Simple toolbox for worldwide topography based soils reclassification for initialization of SWAT

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Why is Topography Important

My h-index of course!

Fuka, Daniel R., Zachary M. Easton, Erin S. Brooks, Jan Boll, Tammo S. Steenhuis, and M. Todd Walter, 2012. A Simple Process-Based Snowmelt Routine to Model Spatially Distributed Snow Depth and Snowmelt in the SWAT Model. Journal of the American Water Resources Association (JAWRA) 1-11. DOI: 10.1111/j.1752-1688.2012.00680.x

And of course

Surface energy budgets

- Snow accumulation and melt
- Crop modeling

- Hydrological processes
  - Interflow, overland flow, VSA
- Soil genesis
  - Depth, components, OM, chemistry, etc

Which will need topography to derive/estimate?

$$\Delta SWE = \frac{(S + L_a - L_t + H + E + G + P - SWE(C\Delta T_s))}{\lambda}$$

ΔSWE - change snow water equivalent

S - net incident solar radiation

L_a - atmospheric long wave radiation

L_t – terrestrial long wave radiation

H - sensible heat exchange

E - energy flux latent heats, vaporization & condensation

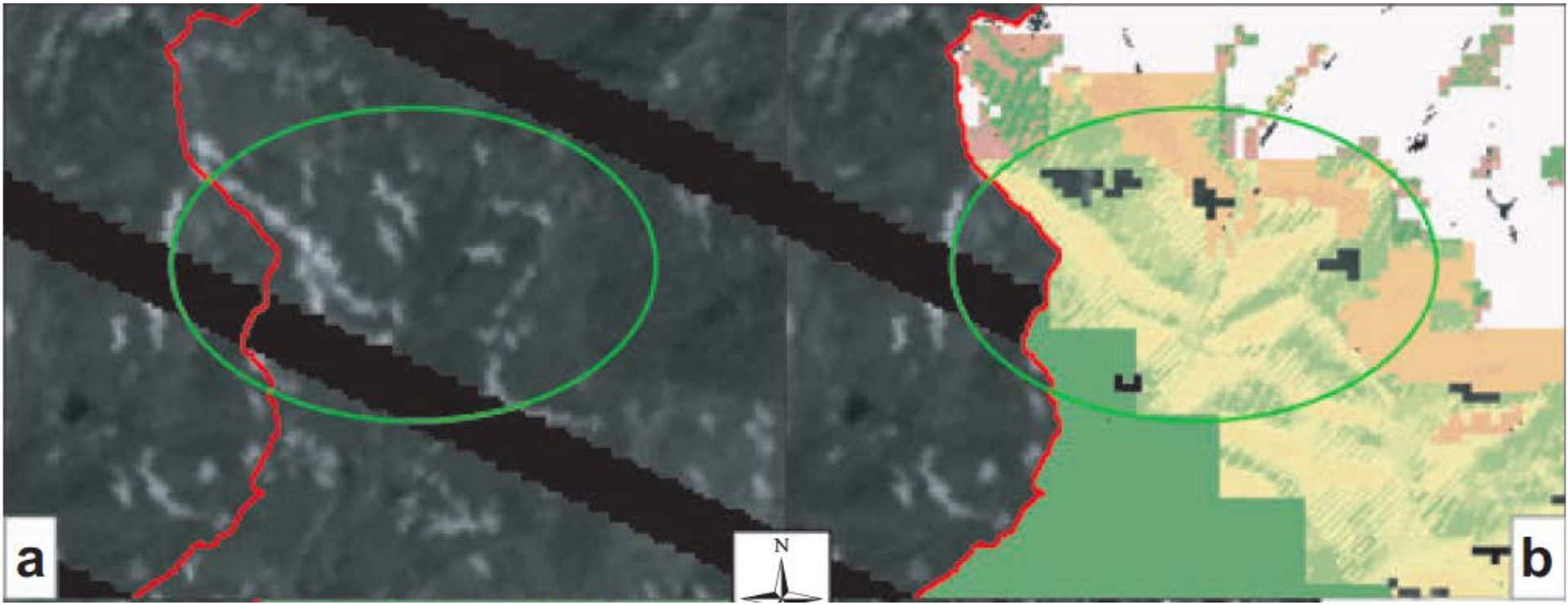
G - ground heat conduction

P - heat added by rainfall

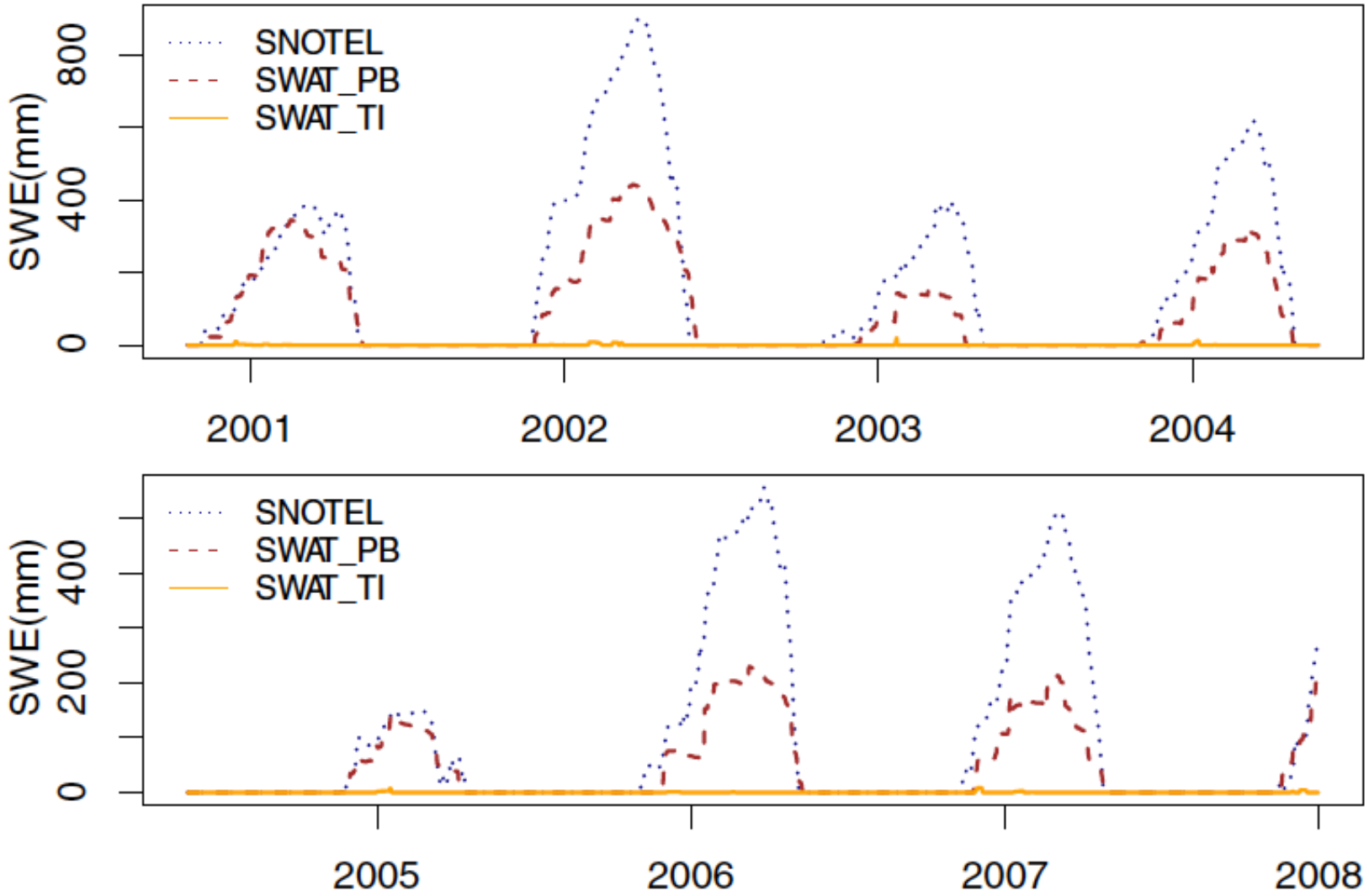
SWE($C\Delta T_s$) - change of snowpack heat storage

λ – latent heat of fusion

Topography in SWAT brings hill-slope hydrology to the basins



More process based helps with autocalibration issues…



Topographic index – not a new concept (Kirby + Beven late 70's)

- used to describe the spatial distribution of the soil moisture and soil properties related landscape processes.
- as contributing area (specific catchment area) increases and slope steepness decreases, topographic index and soil moisture content increase.
- can lead to higher correlations of soil moisture with topographic index than with specific catchment area and slope steepness.

Topographic index 'controls':

flow accumulation, soil moisture, distribution of saturation zones, depth of water table, evapotranspiration, thickness of soil horizons, organic matter, pH, silt and sand content, plant cover distribution.

