold. This is performed to remove certain small area LF pixels, which are results of a local micro topography or of failures in the DEM and increase the difficulty to interpret the dataset.

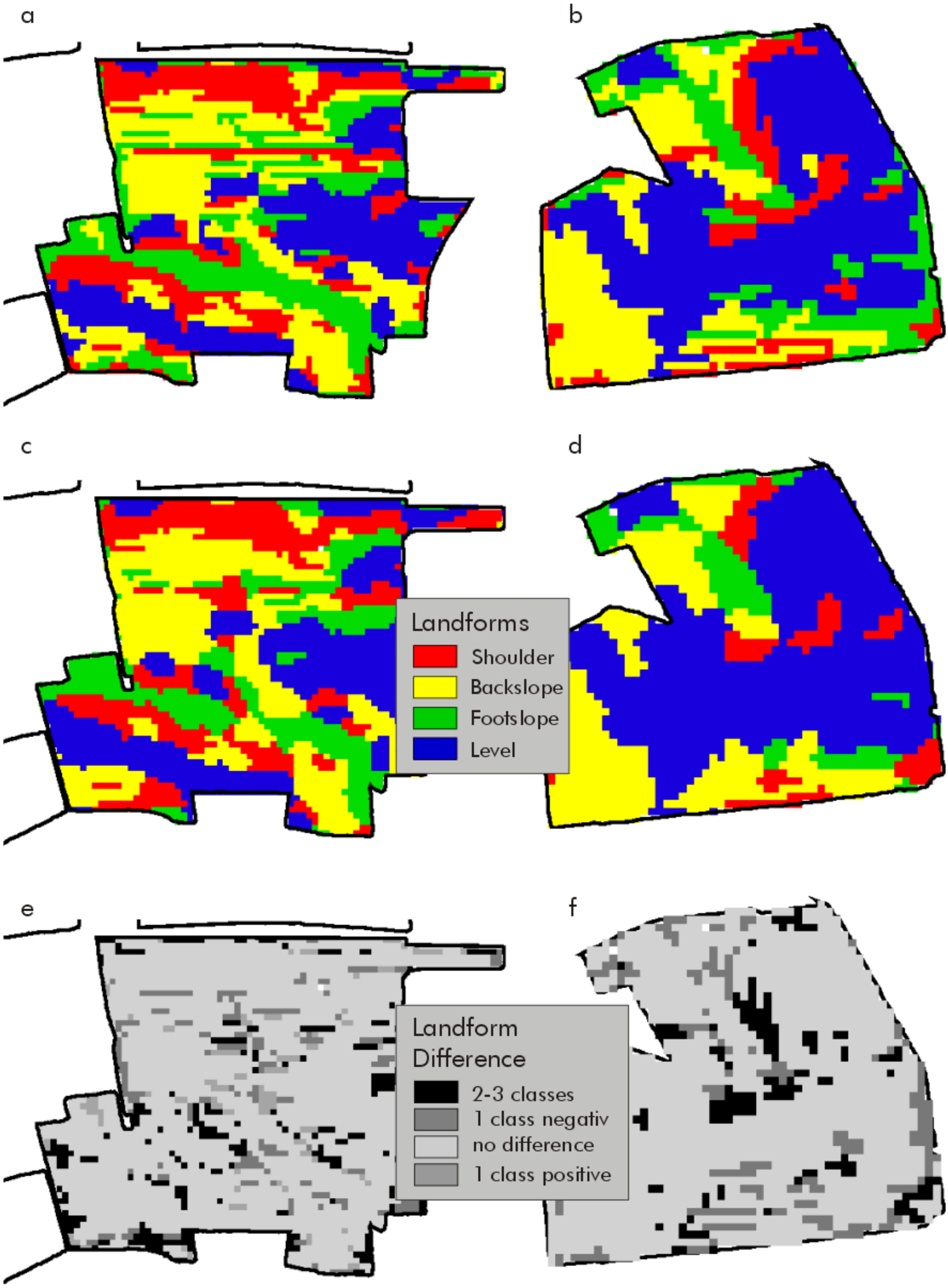

Figure 6 Classification using the original landform classification algorithm (A) using only the major Landform (SH, BS, FS, Level) and a classification using the extended landform classification algorithm (B) for the field site Bei Lotte (left side) and Sportkomplex (right side). Evaluation of both approaches is shown in C.

