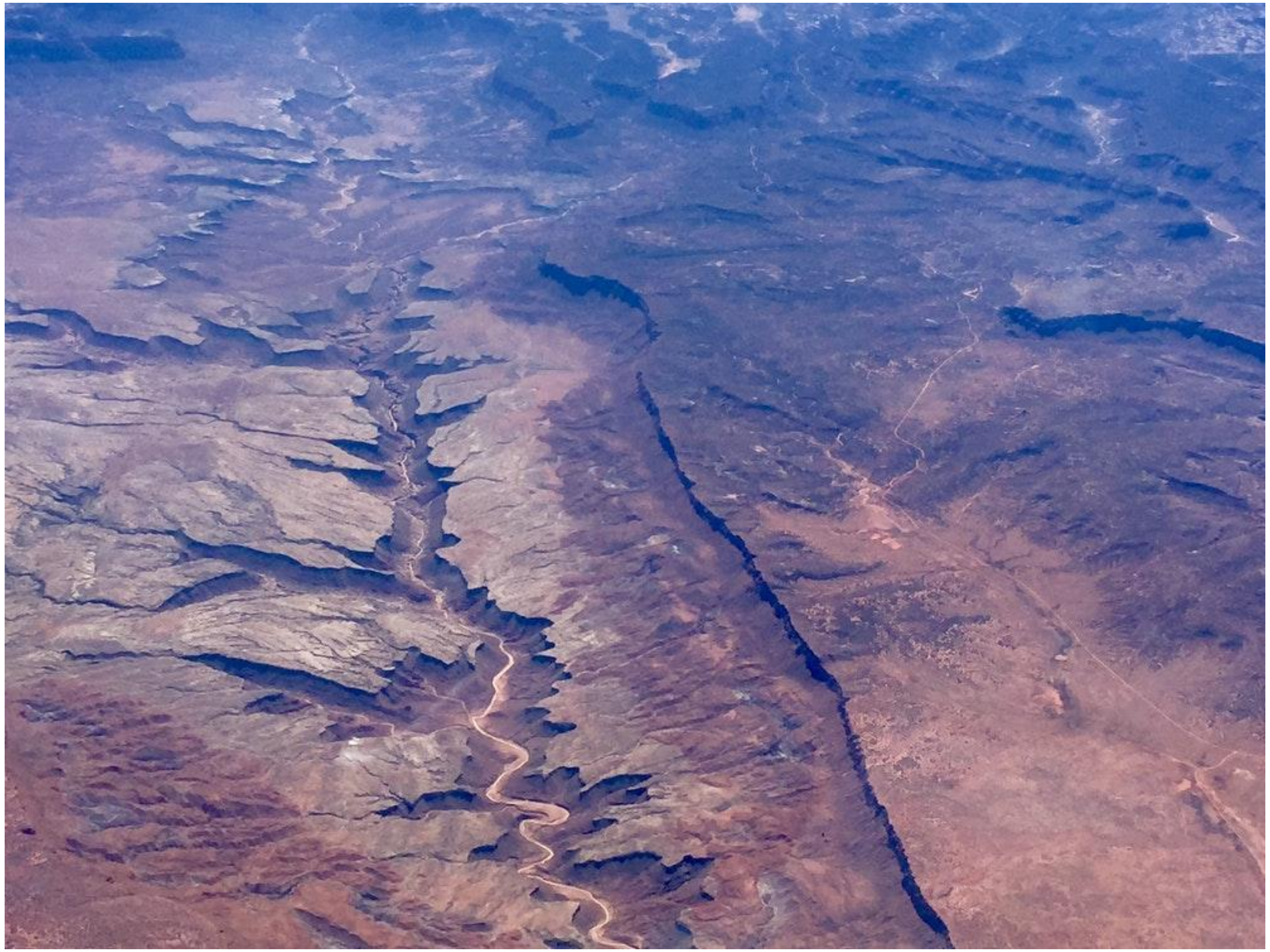
Sediment regulation model

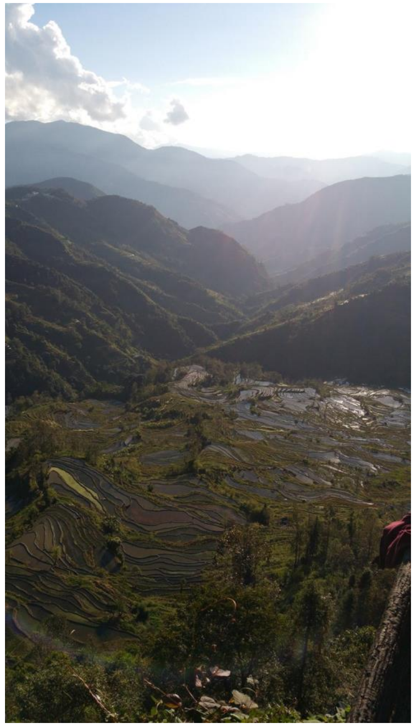


Overview

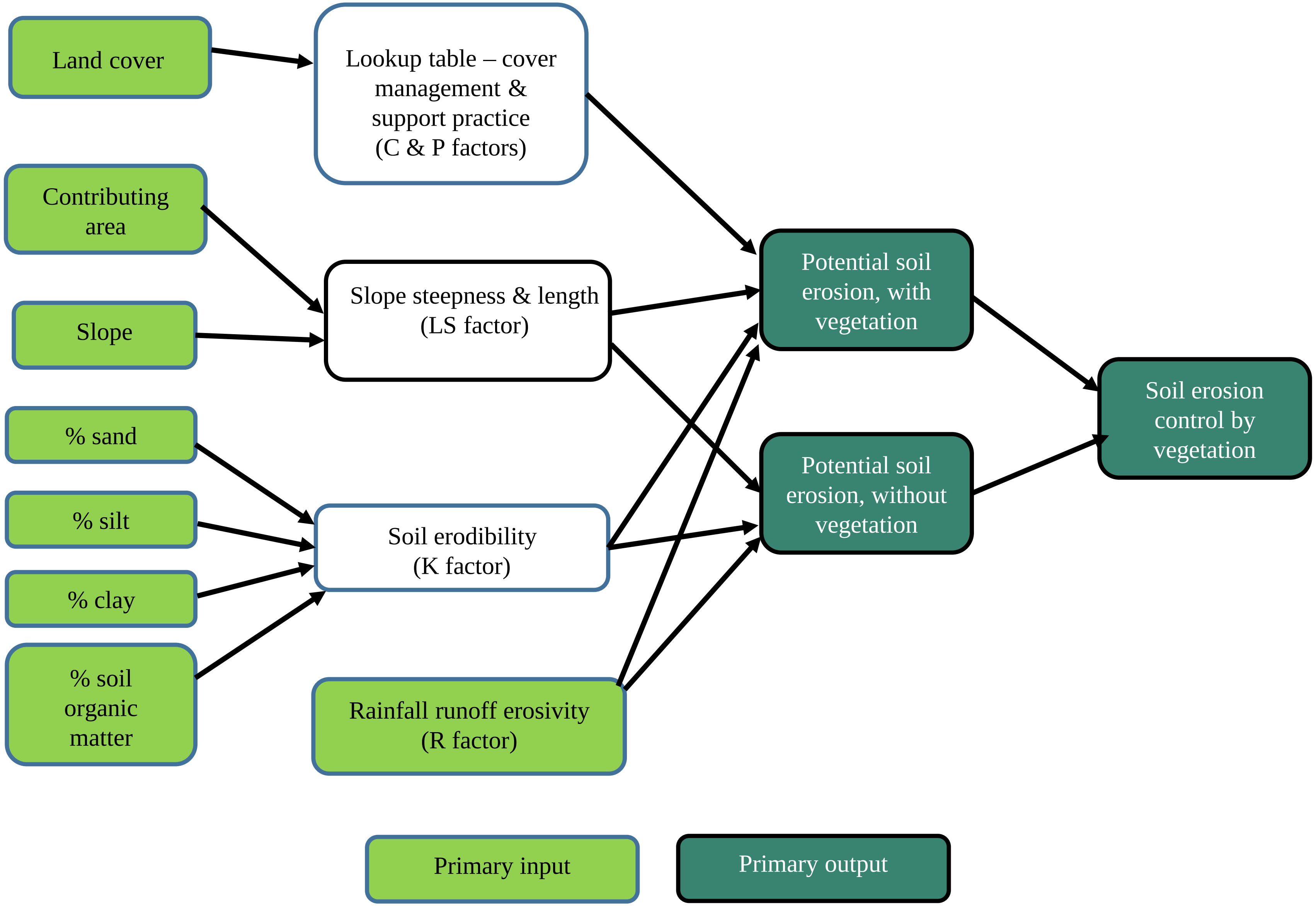
- This model quantifies potential soil erosion with & without vegetation using the Revised Universal Soil Loss Equation (RUSLE, Renard 1997)
  - Difference between potential soil loss with & without vegetation = protective role of vegetation in reducing erosion (the ecosystem service)
- Key limitations:
  - Applies only to rill erosion; does not estimate gully, streambank, or mass erosion
  - Originally developed for agricultural lands in the U.S., but typically used in wide variety of settings

