Introduction to the Cost-Benefit Framework

Highlights from presentation at Sustainable Land Management workshop in Addis, May 2006

Rationale

- Land degradation leads to substantial welfare losses.
- Many promising SLM practices but mixed economic returns. Non-trivial to base extension and up-scaling on research.
- Need to prioritize interventions
  - How much money is needed?
  - How should it be spent?

The CBF should:

- Identify areas ”hot-spots” of serious on- and off-site cost of land degradation.
- Indicate benefits from various SLM treatments.
- Support policy makers and donors to allocate sufficient resources for SLM.
- Help resource planners to prioritize areas and treatments.

Main characteristics of CBF

- It makes use of past data collection and research in an efficient and consistent manner.
- It is inter-disciplinary, drawing mainly on soil science research and applied economics, with heavy use of GIS.
- It is an open framework that can evolve with advancements in data collection and research.

Main steps of the CBF

- Identification of recommendation domains that share the same conditions for applications of treatments.
- Estimation the soil erosion & nutrient depletion rates for each recommendation domain based on explanatory factors proposed in the USLE.
- Estimation of production responses to erosion and treatments for each recommendation domain.
- Translation of soil erosion and nutrient depletion into income losses using different economic valuation techniques.

Main steps cont.

- Computing the net present value (NPV) of each treatment for each development domain (mapping unit).
- Mapping on- and off-site returns from treatment.
- Prioritizing areas with highest return according to budget constraint.
- Dissemination of this information to the relevant users, particularly land use planners and extension staff at regional level and below

Major functions of the CBF

- Compile and utilize the existing relevant data and research on land degradation and various SLM treatments in Ethiopia and elsewhere.
- Provide information on the areas facing largest short- and long-term costs from land degradation.
- Show how SLM treatments could prevent losses in productivity in hydro- and irrigation dams as well as fisheries in affected lakes.

Major functions cont.

- Indicate the relevant size of investments in SLM.
- Prioritize areas and treatments in order to maximize the returns to society from these investments.
- Act as a unifying framework for the design and dissemination of applied research on SLM practices.
- Support the up-scaling of promising SLM practices.

From Soil Erosion Research to Modeling Impacts of Interventions: The Case of Ethiopia

By

Gete Zeleke
GMP

UN expert group meeting on
"Sustainable land management and agricultural practices in Africa: Bridging the gap between research and farmers"
April 16 – 17, 2009, University of Gothenburg, Sweden.

Part I: Overview of Land Degradation

Part II: Some of the major causes

Part III: Experiences on SLM

5. Lack of proper awareness on extent and impacts of LD & other EPs

- **Very poor resource database and utilization**
  - **Eg. Soil database**

- **Lack of or incomplete empirical evidences on extent and impacts of LD and other EPs**

- **Poor way of communication – e.g.. tones of soil/ha/y, ha of forest/y, % siltation, climate change...etc** *******

- No cost benefit analysis

Part IV: Mechanisms of capturing process to influence agricultural development positively

What is needed to make informed decisions on Agri. deve?

- Need to have resource database (at least soil, water, climate and genetic resources…)
- Need to know rate and magnitude of soil erosion/runoff under different AEZ, soil types, land use systems, etc
- Need to know what technology works, where, and under what condition
- Need to know negative impacts of Soil erosion (land degradation) and positive impacts of applying improved land management practices

What are Possible approaches?

Approach 1:

- Measuring soil erosion in all watersheds
- Measuring effects of all land management practices in different parts **(too expensive)**

Approach 2:

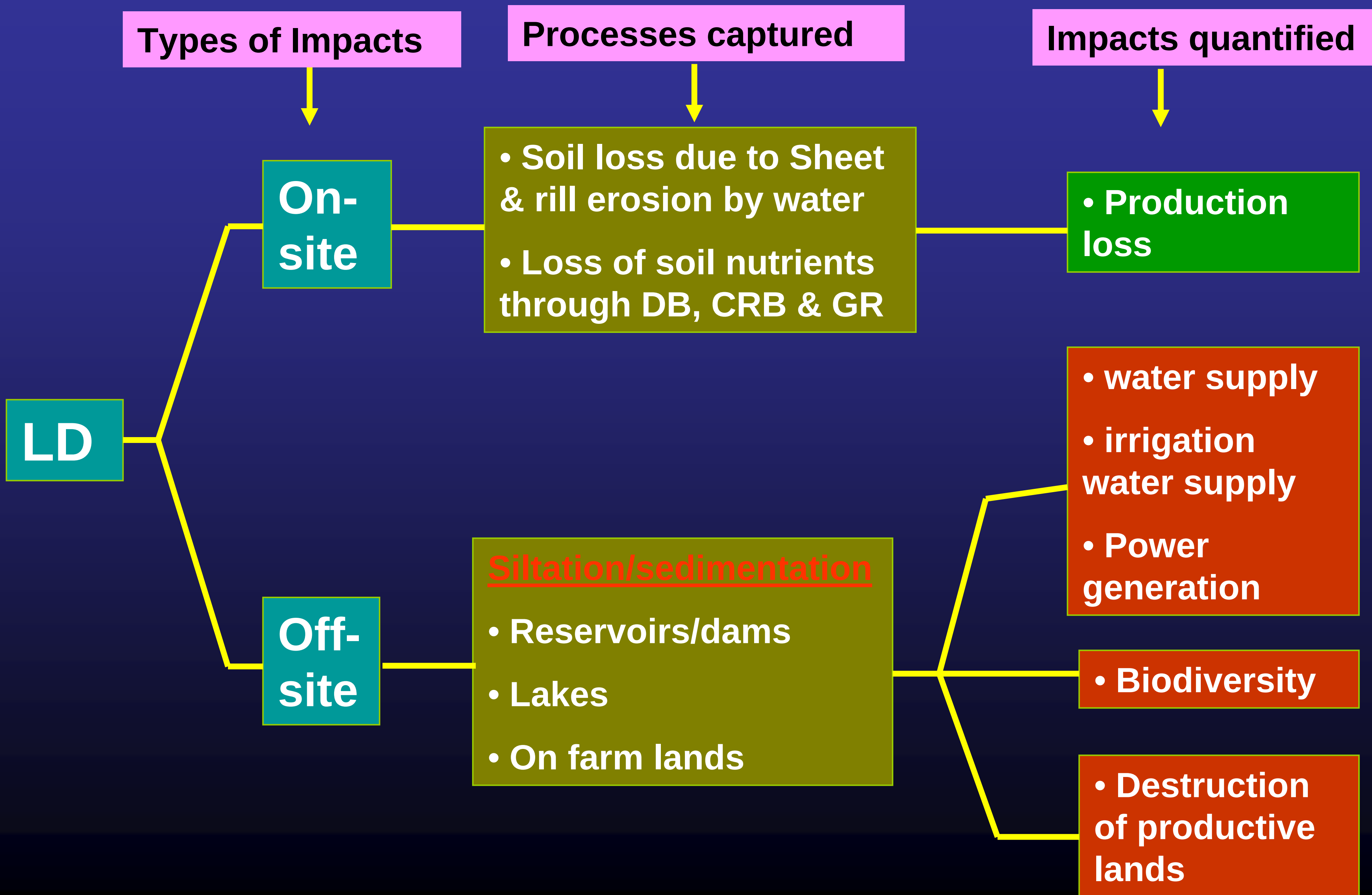
- Measure selective and representative watersheds
- Measure selective and right combinations of LM practices **(Achievable)**

Approach 3:

- Extrapolate the result to ungauged areas using a combination of GIS, biophysical and economic models

(Achievable)

Framework for Assessing Major LD Processes & Impacts (Approach 2)



What do we have on this?