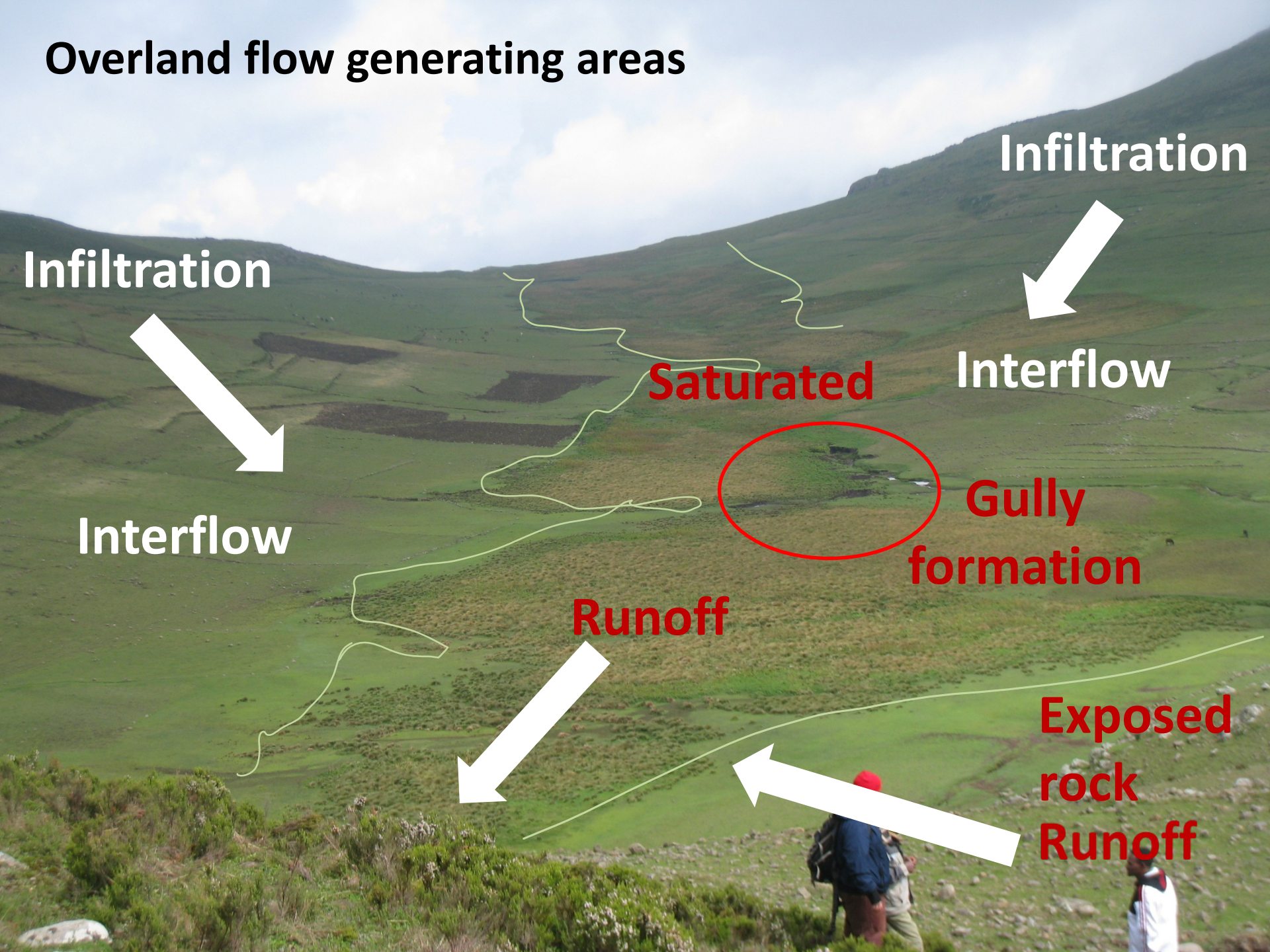
Topographic Index

$$\lambda_i = \ln\left(\frac{\alpha_i}{\tan\beta_i}\right)$$

λ_i = topographic index of grid cell, i
α_i = the upslope contributing area per unit length of contour
β_i = topographic slope of the cell

Topographic Index '*raster calculator-ready*'

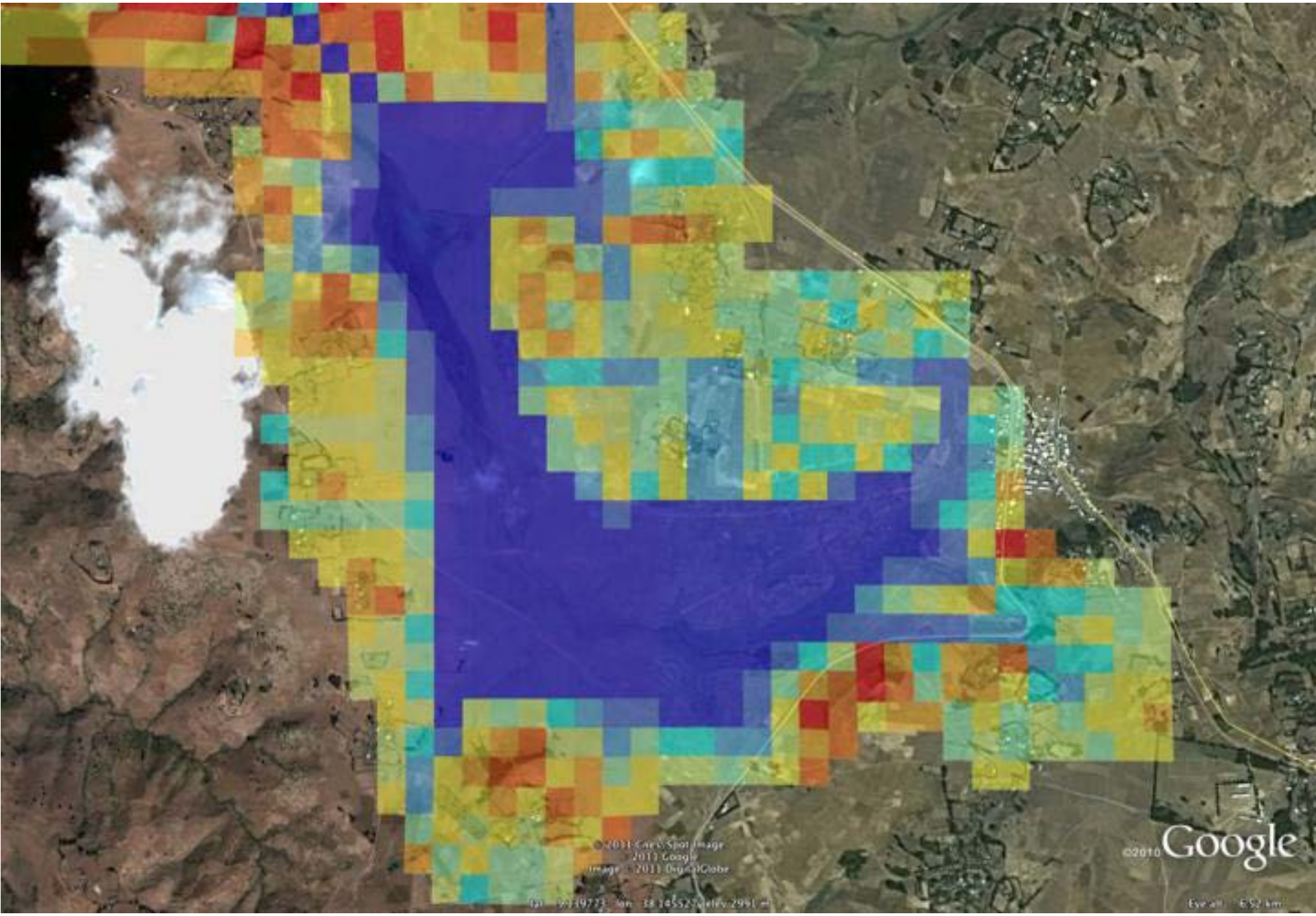
[TI] = Ln (([FlowAcc] + 1) / ([Slope] / 100 + 0.001))


Overland flow generating areas
Infiltration
Infiltration
Interflow
Saturated
Interflow
Gully formation
Runoff
Exposed rock Runoff