Overview

- A = R * K * LS * C * P, where:
  - A – soil loss (T/ha),
  - R – rainfall runoff erosivity,
  - K – soil erodibility,
  - LS – slope steepness and length
  - C – cover management,
  - P – conservation practice



Model Flowchart



R: Rainfall-runoff Erosivity

- Typically modeled using event-based rainfall data (how intense are the rainstorms?); reasonable quality global data exist (JRC 2017)
- Measurement in (MJ*mm)/(ha*h); if using own data make sure data you know whether data are metric or English system (units: *100*ft-T*in)/(ac*hr*year),* can convert, but units are often unusually poorly labeled)

K: Soil Erodibility

- At least 3 ways to calculate:
  1. % sand, silt, clay, organic matter equation (Williams 1995)
  2. Soil texture class & organic matter lookup table (Stone & Hilborn 2012)
  3. % sand, silt, clay equation (Ashiagbor et al. 2012)
- We use 1st method; gives outputs using global data that best match local datasets
- Measurement in (T*h)/(MJ*mm); if using own data make sure data you know whether data are metric or English system (units: (T*ac*h)/(100*ac*ft-T*in), can convert, but units are often unusually poorly labeled)

K: Soil Erodibility

```
@documented(sediment.erodibility)
model soil:SoilErodibility
    observing
        percentage of soil:Sand in soil:TopSoil im:Volume named sand_percentage,
        percentage of soil:Silt in soil:TopSoil im:Volume named silt_percentage,
        percentage of soil:Clay in soil:TopSoil im:Volume named clay_percentage,
        percentage of chemistry:Carbon in soil:TopSoil im:Mass named soil_organic_matter_percentage
    set to [ (clay_percentage + silt_percentage == 0)?0:(

            (0.2 + 0.3 * (Math.exp(-0.256 * sand_percentage * (1 - (silt_percentage / 100))))) *
            ((silt_percentage / (clay_percentage + silt_percentage))**0.3) *
            (1 - ((0.0256 * soil_organic_matter_percentage)/(soil_organic_matter_percentage + Math.exp(3.72 - (2.95 * soil_organic_matter_percentage))))) *
            (1 - ((0.7 * (1 - (sand_percentage / 100))) / ((1 - (sand_percentage / 100)) + Math.exp(-5.51 + (22.9 * (1 - sand_percentage / 100)))))) *
            0.1317
    )
    ];
```

