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Global Assessment of Land Degradation

GIS-procedures for mapping SOTER landform for the LADA partner countries

(Argentina, China, Cuba, Senegal and The Gambia, South Africa and Tunisia)

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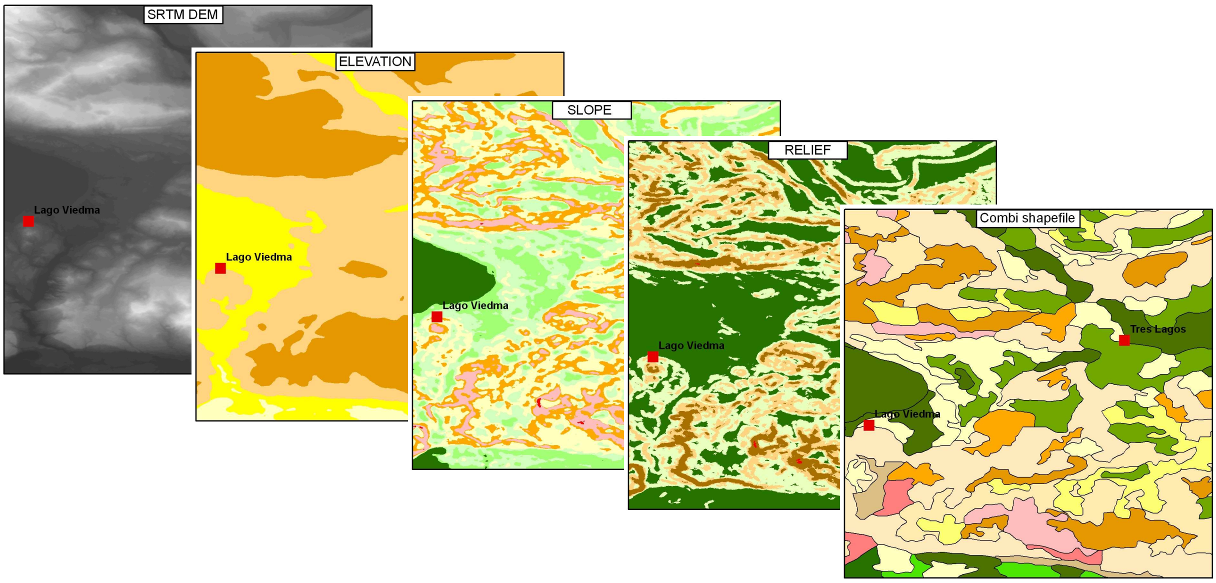
(August 2008)



LADA

ISRIC World Soil Information

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Front cover: SRTM-processed images of the southern part of Santa Cruz Province (Argentina)

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SUMMARY

This report presents the activities of ISRIC – World Soil Information within the framework of the Global Assessment of Land Degradation (GLADA) as a part of the FAO program Land Degradation Assessment in Drylands (LADA). It describes a common topographic format, at scale 1:1 million, for the partner countries Argentina, China, Cuba, Senegal and The Gambia, South Africa and Tunisia. The SRTM-DEM based GIS-procedures and definitions of the terrain-mapping units are described, together with the first outputs of applied procedures for the partner countries.

Keywords: SRTM-DEM derived landform procedures, SOTER landform, SOTER databases, GLADA.

1 INTRODUCTION

This report summarises an initial activity of ISRIC – World Soil Information within the framework of the Global Assessment of Land Degradation (GLADA), which is part of the FAO program Land Degradation Assessment in Drylands (LADA).

A main task of the GLADA program is to make a quantitative, global assessment of land degradation, which is reproducible by defined procedures. This global assessment will be carried out by remote sensing and measurement of deviance from local norms. In this procedure 'hot spots' of land degradation will be assessed by the normalised difference vegetation index (NDVI) derived from the reflected wavebands measured by earth-observation satellites. The quality indicators of these 'hot spots' will be derived from secondary remote sensing analysis and is based on the stratification of the land area according to Soil and Terrain (SOTER) units and land cover.

ISRIC's activities in this program are laid down in a Letter of Agreement PR 35825 between the Food and Agriculture Organisation of the United Nations and ISRIC – World Soil Information, signed in February 2007.

This report describes the GIS-procedures in generating a common topographic format for the six partner countries Argentina, China, Cuba, Senegal and The Gambia, South Africa and Tunisia at a scale 1:1 million. These GIS-procedures are based on the use of digital elevation data of the Shuttle Radar Topography Mission (NASA 1998). The definitions of the terrain-mapping units and the first outputs of such a Soil and Terrain database are presented here.

The method is described in Chapter 2, the preliminary results are discussed in Chapter 3 and recommendations for further research are given in Chapter 4.

Due to the huge amount of raster cells of the China image and therefore problems with some geo-processing tools in ArcGIS, another procedure was followed and described in Chapter 2.2.6. (Data handling for China)

2 MATERIALS AND METHODS

2.1 SRTM DEM information

The digital elevation model (DEM) of the Shuttle Radar Topography Mission (SRTM) data consists of a GRID-map in geographic coordinates (WGS84). The coverage is available between latitudes 60^{O} North and 56^{O} South. The original 1-arc second resolution data has been resampled into 3-arc second resolution data (NASA 1998). Areas with 'no data' have been filled by procedures developed by CGIAR-CSI. This seamless dataset of 5^{O} x 5^{O} tiles was used for the six GLADA partner countries and can be downloaded from:

http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp (CGIAR-CSI 2004).

The GRID-file supplies detailed information on the elevation of the land surface at a resolution of 90 m at the equator and is referred to as DEM data.

The original GRID data has been analysed for three parameters, following a method developed by Dobos *et al.*(2005) and used to generate the GIS layers for:

- Elevation
- Slope
- Relief intensity (RI) - the median difference within one km^2 circle around the pixel in consideration.

The individual values for elevation, slope and relief intensity were combined, recoded and generalized into new, combined classes to assign SOTER landform classes, using slightly adapted SOTER criteria (van Engelen and Wen 1995; van Engelen and Huting 2004), see Annex 1.
The dissection, referred to as potential drainage density (pdd) by Dobos *et al.* (2005) has not been used in the present analysis for the landforms. This criterion did not add much value in discriminating the landform at the present scale, as discrimination was based already on the combination of the three parameters, slope, relief intensity and elevation.

Five steps were made to process the SRTM DEM data, using ArcGIS Desktop version 9.2 (ESRI 2006): (see chapter 2.2)

- pre-treatment of the SRTM-DEM data
- deriving elevation, slope and relief
- reclassification of the GRIDs
- generalization of the combiGRID
- generalization of the shapefiles for individual countries

Finally, a SOTER landform class is assigned to each GRID code and the landform classes added to the shapefiles.

2.2 Data handling

Data handling procedures are described in general terms only.

2.2.1 Pre-treatment SRTM 90m DEM

Convert the image files (GeoTiff format) to raster files (GRIDS) and merge or mosaic the tiles to full coverage for each country.
Convert values >= 32768 to 'no data' using the raster calculator:

    Setnull([GRID] >=32768,[GRID])

Replace all negative values with 0:

    Con([GRID]<0,0,[GRID])

Remark:
The elimination of all negative values implies that all surfaces that lie under mean sea level are displayed as '0' or 'no data' on the map.

"Clip by mask" with polygon theme (+ buffer of 50 km) of the area to be analyzed. Put the resulting GRID in projected coordinates of an equal area projection for metric calculations, e.g. standard projection Lambert Azimuthal Equal Area with 'central meridian' and 'latitude of origin' in geographic coordinates. These two values are the centroïd of the polygon theme.

The resulting GRID is the base for further analyses. →*ElevGRID*

2.2.2 Deriving elevation, slope and relief

Using the previous GRID (elevGRID) and:
Neighbourhood statistics; Focalstats_MEDIAN, circle 6 cells →*Elevgen*

Neighbourhood statistics; Focalstats RANGE, circle 6 cells
Neighbourhood statistics; Focalstats_MEDIAN, circle 6 cells →*Reliefgen*

Spatial Analyst; Surface Analysis; Slope % (slopeGRID)
Neighbourhood statistics; Focalstats_MEDIAN, circle 6 cells →*Slopegen*

Or:
For very large areas (larger than 1 million km^2); multiply slopegrid by 100 and make it an integer.
Use Raster Calculator: Int(slopeGRID)
Neighbourhood statistics; Focalstats_MEDIAN, circle 6 cells →*Slopegen*

2.2.3 Reclassification of GRIDs

Each GRID is reclassified on the basis of elevation, slope and relief intensity (*Elevgen, Slopegen* and *Reliefgen*) and given a code (reclassified). The individual codes are combined (Table 1) and assigned a new combined class code, the Combi-code.

Table 1: GRID derived Combicode

Elevgen (masl)	Code Recl.	*Slopegen* (%)	Code Recl.	*Reliefgen* (m/km^2)	Code Recl.	Combi code
<10	10000	<0.5	1000	<50	100	11100
10-50	20000	0.5-2	2000	50-100	200	22200
50-100	30000	2-5	3000	100-150	300	33300
100-200	40000	5-10	4000	150-300	400	44400
200-300	50000	10-15	5000	>300	500	55500
300-600	60000	15-30	6000			66*x*00
600-1500	70000	30-45	7000			77*x*00
1500-3000	80000	>45	8000			88*x*00
>3000	90000					9*xx*00

Combine reclassified grids: Elevgen + Slopegen + Reliefgen → *CombiGRID*

2.2.4 Generalization of the CombiGRID

Using *CombiGRID* and Neighbourhood Statistix:
Focalstats MAJORITY, circle 6 cells → *Combigen*

"No data" substitution in *Combigen* with data from *CombiGRID:*
Con (Isnull([*Combigen*]),[*CombiGRID]*,[*Combigen*]) → *Combisubst*

Region Group *Combisubst* → *RegionGcombi*

Extract by attributes: for "count>121" → *Extr_Region*

Clusters of grid-cells with a surface area <121 cells are converted to 'no data'; this corresponds with about 1 km^2 on the map and is used as area of generalization.