Maybar, Ethiopia

Chance that rainfall intensity will exceed infiltration capacity is very small


©2010 Google
Imagery Date: 12/17/2006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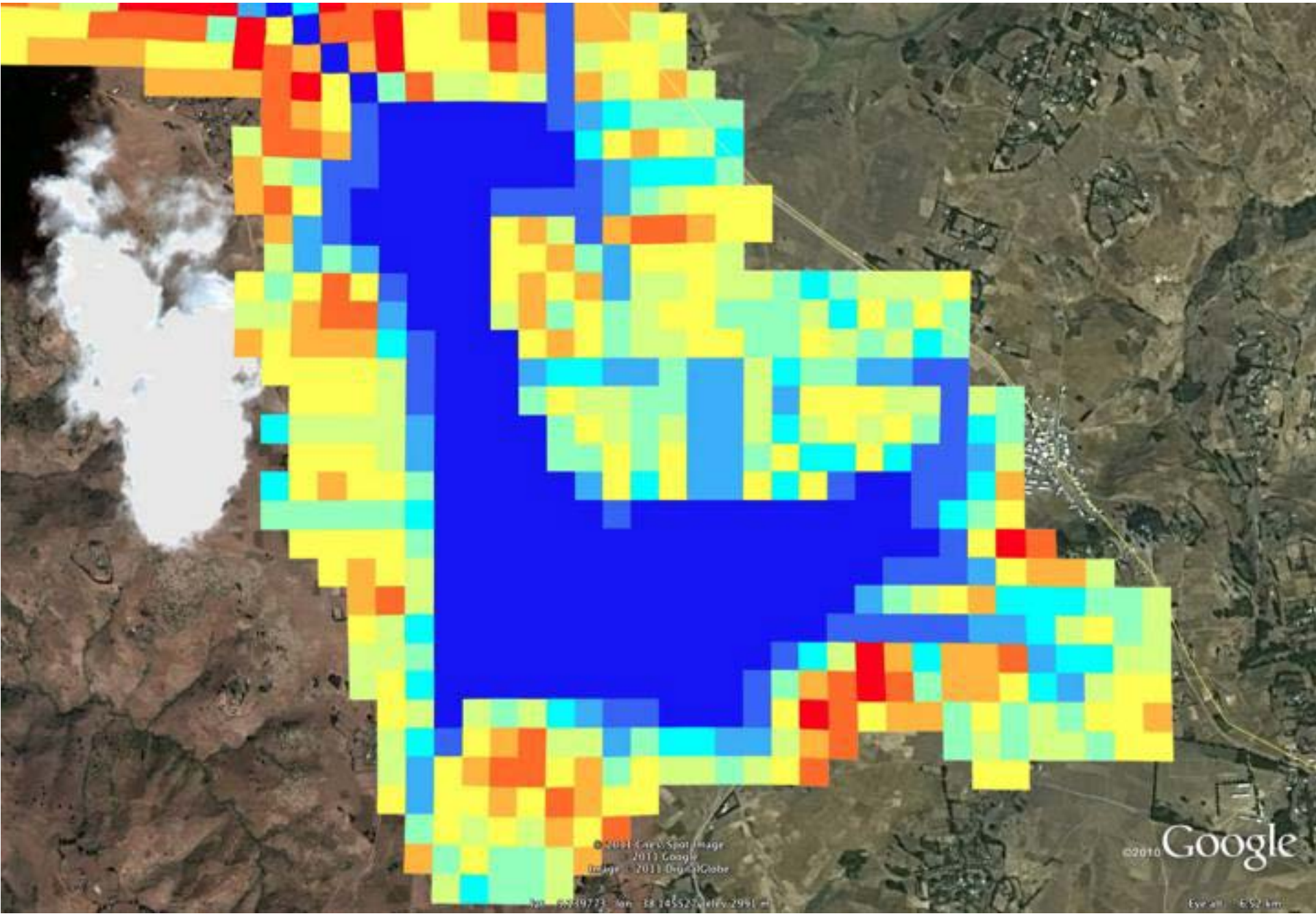
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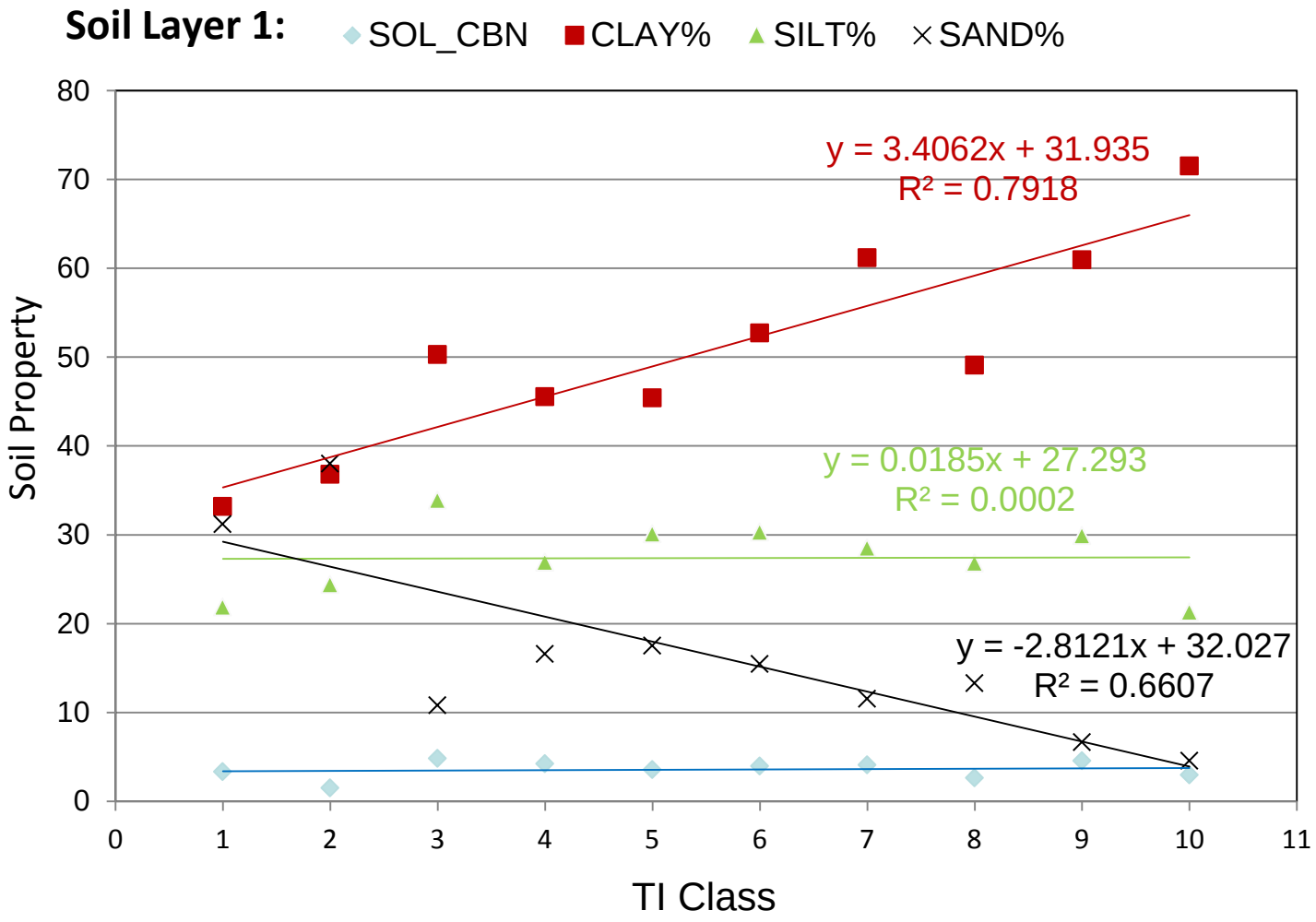
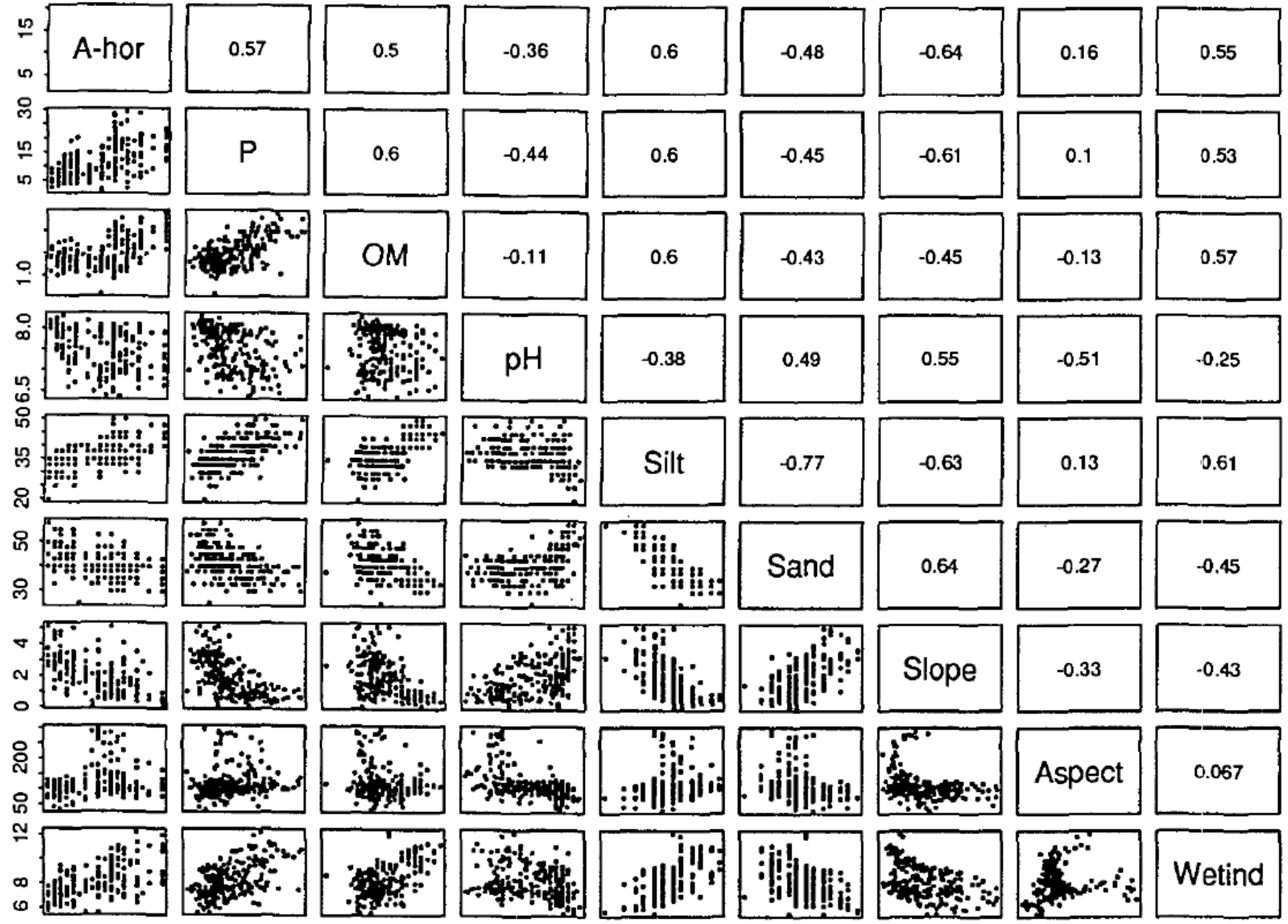
Soil-Topography Dynamics (1)
Ethiopia, borrowed from Solomon Seyoum

