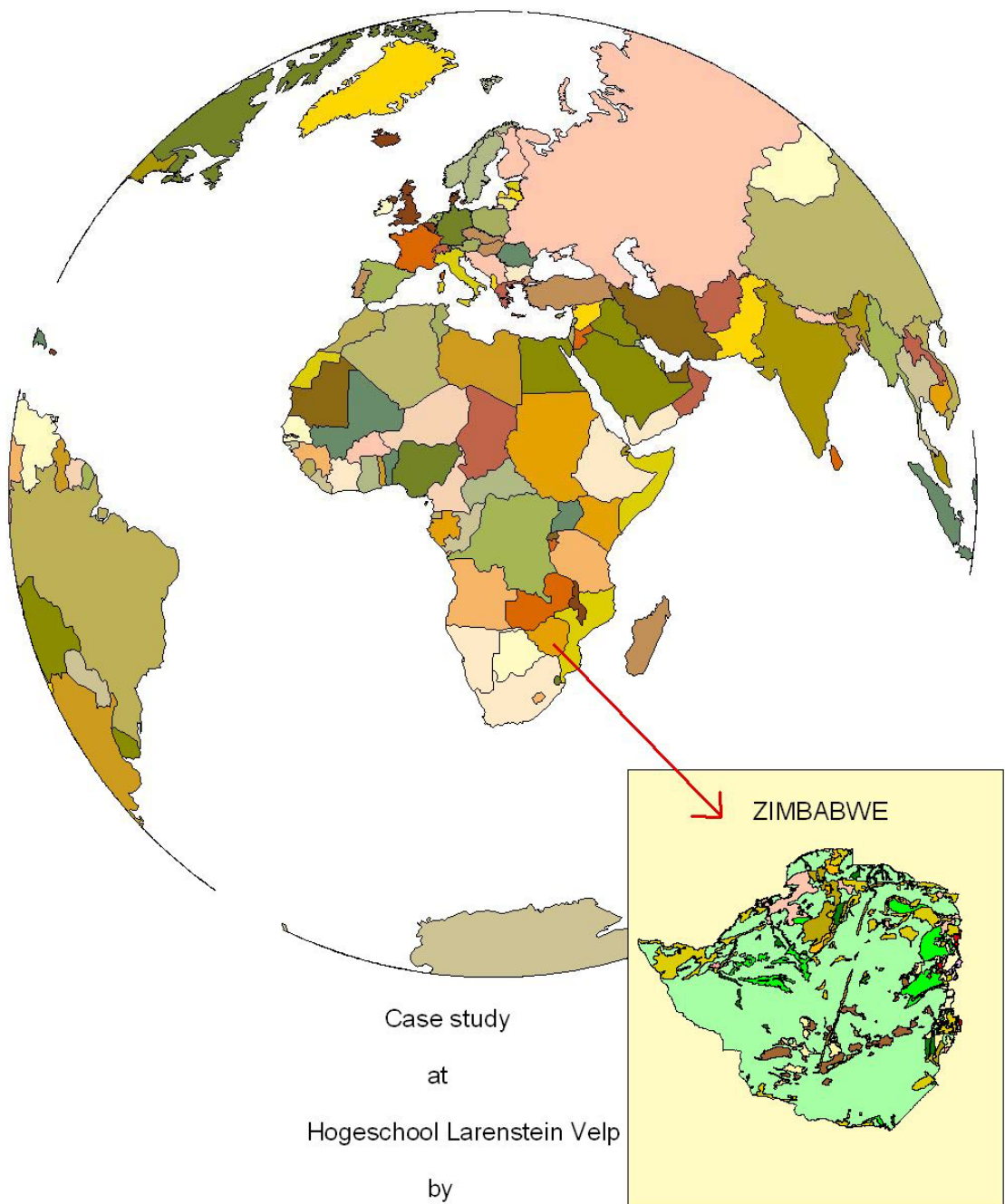DEVELOPMENT OF TERRAIN CLASSES USING DIGITAL ELEVATION MODELS (DEM)
FOR THE SMALL SCALE (1:1M) SOTER DATABASE



ZIMBABWE

Case study

at

Hogeschool Larenstein Velp

by

J. Huting

December 2002

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## Introduction

The SOTER(Global and National Soils and Terrain Digital Database) programme is a joint initiative of ISRIC (International Soil Reference and Information Centre), IUSS (International Union of Soil Sciences), FAO (Food and Agriculture Organization of the United Nations) and UNEP( United Nations Environment Programme).
The development of SOTER map units are based on topographical and lithological information.
The first level of the development of these SOTER units is the 'terrain' unit.
This development is usually based on the "expert" interpretation that relies on ancillary data sources and first hand knowledge of the scientists involved in the project . This expert interpretation may be somewhat subjective. With the increasing capabilities of GIS technology and availability of digital spatial data, new approaches can be used for the characterization process.
Digital Elevation Models (DEM) make elevation data available for spatial analysis using GIS.
Methods are presented how DEM-derived terrain classes can be made.

## Dem uncertainty

DEMs can be produced from different sources such as:
- ➢ Aerial photography
- ➢ Elevation contours from maps (termed the "contour-to-grid" process)
- ➢ Satellite data
- ➢ Laser altimetry
- ➢ Radar (Interferometry)

Elevation data represented in digital format is called a Digital Elevation Model.
So DEMs are models of elevation.
Digital elevation data is often effected by errors due to random sampling error and excessive interpolation. The errors in DEMs propagates itself into error in all parameters derived from the DEM. The lack of knowledge about the reliability of the elevation measurement and its representation of the truth is referred to as uncertainty.
The exact nature and location of errors in elevation data cannot be precisely determined.
Several methodologies has been developed to simulate the effect of uncertainty on DEMs and the derived parameters such as slope, aspect, relief, etc.
(especially the Monte Carlo simulation is well known)
There are three types of error:
1. Blunders

Vertical errors associated with the data collection process and are generally identified and removed prior to release the data.

2. Systematic errors

Results of procedures used in the DEM generating process and can cause bias or artefacts in the final DEM product. When the cause is known, the systematic error can be eliminated or reduced.
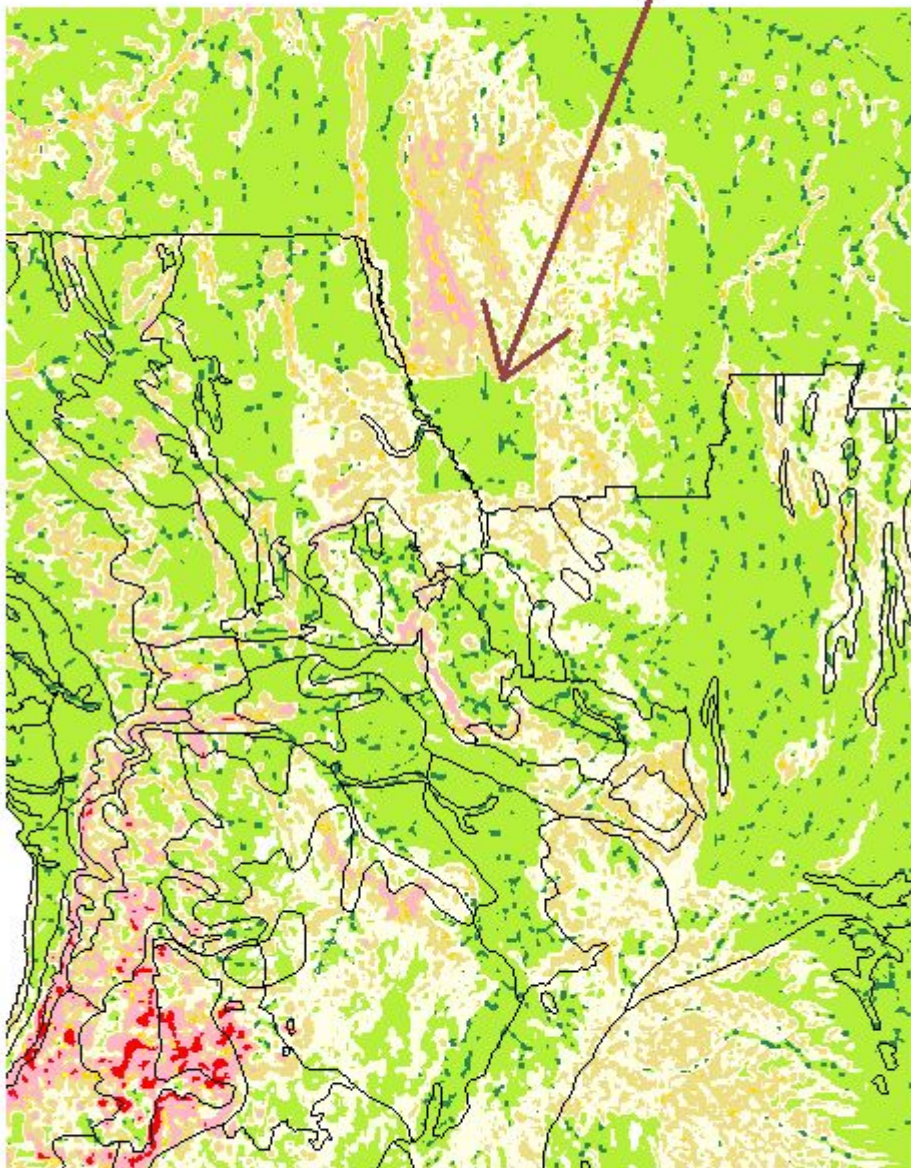
3. Random errors

Remain in the data after blunders and systematic errors are removed.

The users must be aware of the problems of uncertainty in DEM data.

## Software

WinZip
ArcView 3.2(a)
ArcView Spatial Analyst Extension
ArcView 3D Analyst extension (Only for the visualization techniques)

## Retrieving the DEM from the web

De GTOTO30 data set was developed by the U.S. Geological Survey's EROS Data Center.
The data set covers an area that ranges between 90 degrees north to 90 degrees south latitude an between 180 degrees west to 180 degrees east longitude.
The horizontal grid spacing is 30 arc-seconds (0.008333 degrees or approximately 1 kilometer.)
The coordinate system is decimal degrees and longitude referenced to WGS84.
The vertical units represent elevation in meters above sealevel. (from –407 to 8752 meters)
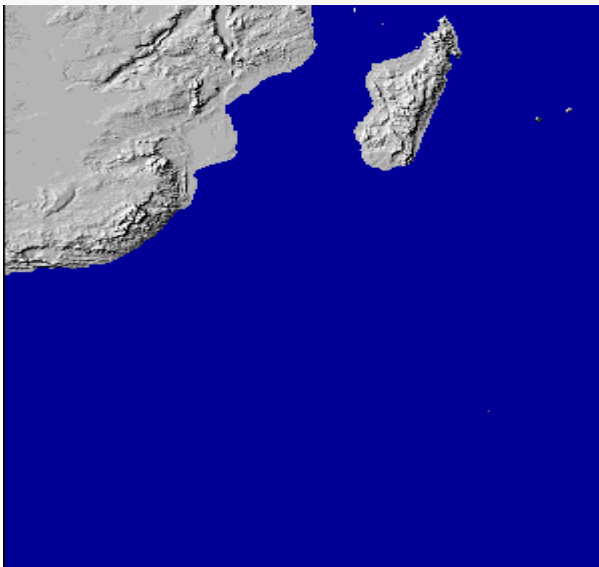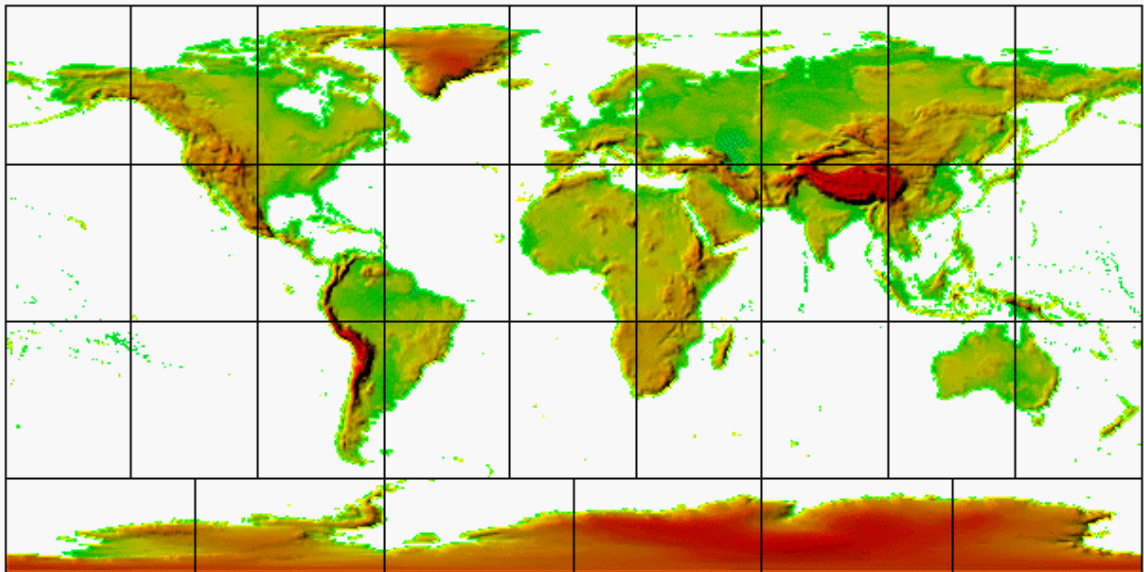




Tile e020s10 (Zimbabwe included)

Download website:
http://edcdaac.usgs.gov/gtopo30/e020s10.html

Oceans have been masked as "no data" and have a value of –9999
The download consists of a compressed e020s10.tar.gz file.
Decompress this file with WinZip into the desired folder.(f.i. the working directory of ArcView)
This folder contains 8 folders with different extensions.
Rename the e020s10.dem to e020s10.bil (Band Interleaved by Line)
This file can be imported in Arcview.