Types of Impacts | **Processes captured** | **Impacts quantified**

We know – SCRP & others

LD

On-site

- Soil loss due to Sheet & rill erosion by water
- Loss of soil nutrients through DB, CRB & GR

- Production loss

Very little

Off-site

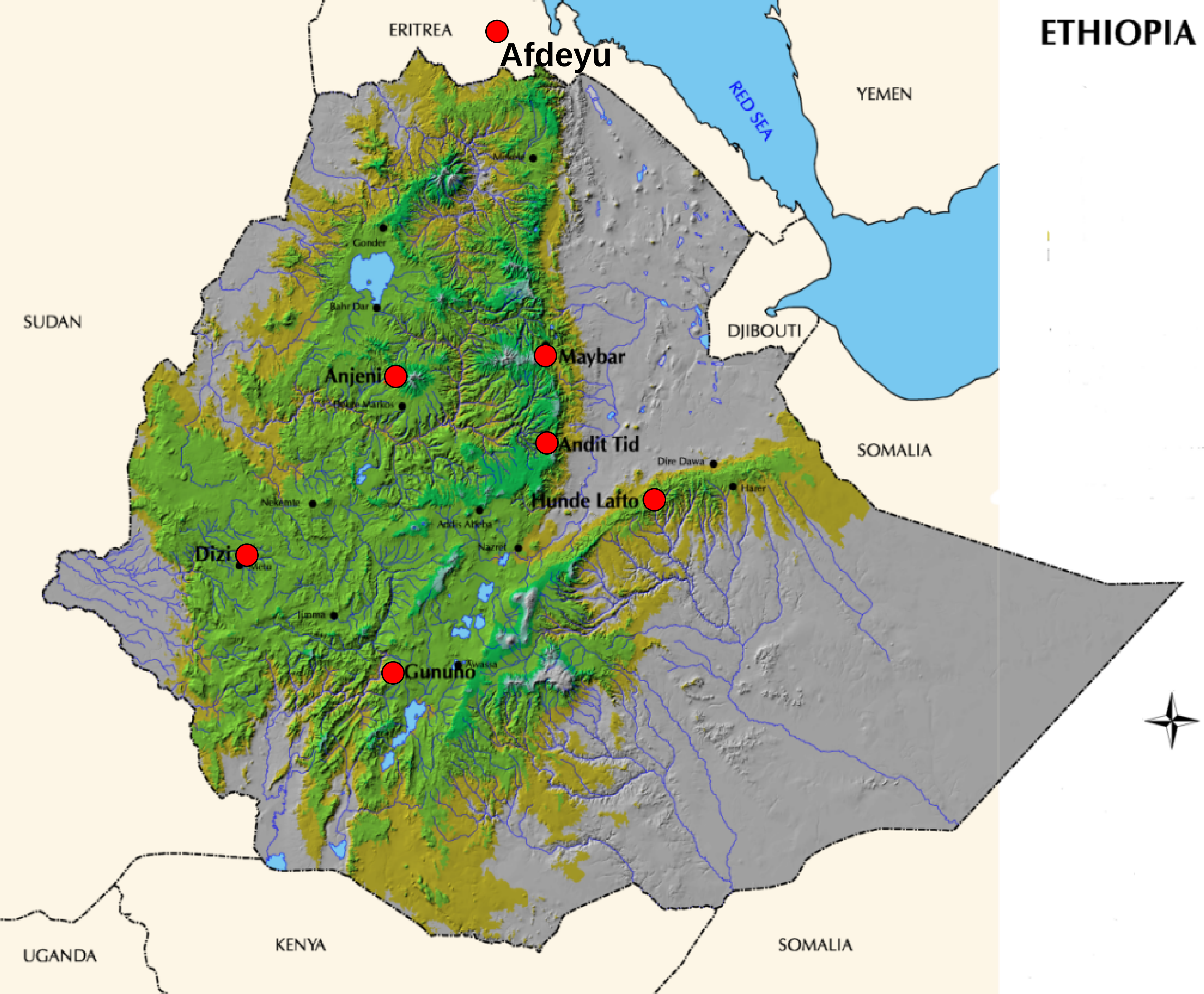
Siltation/sedimentation

- Reservoirs/dams
- Lakes
- On farm lands

- water supply
- irrigation water supply
- Power generation

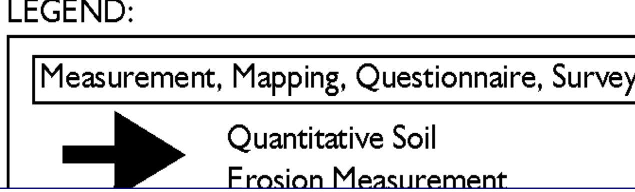
- Biodiversity

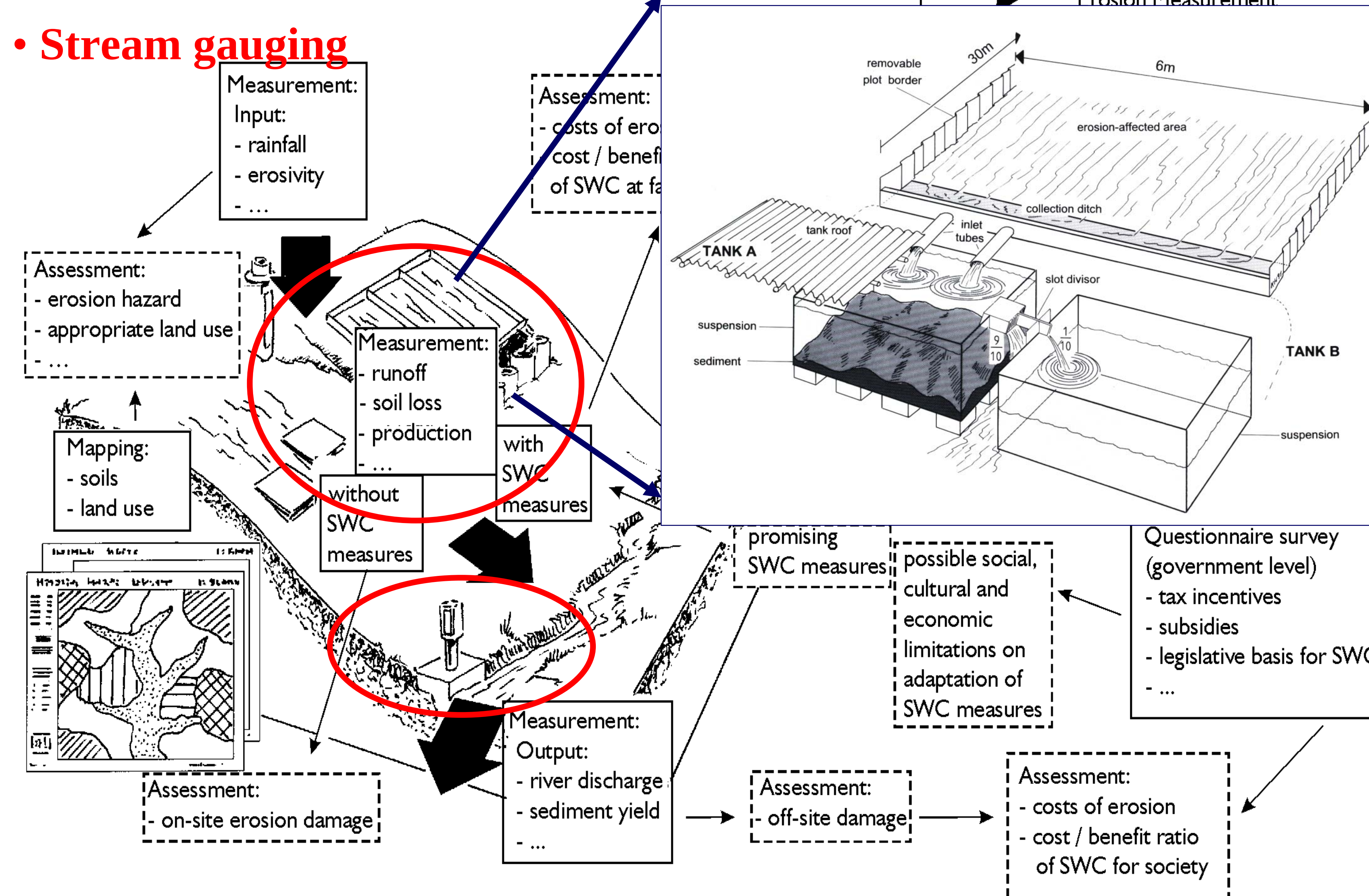
- Destruction of productive lands