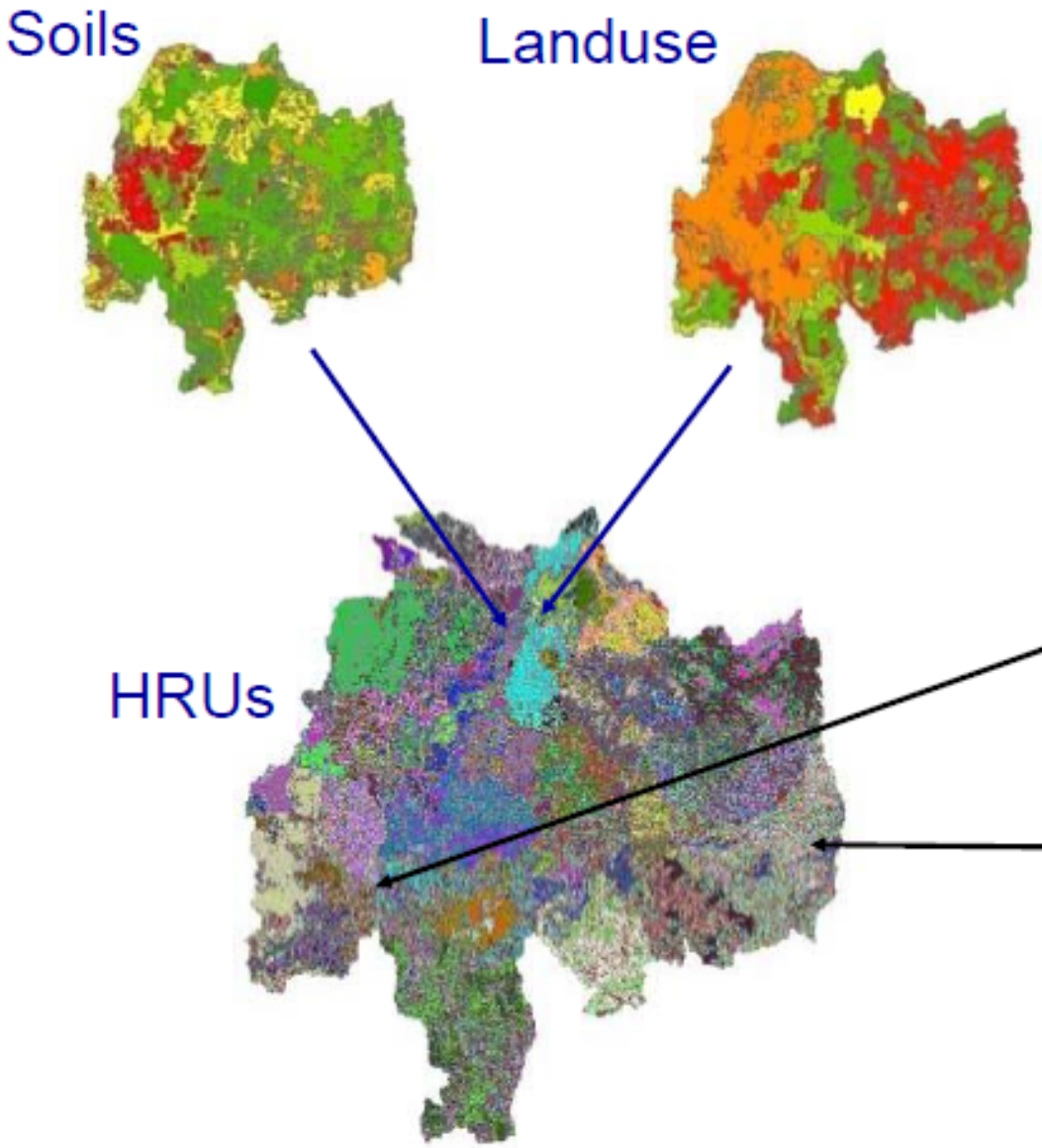


Nothing new here.

- Next image borrowed from Moore et al. 1993


A-hor
0.57
0.5
-0.36
0.6
-0.48
-0.64
0.16
0.55
P
0.6
-0.44
0.6
-0.45
-0.61
0.1
0.53
OM
-0.11
0.6
-0.43
-0.45
-0.13
0.57
pH
-0.38
0.49
0.55
-0.51
-0.25
Silt
-0.77
-0.63
0.13
0.61
Sand
0.64
-0.27
-0.45
Slope
-0.33
-0.43
Aspect
0.067
Wetind
15
5
30
15
5
1.0
8.0
6.5
50
35
20
50
30
4
2
0
200
50
12
8
6