Nibble:
Combisubst (input raster) and *Extr_Region* (input raster mask) → *Nibble_121*

(Nibbling is replacing 'no data' values in the raster with neighbouring values, as follows: replace in the input raster (*Combisubst*) the cells corresponding to "no data" cells of input raster mask (*Extr_Region*) with the nearest neighbours' values of *Combisubst* (input raster).

Extraction by mask with polygon extent: → *Nib_121_extr*

(Both polygon layer and GRID layer must have a defined projection).

Raster to polygon conversion (conversion to shapefiles) → *Nibble_121*

Join the shapefile on GRIDCODE and VALUE of RegionG_combi, and export to a new shapefile in ArcMap.

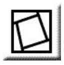
2.2.5 Generalization of the shapefile

Project the shapefile (*Nibble_121*) to geographic coordinates.
→ *Prior_Jenness_geo*

In ArcView 3.x, retrieve the "Prior_Jeness_geo" shapefile.
Check "Dissolve Adjacent Polygons v. 1.8" in file → Extensions

This extension of "Jenness Enterprise" is downloadable from:
http://www.jennessent.com/arcview/dissolve_adjacent_polys.htm (Jenness 2006).

Open in View → Properties: set the map units to Meters and Projection: Projection of Hemisphere: Lambert Azimuthal Equal-Area.
Check "custom", fill in the "Central Meridian" and the "Reference Latitude" and quit with OK → OK

Start extension (button) 

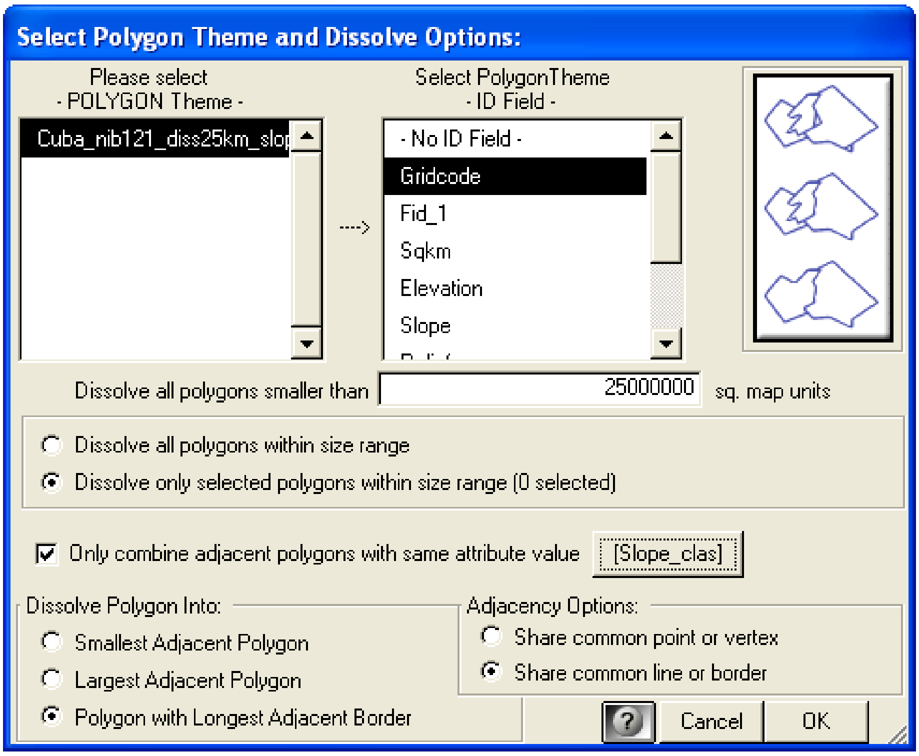


Figure 1: Opening screen of dissolve options

Select Polygon Theme
Select Polygon Theme ID: Gridcode
Dissolve all polygons smaller than 25000000 map units (=25 km^2)
Dissolve all polygons within size range.
Only combine adjacent polygons with same attribute value
Attribute field: Slope_class (1 to 8)
Dissolve Polygon with Longest Adjacent Border

Share common line or border →OK
Give path and name → *After_Jenness_geo*

*When processing is ready, project the shapefile to Lambert Azimuthal
→ *After_Jenness_proj*

The shapefile must have a defined (equal area) projection, e.g. standard Lambert Azimuthal Equal Area.

Add a new field, 'sq_km' to the attribute table of the shapefile and calculate the polygon area;
Type: Double; Precision:10; and Scale: 3

In the field calculator: check for advanced, and fill in the codes;

```
Dim dblArea as double
Dim pArea as IArea
Set pArea = [shape]
dblArea = pArea.area
```

and at 'sq_km=' fill in; dblArea/1000000
Save this expression file as; sq_km.cal (easy use).
Select all polygons < 25 km^2
In Arc toolbox: Eliminate with "Eliminate polygon by border checked on.
→*Eliminate_25*
Recalculate SQKM, select polygons < 25 km^2 and repeat Eliminate procedure
→*Eliminate_25_2*

Check if all polygons (except the stand-alone polygons) have been dissolved (if not: recalculate SQKM, select all polygons < 25 km^2 and repeat Eliminate again)

Remove stand-alone polygons with SQKM <25:

Select all polygons <25 km^2; switch selection in the attribute table (options) and export data to a new shapefile → *Eliminate_25_Islands*
(This is the shapefile without stand-alone polygons <25km^2)
Join the shapefile with the Combi3 table on the code field.
Export this file to a new shapefile → Combi3_25km (the fields of the join table will be included in this new shapefile).

Dissolving on gridcode:

Dissolve Combi3_25km on Gridcode → *Combi_25km_diss*
Convert multipart to single part polygons. → *Combi3_25km_single*
Recalculate the field SQKM
Convert the shapefile from projected to geographic coordinates (WGS 1984)
→ Combi_25km_geo

Dissolve Combi3_25km_single on Landform field (SOTER landform)
→*Combi3_25km_landform*
Convert multipart to single part polygons → *Combi3_25km_landform_single*

Recalculate the field SQKM
Convert the shapefile from projected to geographic coordinates (WGS 1984)
→ *Combi3_25km_geo_SOTER*

Import the both shapefiles in ArcMap and make/import layer files (legends).

Remarks:
A cluster of 3025 grid cells corresponds with about 25 km^2 or 0.25 cm^2 on the map. This is the minimum size of the polygons usually depicted on maps at scale 1:1M.

2.2.6 Data handling for China

The same procedure has been followed as described in chapter 2.2, up to the creation of the input raster "*Combisubst*", under 2.2.4.

Extract China from the Harmonized World Soil Database (HWSD), which is a 30 arc-second raster database (FAO/IIASA/ISRIC/ISSCAS/JRC 2008):

In ArcToolbox →Spatial Analyst Tools →Extraction →Extract by Mask
→Extract_HWSD
(Mask data is the polygon boundary of China)

Convert the raster data to a polygon map:
In ArcToolbox →Conversion Tools →from Raster →Raster to Polygon
→Extract_HWSD.shp

Proceed as mentioned under 2.2.5, *****When processing is ready, project etc.
→*HWSD_poly_geo*

Attach the combicodes to the shapefile:
ArcToolbox →Spatial Analyst Tools →Zonal →Zonal Statistics
Input raster or feature zone data: *HWSD_poly_geo.shp*
Zone field: *ID*
Input value raster: *Combisubst*
Output raster: *ZonalSt_HWSD*
Statistics: *MAJORITY*

Join the resulting table to the shapefile and export to a new shapefile:
→*HWSD_poly_zonal_geo*

Join the shapefile with the Combi3 table on the code field and export to a new shapefile **→*HWSD_poly_final_geo***

2.3 Conversion of GRID maps to landform maps

The reclassified codes for elevation, slope and relief intensity are combined in a new GRID code that comprises five digits of which the last two are zero for the (presently not used) drainage density. See also 2.1. These combined GRID codes are similar to the Combicodes in Table 1.

The GRIDCODE is used to link the GIS file to the key table for landform and to generate a SOTER landform map. Appendix 2 gives the major landform classes as assigned to the combined GRIDCODE or Combicodes that occur in the GIS derived landform database. A SOTER landform alternative is given for those Combicodes where the assigned landform does not fit completely the existing SOTER criteria or, when more than one landform is possible.

This particular problem arises when one of the classes on slope or relief intensity does not fit the combination of SOTER criteria. This is the case e.g. when the relief intensity is sufficiently high to fall in the landform category SP (dissected plain) or even SH (medium gradient hill), but the slope is only between 5-10 percent and classifies as level land. In such cases, dissected plain is selected, because of its high relief intensity, and alternative landforms are indicated in the adjacent column. More of such cases will occur for different combinations of elevation, slope and relief intensity. These cases have still to be reviewed, using the different layers in the GIS analyses, and taking into account the surrounding landform.

Because of the rather rigid conversion from the GRIDCODE into the SOTER landform, available information is not shown on the map. Using a different legend can help to retain more information. The use of a legend with multi-stage classes or a more sliding scale, formed on basis of **s**lope, **r**elief intensity and **e**levation (SRE classes) show already more detail, also for those areas where the SOTER landform maps appears to be very uniform.

Under the heading, 'Meaning' (Appendix 2), combinations of the maximum possible values of the SOTER criteria ranges are given for elevation (E), slope (S) and relief intensity (R). The GRIDCODE and the SRE class in the table represent a unique code for each of the combinations and is depicted on a map (Figure 2 to Figure 13).

For the SOTER landform codes and criteria, see Appendix 1.

3 RESULTS AND DISCUSSION

The SOTER landform maps of the six LADA partner countries at scale 1:1 million are presented in the Figures 2 to 13 (jpeg format), together with the maps of grouped SRE classes (also included on CD-rom in ArcMap format).