ETHIOPIA
ERITREA
Afdeyu
RED SEA
YEMEN
Gonder
Bahr Dar
SUDAN
DJIBOUTI
Maybar
Anjeni
Andit Tid
SOMALIA
Dire Dawa
Hunde Lafto
Nekemte
Addis Abeba
Nazret
Dizi
Jimma
Gununo
Awassa
UGANDA
KENYA
SOMALIA

Two key processes to be captured:

- Watershed status (hill slope Processes
- Stream gauging





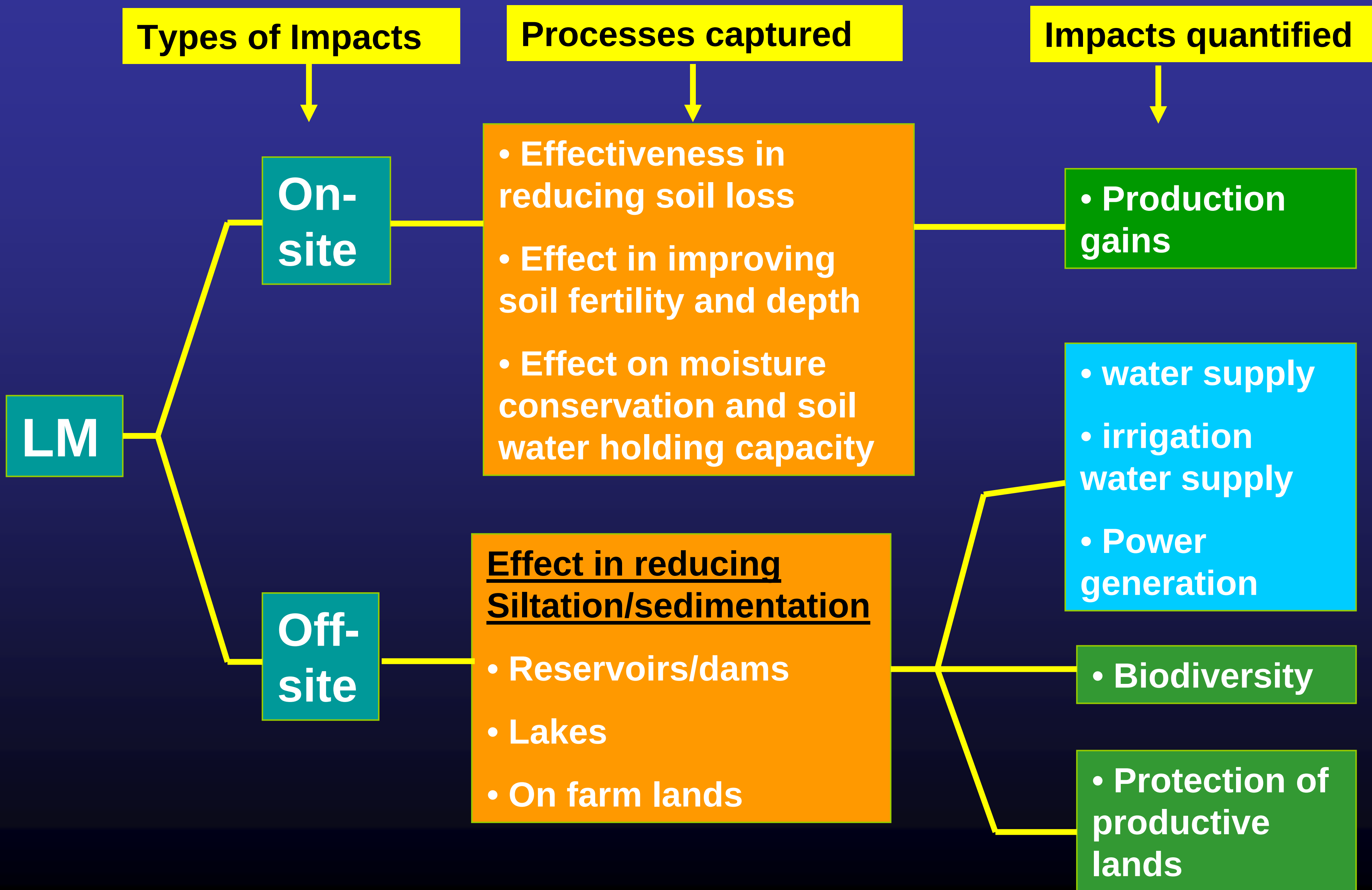
Database from SCRP

1. Watershed level
   - Catchment runoff - hydrographs
   - Sediment yield
   - Climate
   - Land use
   - Harvest
   - Soil depth
   - Socio-economic data