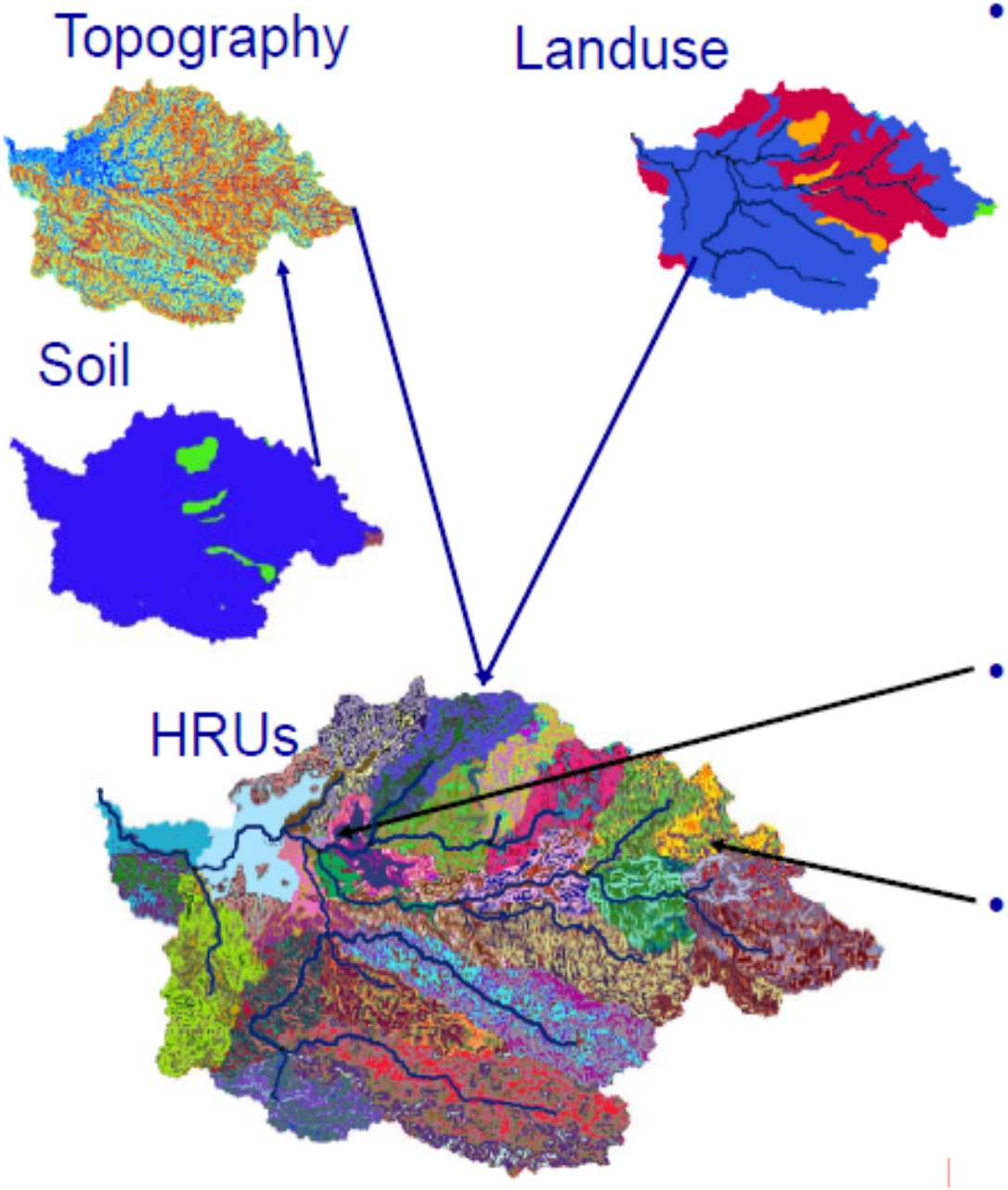
‘Traditional’ SWAT



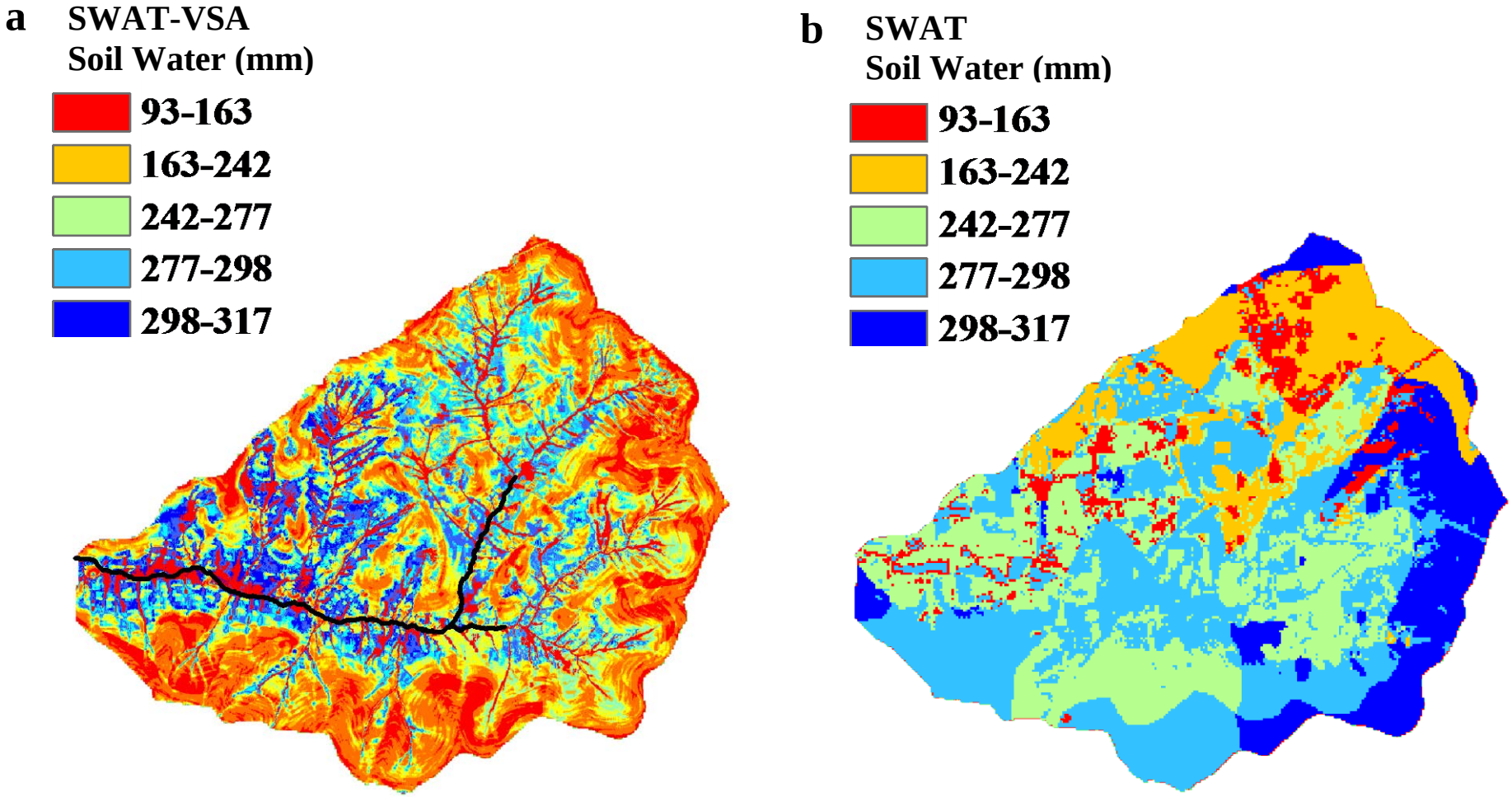
- SWAT defines HRUs as the coincidence of soil type and landuse
  - Hydrological/chemical properties are defined at the HRU

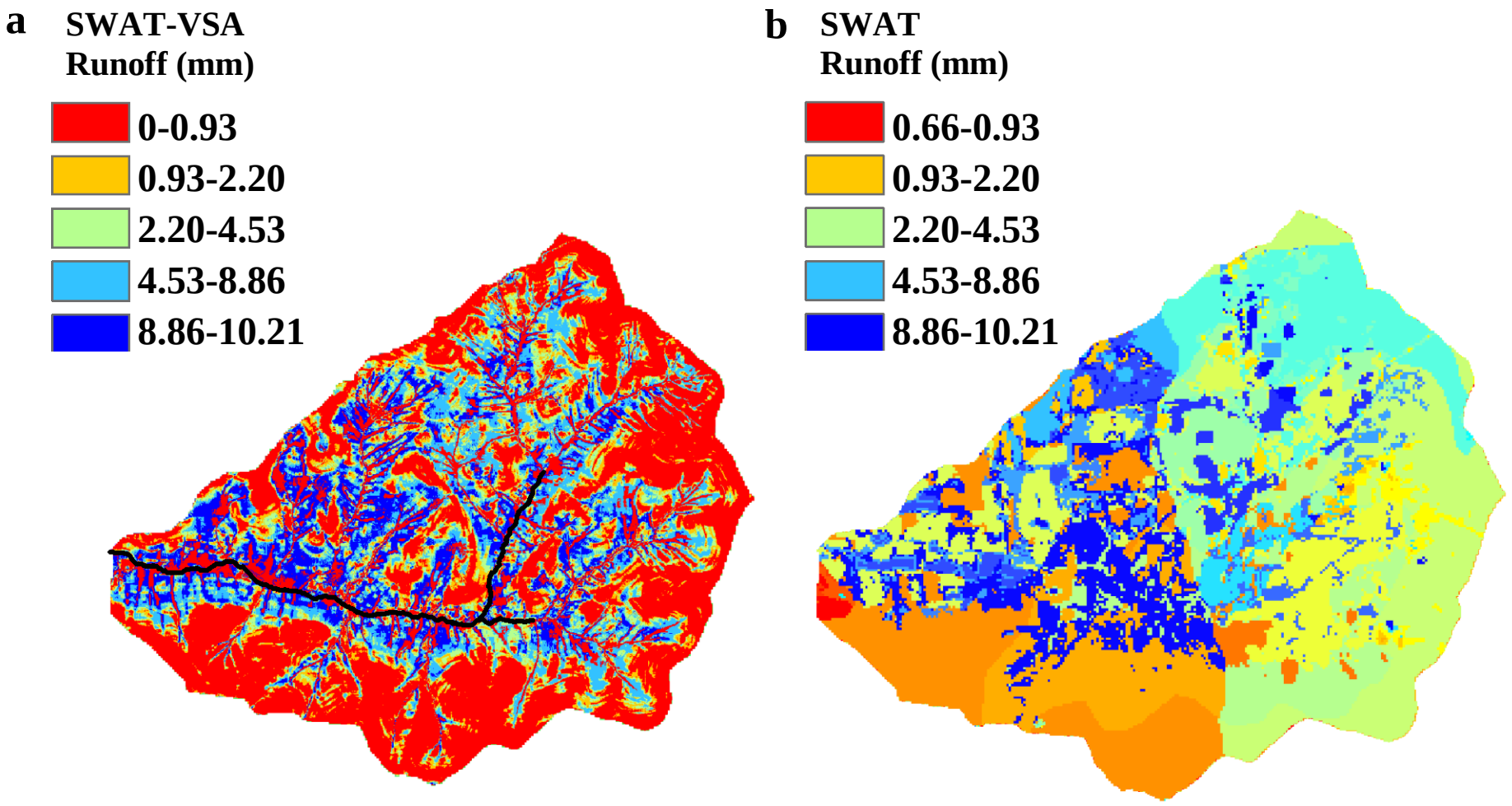
- So runoff/sediment loss is the same here (lowland pasture)
- As here (upland pasture)
- Not the case?

SWAT VSA



- Defines HRUs as the coincidence of soil topographic index (and soil) and landuse
- So runoff/sediment loss is now not the same here (lowland pasture)
- As here (upland pasture)