Two different approaches using a majority aggregation for the 27 x 27 m investigation raster are shown in Table 3, one without the area threshold (Raw data) and the other using an area threshold (Filtered data). The number of SH positions decrease from 26 to 20 as well as for FS positions decreases from 20 to 16 using the filtering approach, which in turn leads to an increase in the number of Level positions (96 to 110). However, even if we loose some information about LF at SH and FS positions using the area threshold approach, it is certainly a better way to aggregate LF than just using the raw data due to two reasons. Firstly, the data might hardly be useable due to the highly scattered appearance, and secondly the results shown here, depend strongly on the cell size of the aggregation cover.

Table 3 Frequency of unclassified and classified landform analysis for the field site "Bei Lotte" using a majority aggregation, LF classification based on the LS with 10 m resolution.

Landform	*DSH*	*PSH*	*DBS*	*PBS*	*CBS*	*PFS*	*CFS*	*LCL*	*HCL*
Filtered	2	15	3	43	3	7	9	47	63
Raw	11	17	8	36	4	16	4	44	52

4 AML to compute relief parameters

&r topo <INPUTDEM> {streamflow threshold} {streamcover} (i.e. &r topo ls10 150)

- INPUTDEM - a grid representing a continuous surface.
- streamflow threshold - a threshold value to select cells with a high accumulated flow to create a stream network, if not provided a value of 100 will be assumed
- streamcover – instead of a threshold value an existing stream network can be used.

&r elevres <INPUTDEM> {MOVING_WINDOWSIZE} (i.e. &r elevres ls10 20)

- INPUTDEM - a grid representing a continuous surface.
- MOVING_WINDOWSIZE the size of the window in cells to aggregate the DEM, if not provided a value of 200 is assumed, if MOVING_WINDOWSIZE is larger than DEM, the AML will stop with an error code.

&r pennock95 <INPUTDEM> <OUTPUTDEM> {method} {threshold} {profile} {planform} {slope} {watershedarea} {all/original} {graphik y/n}

- INPUTDEM - a grid representing a continuous surface, xyz units in meters, for the default parameters provided below a DEM resolution of 10 x 10 m is assumed.
- OUTDEM – the output grid showing the landform classification, additionally an Grid named OUTDEMc is provided automatically which shows the area filtered landform classification.
- {method} – use 11 or 8 – leads to a total number of 11 landform units (classifying planar sites) or 8 landform units (planar sites will be classified either as convergent or divergent landform units), if not provided a value of 11 will be used.
- {threshold} – use integer value, indicated the area threshold value to filter small scale landform units, if not provided a value of 5 will be used.
- {profile} – profile curvature threshold, if not provided a value of 0.1 will be used.
- {planform} – planform curvature threshold, if not provided a value of 0.1 will be used.
- {slope} – slope threshold, if not provided a value of 3.0 will be used.
- {watershedarea} – Area Threshold to differentiate between low and high catchment level areas, if not provided a value of 500 will be used.
- {all/original} – switch to compute landform units as closely as possible to pennocks original work (*original)* (only SH; BS; FS; LEVEL will be used in the are filtering procedure), by default the implemented *all* algorithm is used, providing a wider range of landform units.
- {graphik y/n} – switch to allow for graphic representation of the area filtering procedure, turned off by default for speed.
- WARNING: the default parameter used by the landform classification process are published for a 10 x 10 m DEM. Different resolutions need DIFFERENT parameters.

&r montewi <INPUTDEM> <OUTPUTDEM> <standard deviation> <number of iterations> {break}

- <inputDEM> - a grid representing a continuous surface, xyz units in meters.
- <outputdem> - a grid name for the resulting file
- <standard deviation> - standard deviation to be used in the monte carlo (MC) simulation
- <number of iterations> - number of iterations to be performed in the MC-simulation
- {break} – The AML will stop if (I) the number of iterations is reached or (II) the difference between two iterations gets smaller than *break*. The threshold *break* is computed by dividing the <standard deviations> by <number of iterations>. This is done to decrease computing times. If you want to perform always the same number of iterations, set *break* to a very small value.