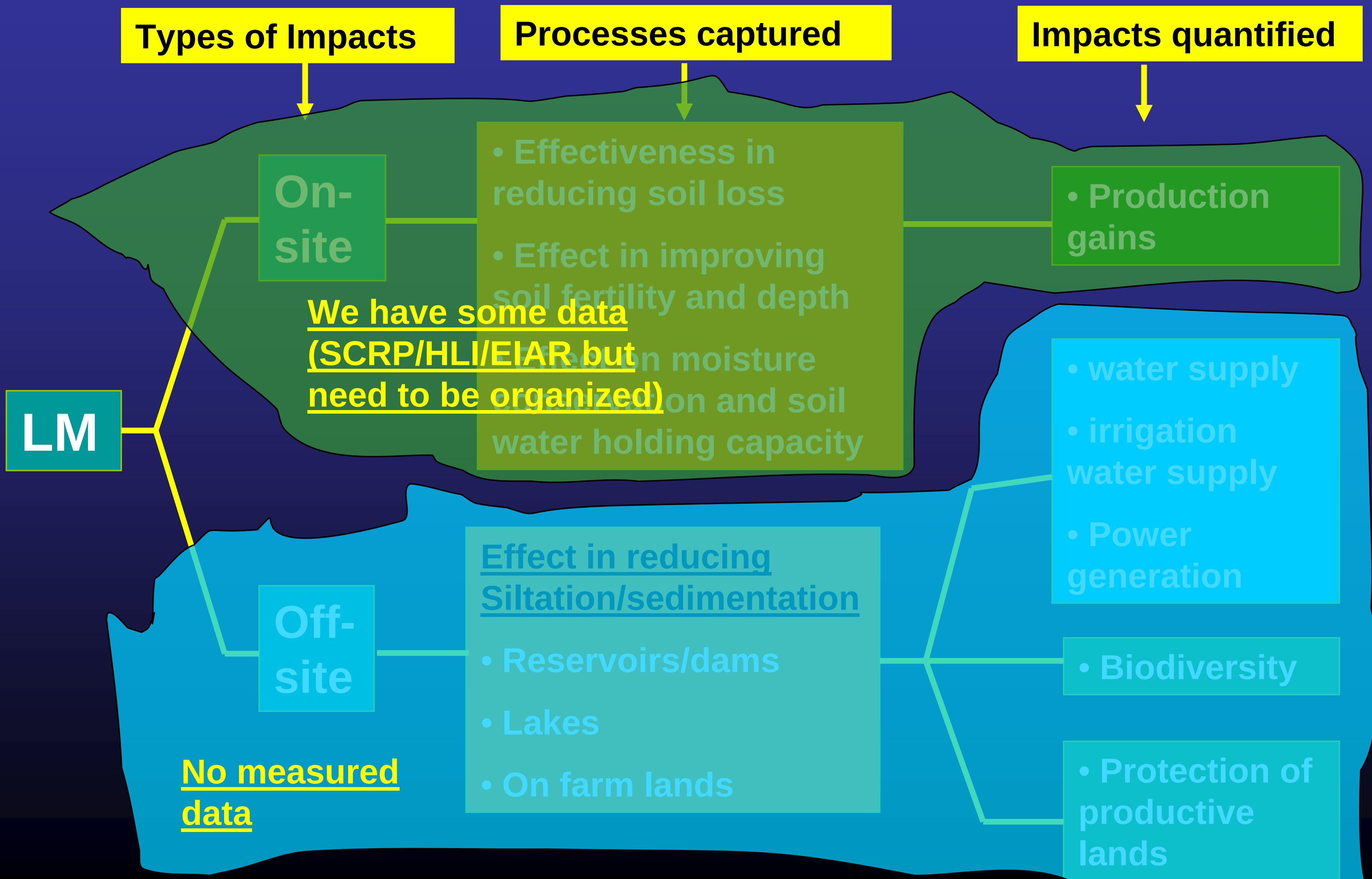
   } **With and without scenario**

2. Plot level
   - Soil loss
   - Runoff
   - Yield
   - SWC measures impact/land use/design/type

Framework for Assessing Impacts of LM Practices (Approach 2 cont..)



What do we have?



What is missing or less addressed?

- Offsite processes and impacts of LD
- Info on impacts of LM practices (only few)
- Info on impacts of integrated land management practices
- Socio-economic aspects of SLM and LD (need more work)

Approach 3: Methods of extrapolation

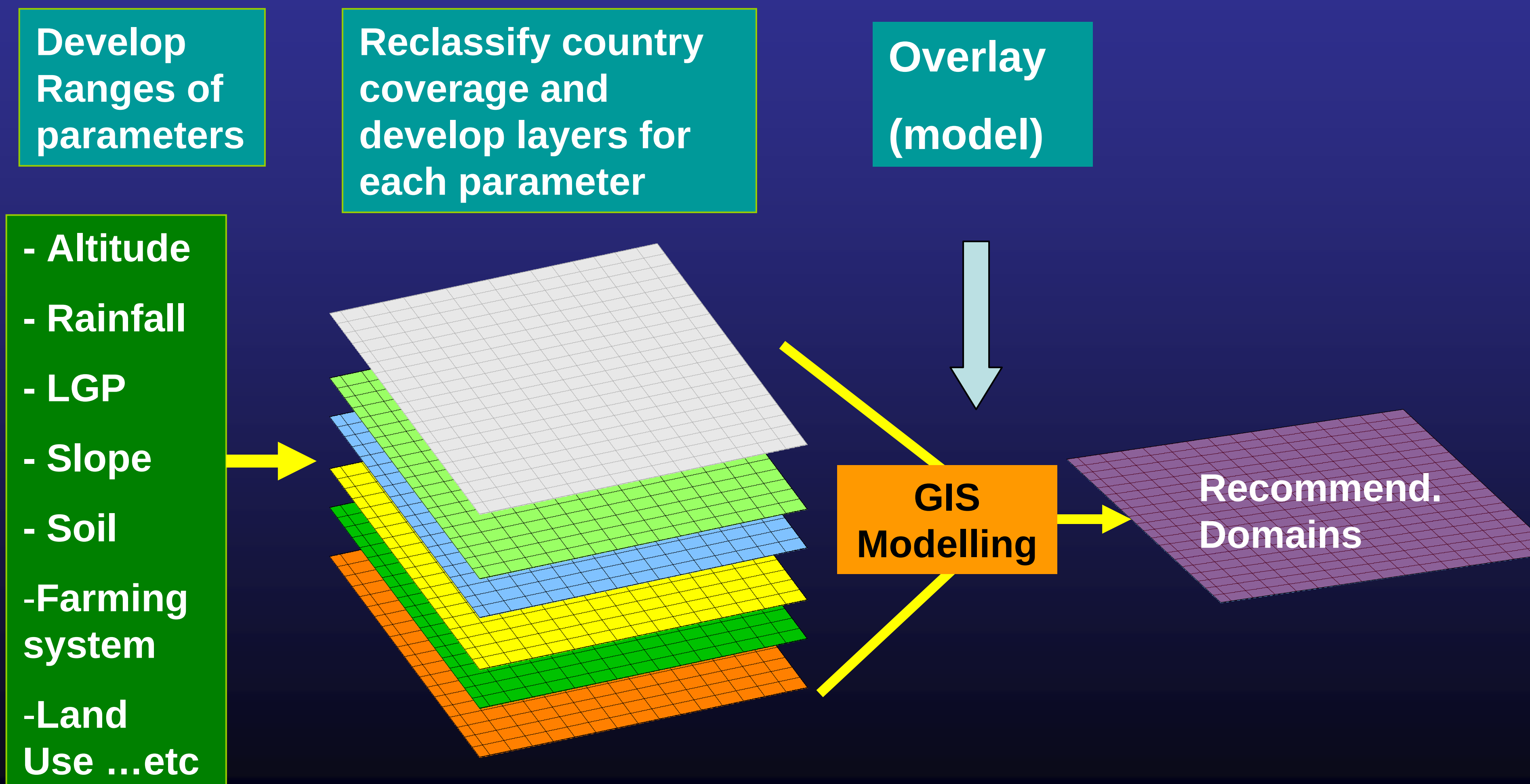
1. **Selection of appropriate models and tools**
   - Modeling
     - Model
       - Choice of appropriate model
         - » USLE – On-site processes (soil loss)
         - » SWAT- Off-site process (siltation)
     - Gauged values to calibrate and validate model
         - » SCRP watersheds
   - GIS
     - To identify recommendation domains