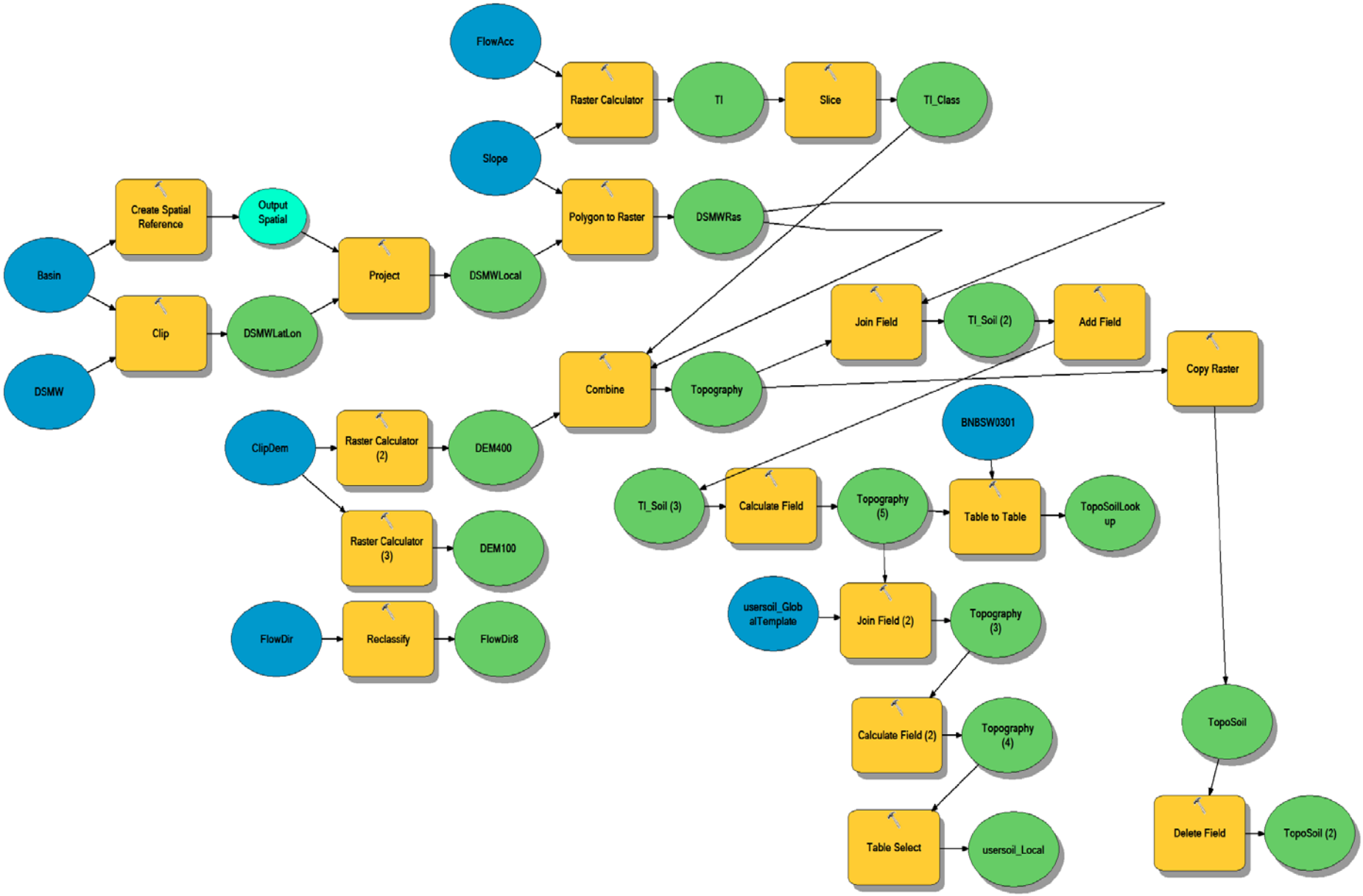

a
SWAT-VSA
Soil Water (mm)
93-163
163-242
242-277
277-298
298-317
b
SWAT
Soil Water (mm)
93-163
163-242
242-277
277-298
298-317


a
SWAT-VSA
Runoff (mm)
0-0.93
0.93-2.20
2.20-4.53
4.53-8.86
8.86-10.21
b
SWAT
Runoff (mm)
0.66-0.93
0.93-2.20
2.20-4.53
4.53-8.86
8.86-10.21

Arc Toolbox to Expand ArcSWAT

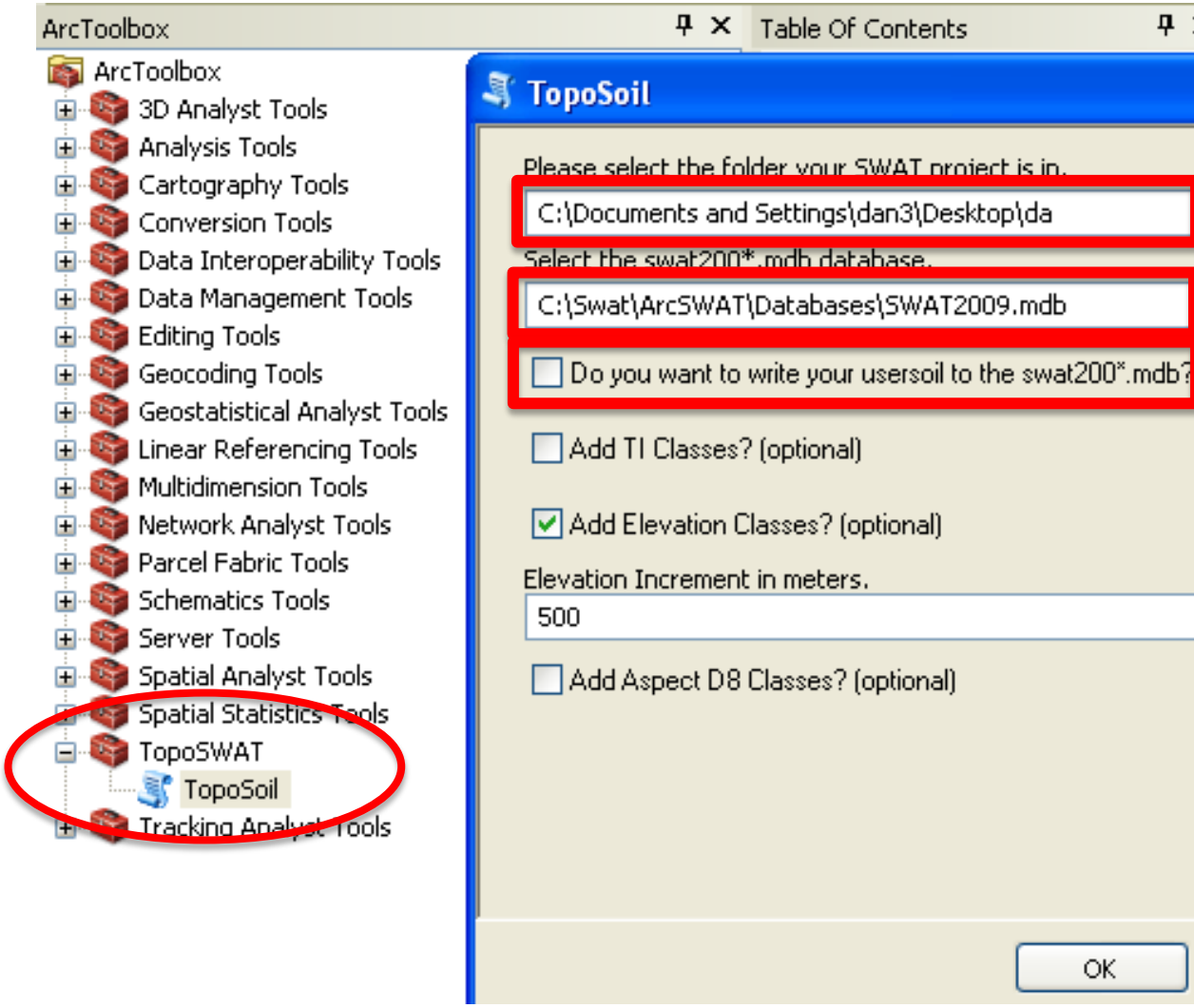
- Allows better initialization based on type of SWAT modeling project you want to perform.
  - International FAO soils
    - Low resolution, but works anywhere
  - Aspect
    - Better surface energy budget
      - Crop centric modeling
      - Snow dominated processes
  - Elevation
    - Better temperature and precipitation distribution
      - Crop Centric modeling
      - Snow dominated processes
      - Intra-basin hydrology
  - Topographic Index
    - Hill slope hydrology
    - Surface and interflow routing (In the latest version of SWAT, per Arnold)