## Retrieving and manipulating the DEM in ArcView


Start Arcview  and  under File►Extensions make sure the Spatial Analyst  is loaded.
Set the Working Directory under File to your folder.
Open a new View and under View►Properties set the Map Units to meters and the Distance Units
to kilometers.
Projections Properties ►Category:Projections of a Hemisphere Type:Lambert Equal-Area
Azimuthal (Equatorial). Select Custum and type +20 for the Central Meridian and +5 for the
Reference Latitude.


Add the e020s10.bil image file to the View as Image Data Source.
Make the theme active and display.
Convert the image to grid by choosing Theme►Convert to Grid, put it in your folder and give it a
name.
Because a grid cannot be projected in theView,  it first must be projected in ArcInfo.
Statements:
projectcover inputfile outputfile
input
projection geographic
units dd
datum WGS84
spheroid WGS84
parameters
output
projection Lambert Azimuthal Equal Area
units meters
longitude center: 20 00 00
latitude center :   05 00 00


An alternative way to project the data, if you don't possess ArcInfo or ArcGis is  to download the
ArcView extension patch analist.avx from the web and put it in the directory
\esri\av_gis30\arcview\ext32.
Retrieve the projected gridfile into Arcview and give it the name Elevgrid.

Browse to the esri\esridata\world folder and add the cntr98.shp to your View as a Feature Data Source. Make it active and display.
With "Select Feature" select Zimbabwe and choose Theme►Create buffers.(Only for the selected features)
Now you are creating a buffer of 50 km only outside the polygons.
Theme►Convert to Shapefile, put it in your folder and name it Zimbuf. Remove the cntr98 shape file from the View.

.
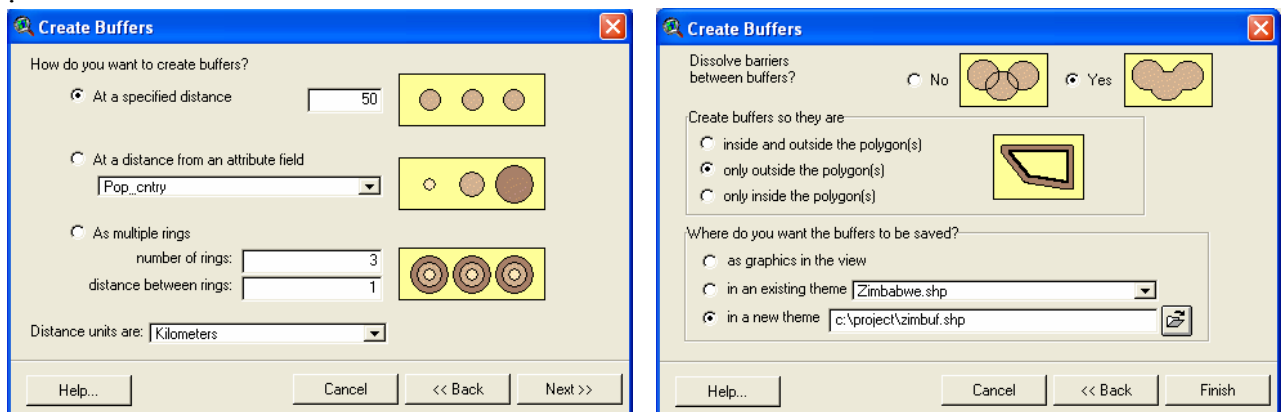


Add your Zimbabwe reference (Esri) shape file to the projected View.
Make Zimbuf.shp active: Theme►Convert to Grid . In the dialog box fill in for the -Output Grid Extent-: *Same As Zimbuf.shp*, for the -Output Grid Cell Size-: *Same As Elevgrid*►OK
Accept the -Pick field for cell values-►OK and add the theme to the View under the name Zimgrid.

The calculations are performed only for the desired area (Zimgrid) :
  Analyses ► Properties
-Analyses Extent- *Same As Zimgrid*
-Analysis Cell Size- *Same As Elevgrid* (1000m)
-Analyses Mask- *No Mask Set*

Manipulating the grid values in the Grid theme:
Analyses►Map Calculator:
([Elevgrid] >=32768).con([Elevgrid]-65536,[Elevgrid])

In this formula 32768 represents $2^{15}$ and 65536 represents $2^{16}$.
In the GTOPO30 DEM, 1 bit is used for the sign and 15 bits for the number.
This means $2^{15}$ is the maximum value that can be presented.
Arcview interprets the integer data as unsigned and uses all 16 bits for the number.
The values are in the range of 0 – 65536.
The outputgrid is Mapcalculation 1

As earlier mentioned, GTOPO datafiles use –9999 for the ocean.
These values need to be changed to 0.
Analyses►Map Calculator:
([Map Calculation 1]=-9999).setnull([Map Calculation 1])
The outputgrid is Mapcalculation 2

Double Click on theme Map Calculations 2
-Classify-        *Number of classes:* 5
                  *Round values at:* d

Make classes in the field "Value" of  0-200; 200-300; 300-400; 400-600; 600-1000; 1000-1500; 1500-3000; 3000-5000; >5000  Color Ramps: Terrain Elevation #3
Save the legend as elevation.avl

With Map Calculation 2 active: Theme ► Properties Rename the Theme Name to <u>Elevation</u>

This elevation grid is the base for further calculations.
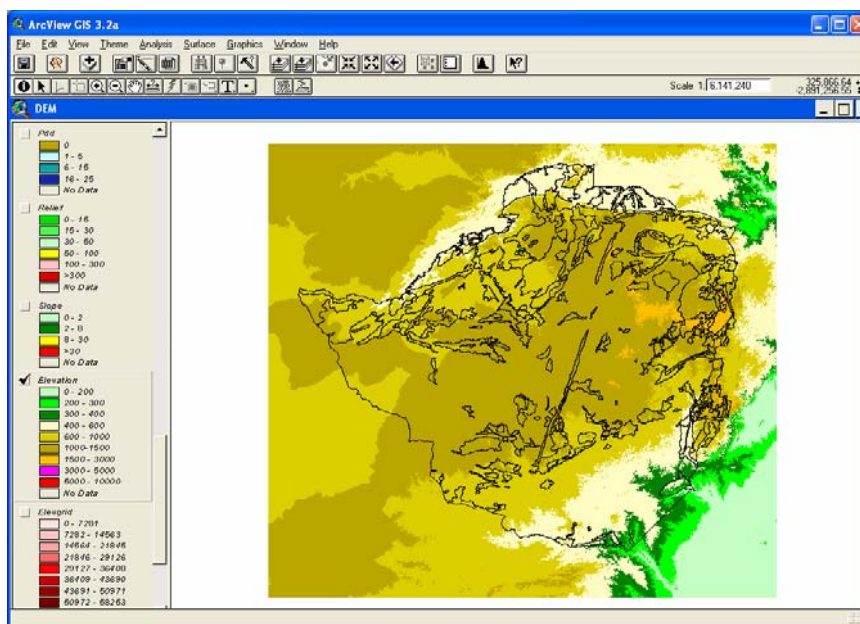


# <u>Visualization and analysing techniques</u>

*To create a Profile Graph:*

View ►New Themes
In the New Theme dialog box fill choose for the Feature type "*Line*"; OK and accept the File Name
Select the "Draw Line" button and draw a line in the map of the zone to be analysed.
With the line selected:
Theme ►Convert to 3D Shape file
In the dialogbox : Get Z values from: *Surface*; OK
Choose theme to use as surface: *Elevation*
Sample distance on grid: *1000*; OK
Accept the file name and add the 3D shapefile as theme to the view.
Make the line somewhat thicker and make it black.
View ► Layout
Modify the layout and put the elevation map at the top.

Choose the "Profile Graph" button and draw a box beneath the elevation map.

*To create Hillshade grid:*
a. Surface ► Compute Hillshade
Or with the Map Calculator:
b. [Elevation].Hillshade(315,45,2)
Where 315 is the value for the azimuth (0-360); 45 the value for the altitude (0-90)
2 is a zfactor. Nil for no zfactor.
(a disadvantage of method a is that there is not a possibility for giving it a zfactor)
With the elevation theme active doubleclick  this theme and in the Legend Editor open the
Advanced button and choose *Hillshade of Elevation* under Brightness Theme and accept the
Minimum/Maximum  Cell Brightness (20/80); OK
Now the elevation theme gives a relief.

Hillshade
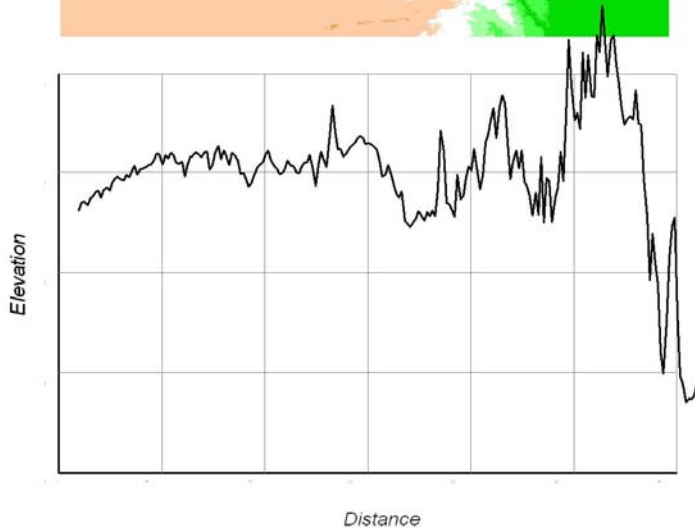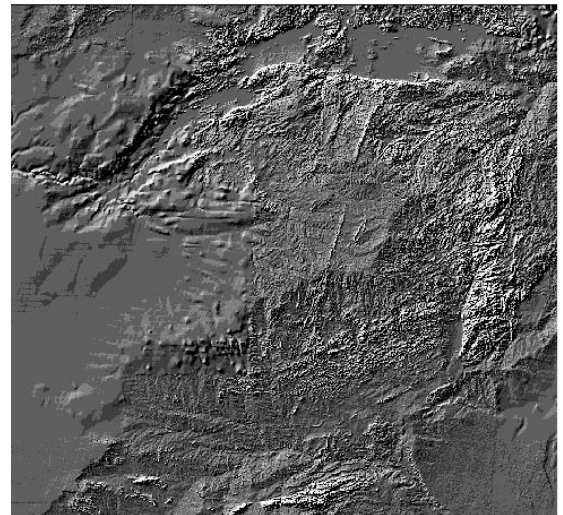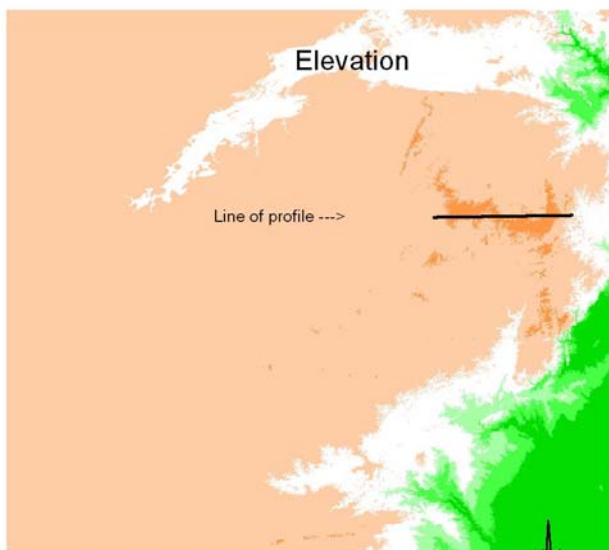
# The Moving window



◻ (yellow) =  moving window

◻ (gray) =  area that is affected by edge effects.
When the processing cell is in this area, part of the moving window has no data when calculations are performed on the input theme.
Therefore, the output values located in the gray area are based on incomplete information. This is the main reason to create a buffer around Zimbabwe to enlarge the analysis extent.