Methods of extrapolation cont…

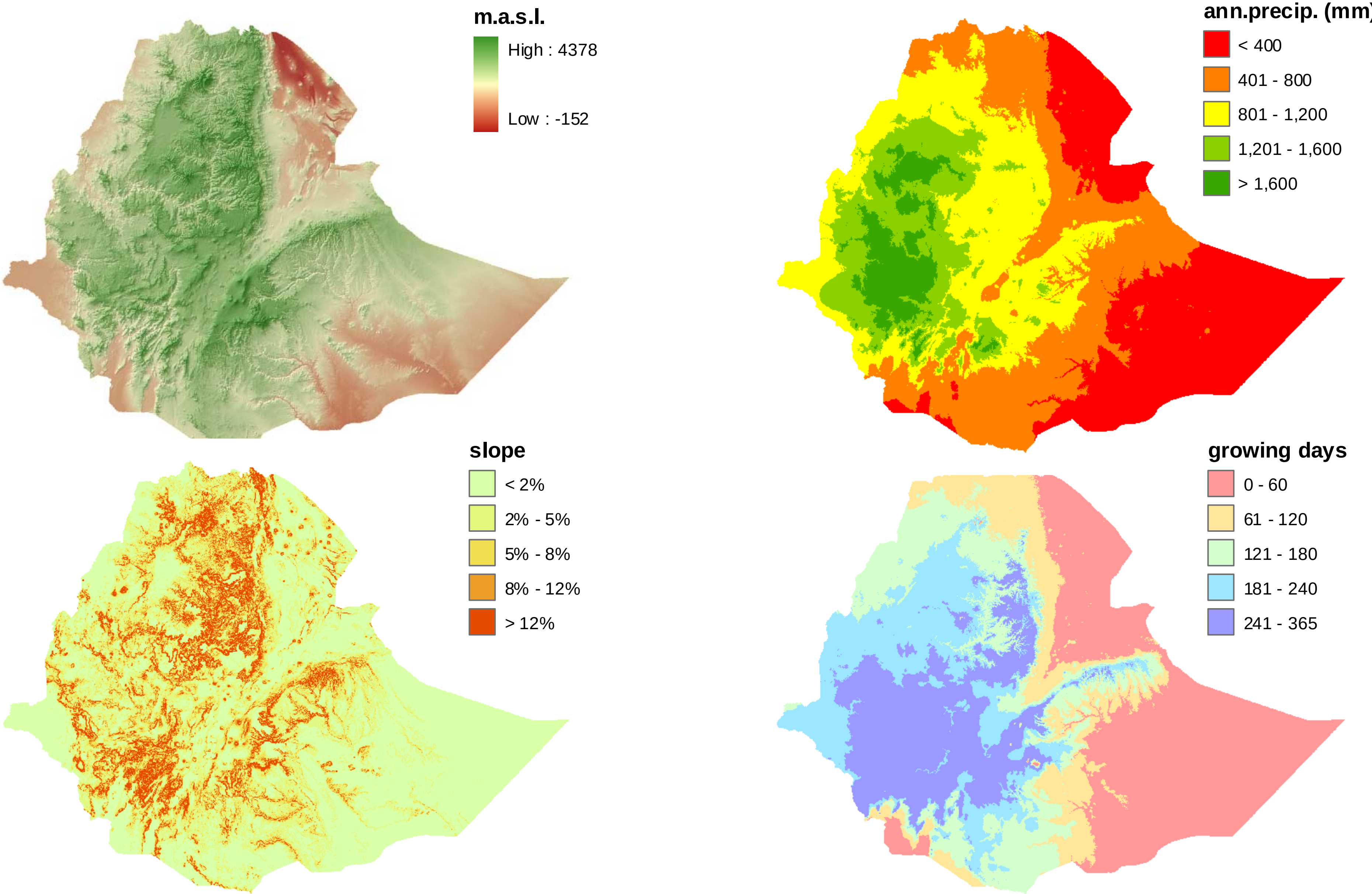
2. Steps to be followed

- Characterize each station
  - Biophysical parameters
  - Socio-economic parameters
- Reclassify country coverages of bio-physical and SE parameters
- Identify recommendation domains
- Test model on station
- Calibrate and validate model using gauged station data
- Apply model on recommendation domains

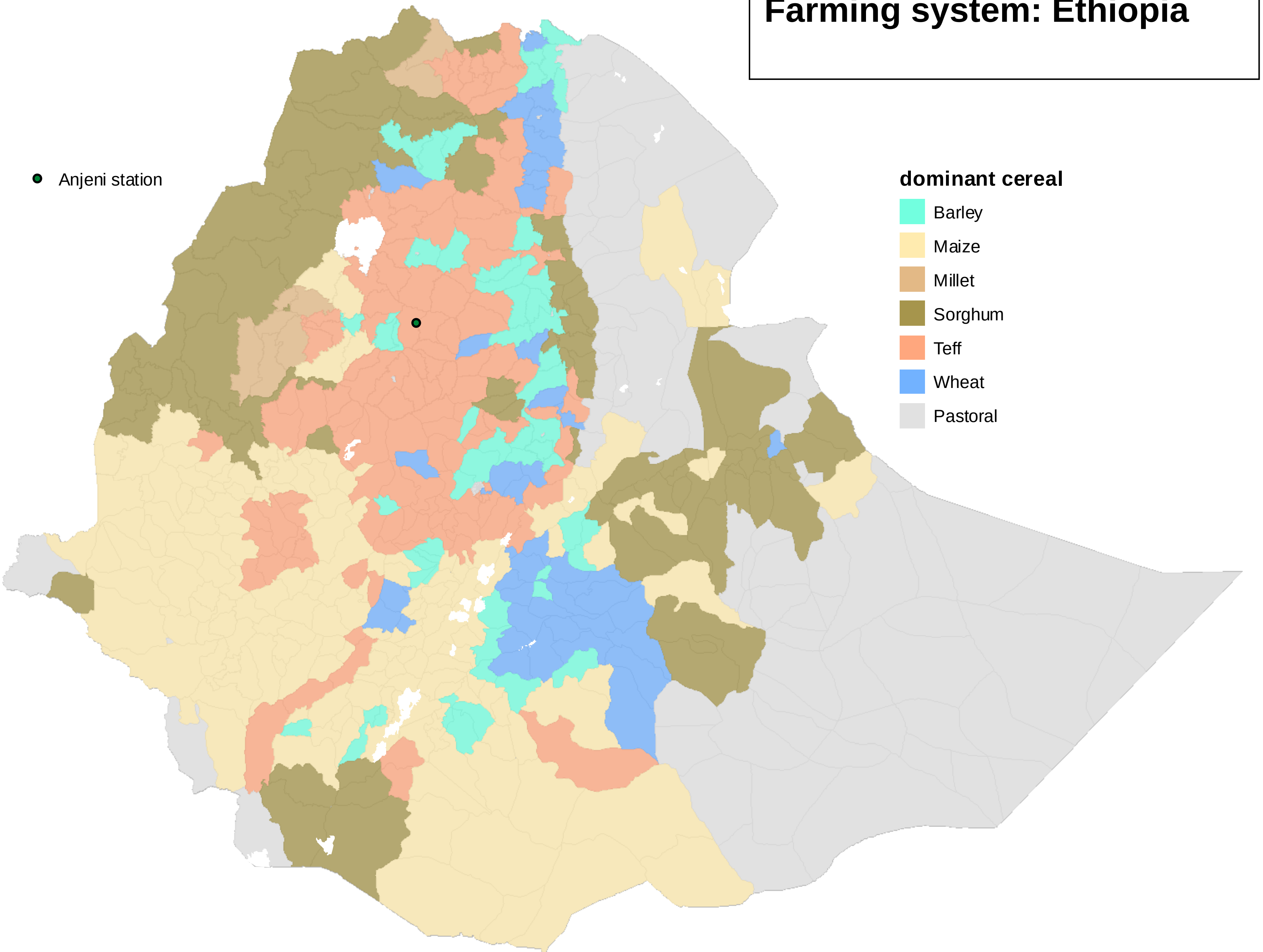
Processes of Identifying Recommendation Domains using GIS Environment (soil loss, Nutrient loss & SLM)