‘Automating’ the Topographic Index in ArcGIS

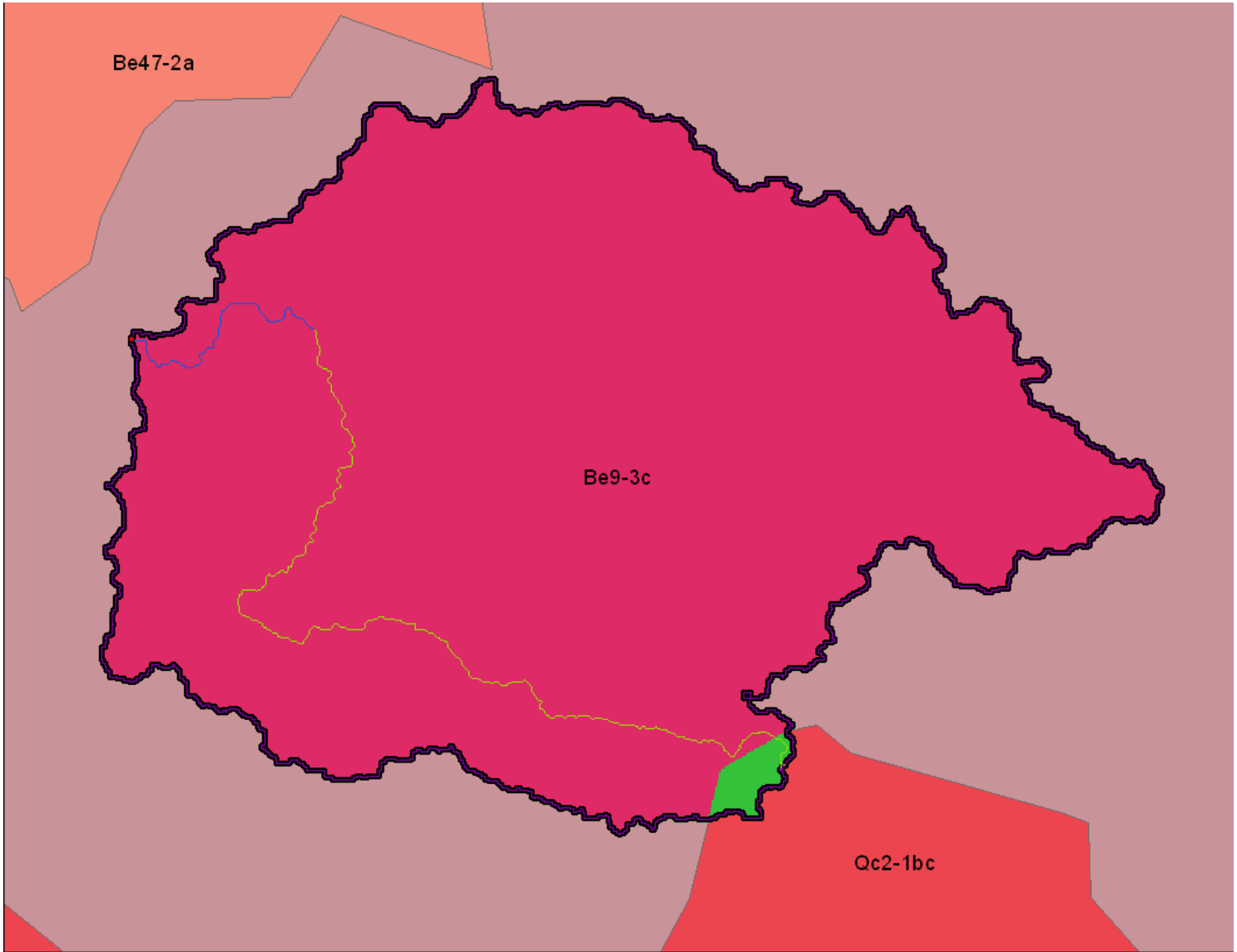


Simple add to ArcSWAT Initialization

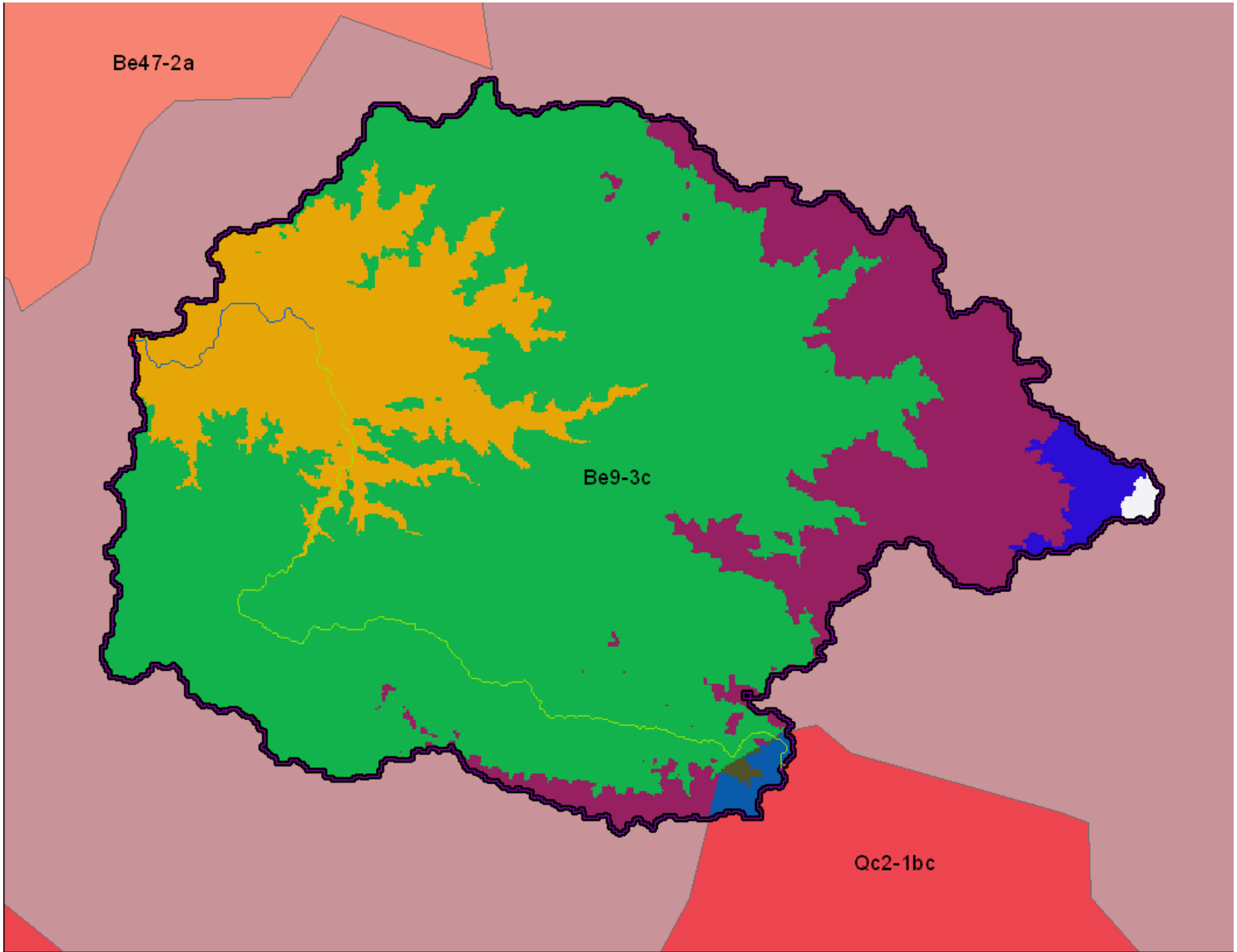
- Select project
- Select database
- Choose what you want represented
- Topographic Index
- Elevation increment in meters
- D8 Aspect



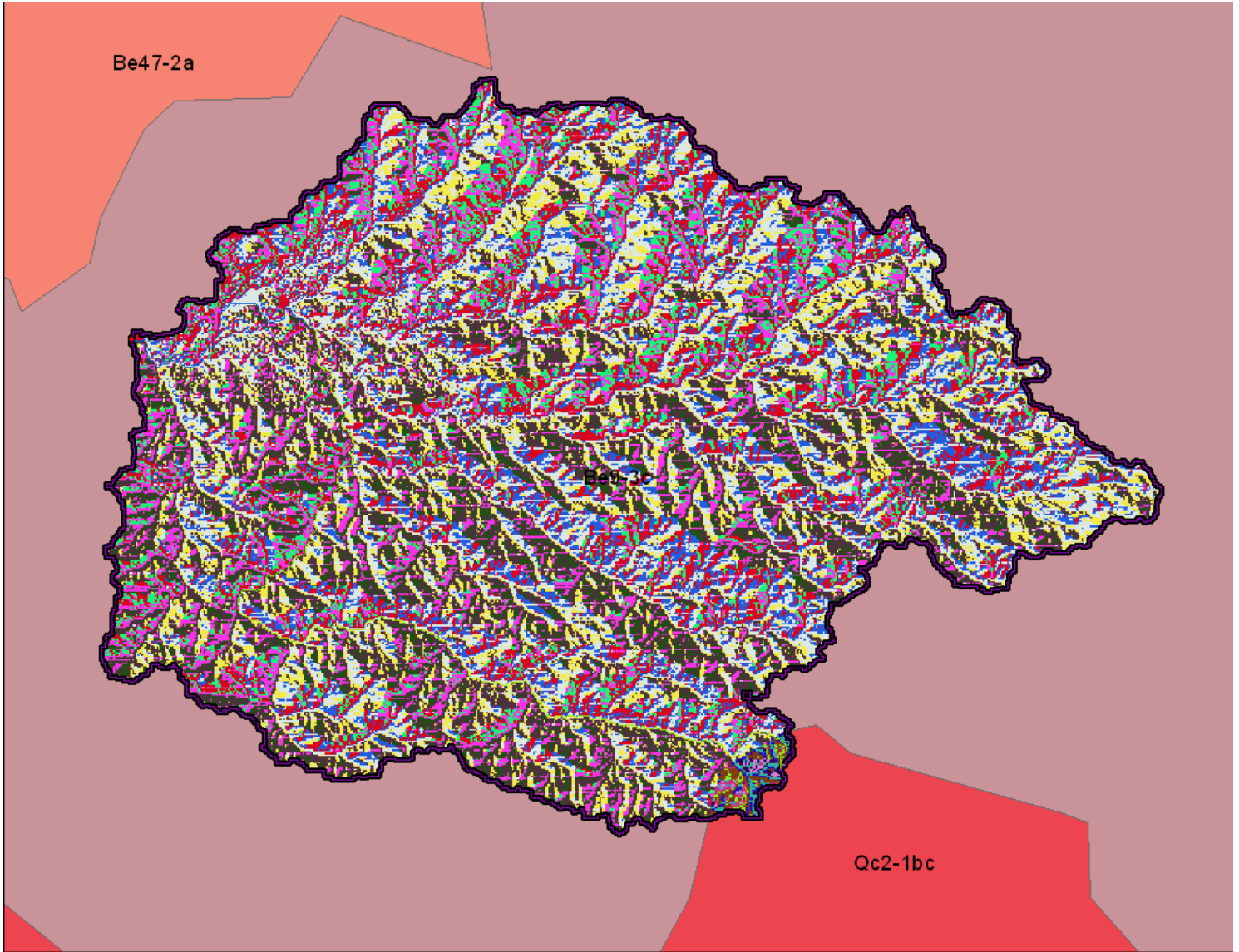
Just Soil, only 2 classes for 1200km^2
Two Few for your project?