All polygons smaller than 25 km^2 were eliminated from the spatial database and assigned to a neighbouring polygon with the longest common border, using the Jenness procedure (Jenness 2006). The Jenness procedure, dissolving small, adjacent polygons, is the best solution to eliminate small polygons. This is allowed at the present scale of 1:1 million, but elimination of these polygons smaller than 25 km^2 created a much more generalized landform map. The question is if elimination of all these small polygons is not a too large loss of information that is originally available.

Therefore, different types of legends are tried to depict the classified information on a map. Included are maps showing a legend with multi-stage classes, based on slope, relief and elevation (SRE classes), which are also derived from the same GRIDCODE, but in a different sequence. See Appendix 2. Slope is here the dominant criteria, followed by relief intensity and elevation; the groupings for the legend follow the standard criteria as given in the SOTER manual (van Engelen and Wen 1995). These maps, giving the landform with only eight SRE classes in their legend, have retained more of its detail. It demonstrates one of the possibilities of the SRTM 90m DEM analysis (much detail) compared to the SOTER landform map (less detail). However, a legend with only coding does not link to or give any recognition with actual landform features, as experienced when doing fieldwork.

Another problem arises in the SOTER landform classification. All land with relief intensity (RI) less than 50 m and slope less than 10% is termed ‘level land’ and indicated as plain (LP). No other level landform, as plateau (LL) or valley floor (LV), could automatically be assigned as the SOTER criteria for these landforms are similar to those for plain. See Appendix 1. Only in their position compared to the surrounding landform can they be sufficiently discriminated. This holds also for some sloping and steep SOTER landforms; criteria to discriminate these SOTER landforms have yet to be developed. Assigning only one landform to ‘level land’ has limited the number of landforms in the database. In the present database, seven landforms are indicated, while potentially the SOTER manual distinguished 14 landforms (Appendix 1).

The conversion of the GRIDCODES (Combicodes) to the SOTER landforms is not obvious for all cases and more landform possibilities exist, e.g. when slope is <10% and RI > 100 mkm^2. In such cases, a single (SOTER) landform and an alternative landform are indicated, e.g. LP/LF/SP/SH; this can be described as ‘level to sloping land’ (Appendix 2). When more then one landform is possible, the assignment is first based on slope and secondly on RI. In the Figure 2 to Figure 13 only single (SOTER) landforms are given.

Polygons for water bodies and lakes are imported from the ESRI World Base Map data (ESRI 2005). In two cases, the database gives temporal lakes as permanent water surface; these are the 'salinas' in Argentina and the "shotts" Tunisia (Times 2003). Especially in Tunisia, more temporary water bodies are given as lakes.

Due to the followed procedures, depressions below mean sea level (negative elevation) are not shown on the landform maps. Examples are the Turpan depression in China (south of the city Ürümqi) and in Argentina the depressions 'Salina Gaulicho' (north of San Antonia Oeste, Rio Negro province) and a part of the 'Gran Baja de San Julian' (north of Rio Chico between San Julian and Santa Cruz, Santa Cruz province). In Tunisia, this Shott el Gharsa lies about 15 m. below sea level.