English-Metric conversion factor

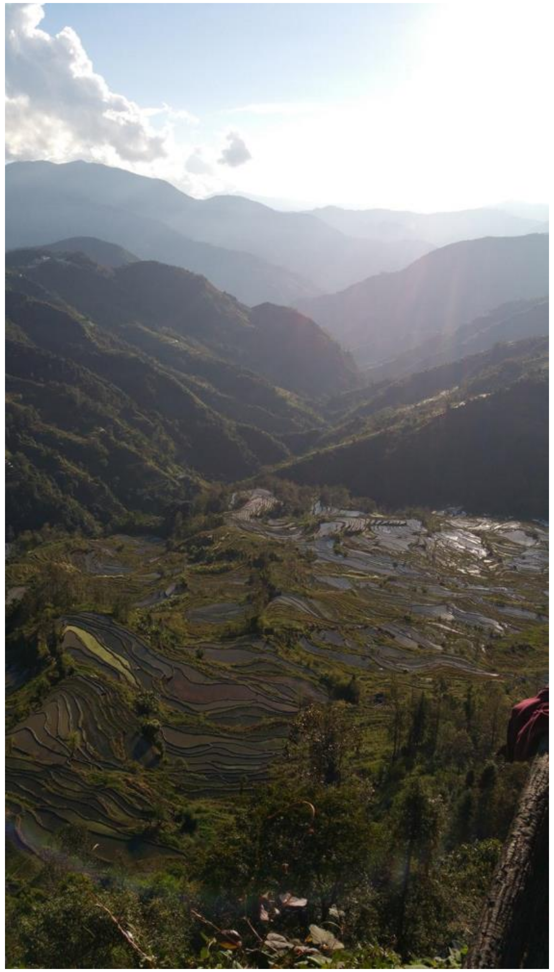
LS: Slope Steepness & Length

- Multiple methods for computation (Panagos *et al*, 2015; Phinzi & Ngetar, 2019)
- Unitless
- Key inputs are slope and contributing area (Van Remortel *et al*, 2004)
- Sensitive to DEM resolution
- *Working on update – current results too large*

```
model soil:SlopeSteepnessAndLength
    observing
        geography:Slope in degree_angle named slope,
        hydrology:ContributingArea in m^2 named contributing_area
    on definition set to [
        Math.pow((contributing_area * space.width)/22.1, 0.4) * Math.pow(Math.sin(slope * 0.01745)/0.09, 1.4) * 1.4
    ];
```

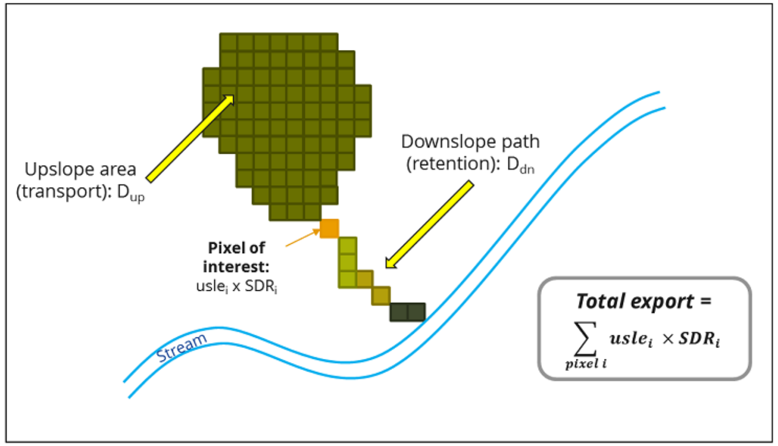
C: Cover Management & P: Support Practice

- Values from 0-1 (lower values = greater reduction in soil erosion)
  - C: mature forests have low values, bare soil high values
  - P: function of agricultural management practices; typically 1 for non-agricultural land cover types & lower values with better crop management (terracing, contour farming, stone walls, grass margins)
- Typically classified by land cover type using a lookup table (Yang et al. 2003, Borelli et al. 2017 global references)
- Could use NDVI to estimate C