◻ (red) =  Processing cell
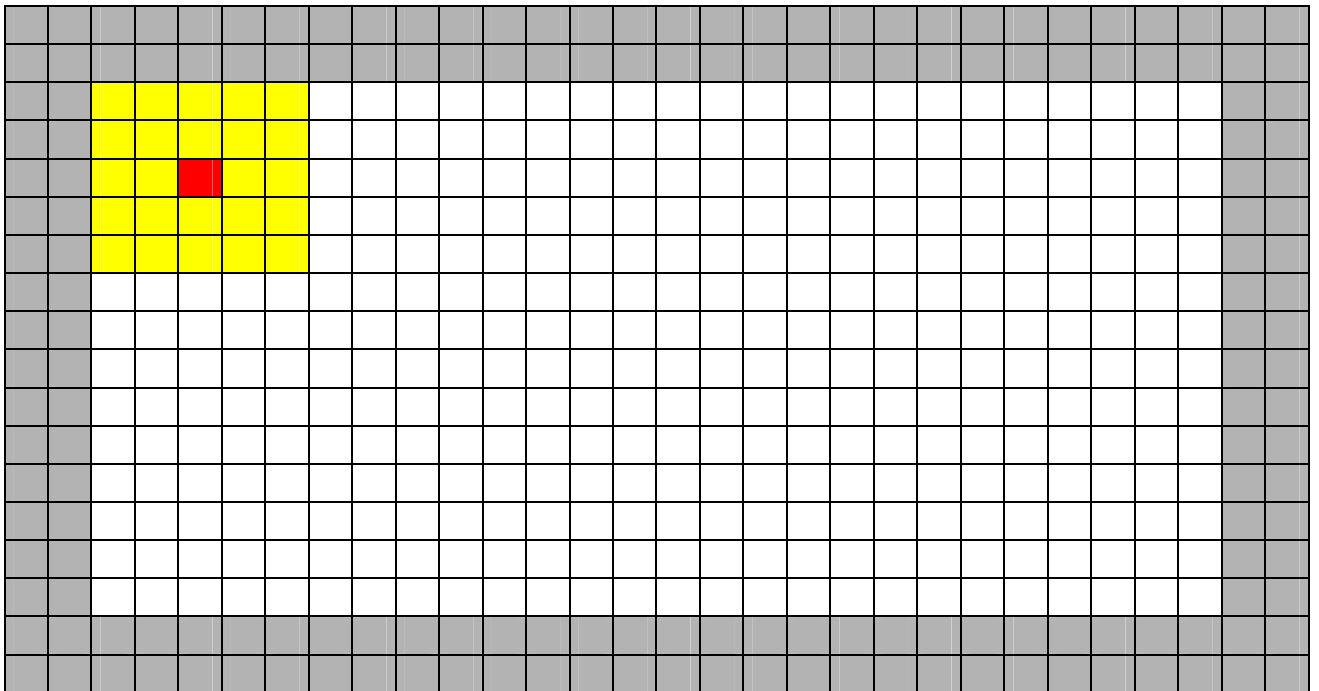
The moving window is used on raster data to perform neighborhood analyses such as mean, sum, minimun, maximum, median, range, standard deviation, minority, majority and variety. Calculations are performed in the window (yellow) and in the new output grid this value is stored at the place of the processing cell. The window is then moved one cell position and calculations are repeated until the entire grid has been processed.

The moving window is a square window and has a dimension of 5 x 5 cells.
The window does not necessarily have to be square. It can be circular or defined as a rectangle
A disadvantage of the square or rectangle window is that the diagonal neighborhood cells have not the same distance from the processing cell.
A circle seems more appropriate than a square because the boundary of a circle will always be of equal distance to the focal point. (the processing cell)

The distance from the centre of the red cell to the yellow one = $\sqrt{2}$ = 1.41 km in a 1 km grid

## Slope

Many different algorithms exist to compute slope from an elevation grid. Most systems pass a 3x3 moving window over a grid where the slope for the center cell is computed.
ArcView computes slope using a method called "Kings Case" that incorporates all surrounding eight cells where the slope for the centre cell E is computed from the surrounding cells
A, B, C, D, F, G, H and I (Burrough and McDonnell,1998; ESRI, 1998)

| A | B | C |
|---|---|---|
| D | E | F |
| G | H | I |
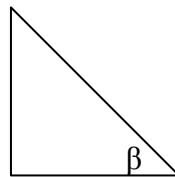
$$Slope = Tan\beta = \sqrt{\left(\frac{\Delta z}{\Delta x}\right)^2 + \left(\frac{\Delta z}{\Delta y}\right)^2} *100$$

where $\left(\frac{\Delta z}{\Delta x}\right)^2$ and $\left(\frac{\Delta z}{\Delta y}\right)^2$ are computed from the 3 x 3 matrix as follows :

$$\left(\frac{\Delta z}{\Delta x}\right)^2 = [((A + 2D + G) - (C + 2F + I)) : (8 * x \text{ grid spacing})]^2$$

$$\left(\frac{\Delta z}{\Delta y}\right)^2 = [((A + 2B + C) - (G + 2H + I)) : (8 * y \text{ grid spacing})]^2$$

To derive slope:

Analyses ► Map Calculator:
[Elevation].Slope(2.5,TRUE)
Evaluate
The factor 2.5 has been chosen because the slope in a 1 km DEM is in reality 2.5 times of this value. One has approved this by comparing the slope values with higher resolution DEM's.

Double click the theme and make 4 classes of respectively 0-2; 2-8; 8-30 and >30 % slope
*Round values at:* did
Rename the theme name to "slope" under Theme Properties.
Analyses ► Map Calculator:
Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *3* Height: *3* Units :*Cell*
Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *5* Height: *5* Units :*Cell*
Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *7* Height: *7* Units :*Cell*



## **Relief**

The 5 x 5 moving window is used to derive the maximum and the minimum elevations.
The Relief = Elevation$_{MAX}$ - Elevation$_{MIN}$

There are two ways to calculate the index:
1. Analysis ► Map Calculator (this example only uses the 5 x 5 moving window)
([Elevation].Focalstats(#Grid_statype_MAX,NbrHood.MakeRectangle(5,5,false)-
([Elevation].Focalstats(#Grid_statype_MIN,NbrHood.MakeRectangle(5,5,false)
Evaluate
The mean of the Relief:
([Reliefgrid].Focalstats(#Grid_statype_MEAN,NbrHood.MakeRectangle(5,5,false)
Evaluate
The other way is straight from the Analysis menu:
2. With the elevation theme active:
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *3* Height: *3* Units :*Cell*
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *5* Height: *5* Units :*Cell*
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *7* Height: *7* Units :*Cell*
Respectively:
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *3* Height: *3* Units :*Cell*
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *5* Height: *5* Units :*Cell*
Neighborhood statistiscs: Statistic: *MAX* Neighborhood: *Rectangle* Width: *7* Height: *7* Units :*Cell*

Neighborhood Statistics

Statistic   Maximum

Neighborhood   Rectangle

Width 5   Cells

Height 5   Cells

Units ○ Distance   ● Cell

OK   Cancel

mines

Neighborhood Statistics

Statistic   Minimum

Neighborhood   Rectangle

Width 5   Cells

Height 5   Cells

Units ○ Distance   ● Cell

OK   Cancel

→   Relief

Analyses ►

Map Calculator:
([NbrMax of Elevation] – [NbrMin of Elevation])
Evaluate
The mean of the relief:
Analyses ► Map Calculator:
Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *3* Height: *3* Units :*Cell*
Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *5* Height: *5* Units :*Cell*
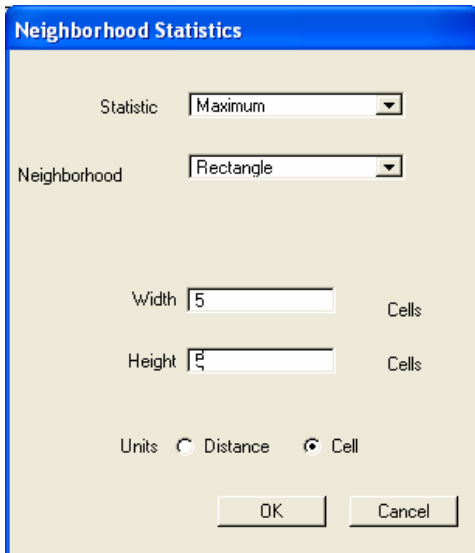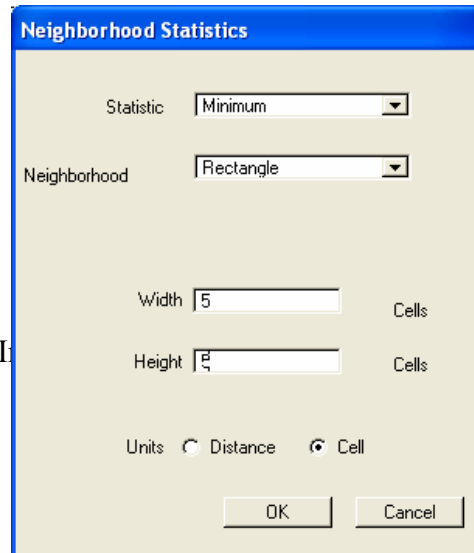Neighborhood statistics: Statistic: *Mean* Neighborhood: *Rectangle* Width: *7* Height: *7* Units :*Cell*


Rename the in method 1 or method 2 obtained resulting grid to "Relief "
Double click the theme and make 7 classes of 0-15; 15-30; 30-50; 50-100; 100-300 and >300
Choose a dichromatic Color Ramp.

## **Effect of slope and relief on window size**
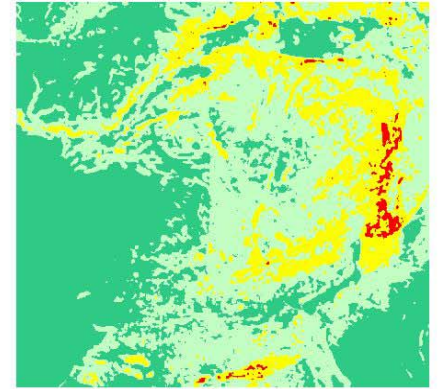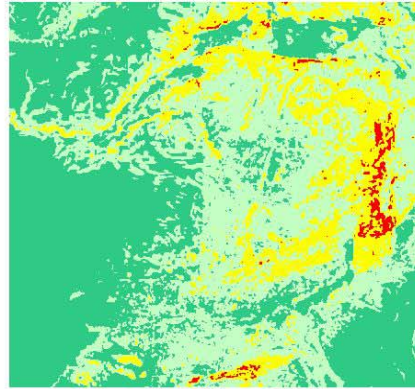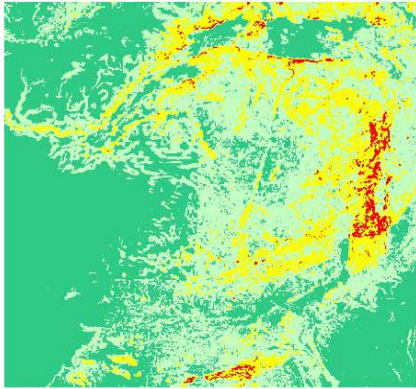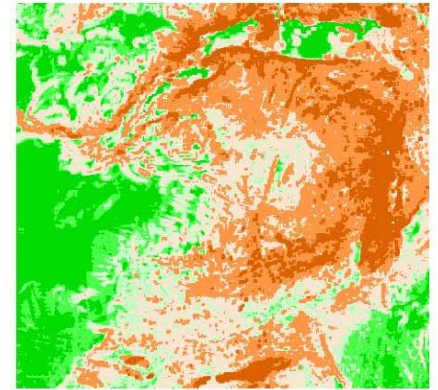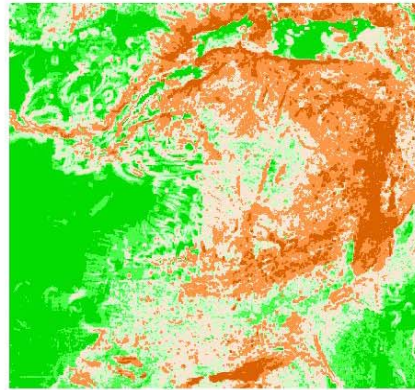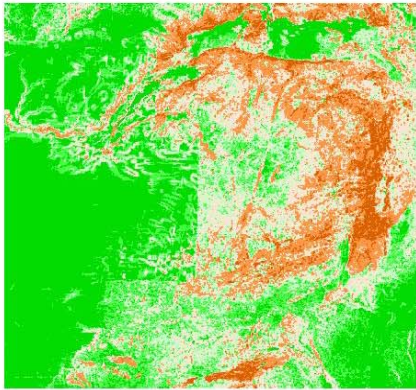
Effects of slope and relief on window size of resp. 3x3, 5x5 and 7x7