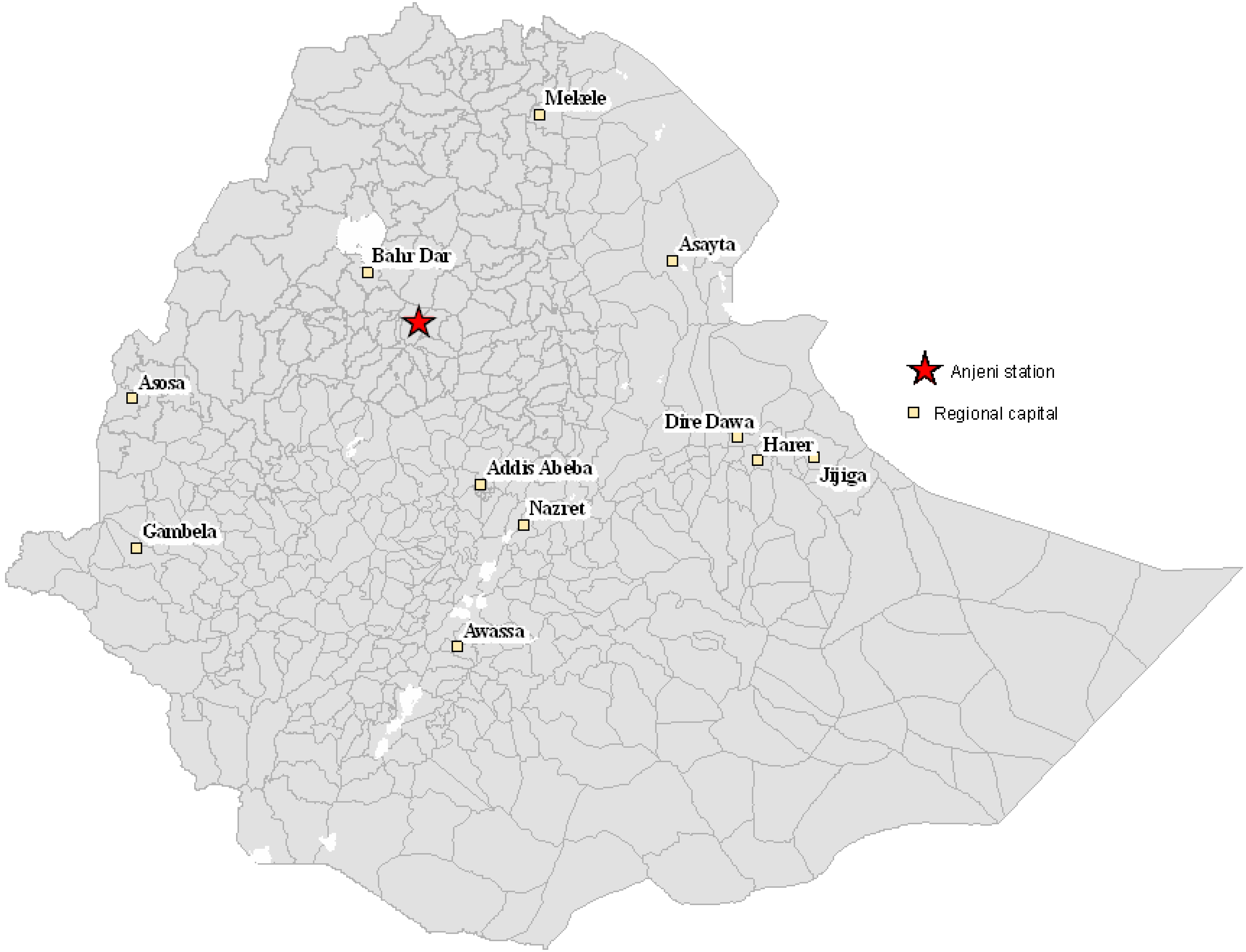


Examples of National coverage for key parameters



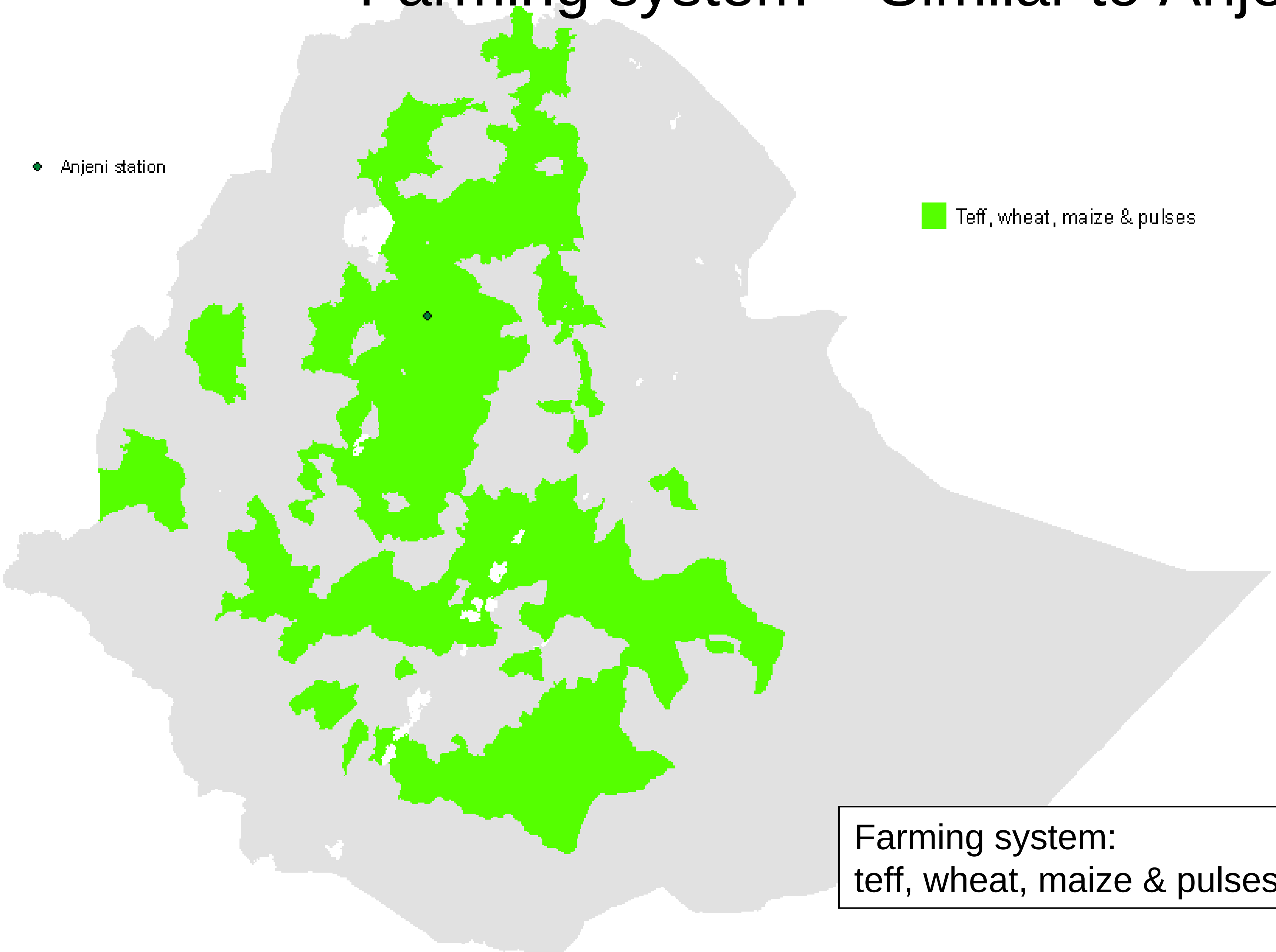
Farming system: Ethiopia