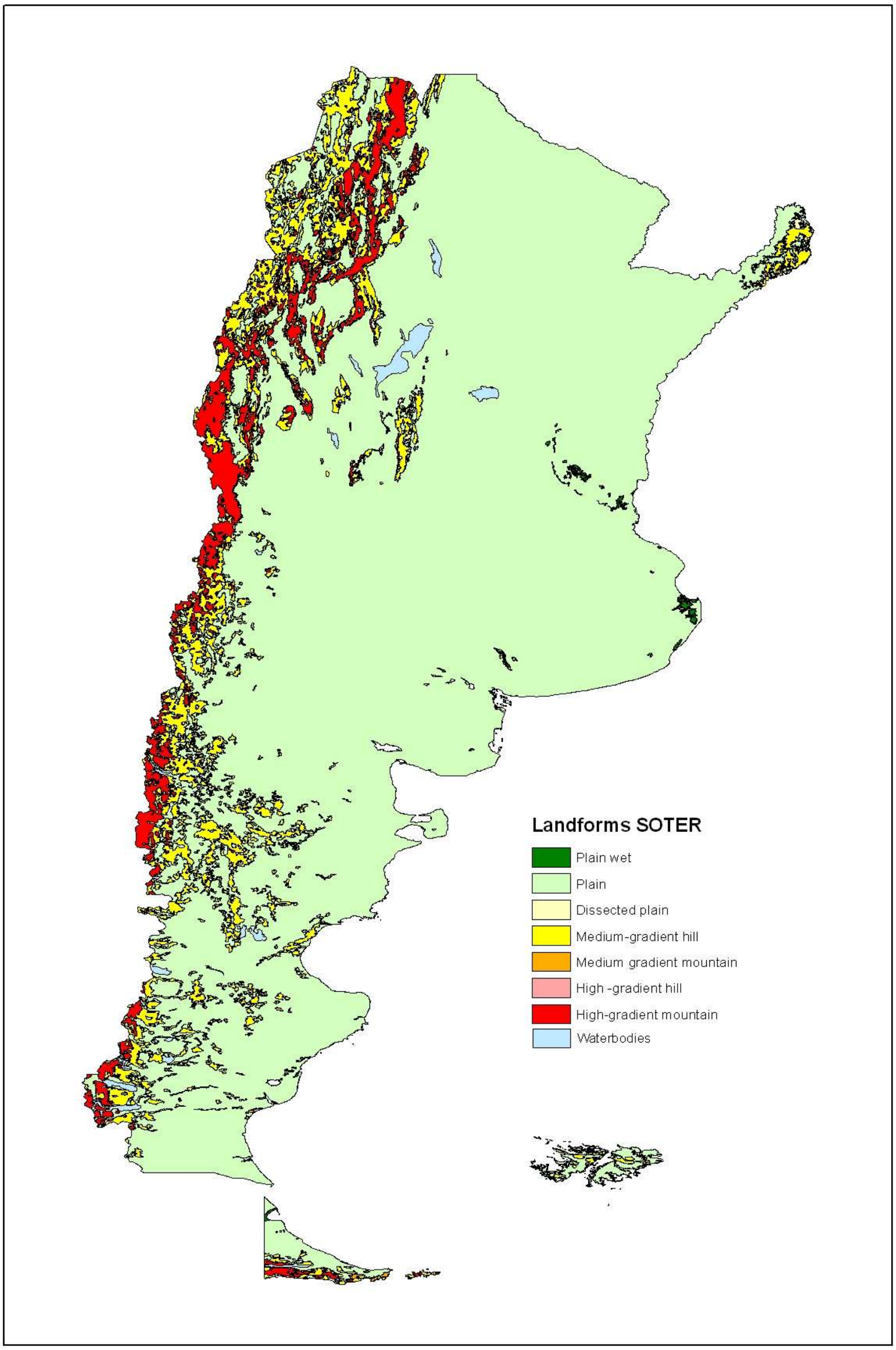


Figure 2: SOTER landform of Argentina

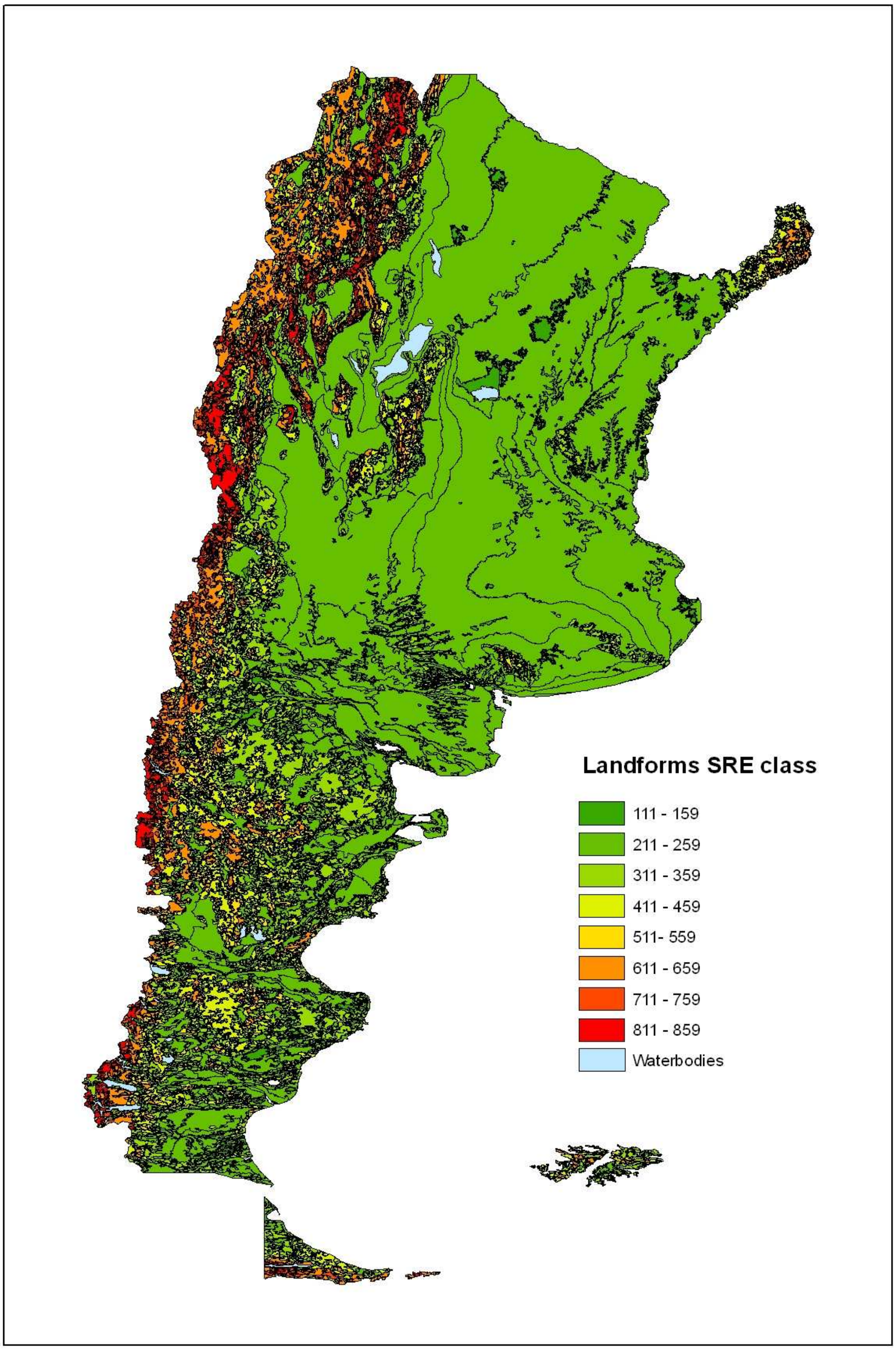


Figure 3: Landform with SRE classes for Argentina

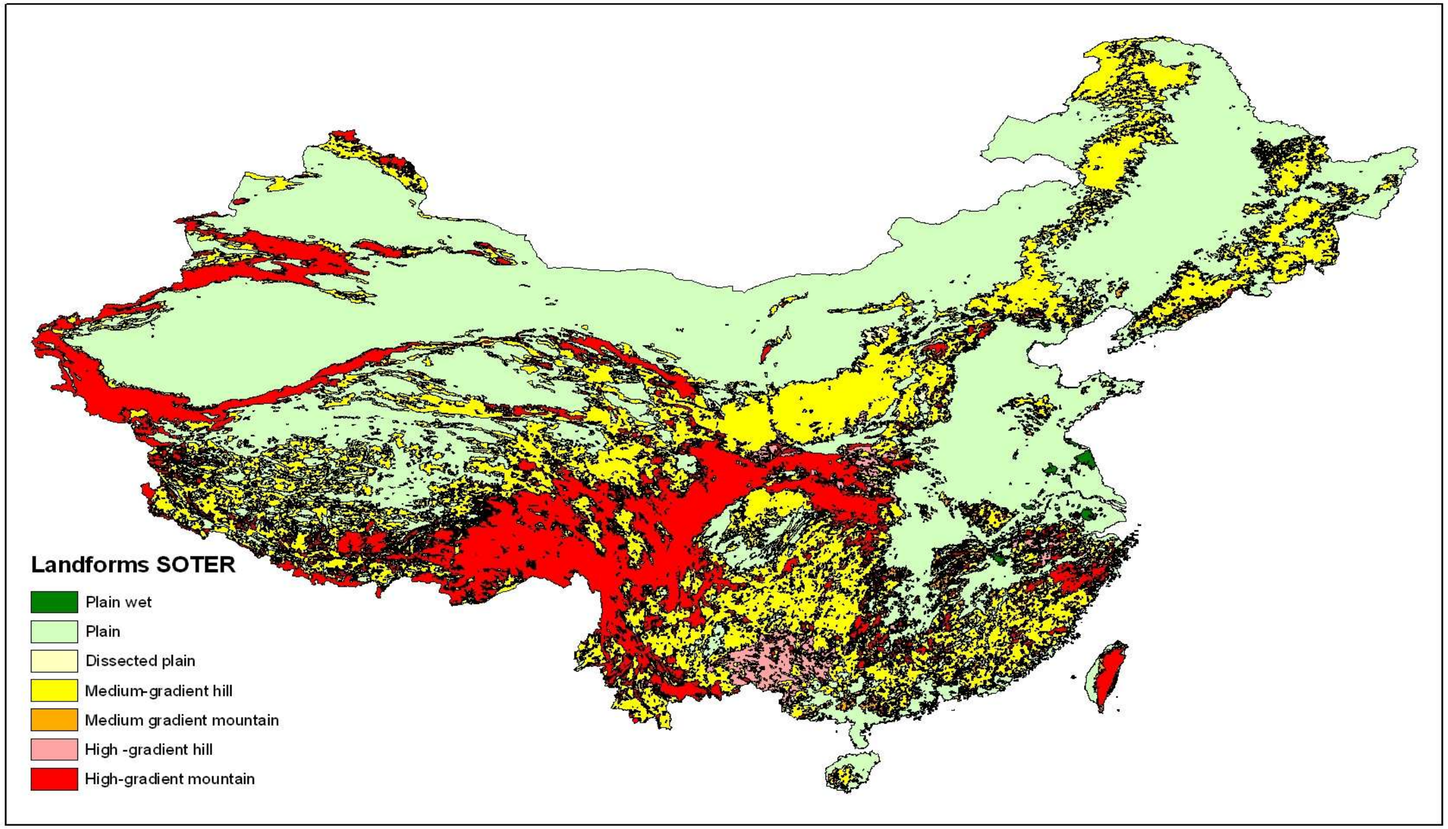


Figure 4: SOTER landform of China

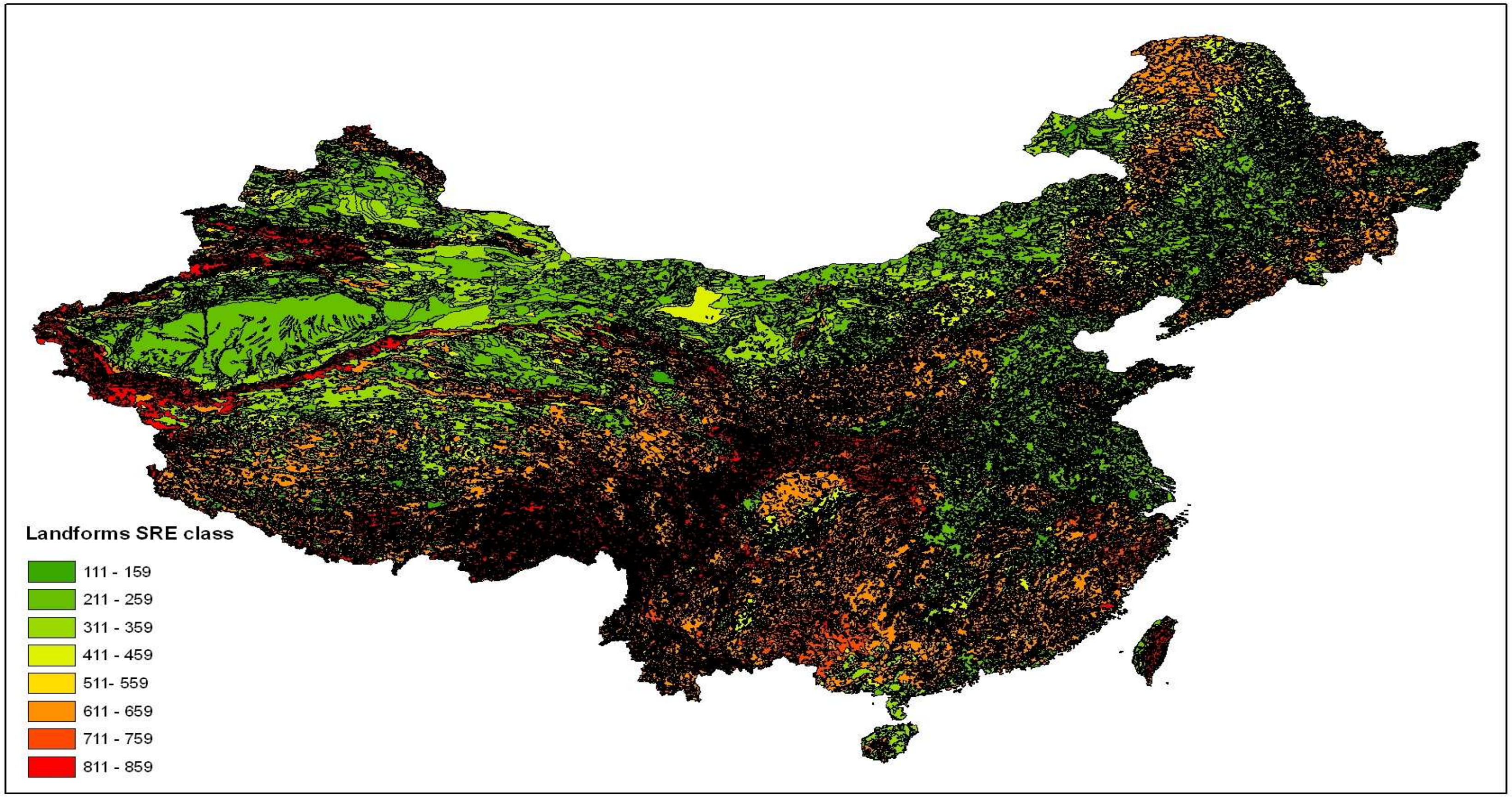


Figure 5: Landform with SRE classes for China

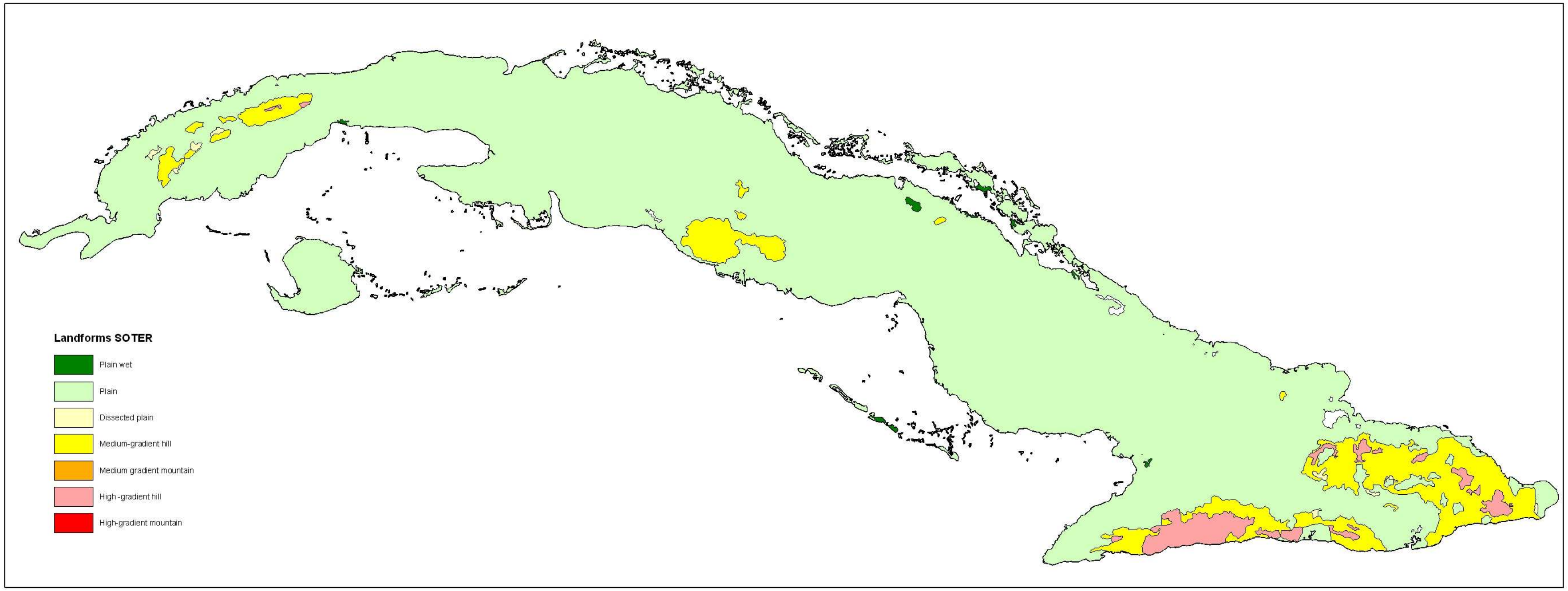


Figure 6: SOTER landform of Cuba

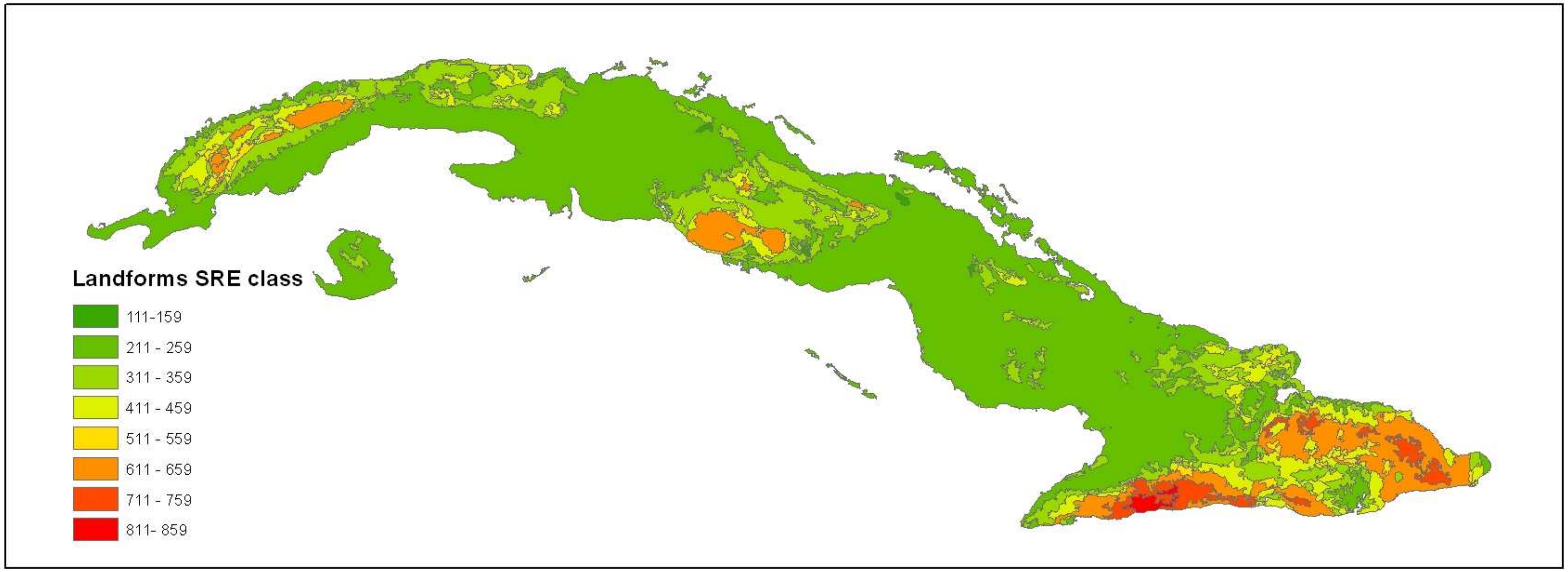


Figure 7: Landform with SRE classes for Cuba

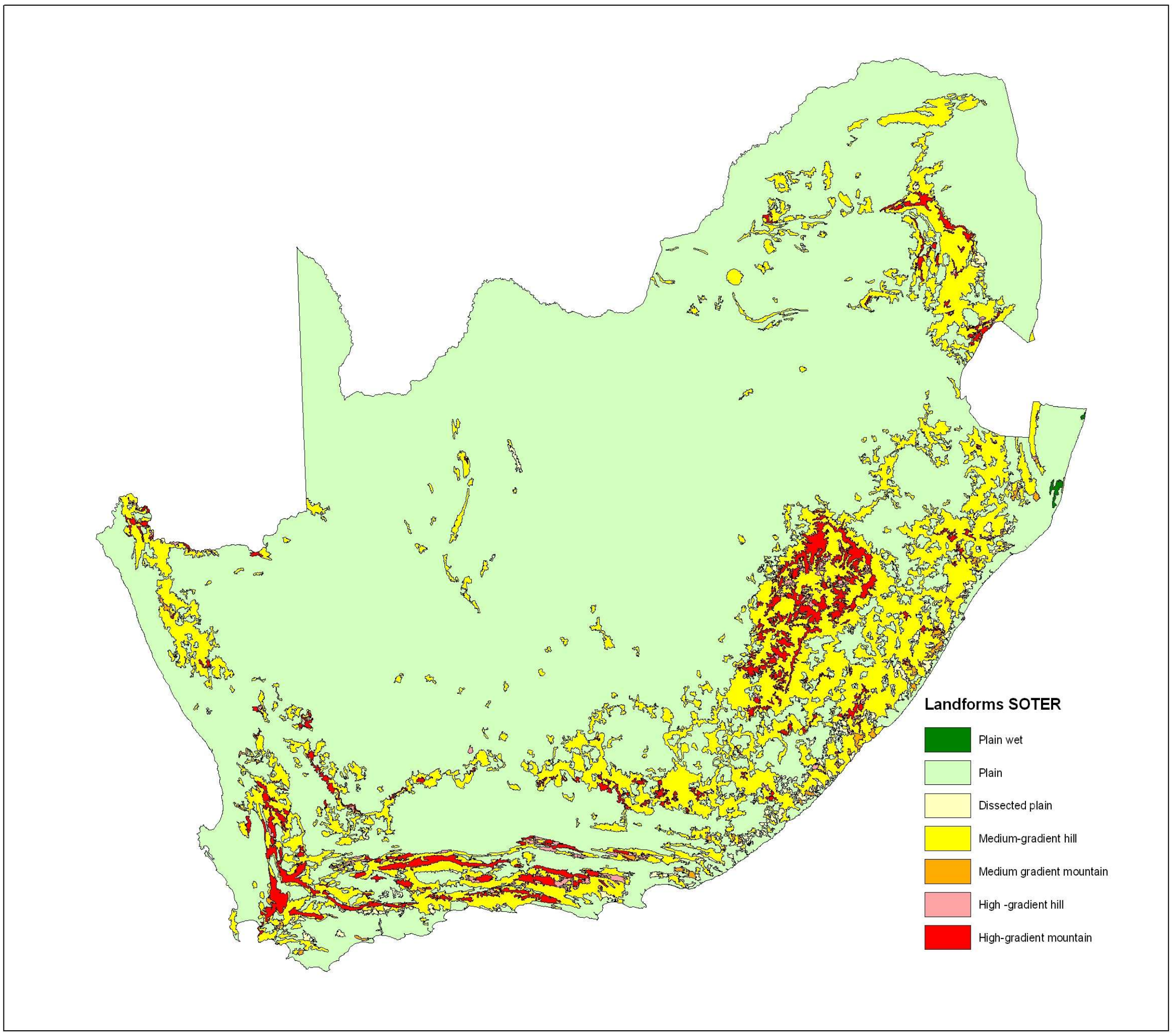


Figure 8: SOTER landform of South Africa

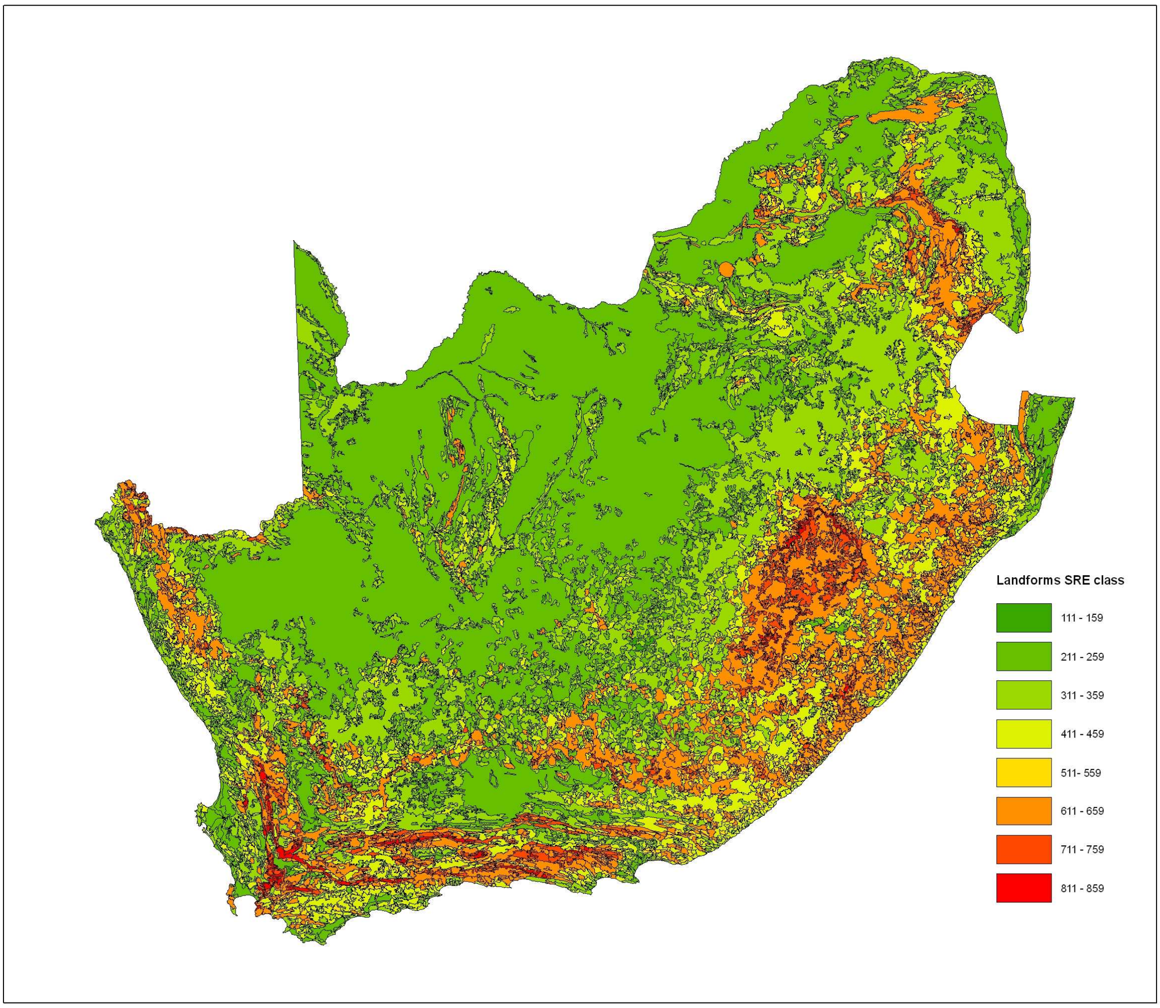


Figure 9: Landform with SRE classes for South Africa

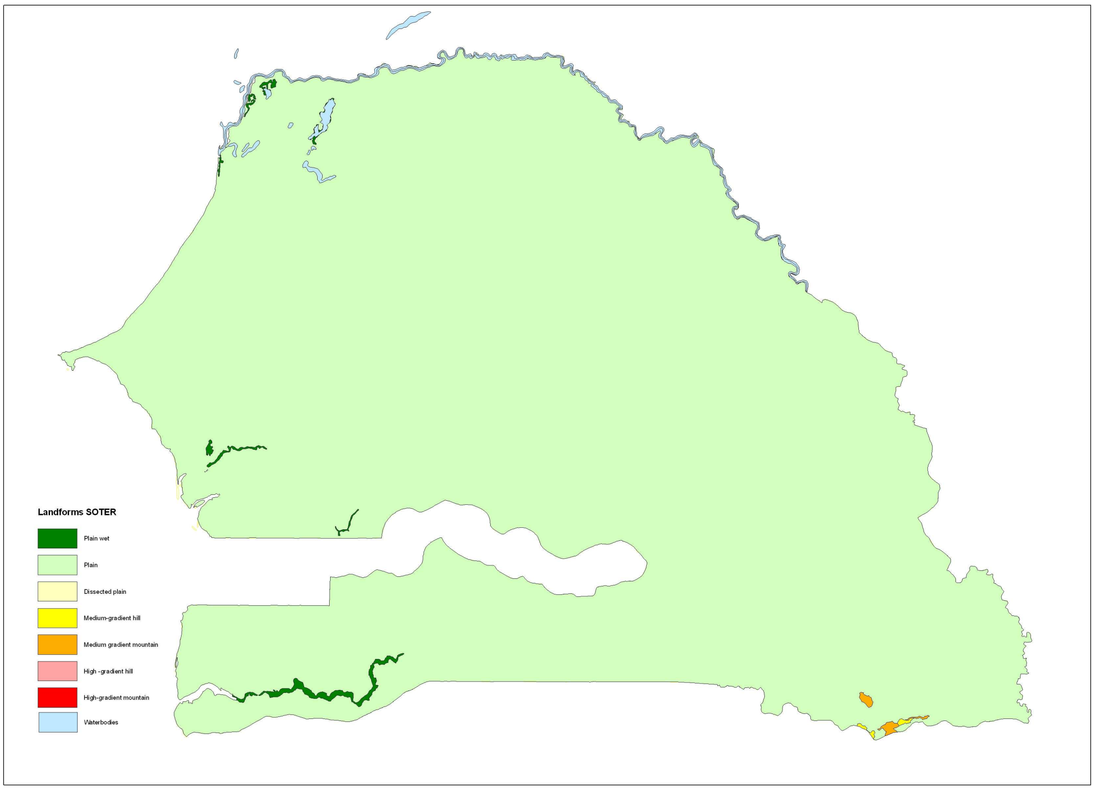


Figure 10: SOTER landforms of Senegal and The Gambia

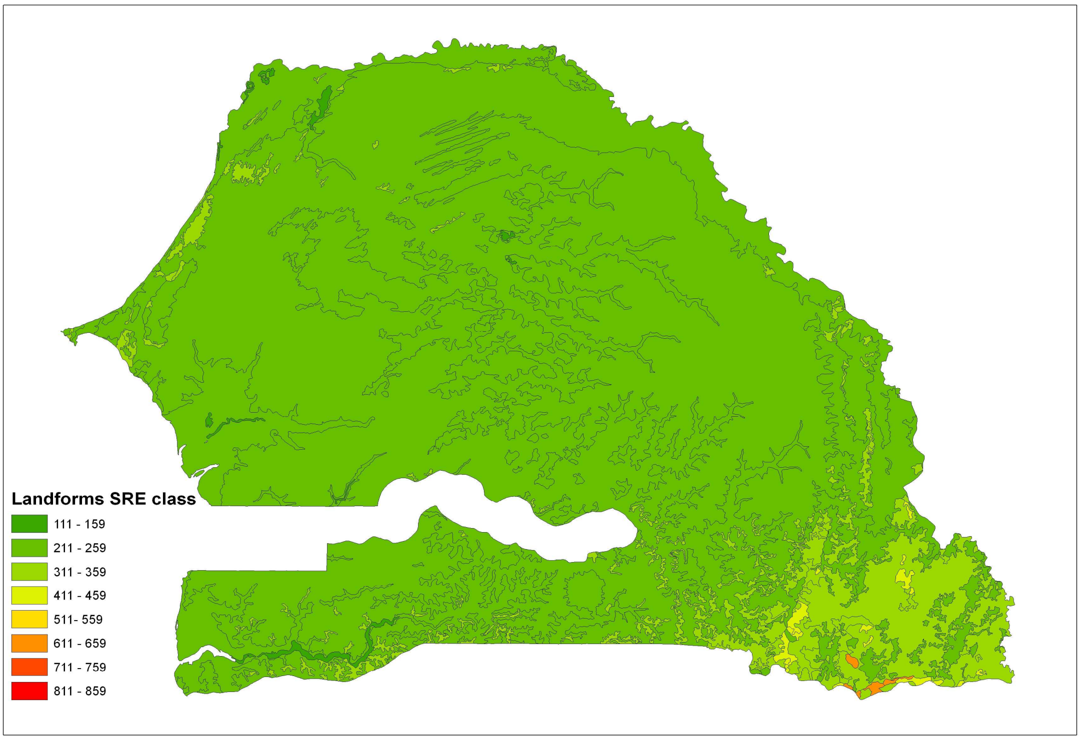


Figure 11: Landforms with SRE classes for Senegal and The Gambia

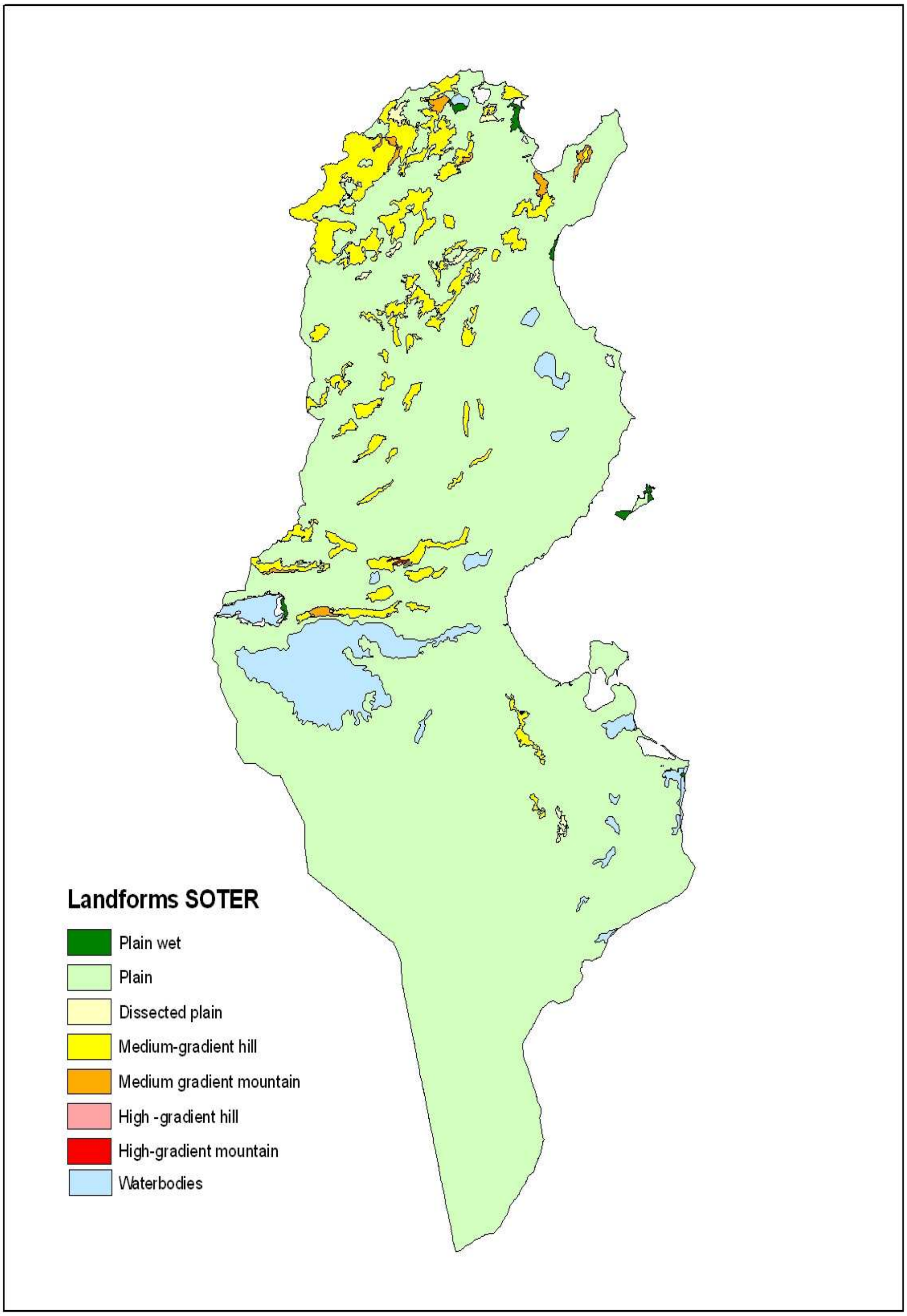


Figure 12: SOTER landform of Tunisia

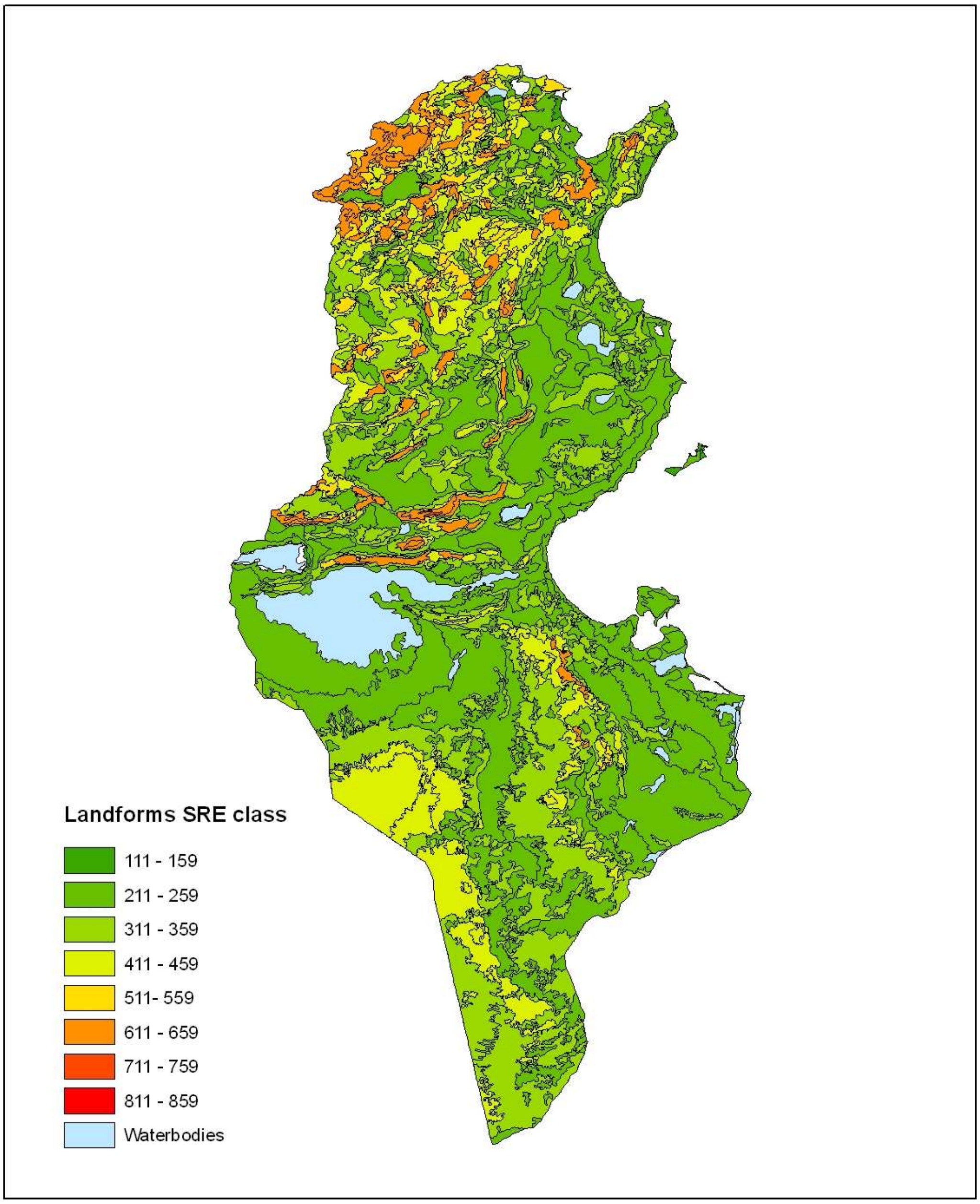


Figure 13: Landform with SRE classes for Tunisia