## **<u>Reclassifying the grids</u>**

With the elevation resp. slope and relief theme active:
Analyses ► Reclassify
Classify: *Number of classes*: 6(elevation) resp.  4(slope)  and 6(relief); *Round values at* : d; OK
Fill in the Old Values and the New Values (see figure)
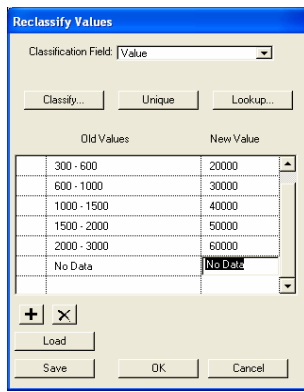
Elevation (10000-20000 etc.)     Slope  (1000-2000 etc)     Relief (100-200 etc.)
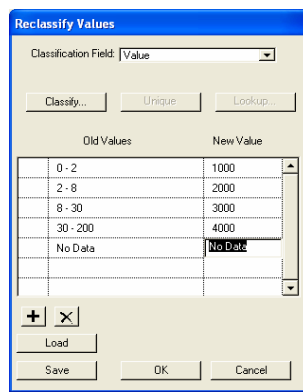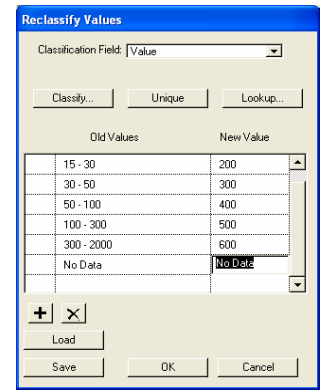
## **Potential Drainage Density**

To obtain the **P**otential **D**rainage **D**ensity grid the following grids are produced:

From the Elevgrid resp.: ►FlowDirection►FlowAccumalation►Stream►Drain►PDD

Analyses ► Map Calculator:
[Elevation].Flowdirection(FALSE)
If TRUE, all cells of the surface will flow away from the surface.
If FALSE then flow is calculated for cells with the edge being slightly lower than the cell.
evaluate
aGrid.FlowDirection request calculates the direction of flow out of each cell into one of its eight neighbors. The output is an integer Grid.
The cell flows to the cell with the lowest elevation.
The values for each <u>direction</u> from the center are:

| 32 | 64 | 128 |
|----|----|-----|
| 16 | X | 1 |
| 8 | 4 | 2 |

X = the processing cell

| 78 | 72 | 69 | 71 | 58 |
|----|----|----|----|----|
| 74 | 67 | 56 | 49 | 46 |
| 69 | 53 | 44 | 37 | 38 |
| 64 | 58 | 55 | 22 | 16 |
| 74 | 54 | 34 | 38 | 11 |

⇒

| 2 | 2 | 2 | 2 | 4 |
|----|----|----|----|----|
| 2 | 2 | 2 | 4 | 8 |
| 1 | 1 | 2 | 2 | 4 |
| 128 | 2 | 2 | 1 | 4 |
| 1 | 1 | 128 | 1 | 64 |

ElevGrid (with elevation values)    FlowGrid (with direction codes)

<u>Flow Accumulation:</u>

Analyses ► Map Calculator:
[Flowdirection].Flowaccumulation(NIL)
If NIL, a weight of 1 is used for each cell.
Instead of NIL you can use a <u>grid</u> that assigns a weight to each cell

aGrid.FlowAccumulation request creates a Grid of accumulated flow to each cell, by accumulating the weight for all cells that flow into each downslope cell.

For understanding the procedure ArcView executes:
With the flowdirection codes in mind add the cells that flow into the other cells for the resulting AccumGrid.

| | | | | |
|---|---|---|---|---|
| 2 | 2 | 2 | 2 | 4 |
| 2 | 2 | 2 | 4 | 8 |
| 1 | 1 | 2 | 2 | 4 |
| 128 | 2 | 2 | 1 | 4 |
| 1 | 1 | 128 | 1 | 64 |

$\Rightarrow$

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 2 |
| 0 | 3 | 6 | 4 | 0 |
| 0 | 0 | 0 | 8 | 7 |
| 0 | 1 | 3 | 1 | 10 |

FlowGrid                                    AcummGrid

StreamGrid = (flowAcc < 100.AsGrid).SetNull(1.AsGrid)
All cells that have more than 100 cells flowing into them are assigned 1(the pixels which had more than 100 km$^2$ catchments area) all other cells are assigned No Data.

DrainGrid=StreamGrid.Focalstats(#Grid_statype_sum,Nbrhood.MakeRectangle(5,5,false),false)
Summerizes the cells of the StreamGrid in the moving window.
The *Focalsum* function is used in the moving window.
This sum means a simple count of the pixels which represent drainage ways, because these pixels have a value of 1. All other pixels value 0.
The resulting value of the pixels refer to the drainage ways and can have a maximum of 25 (in a moving window of 5 x 5).

The resulting " Potential Drainage Density" Grid file:
PDDGrid=DrainGrid.IsNull.con(0.AsGrid,DrainGrid)
"Nodata" will be transferred to 0

The term "drainage density"is not identical to the one used by the geographers and geomorphologists. It is not based on the real drainage network. It is derived from a DEM.
It does not take into consideration the loss of surface water due to infiltration into the soil.
So the PDD is always >= the real density.

With the pdd theme active:
Analyses ► Reclassify
Classify: *Number of classes*:. 4; *Round values at* : d; OK


# Combigrid


Analyses ► Map Calculator:
( [Reclass of Slope] + [Reclass of Elevation] + [Reclass of Relief] + [Reclass of PDD])
The resulting new grid (combigrid) has combinations with unique values for the combined classes.

With the combigrid theme active:
Theme ►Convert to Shapefile
New Shapefile  -- Open Theme Table – Summarize and save as "classtable"

Delete the temporary shapefile.
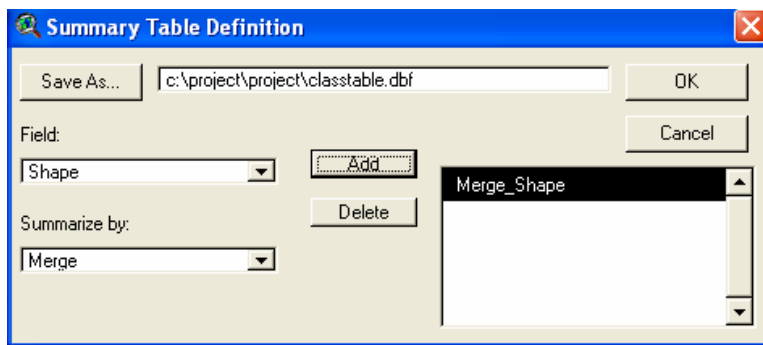


# Building the "Classtable"

Open the classtable in ArcView and start editing.
Add fields (Edit ►Add fields) resp. "elevation", "slope", "relief", "pdd" and "class"
as string fields. Fill in the classes of resp. elevation, slope, relief and pdd according the unique code
It is easy now to query for the several combinations of these parameters in order to analyse and
finally to fill in the (soter)classification in the "class"field.
In the script this table will join to the attribute grid file, because this table and the attribute table as
well have the same unique gridcode field.



Join the table to the combigrid and in the Legend Editor of this theme make a legend on this
 "class" field and save this legend in your working directory as combi.avl
In the automated process this legend is automatically added to the "combigrid

# Classifications

Classifications used :

| Elevation | | Slope | | Relief | | PDD | |
|---|---|---|---|---|---|---|---|
| *meter* | *code* | *%* | *code* | *meter* | *code* | *pixel* | *code* |
| 0-200m | 10000 | 0-2 | 1000 | 0-15 | 100 | 0 | 1 |
| 200-400m | 20000 | 2-8 | 2000 | 15-30 | 200 | 1-5 | 2 |
| 300-400m | 30000 | 8-30 | 3000 | 30-50 | 300 | 6-15 | 3 |
| 400-600m | 40000 | >30 | 4000 | 50-100 | 400 | 16-25 | 4 |
| 600-1000m | 50000 | | | 100-300 | 500 | | |
| 1000-1500m | 60000 | | | >300 | 600 | | |
| 1500-3000m | 70000 | | | | | | |
| >3000m | 80000 | | | | | | |

## The automated process

### Preparing the defaultdem:

Start Arcview and under File►Extensions make sure the Spatial Analyst is loaded. Set the Working Directory under File to the desired directory.
Open a new View and under View►Properties set the Map Units to meters and the Distance Units to kilometers.
Projections Properties ►Category:Projections of a Hemisphere Type:Lambert Equal-Area Azimuthal (Equatorial). Select Custum and type +20 for the Central Meridian and +5 for the Reference Latitude.
In the TOC doubleclick on script and rename the script1 to DEM.
Paste the avenue text file in this window and compile it.
With the View active doubleclick on the tool or button bar.
In the customize dialog window set the type to View and the Category to buttons.
Click on NEW; doubleclick on "click"and choose DEM from the Script Manager.
Doubleclick on "Icon" and select an icon in the Icon Manager.
Save this project file as defaultdem.apr
This projectfile is the base for your DEM cooking.
Prior to the DEM cooking put the legend files and the combiclass.dbf in the working directory.
Set the elevgrid theme active in the active window.

### The Avenue script:

' Add several theme's (parameters derived from elevationgrid)
' and combine it to one grid with the predefined combination classes. J. Huting, dec. 2002
'****************************************************************************
' This script executes with from the DEM derived elevgrid file as inputfile.
' The particular legends must be predefined as elevation.avl; slope.avl; relief.avl; pdd.avl
' and combi.avl. and the classcombi.dbf table as well. They have to be placed in the working directory.
' The View window must be the active document with the elevgrid as the active theme.
'****************************************************************************