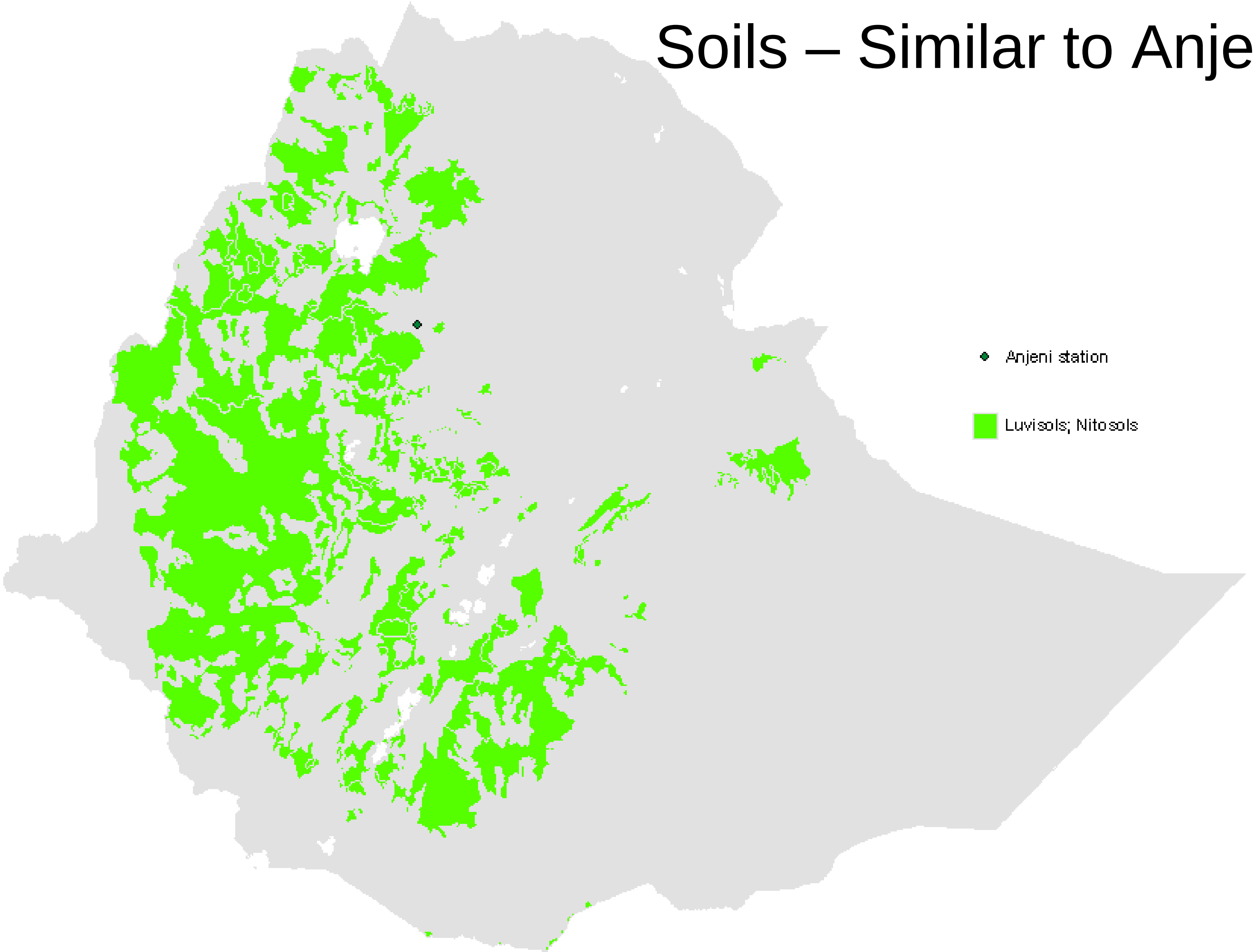
Mekele
Bahr Dar
Asayta
Asosa
Dire Dawa
Harer
Jijiga
Addis Abeba
Nazret
Gambela
Awassa
Anjeni station
Regional capital