5 Example of a typical relief classification:

```
Arc: |> lg  <|
 Workspace:        /DATEN/BOD_VOL/REUTER/DGM/TEST/TEST

 Available GRIDs
 -------------------
  LS10

Arc: |> &r topo <|
USAGE: topo <DEM> {streamflow threshold} {streamcover}
Arc: |> &r topo ls10 <|

Set streamflow threshold to 100

LOG OFF
Copyright (C) 1982-2002 Environmental Systems Research Institute, Inc.
All rights reserved.
GRID 8.2 (Thu Mar 14 16:26:27 PST 2002)

Compute general indices

Calculating curvatures...
  Computing flow direction...
  Computing flow accumulation...
  Running...
 Running...
 Computing stream order...
  Labeling stream links...
  Killed TMP12346 with the ARC option
Delineating drainage basin...
  Getting data ..
Computing Statistics ...
Percentage of Cells Processed:
 Writing Output ...
Percentage of Cells Processed:
 Running... Delineating watershed...
  Killed TMP12345 with the ARC option

COMPUTING INDICES NOW

Running... Killed TMP12345 with the ARC option
Running... Killed TMP12345 with the ARC option
computing Wetness index

Running... Running... Killed LS10SLP1 with the ARC option

computing stream power index

Running...
computing Sediment transport index

Running...
WI, SPI and STC are done


Compute Relative Relief Position

Killed TMP12346 with the ARC option
Getting data ..
Computing Statistics ...
```

```
Percentage of Cells Processed: Writing Output ...
Percentage of Cells Processed: Getting data ..
Computing Statistics ...
Percentage of Cells Processed: Writing Output ...
Percentage of Cells Processed: Running...
Compute Relief energy

Running...
Ready for landform classification

LOG ON
Leaving GRID...

######################################
Up to here ALL RELIEF PARAMETERS FOR landform.aml should be generated.
You can generate them also manually for slope naming DEMNAMEslp, for
profile curvature DEMNAMEprofm, for planform curvature DEMNAMEplan, and the
flowaccumulation area DEMNAMEflacc-
############################################################

Arc: |> &r pennock95 <|
USAGE: landform <DEM> <OUTDEM> {method} {threshold} {profile} {planform}
{slope} {watershedarea} {all/original} {graphik y/n}
Arc: |> &r pennock95 ls10 ls10180603  <|

Delete old temporary files

Killed tmp12345 with the ALL option
Killed tmp12346 with the ALL option
LOG OFF
Copyright (C) 1982-2002 Environmental Systems Research Institute, Inc.
All rights reserved.
GRID 8.2 (Thu Mar 14 16:26:27 PST 2002)


Process DEM ls10 with Parameters SLOPE 3, PROFILE CURVATURE 0.1 and
PLANFORM CUVRATURE 0.1.
Classification threshold is set to 5 cells
Classify will run on all method

iterative count 3
1000
814.5809017421
iterative count 4
185.4190982579
34.5017965362
iterative count 5
150.9173017217
16.907639886
iterative count 6
134.0096618357
19.6338736894
iterative count 7
114.3757881463
10.2789538819
iterative count 8
104.0968342644
3.6748933361
iterative count 9
100.4219409283
-0.0044983041
iterative count 10
100.4264392324
-0.0018262922
```

```
iterative count 11
100.4282655246

0

Done with Iteration

Looking for Tie cells

--> No grids match specification tmp1234*
200

Filling Count 3
193.3628318584
6.637168141593

Filling Count 5
8.637168141593
-2

Filling Count 7
0

Done with filling

Final Fill

count 9

LOG ON
Leaving GRID...

########################
that is the end of the landform algorithm
Next few lines provide moving window ( elevres.aml) results
########################

Arc: |> &r elevres ls10 20 <|

BE CAREFULL - LARGE WINDOW SIZE NEED HUGE COMPUTING TIMES

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GRID 8.2 (Thu Mar 14 16:26:27 PST 2002)

Running... 100%
done with mean
Running... 100%
done with diff
Running... 100%
done with SD
Running... 100%
done with range
Running... 100%
done with deviation
compute min and max - needed parameter for percentage
Running... 100%
Running... 100%
Running... 100%
done with percentage
performed elevation residual analysis

########################
that is the end of the elevres.aml
```

```
Next few lines show analysis for monte carlo wetness index computations.
########################

Grid: &r montewi mb10
Warning: ridiculously long PATH truncated
LOG OFF
Usage: MONTEWI <dem> <stdev> <n steps> <out-grid> {break}
Grid: &r montewi mb10 mb10mwi 0.1 50
---> Saved LOG (log.save) already exists, quitting

Break occurs at 0.002, if you want more iterations, set break to a smaller
value
--> No grids match specification temp*
--> No grids match specification sum*
Computing tempdem ...
computing Wetness index
done 1 of 50 loops ...
Computing tempdem ...
computing Wetness index
. . . . .
done 14 of 50 loops ...

The Stddev of loop 14 showed only a difference of 0.001136525389 to the
Stddev of the run before
therefore MC is stopped here.

--> No grids match specification tmp*

 statistics for mb10test
____________________________________

minimum value: 6.6825
maximum value: 13.9277
mean value: 8.6929
standard deviation: 1.0893

Warning: ridiculously long PATH truncated
LOG ON
Grid:
########################
that is the end of the montewi.aml
next few lines show results
########################
Grid: lg
 Workspace:        /DATEN/BOD_VOL/REUTER/DGM/TEST/TEST

 Available GRIDs
 -------------------
  LS10               LS10180603        LS10180603C       LS10ASP
  LS10BAS            LS10BASA          LS10CUR           LS10DEV
  LS10DIFF           LS10FL1           LS10FLACC         LS10FLDIR
  LS10LF11           LS10LFR11         LS10MAX           LS10MEAN
  LS10MIN            LS10PCTG          LS10PCTG1         LS10PLAN
  LS10PROF           LS10RANGE         LS10RE            LS10SD
  LS10SLP            LS10SPI           LS10STC           LS10STRLNK
  LS10STRNET         LS10STRORD        LS10WI            LS10WSHA
  LS10WSHD
Grid: q
Leaving GRID...
Arc: q
```