'set working directory
            aFilename="d:\dem".AsFilename
            av.GetProject.SetWorkDir(aFilename)

```
                    aFilename.SetCWD
'select grid theme
            theProject=Av.GetProject
            theView = Av.GetActiveDoc
'check to make sure that there is a theme selected.
            if (theView.GetActiveThemes.Count=0) then
            Msgbox.Info("Must have a Grid theme selected","")
            exit
            end
'get the grid
            theGridTheme =theView.GetActiveThemes.Get(0)
            elevGrid = theGridTheme.GetGrid
'real elevation values
            elevatigrid=(elevGrid>=32768.AsGrid).con
            (elevGrid-65536.AsGrid,elevGrid)
'eventueel nodata eruit
            elevationgrid=(elevatigrid=-9999.AsGrid).setnull(elevatigrid)
'make elevationgrid
            elevationGrid.Rename("Elevation".AsFileName)
            elevation=Gtheme.make(elevationGrid)
            theView.AddTheme(elevation)
'calculate slope
            slopeAGrid=elevgrid.Slope(2.5,TRUE)
'the mean value of the slope in the moving window
slopeGrid=slopeAGrid.Focalstats(#Grid_statype_mean,Nbrhood.MakeRectangle(5,5,false),false)
'make slope theme in the View
            slopeGrid.Rename("Slope".AsFileName)
            slope=Gtheme.make(slopeGrid)
            theView.AddTheme(Slope)
'calculate Relief
MAXGrid=elevationGrid.Focalstats(#Grid_statype_max,Nbrhood.MakeRectangle(5,5,false),false)
MINGrid=elevationGrid.Focalstats(#Grid_statype_min,Nbrhood.MakeRectangle(5,5,false),false)
reliefAGrid=MAXGrid-MINGrid
reliefGrid=reliefAGrid.Focalstats(#Grid_statype_mean,Nbrhood.MakeRectangle(5,5,false),false)
'make relieftheme in the View
            ReliefGrid.Rename("Relief".asFileName)
            Relief=Gtheme.make(ReliefGrid)
            theView.AddTheme(Relief)
'calculate flow direction
            flowDirGrid = elevationGrid.FlowDirection(FALSE)
'make FlowDir Theme (not added to the View)
            flowDirGrid.Rename("FlowDir".asFileName)
            flow=GTheme.Make(flowDirGrid)
'theView.AddTheme(flow)
'calculate flow accumulation
            flowAccGrid = flowDirGrid.FlowAccumulation(NIL)
'make FlowCum Theme (not added to the View)
            flowAccGrid.Rename("FlowCum".asFileName)
            flow=GTheme.Make(flowAccGrid)
'theView.AddTheme(Flow)
```

```
'extract streams from flow accumulation
          streamGrid = (flowAccGrid<100.AsGrid).SetNull(1.AsGrid)
'summerize the cells of the streamgrid in the moving window
DrainGrid=streamgrid.Focalstats(#Grid_statype_sum,Nbrhood.MakeRectangle(5,5,false),false)
'the Nodata will be transferred to the value 0
          PDDGrid=DrainGrid.IsNull.con(0.AsGrid,DrainGrid)
'make PDD Theme in the View
          PDDGrid.Rename("PDD".asFileName)
          PDD=Gtheme.Make(PDDGrid)
          theView.AddTheme(PDD)
'OPTIONAL
'delineate stream links
'streamLinkGrid = streamGrid.StreamLink(flowDirGrid)
'delineate watersheds for each stream link
'watershedGrid = flowDirGrid.Watershed(streamLinkGrid)
'make Watershd Theme in View
'watershedGrid.Rename("Watershd".AsFileName)
'watershed=GTheme.make(watershedGrid)
'theView.AddTheme(watershed)

'SET THE LEGENDS
'to identify
          theView=av.GetActiveDoc
          for each T in theView.GetActiveThemes
          theView = av.GetActiveDoc
          for each t in theView.GetThemes
          if (t.IsVisible.not) then t.SetVisible(FALSE)
          end
          theSourceName=T.GetSrcName
          theFileName=theSourceName.GetFileName
          theThemeLegend=T.GetLegend
          theFileString=theFileName.GetFullName
          theFileStringLength=theFileString.Count
'Determine the name of the legend file
          if(theFileString.Middle((theFileStringLength-4),1)="")then
          theLegendString=(theFileString.Left(theFileStringLength-4))+".avl"
          theLegendFile=theLegendString.AsFileName
          else
          theLegendString=theFileString+".avl"
          theLegendFile=theLegendString.AsFileName
          end
'Load the legend
          if(File.Exists(theLegendFile))then
          theThemeLegend.Load(theLegendFile,#LEGEND_LOADTYPE_ALL)
          T.InvalidateLegend
          else
          MsgBox.Info("Sorry"++theFileString++"has no locallegend","Missing avl....")
          end end end
'making the reclassify gridthemes (not added to the View)
          theView=av.GetActiveDoc
```

```
        theTheme=elevation
        theLegend=theTheme.GetLegend
        theGrid=theTheme.GetGrid
        theFldName=theLegend.GetFieldNames.Get(theLegend.GetFieldNames.Count-1)
        aClassList=theLegend.GetClassifications
        theClassList=aClassList.DeepClone
        count=10000
        for each c in theClassList
        c.SetLabel(count.AsString)
        count=count+10000
        end
        ElevationGrid = theGrid.ReclassByClassList(theFldName,theClassList,FALSE)
        ElevationGrid.Rename("Recelev".AsFileName)
        Recelev=Gtheme.Make(ElevationGrid)
'theView.AddTheme(Recelev)
        theTheme=slope
        theLegend=theTheme.GetLegend
        theGrid=theTheme.GetGrid
        theFldName=theLegend.GetFieldNames.Get(theLegend.GetFieldNames.Count-1)
        aClassList=theLegend.GetClassifications
        theClassList=aClassList.DeepClone
        count=1000
        for each c in theClassList
        c.SetLabel(count.AsString)
        count=count+1000
        end
        SlopeGrid = theGrid.ReclassByClassList(theFldName,theClassList,FALSE)
        SlopeGrid.Rename("Recslope".AsFileName)
        Recslope=Gtheme.Make(SlopeGrid)
'theView.AddTheme(Recslope)
        theTheme=Relief
        theLegend=theTheme.GetLegend
        theGrid=theTheme.GetGrid
        theFldName=theLegend.GetFieldNames.Get(theLegend.GetFieldNames.Count-1)
        aClassList=theLegend.GetClassifications
        theClassList=aClassList.DeepClone
        count=100
        for each c in theClassList
        c.SetLabel(count.AsString)
        count=count+100
        end
        ReliefGrid=theGrid.ReclassByClassList(theFldName,theClassList,FALSE)
        ReliefGrid.Rename("Recrelief".AsFileName)
        Recrelief=Gtheme.Make(ReliefGrid)
'theView.AddTheme(Recrelief)
        theTheme=PDD
        theLegend=theTheme.GetLegend
        theGrid=theTheme.GetGrid
        theFldName=theLegend.GetFieldNames.Get(theLegend.GetFieldNames.Count-1)
        aClassList=theLegend.GetClassifications
```

```
                theClassList=aClassList.DeepClone
                count=1
                for each c in theClassList
                c.SetLabel(count.AsString)
                count=count+1
                end
                PDDGrid = theGrid.ReclassByClassList(theFldName,theClassList,FALSE)
                PDDGrid.Rename("Recpdd".AsFileName)
                Recpdd=Gtheme.Make(PDDGrid)
```
'theView.AddTheme(Recpdd)
'combination reclass grids van elevation, slope, relief and pdd
```
                combiGrid=ElevationGrid+ReliefGrid+SlopeGrid+PDDGrid
```
'make combi theme in View
```
                CombiGrid.Rename("Combi".asFileName)
                Combi=Gtheme.Make(CombiGrid)
                theView.AddTheme(Combi)
```
'retrieving the classcombi.dbf from the working directory
```
                theView=theProject.FindDoc("View1")
                theTheme=theView.FindTheme("combi")
                patterns = {"*.dbf", "arcdr9", "*.txt"}
                labels = {"dBASE (*.dbf)", "INFO", "Delimited Text (*.txt)"}
                files = FileDialog.ReturnFiles(patterns, labels, "Add Table", 0)
                for each f in files
                v = VTab.Make(f, FALSE, FALSE)
                if (v.HasError) then
                if (v.HasLockError) then
                MsgBox.Error("Unable to acquire Read Lock for file " + f.GetBaseName, "")
                else
                MsgBox.Error("The file '" + f.GetBaseName + "' is not valid.", "")
                end
                else
                gui = av.GetProject.GetSelectedGUI
                if (gui.GetType <> "Table") then
                GUIName = "Table"
                else
                GUIName = gui.GetName
                end
                t = Table.MakeWithGUI(v, GUIName)
                t.SetName(v.GetName)
                t.GetWin.Open
                end
                end
```
'joining the classcombi table to the "combi" attribute table
```
                theView=theProject.FindDoc("View1"
                theGridTheme=theView.FindTheme("elevgrid")
                elevgrid=theGridTheme.GetGrid
                theGridTheme.SetActive(FALSE)
                theGridTheme.SetVisible(FALSE)
                theGridTheme=theView.FindTheme("combi")
                combi = theGridTheme.GetGrid
```

```
        theGridTheme.SetActive(TRUE)
        theGridTheme.SetVisible(TRUE)
        Tab2=av.Getproject.FindDoc("classcombi.dbf")
        Tab2 = av.GetActiveDoc
        VTab2=Tab2.GetVTab
        field2=VTab2.FindField("Gridcode")
        theView=av.GetProject.FindDoc("Combi")
        combiFTab=combi.getVTab
        field1=combiFTab.FindField("Value")
        CombiFTab.Join(field1,VTab2,field2)
'making the theme the first in the TOC
        theView=theProject.FindDoc("View1"
        theThemeList=theView.GetThemes
        theThemeList.Shuffle(theThemeList.Get(0),(theThemeList.Count))
        theThemeList.Get(theThemeList.Count-1).SetActive(TRUE)
        theView.InvalidateTOC(nil)
        theView.GetDisplay.Invalidate(true)
'retrieving the legend of the combi grid from the working directory
        theGridTheme =theView.GetActiveThemes.Get(0)
        combi = theGridTheme.GetGrid
        theGridTheme.setactive(TRUE)
        theTheme = theView.GetActiveThemes.Get(0)
        theLegendFile="combi.avl".AsFileName
        theThemeLegend = theTheme.GetLegend
        theThemeLegend.Load(theLegendFile,#LEGEND_LOADTYPE_ALL)
        TheGridTheme.InvalidateLegend
```

Optional:
To prevent the projectfile to be saved as demfault.apr you can append the system script
"Project.Save as" (you can find this script in the scripteditor under Script►Load System Script)
to the DEM script.


**Running the script:**

Open the defaultdem.apr in ArcView, retrieve your elevgrid and make it active.
Click on the DEM button.

**Short description of the script:**

In the View the script is generating respectively:

*1. Elevation*    The real elevation values are produced
                    No data is removed

*2. Slope*        (In %, multiplied with factor 2.5)
                    INRA (Institute National de la Recherche Agronomique France) has compared the % slope in a 1 km DEM with % slope in high resolution DEMs and found this empirical factor 2.5. Probably this factor is not the same as for Zimbabwe, but due to the lack of high resolution DEM's for Zimbabwe we adopted this one.
                    The mean of the result is calculated in a 5 x 5 window

*3. Relief*      Maximum minus Minimum elevation in a 5 x 5 moving window.
                    The mean of the result is calculated in the moving window.

*4. PDD*
        a. Flowdirection
        b. Flowaccumulation
        c. Streamgrid
        d. Draingrid
        e FocalSUM in a 5 x 5 moving window
        f. PDD = The draingrid, but "Nodata" is set to 0

*5. Legends*
                    The legends are retrieved from the working directory.
                    (The legend name is the same as the theme name)

*6. Reclassify*
                    The script generates the reclassify grids for the 4 themes.

*7. Combigrid*
                    The grids are combined to 1 grid: the combigrid

*8. Combiclass table*
                    The combiclass table is retrieved from the working directory and joined to the combigrid attribute table.

*9. Legend combigrid*

                    Set the combigrid active and visible as the first theme in the Table of Contents retrievs the legend for the combigrid.

*10. Save the project*
                    The script asks for a name.

# Hierarchy of major landforms according Soter manual

| | | % slope | relief |
|---|---|---|---|
| **L** level land | LP plain | <8 | <100m/km |
| | LL plateau | <8 | <100m/km |
| | LD depression | <8 | <100m/km |
| | LF low-gradient footslope | <8 | <100m/km |
| | LV valley floor | <8 | <100m/km |
| | | | |
| **S** sloping land | SM medium-gradient mountain | 15-30 | >300m/km |
| | SH medium-gradient hill | 8-30 | >50m/km |
| | SE medium-gradient esc.zone | 15-30 | <300m/km |
| | SR ridges | 8-30 | >50m/km |
| | SU mountainous highland | 8-30 | >300m/km |
| | SP dissected plain | 8-30 | <50m/km |
| | | | |
| **T** steep land | TM high-gradient mountain | >30 | >300m/km |
| | TH high-gradient hill | >30 | <300m/km |
| | TE high-gradient esc. zone | >30 | >300m/km |
| | TV high gradient valleys | >30 | >300m/km |
| | | | |
| **C** land with composite | | | |
| landforms | CV valley | >8 | variable |
| | CL narrow plateau | >8 | variable |
| | CD major depression | >8 | variable |

# Discussion

A basic understanding of the terrain is necessary in order to adjust the moving window size.
This is accomplished by examining the pre-existing SOTER "expert" landform map.
The DEM resolution also plays a roll in determining the window size. In this study case a DEM with a 1 km resolution and window size of 5 x 5 may be appropriate for the analysis.
It is important to note that the window size will affect the slope and especially the relief component.
The resulting map contain many classes, which can be grouped based on topographic similarities.
Generalizing the classes can be used to derive general terrain patterns.
Viewing these patterns can aid in deciding a further breakdown in classes if necessary.
The user must understand the characteristics of the DEM and the size of the terrain features in order to select window size and to make decisions for generalizing the classes.

Comparing the landform "expert" map( see map 1)  with the resulting combigrid map (see map 2) you can notice the unclassified mountainous area in the south on map 1.
Also comparing the other classified terrain units on map 1 with map 2 you can notice the differences. Looking at map 3 you can clearly see the part of the depression of Botswana in Zimbabwe's area.