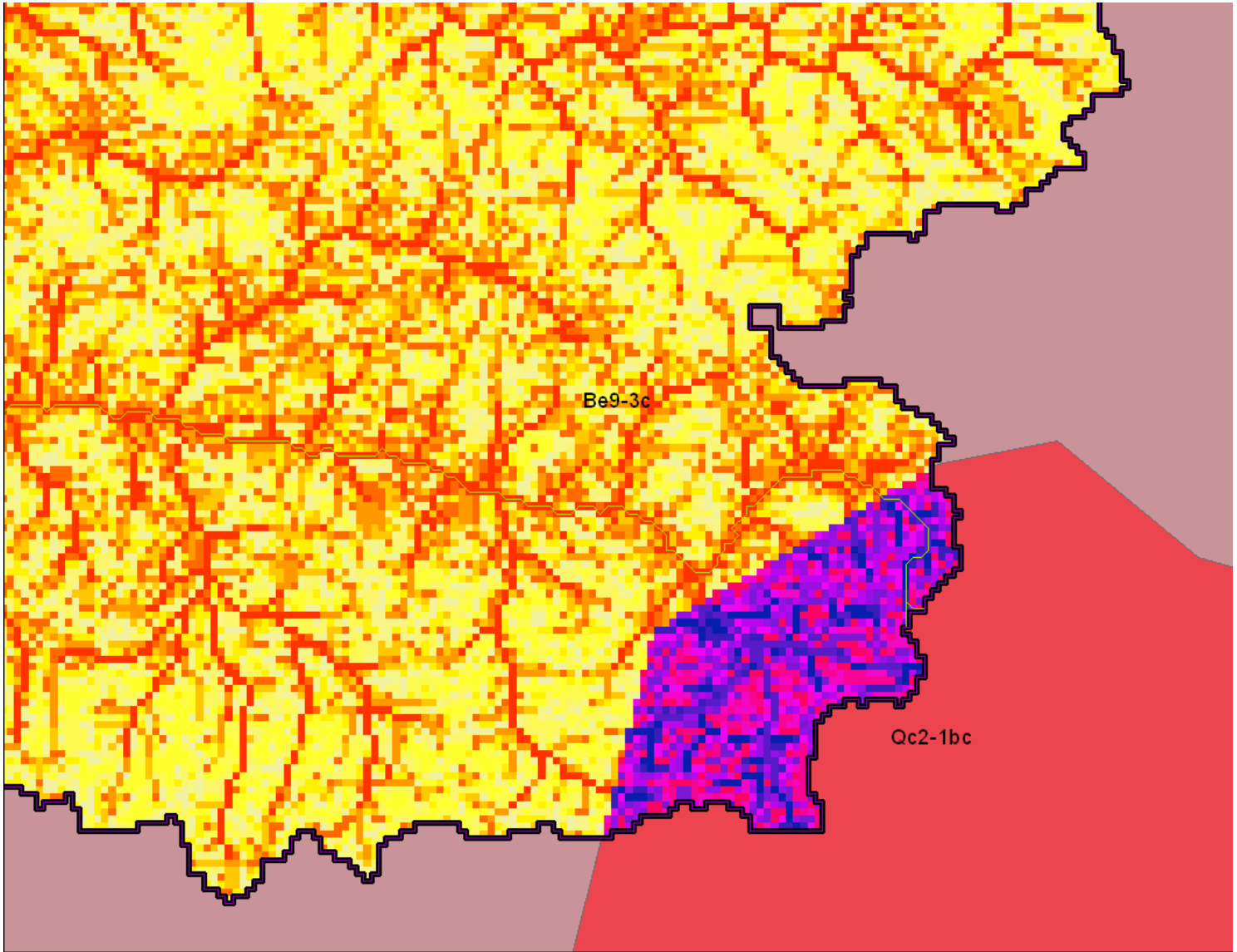
Elevation at 500m/5^0 increments
7 soils



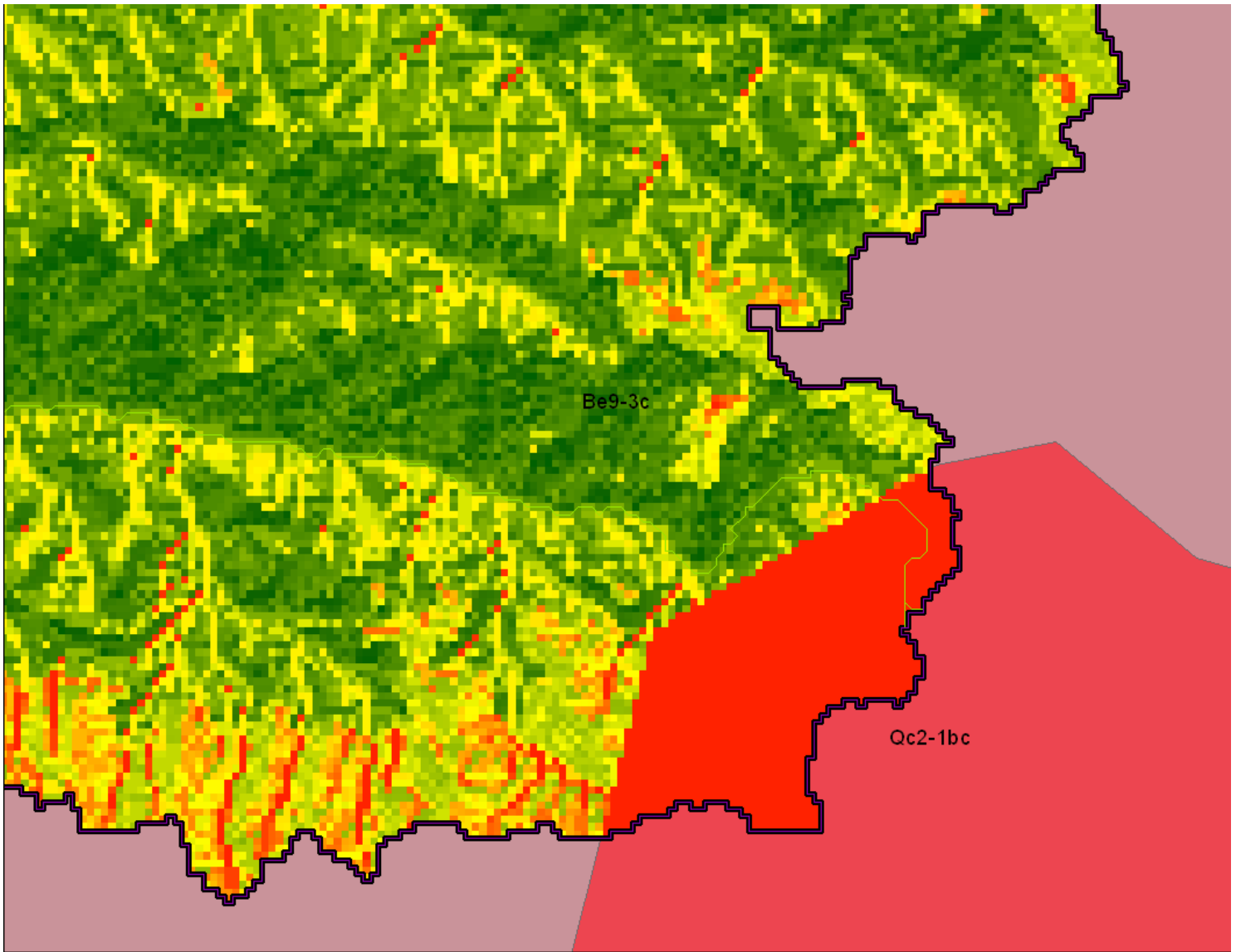
D8 Aspect
16 soils



Topographic Index
20 soils



Elevation 500m, TI, D8 Aspect
504 soils



Building a Topography Layer ArcSWAT Delineation vs TopoSWAT

Procedure	System
Calculating D8 aspect	ArcSWAT
Calculating slope	ArcSWAT
Calculating flow accumulation	ArcSWAT
Calculating TI	TopoSWAT
Splitting TI into equal area or weighted distribution classes	TopoSWAT
Splitting DEM into elevation gradient classes	TopoSWAT
Combining selected D8, TI, elevation	TopoSWAT
Build soil name and update project MDB	TopoSWAT
Building lookup table	TopoSWAT
Combine Soils/Slope/Landuses	ArcSWAT

Current Toolbox Status

- Currently supported on ArcSWAT2009 Arc10
- Porting to ArcSWAT 9.x
- Porting to ArcSWAT2012 (Arc10)
- Available from zeaston@vt.edu

Conclusions

- Adding topography is only really necessary for those that want to model energy based processes, management practices, climate change effects in watersheds… general speaking.. hydrology.

- Hoping for initial feed back to support the integration of these simple steps into the main ArcSWAT distribution, but the toolbox needs more testing before we actively pester for it being included.