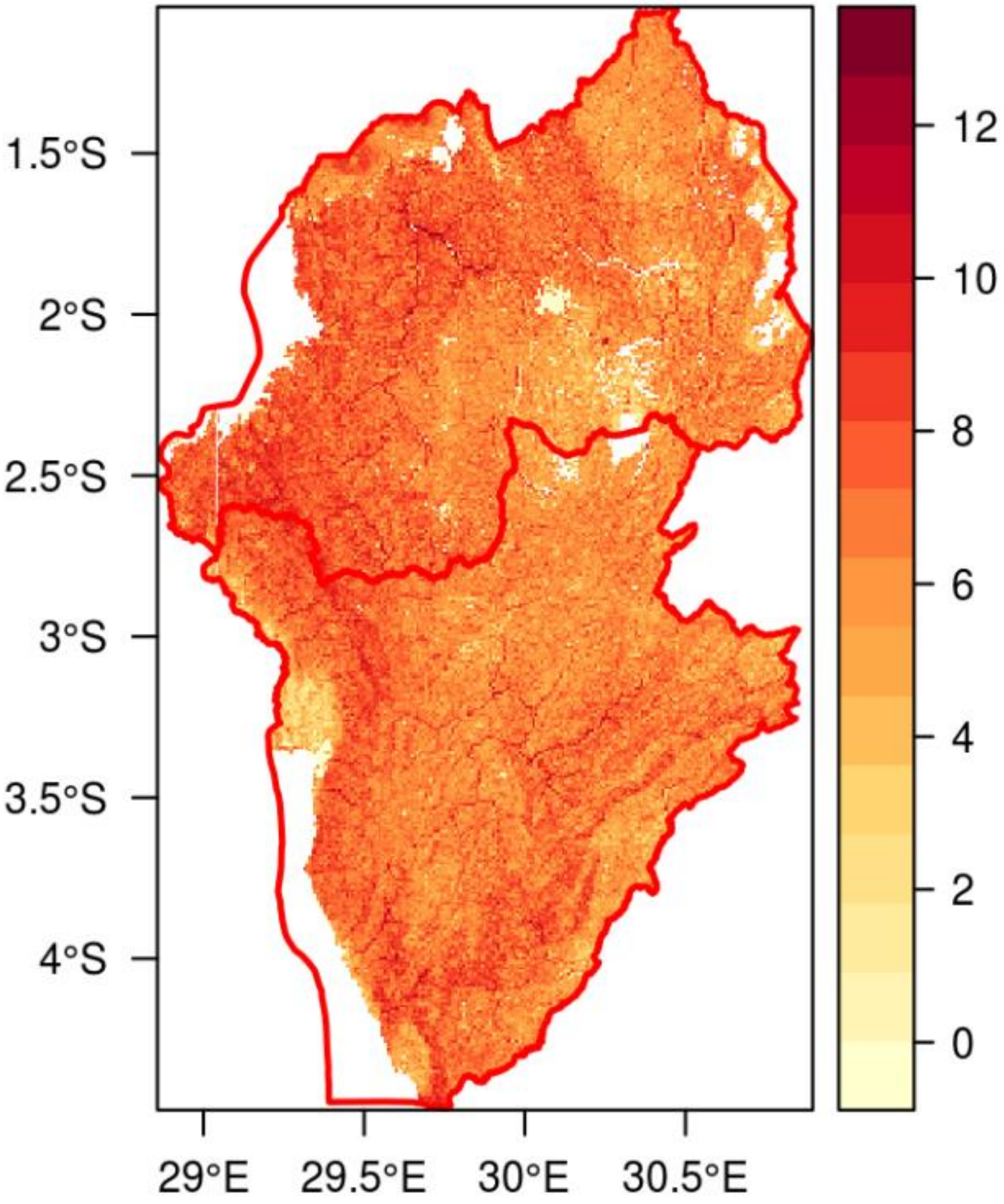
Model Assembly

- A = R * K * LS * C * P
  - Calculating with all factor values gives potential soil loss
  - Setting C & P to the equivalent of bare soil (0.35 & 1, respectively) gives potential soil loss without vegetation
  - Difference between these two is the soil erosion control benefit provided by vegetation
  - *Actual* soil loss would need to look at how much soil can leave a cell and travel downstream based on hydrologic connectivity (e.g., InVEST model)



Sharp et al. 2016

Avoided soil erosion (log+1)



Examples of model customization

- Local data for land cover, slope, soils, climate
- Local RUSLE factor spatial data (U.S. Southwest)
- Local lookup tables for C & P factors (InVEST parameter database)
  - For all customizations, code in the conditions under which the customization should take place (Rwanda, East Africa, tropical rainforests, cities, temperate zones, etc…)