# Conclusion

A 1 km resolution DEM has been used to derive terrain classes for the development of SOTER map units. The procedure here is based on measurements which are repeatable.
In fact the application can be used on any part of the world.
GTOPO30 DEMs are available for free and can be processed for all these areas on the Earth.
Terrain classes can be obtained using the elevation and derivatives as presented here, but some (sub) classes, especially in the level land cannot be distinguished as those defined in the SOTER procedures manual.
However, it is strongly recommended to use higher resolution DEMs.
Higher resolution DEM data will be increasingly available world wide.
In February, 2000 there was a U.S. Shuttle Radar Topographic mission that collected data for 80% of the Earth's land surface using radar interferometry. These data with a 30 m resolution will be available in the next 2 or 3 years. Future initiatives need to examine these DEM data and to derive or enhance terrain classes for the SOTER database.
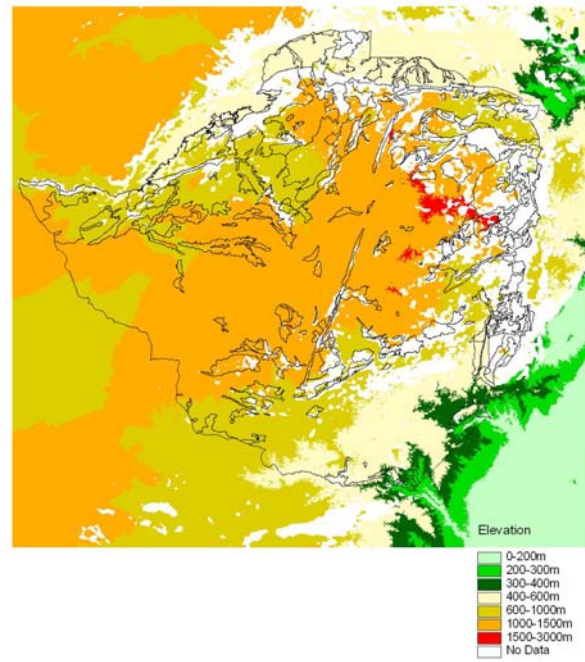
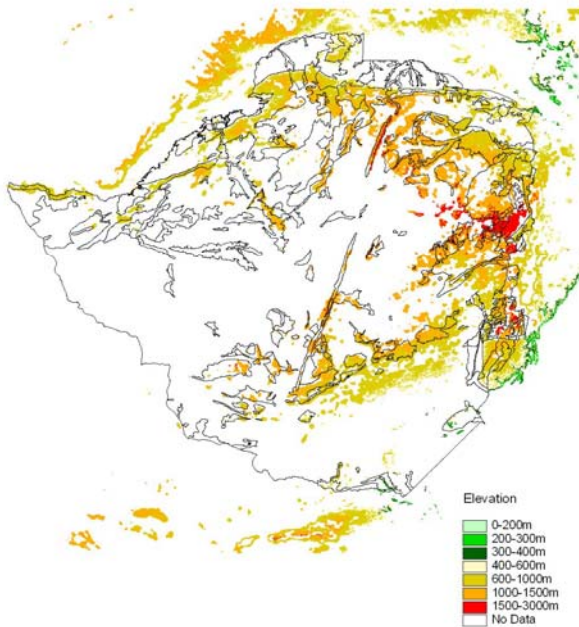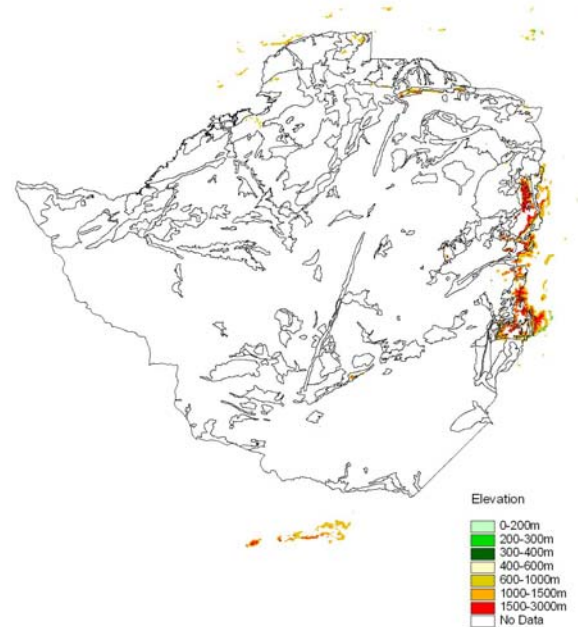# Zimbabwe

## Landforms ("expert")
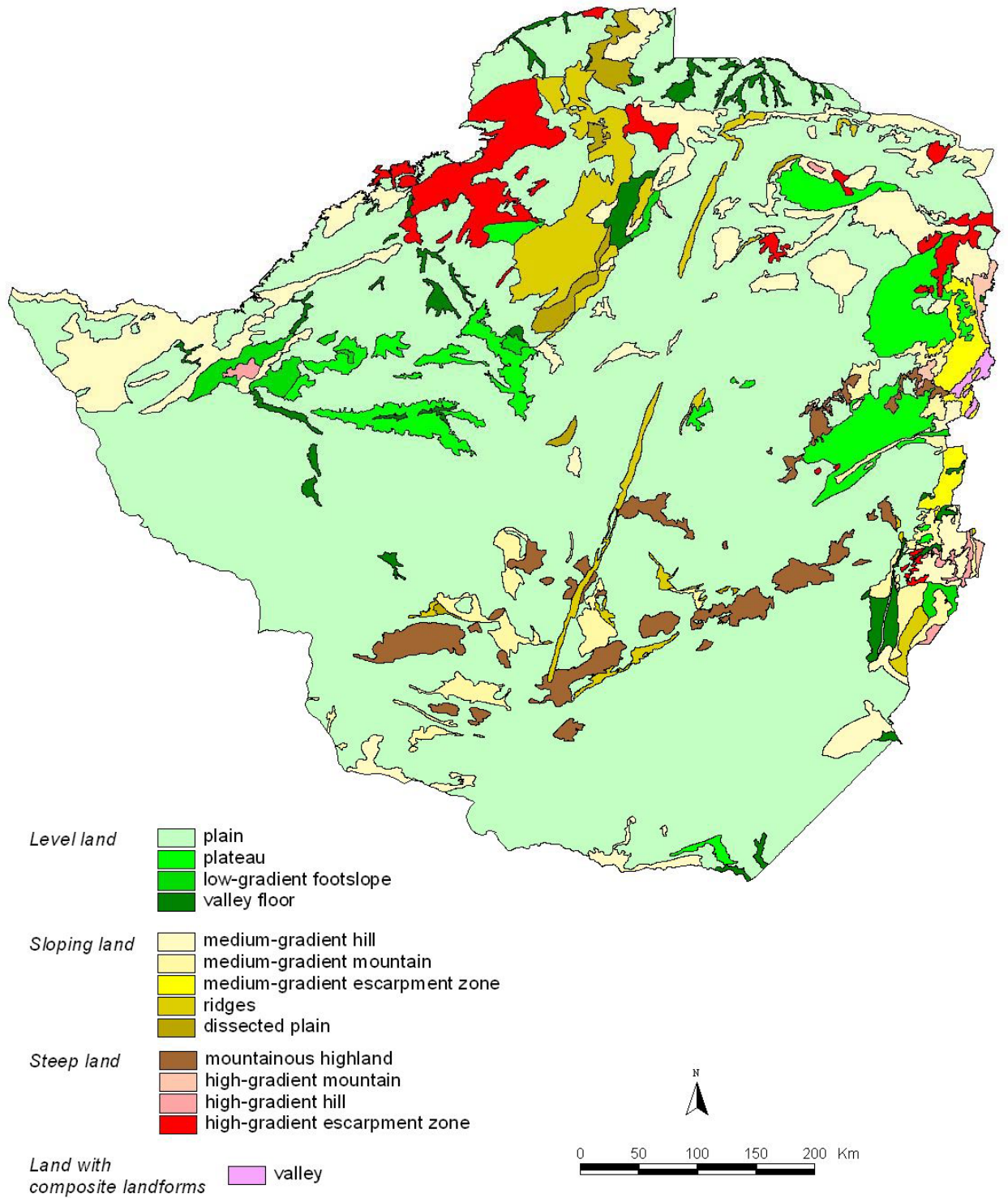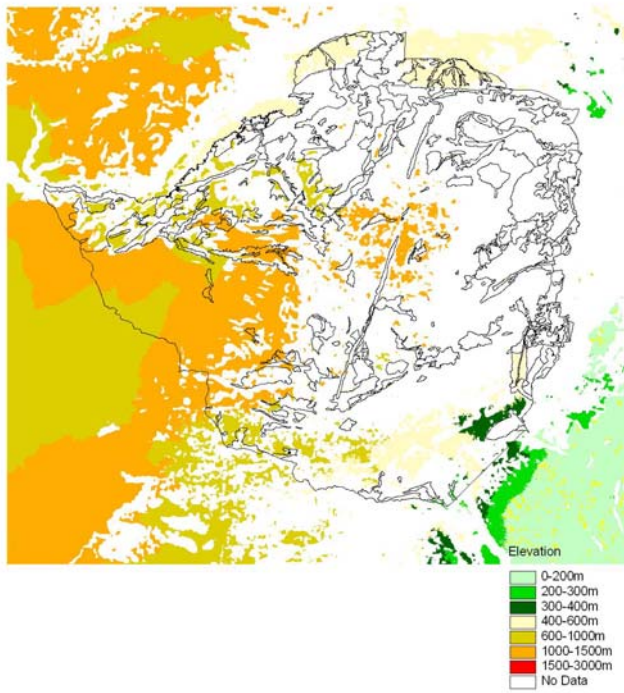


**Level land**
- plain
- plateau
- low-gradient footslope
- valley floor

**Sloping land**
- medium-gradient hill
- medium-gradient mountain
- medium-gradient escarpment zone
- ridges
- dissected plain