4 CONCLUSIONS

The SRTM 90m DEM-derived landform maps give more detail compared to the manually-derived landform maps from the traditional SOTER database for Argentina and Cuba (Dijkshoorn *et al.* 2005; FAO *et al.* 1998), and South Africa (FAO *et al.* 2003). Landform, based on SRE class groupings gives even more detail, but is not linked to actual SOTER landforms.

Further work is needed to discriminate between landforms that are based on not yet GIS-quantified SOTER criteria. This is e.g. the case for the landforms *plateau* and *depression*, which are level land at higher respectively lower position than the surrounding land, and in transition bounded by an escarpment, respectively by sloping land. All level land is now assigned as plain (LP), but may include the traditional SOTER landform plateau, depression, footslope and river basin/valley floor. These landforms are not assigned in the present database, as no GIS-based discrimination could be made. A further refinement of the GIS-based methods is needed to discriminate between these other landforms of 'level land'. Likely, a manual inspection of a number of polygons and expert judgement will be necessary now to differentiate such units from the landform plain.

Further research on the refinement of the GIS procedures are needed e.g. in generalization procedures and standards, in potential drainage density (pdd), which was not used for our analysis and likely in a slight adaptation of the SOTER landform criteria.

The present procedure without discrimination between 'level land' has resulted in an overestimation of the landform plain (LP). A similar situation can occur for dissected plain (SP). Polygons e.g. with a too low relief intensity for 'medium gradient hill' (RI < 100 m/km^2, but with slopes >15%) are assigned dissected plain. Underestimated are the landform plateau, depression, low gradient footslope, valley floor, medium and high gradient escarpment zone, and medium and high gradient valley.

Due to the procedure followed, depressions with elevations reaching below mean sea level (negative elevation), are left blank on the map, e.g. Turpan depression in China. Some of them are indicated water bodies and are temporal lakes, e.g. Chott el Gharsa.

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APPENDICES

Appendix 1: Hierarchy of major landforms (adapted)

1st level	2nd level	gradient (%)	relief intensity ($m.km^{-2}$)
L level land	**LP** plain	<10	<50
	LL plateau	<10	<50
	LD depression	<10	<50
	LF low gradient footslope	<10	<50
	LV valley floor	<10	<50
S sloping land	**SE** medium-gradient escarpment zone	10-30	100-150
	SH medium-gradient hill	10-30	100-250
	SM medium-gradient mountain	15-30	150-300
	SP dissected plain	10-30	50-100
	SV medium-gradient valley	10-30	100-150
T steep land	**TE** high-gradient escarpment zone	>30	150-300
	TH high-gradient hill	>30	150-300
	TM high-gradient mountain	>30	>300
	TV high-gradient valley	>30	>150

Source: SOTER manual (van Engelen and Wen 1995), revised not published

Appendix 2: GRIDCODE key for landform and SREclass (slope, relief intensity and elevation)