Table 4 Names of computed relief parameters for the example DEM MB10

MB10	DEM with 10 x 10 m resolution
MB10180603	Pennocks LF classification without area filter (raw classification results
MB10180603C	Pennocks LF classification with area filter
MB10ASP	Exposition
MB10BAS	Basin numbered
MB10BASA	Basin Area
MB10CUR	Curvature
MB10DEV	Deviation based on mowing window
MB10DIFF	Diff based on mowing window
MB10FL1	Flowaccumulation (adapted for used in TWI)
MB10FLACC	Flowaccumulation
MB10FLDIR	Flowdirection
MB10LF11	LF-classification intermediate result- before area filtering
MB10LFR11	LF-classification intermediate result- reclassed for SH,BS,FS,LEVEL
MB10MAX	Maximum Elevation based on mowing window
MB10MEAN	Average Elevation based on mowing window
MB10MIN	Minimum Elevation based on mowing window
MB10MWI	Monte Carlo Simulated Topographic wetness index
MB10PCTG	Percentage of Landscape based on mowing window
MB10PCTG1	Percentage of Landscape based on watershed area
MB10PLAN	Planform curvature
MB10PROF	Profile curvature
MB10RANGE	Elevation Range based on mowing window
MB10SD	Elevation Standard Deviation based on mowing window
MB10SLP	Slope
MB10SPI	Stream Power Index
MB10STC	Sediment Transport Capacity
MB10STRLNK	Stream Link
MB10STRNET	Stream Network
MB10STRORD	Stream Order
MB10WI	Topographic Wetness Index
MB10MRDG	Ridge Positions

6 Reference List

Huising,E.J. and Gomes Pereira,L.M., 1998. Errors and accuracy estimates of laser data acquired by varois laser scanning systems for topographic applications. ISPRS Journal of Photogrammery & Remote Sensing, 53: 245-261.

Moore,I.D., Gessler,P.E., Nielsen,G.A., and Peterson,G.A., 1993. Soil Attribute Prediction Using Terrain Analysis. SSSAJ, 57: 443-452.

Pennock,D.J., Anderson,D.W., and De Jong,E., 1994. Landscape-scale changes in indicators of soil quality due to cultivation in Saskatchewan, Canada. Geoderma, 64: 1-19.

Pennock,D.J. and Corre,M.D., 2001. Development and application of landform segmenation procedures. Soil & Tillage Research, 58: 151-162.

Pennock,D.J., Zebarth,B.J., and De Jong,E., 1987. Landform Classification and Soil Distribution in Hummocky Terrain, Saskatchewan, Canada. Geoderma, 40: 297-315.

Wilson,J.P. and Gallant,J.C., 2001. Terrain Analysis - Principles and Applications. John Wiley & Sons,Inc., New York.

Young,A., 1972. Slopes. Edingburgh.