**Steep land**
- mountainous highland
- high-gradient mountain
- high-gradient hill
- high-gradient escarpment zone

**Land with composite landforms**
- valley

0    50    100    150    200  Km
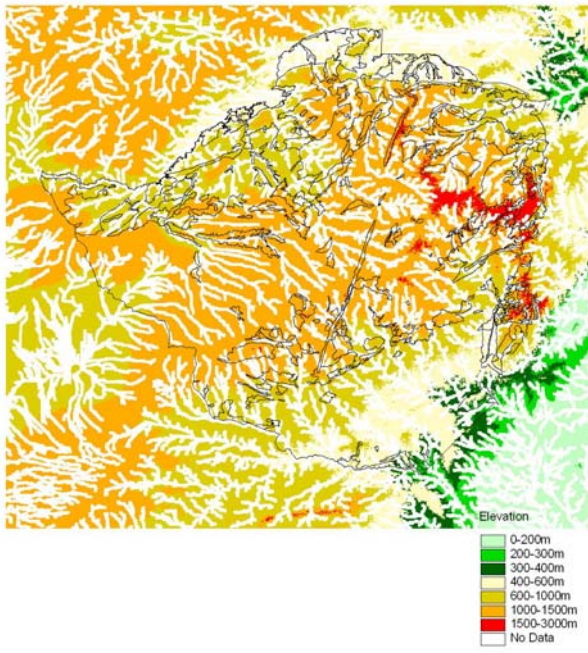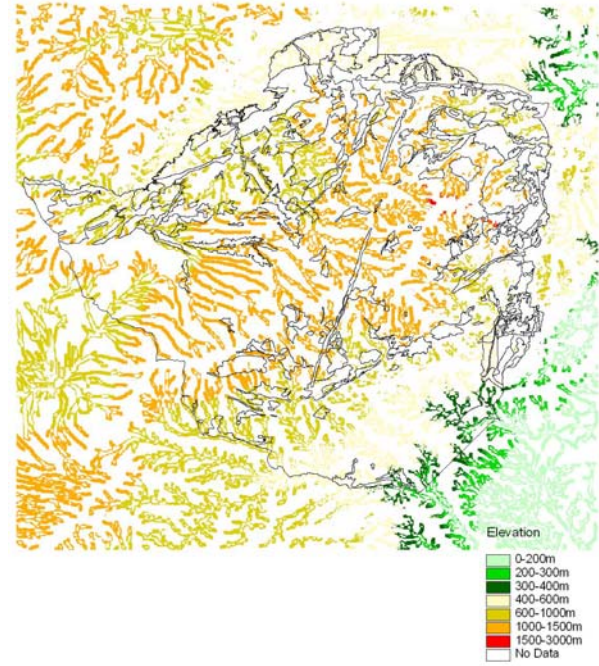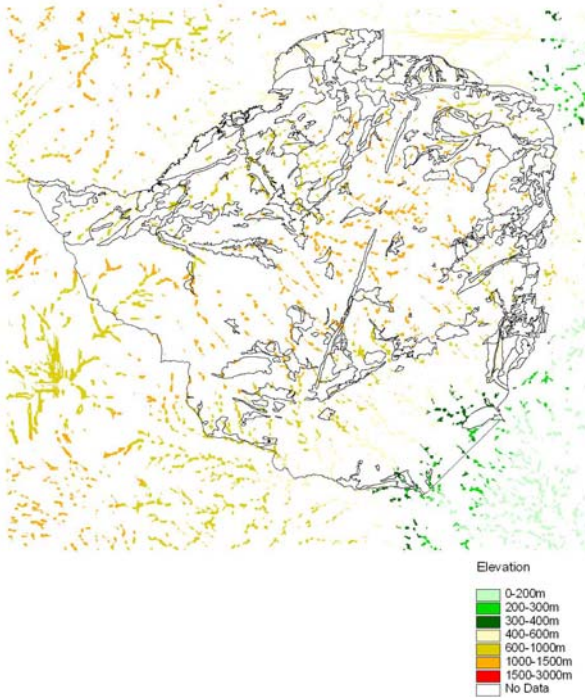
Slope thresholds, based on a GTOPO30 1km resolution DEM and a window size of 5 x 5 in combination with the elevation classes.
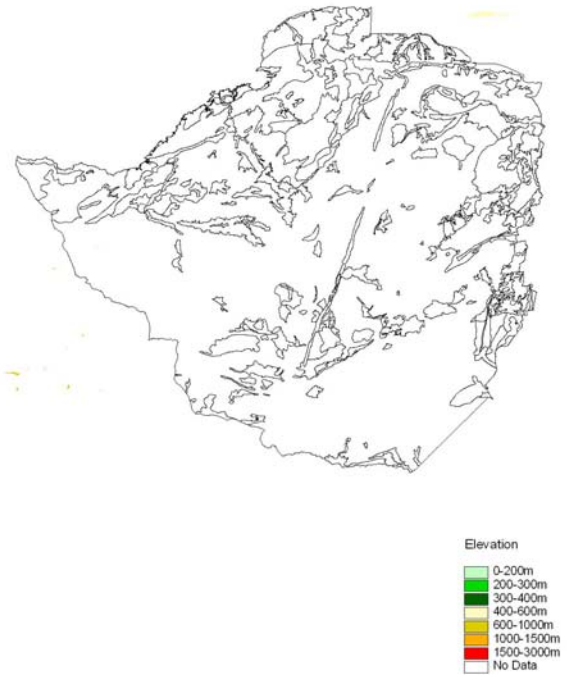
PDD thresholds, based on a GTOPO30 1 km resolution DEM and a window size of 5 x 5 in combination with a slope threshold of 0-8% and the elevation classes.
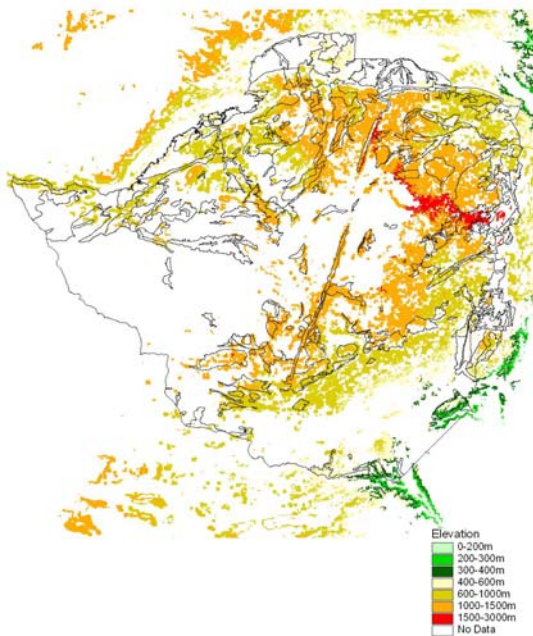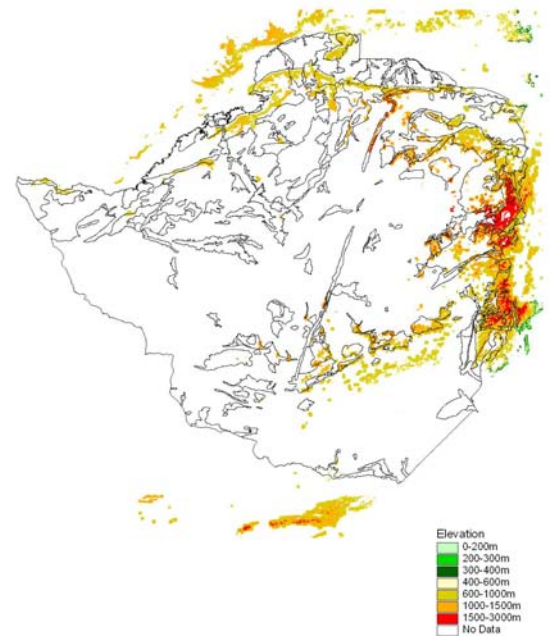
Relief 0-50m
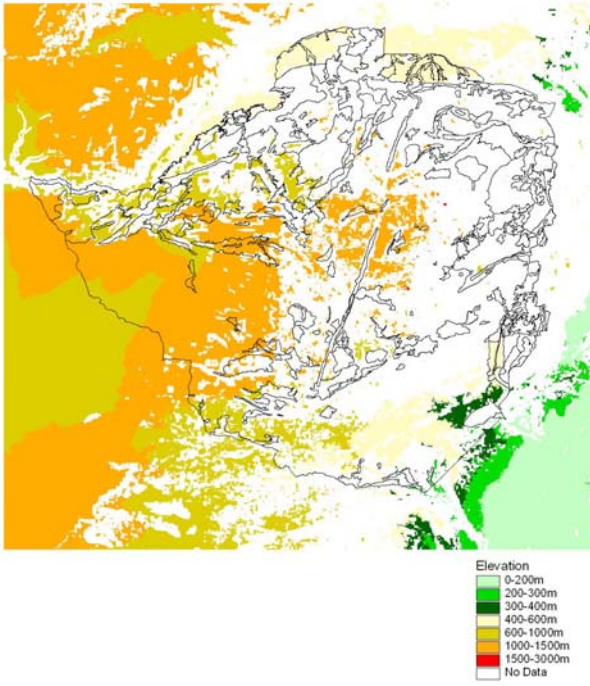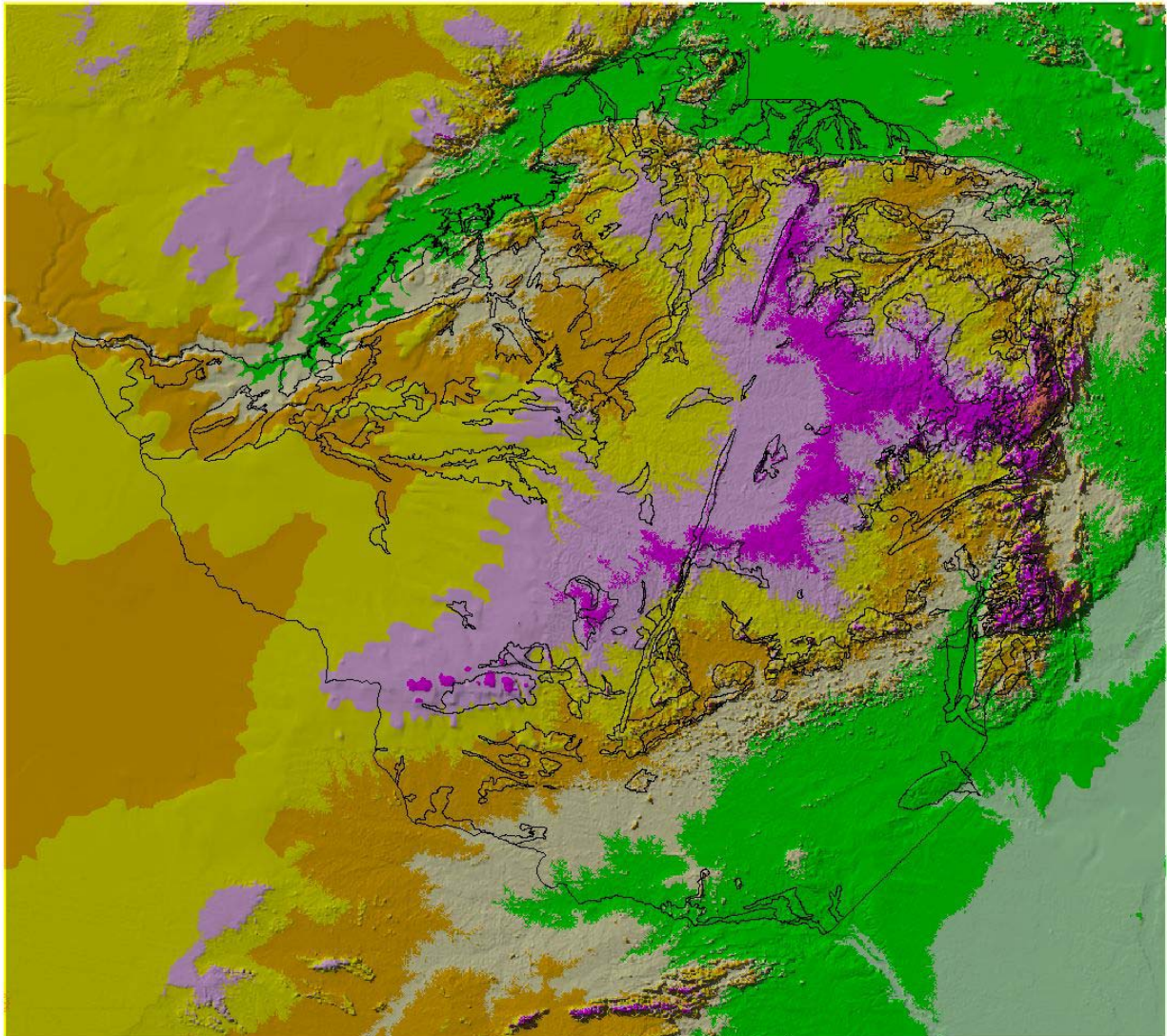
Relief 50-100m
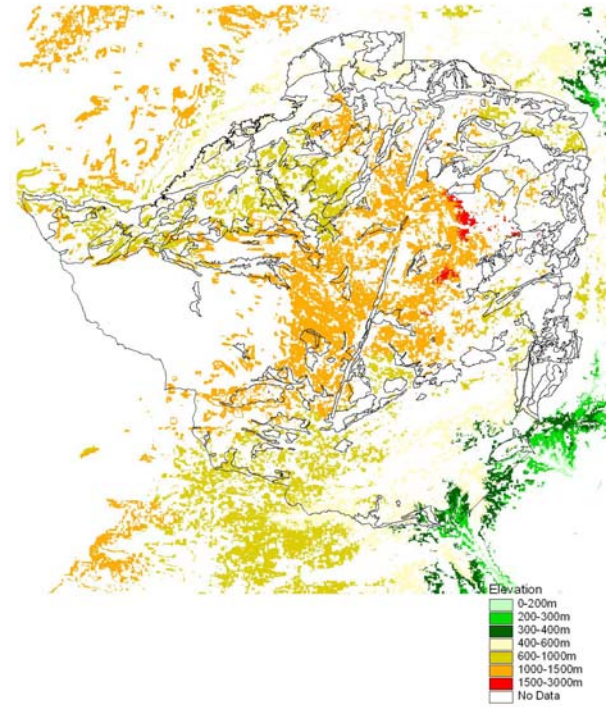
Relief 100-300m

Relief >300m



Relief thresholds, based on a GTOPO30 1 km resolution DEM and a window size of 5 x 5 in combination with the elevation classes.