GRID CODE	SRE class	Elevation m	Slope %	Relief m	Meaning	Landform (SOTER)	Landform alternative
11100	111	<10	0-0.5	0-50	E10_S0.5_R50	LP wet	
12100	211	<10	0.5-2	0-50	E10_S2_R50	LP	
13100	311	<10	2-5	0-50	E10_S5_R50	LP	
14200	421	<10	5-10	50-100	E10_S10_R100	LP	SP
21100	112	10-50	0-0.5	0-50	E50_S0.5_R50	LP	
22100	212	10-50	0.5-2	0-50	E50_S2_R50	LP	
22300	232	10-50	0.5-2	100-150	E50_S2_R150	LP	
23100	312	10-50	2-5	0-50	E50_S5_R50	LP	
23200	322	10-50	2-5	50-100	E50_S5_R100	LP	LF/SP/SH
24100	412	10-50	5-10	0-50	E50_S10_R50	LP	
24200	422	10-50	5-10	50-100	E50_S10_R100	LP	SP
25200	522	10-50	10-15	50-100	E50_S15_R100	SP	
26200	622	10-50	15-30	50-100	E50_S30_R100	SH	SE/SV
26300	632	10-50	15-30	100-150	E50_S30_R150	SH	
31100	113	50-100	0-0.5	0-50	E100_S0.5_R50	LP	
32100	213	50-100	0.5-2	0-50	E100_S2_R50	LP	
32200	223	50-100	0.5-2	50-100	E100_S2_R100	LP	
33100	313	50-100	2-5	0-50	E100_S5_R50	LP	
33200	323	50-100	2-5	50-100	E100_S5_R100	LP	LF/SP/SH
34100	413	50-100	5-10	0-50	E100_S10_R50	LP	
34200	423	50-100	5-10	50-100	E100_S10_R100	LP	SP
35200	523	50-100	10-15	50-100	E100_S15_R100	SP	
35300	533	50-100	10-15	100-150	E100_S15_R150	SH	SE/SV
36300	633	50-100	15-30	100-150	E100_S30_R150	SH	
36400	643	50-100	15-30	150-300	E100_S30_R300	SH	SM
41100	114	100-200	0-0.5	0-50	E200_S0.5_R50	LP	
42100	214	100-200	0.5-2	0-50	E200_S2_R50	LP	
43100	314	100-200	2-5	0-50	E200_S5_R50	LP	
43200	324	100-200	2-5	50-100	E200_S5_R100	LP	LF/SP/SH
44100	414	100-200	5-10	0-50	E200_S10_R50	LP	
44200	424	100-200	5-10	50-100	E200_S10_R100	LP	SP
44300	434	100-200	5-10	100-150	E200_S10_R150	LP	SE/SV/SP
45200	524	100-200	10-15	50-100	E200_S15_R100	SP	
45300	534	100-200	10-15	100-150	E200_S15_R150	SH	SE/SV
46200	624	100-200	15-30	50-100	E200_S30_R100	SH	SE/SV/SP
46300	634	100-200	15-30	100-150	E200_S30_R150	SH	
46400	644	100-200	15-30	150-300	E200_S30_R300	SH	SM
47400	744	100-200	30-45	150-300	E200_S45_R300	TH	TM/TE/TV
51100	115	200-300	0-0.5	0-50	E300_S0.5_R50	LP	LD
52100	215	200-300	0.5-2	0-50	E300_S2_R50	LP	
52200	225	200-300	0.5-2	50-100	E300_S2_R100	LP	SP
53100	315	200-300	2-5	0-50	E300_S5_R50	LP	
53200	325	200-300	2-5	50-100	E300_S5_R100	LP	LF/SP/SH
54100	415	200-300	5-10	0-50	E300_S10_R50	LP	
54200	425	200-300	5-10	50-100	E300_S10_R100	LP	SP
54300	435	200-300	5-10	100-150	E300_S10_R150	LP	SE/SV/SP
55200	525	200-300	10-15	50-100	E300_S15_R100	SP	

GRID CODE	SRE class	Elevation m	Slope %	Relief m	Meaning	Landform (SOTER)	Landform alternative
55300	535	200-300	10-15	100-150	E300_S15_R150	SH	SE/SV
56300	635	200-300	15-30	100-150	E300_S30_R150	SH	
56400	645	200-300	15-30	150-300	E300_S10_R300	SH	SM
57300	735	200-300	30-45	100-150	E300_S45_R150	TH	TE/TV
57400	745	200-300	30-45	150-300	E300_S45_R300	TH	TM/TE/TV
61100	116	300-600	0-0.5	0-50	E600_S0.5_R50	LP	
62100	216	300-600	0.5-2	0-50	E600_S2_R50	LP	
62200	226	300-600	0.5-2	50-100	E600_S2_R100	LP	SP
63100	316	300-600	2-5	0-50	E600_S5_R50	LP	
63200	326	300-600	2-5	50-100	E600_S5_R100	LP	LF/SP/SH
64100	416	300-600	5-10	0-50	E600_S10_R50	LP	
64200	426	300-600	5-10	50-100	E600_S10_R100	LP	SP
64300	436	300-600	5-10	100-150	E600_S10_R150	LP	SE/SV/SP
65200	526	300-600	10-15	50-100	E600_S15_R100	SP	
65300	536	300-600	10-15	100-150	E600_S15_R150	SH	SE/SV
66200	626	300-600	15-30	50-100	E600_S30_R100	SH	SE/SV/SP
66300	636	300-600	15-30	100-150	E600_S30_R150	SH	
66400	646	300-600	15-30	150-300	E600_S30_R300	SH	SM
66500	656	300-600	15-30	>300	E600_S30_R>300	SM	SE
67300	736	300-600	30-45	100-150	E600_S45_R150	TH	TM/TE/TV
67400	746	300-600	30-45	150-300	E600_S45_R300	TH	TM/TE/TV
67500	756	300-600	30-45	>300	E600_S45_R>300	TM	
68400	846	300-600	>45	150-300	E600_S>45_R300	TH	TM
68500	856	300-600	>45	>300	E600_S>45_R>300	TM	
71100	117	600-1500	0-0.5	0-50	E1500_S0.5_R50	LP	
72100	217	600-1500	0.5-2	0-50	E1500_S2_R50	LP	
73100	317	600-1500	2-5	0-50	E1500_S5_R50	LP	
73200	327	600-1500	2-5	50-100	E1500_S5_R100	LP	LF/SP/SH
74100	417	600-1500	5-10	0-50	E1500_S10_R50	LP	
74200	427	600-1500	5-10	50-100	E1500_S10_R100	LP	SP
74300	437	600-1500	5-10	100-150	E1500_S10_R150	LP	SE/SV/SP
75200	527	600-1500	10-15	50-100	E1500_S15_R100	SP	
75300	537	600-1500	10-15	100-150	E1500_S15_R150	SH	SE/SV
75400	547	600-1500	10-15	150-300	E1500_S15_R300	SH	
76200	627	600-1500	15-30	50-100	E1500_S30_R100	SH	SE/SV/SP
76300	637	600-1500	15-30	100-150	E1500_S30_R150	SH	
76400	647	600-1500	15-30	150-300	E1500_S30_R300	SH	SM
77300	737	600-1500	30-45	100-150	E1500_S45_R150	TH	TE/TV/SH
77400	747	600-1500	30-45	150-300	E1500_S45_R300	TH	
77500	757	600-1500	30-45	>300	E1500_S45_R>300	TM	
78400	847	600-1500	>45	150-300	E1500_S>45_R300	TH	TM/TE/TV
78500	857	600-1500	>45	>300	E1500_S>45_R>300	TM	
81100	118	1500-3000	0-0.5	0-50	E3000_S0.5_R50	LP	
82100	218	1500-3000	0.5-2	0-50	E3000_S2_R50	LP	
83100	318	1500-3000	2-5	0-50	E3000_S5_R50	LP	
83200	328	1500-3000	2-5	50-100	E3000_S5_R100	LP	LF/SP/SH
84100	418	1500-3000	5-10	0-50	E3000_S10_R50	LP	
84200	428	1500-3000	5-10	50-100	E3000_S10_R100	LP	SP
84300	438	1500-3000	5-10	100-150	E3000_S10_R150	LP	SE/SV/SP
85200	528	1500-3000	10-15	50-100	E3000_S15_R100	SP	
85300	538	1500-3000	10-15	100-150	E3000_S15_R150	SH	SE/SV

GRID CODE	SRE class	Elevation m	Slope %	Relief m	Meaning	Landform (SOTER)	Landform alternative
86200	628	1500-3000	15-30	50-100	E3000_S30_R100	SH	SE/SV/SP
86300	638	1500-3000	15-30	100-150	E3000_S30_R150	SH	
86400	648	1500-3000	15-30	150-300	E3000_S30_R300	SH	SM
87300	738	1500-3000	30-45	100-150	E3000_S45_R150	TH	TE/TV/SH
87400	748	1500-3000	30-45	150-300	E3000_S45_R300	TH	TM/TE/TV
87500	758	1500-3000	30-45	>300	E3000_S45_R>300	TM	
88400	848	1500-3000	>45	150-300	E3000_S>45_R300	TH	TM/TE/TV
88500	858	1500-3000	>45	>300	E300_S>45_R>300	TM	
91100	119	3000-5000	0-0.5	0-50	E5000_S0.5_R50	LP	
92100	219	3000-5000	0.5-2	0-50	E5000_S2_R50	LP	
93100	319	3000-5000	2-5	0-50	E5000_S5_R50	LP	
93200	329	3000-5000	2-5	50-100	E5000_S5_R100	LP	LF/SP/SH
94100	419	3000-5000	5-10	0-50	E5000_S10_R50	LP	
94200	429	3000-5000	5-10	50-100	E5000_S10_R100	LP	SP
94300	439	3000-5000	5-10	100-150	E5000_S10_R150	LP	SE/SV/SP
95200	529	3000-5000	10-15	50-100	E5000_S15_R100	SP	
95300	539	3000-5000	10-15	100-150	E5000_S15_R150	SH	SE/SV
95400	549	3000-5000	10-15	150-300	E5000_S15_R300	SH	
96300	639	3000-5000	15-30	100-150	E5000_S30_R150	SH	
96400	649	3000-5000	15-30	150-300	E5000_S30_R300	SH	SM
97400	749	3000-5000	30-45	150-300	E5000_S45_R300	TH	TM/TE/TV
97500	759	3000-5000	30-45	>300	E5000_S45_R>300	TM	
98400	849	3000-5000	>45	150-300	E5000_S>45_R300	TH	TM/TE/TV
98500	859	3000-5000	>45	>300	E5000_S>45_R>300	TM	

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