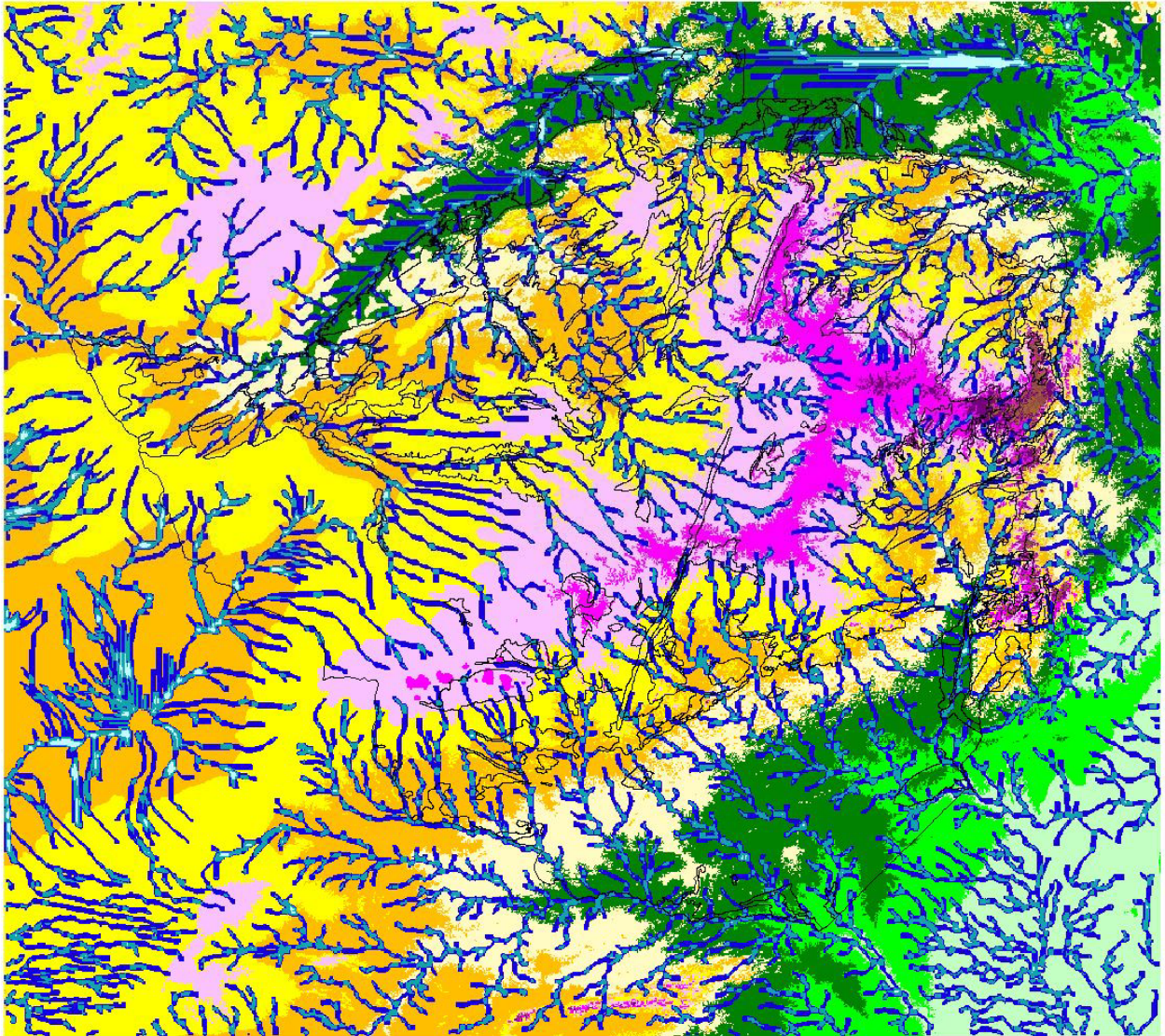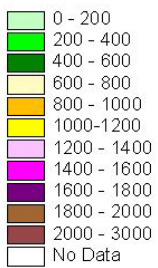Elevation with brightness of Hillshade theme



Elevation
- 0 - 200
- 200 - 400
- 400 - 600
- 600 - 800
- 800 - 1000
- 1000-1200
- 1200 - 1400
- 1400 - 1600
- 1600 - 1800
- 1800 - 2000
- 2000 - 3000
- No Data

0    100    200 Km

# Combination of elevation, drainage density
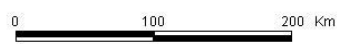## (top layer is Zimbabwe vector theme)



Elevation (m)

- 0 - 200
- 200 - 400
- 400 - 600
- 600 - 800
- 800 - 1000
- 1000-1200
- 1200 - 1400
- 1400 - 1600
- 1600 - 1800
- 1800 - 2000
- 2000 - 3000
- No Data

Zimbabwe

N

0          100          200    Km

Drainage Density (pixels)

- 0 - 3
- 3 - 5
- 5 - 10
- 10 - 25
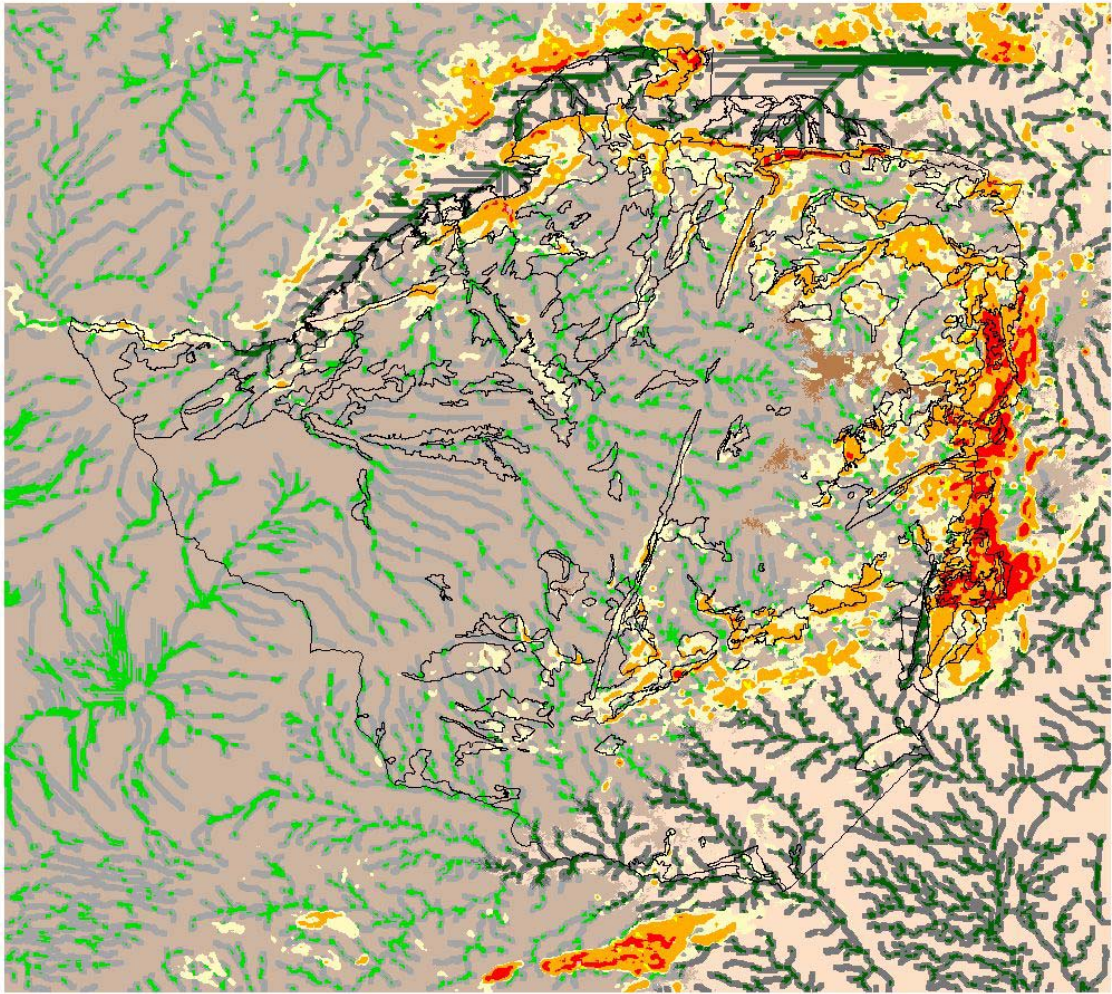- No Data
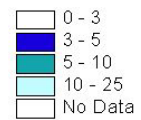
# Combi grid with brightness of hillshade of combigrid
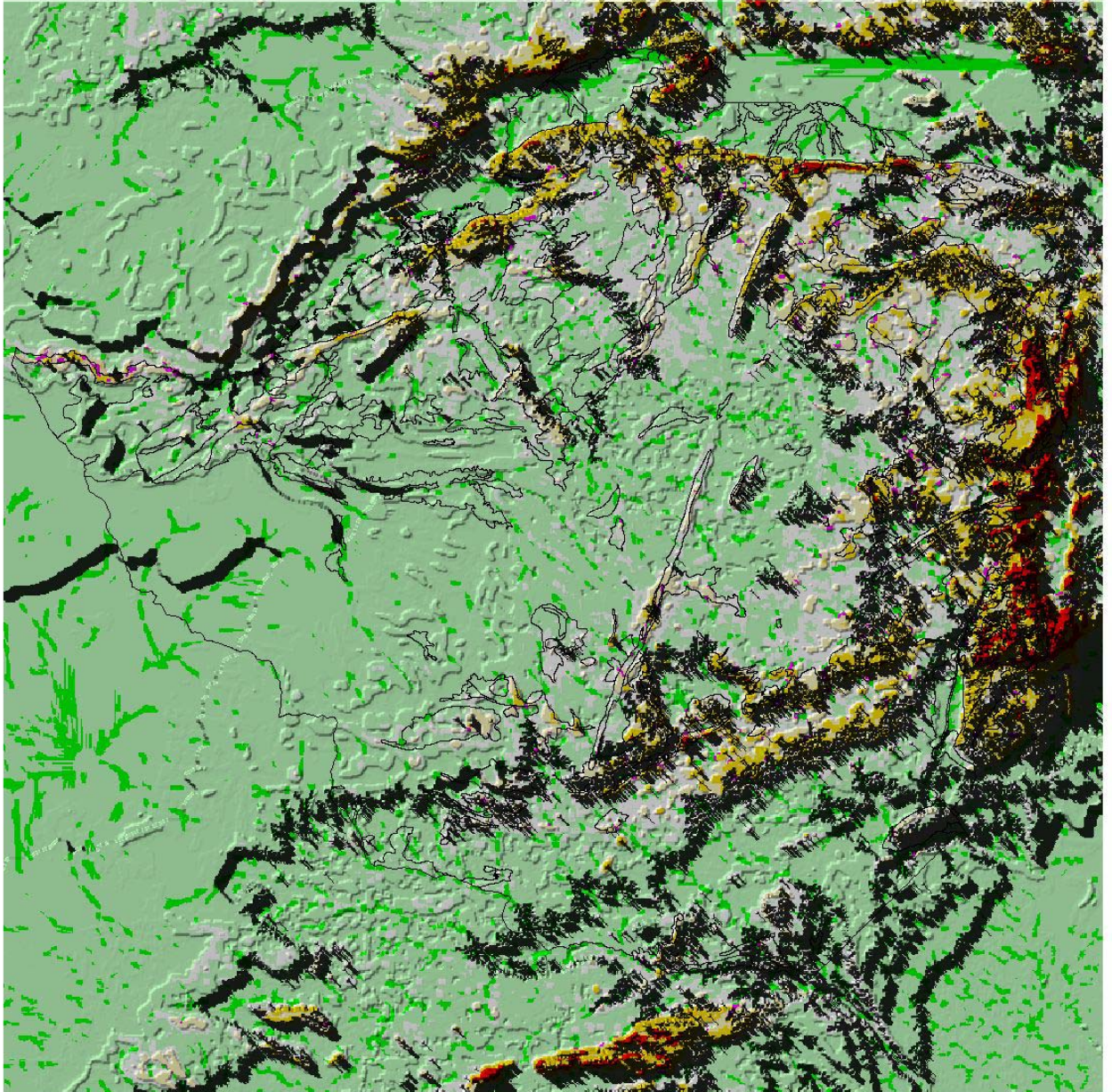
# DEM classification
## Zimbabwe

| Elevation (m) | Slope (%) | Relief (m) | PDD (pixel) | Classification | Legend | |
|---|---|---|---|---|---|---|
| 0-600 | 0-8 | <100 | 6-25 | L-L-L | ■ | Low level very low |
| 600-1500 | 0-8 | <100 | 6-25 | L-L-M | ■ | Medium level very low |
| 1500-3000 | 0-8 | <100 | 6-25 | L-L-H | ■ | High level very low |
| 0-600 | 0-8 | <100 | 1-5 | L-M-L | ■ | Low level medium low |
| 600-1500 | 0-8 | <100 | 1-5 | L-M-M | ■ | Medium level medium low |
| 1500-3000 | 0-8 | <100 | 1-5 | L-M-H | ■ | High level medium low |
| 0-600 | 0-8 | <100 | 0 | L-H-L | ■ | Low level low |
| 600-1500 | 0-8 | <100 | 0 | L-H-M | ■ | Medium level low |
| 1500-3000 | 0-8 | <100 | 0 | L-H-H | ■ | High level low |
| variable | 8-30 | >50<300 | 0-25 | SH | ■ | Medium-gradient hill |
| variable | 8-30 | >300 | 0-5 | SU | ■ | Medium-gradient mountain |
| variable | 8-30 | >300 | 6-25 | SM | ■ | Mountainous highland |
| variable | >30 | >300 | 6-25 | TML | ■ | High-gradient mountain (low) |
| variable | >30 | >300 | 0-5 | TM | ■ | High-gradient mountain |

N

0    100    200    300    400    500  Km