Farming system – Similar to Anjeni

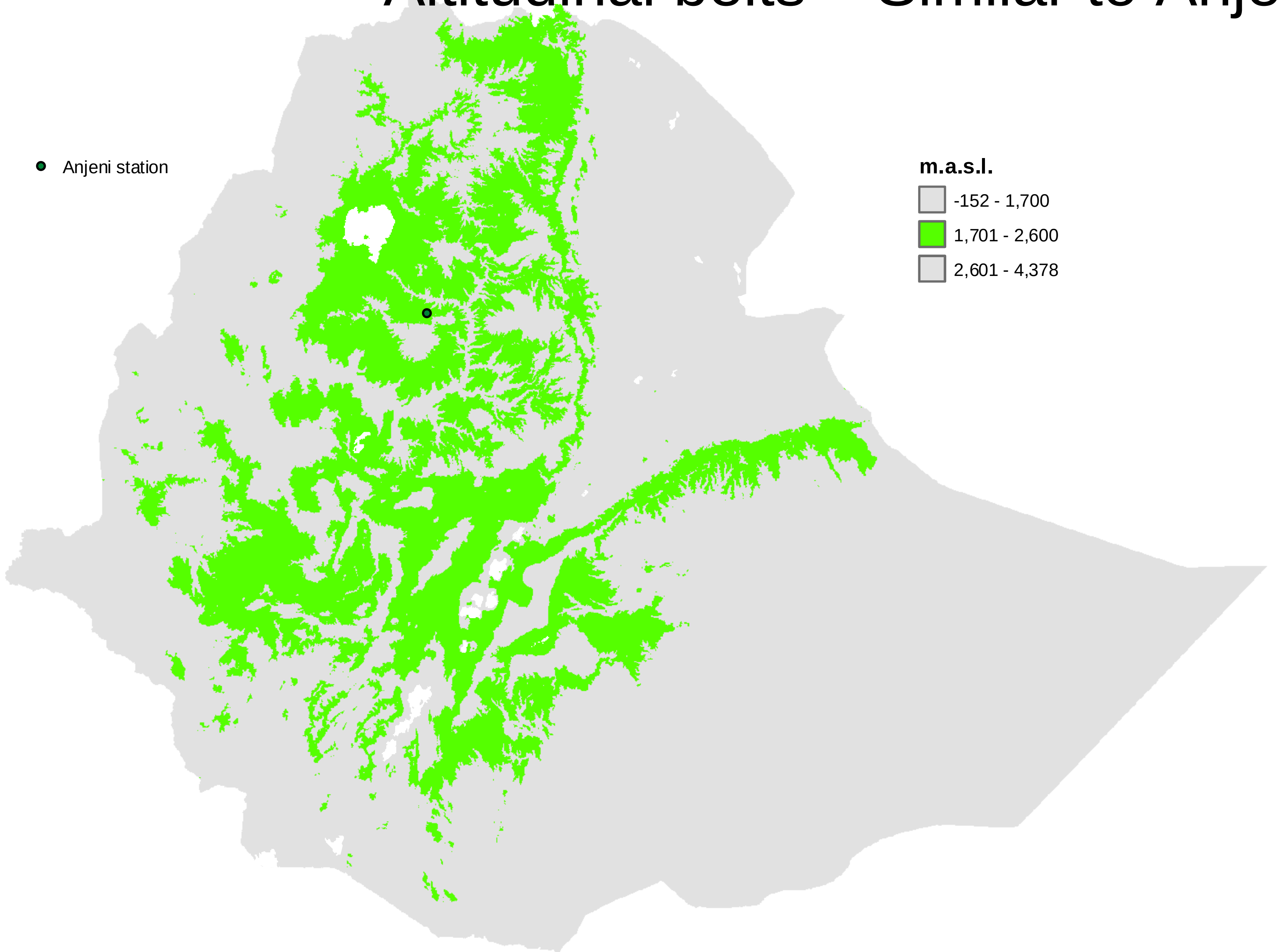


Farming system:
teff, wheat, maize & pulses

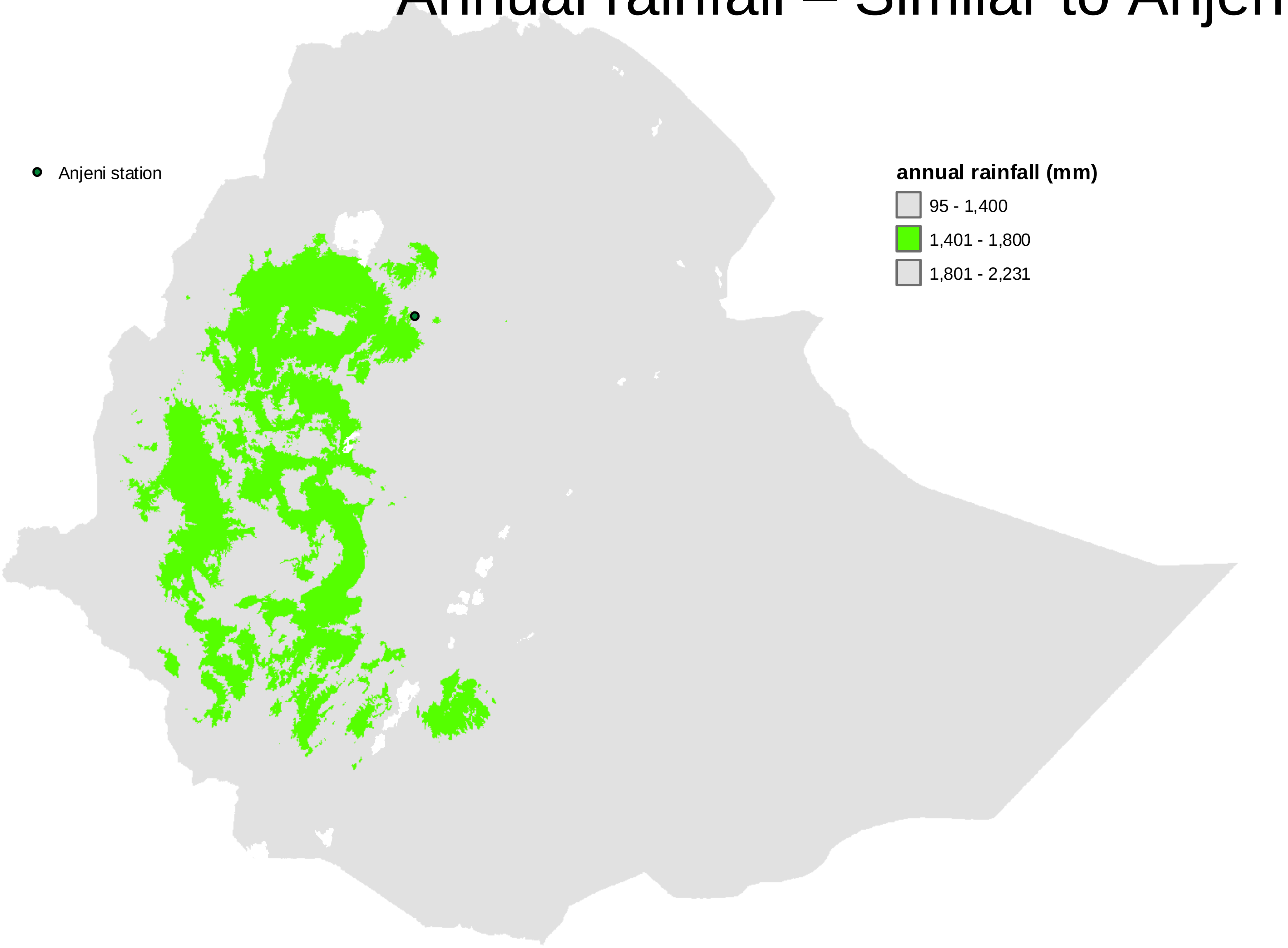
Soils – Similar to Anjeni



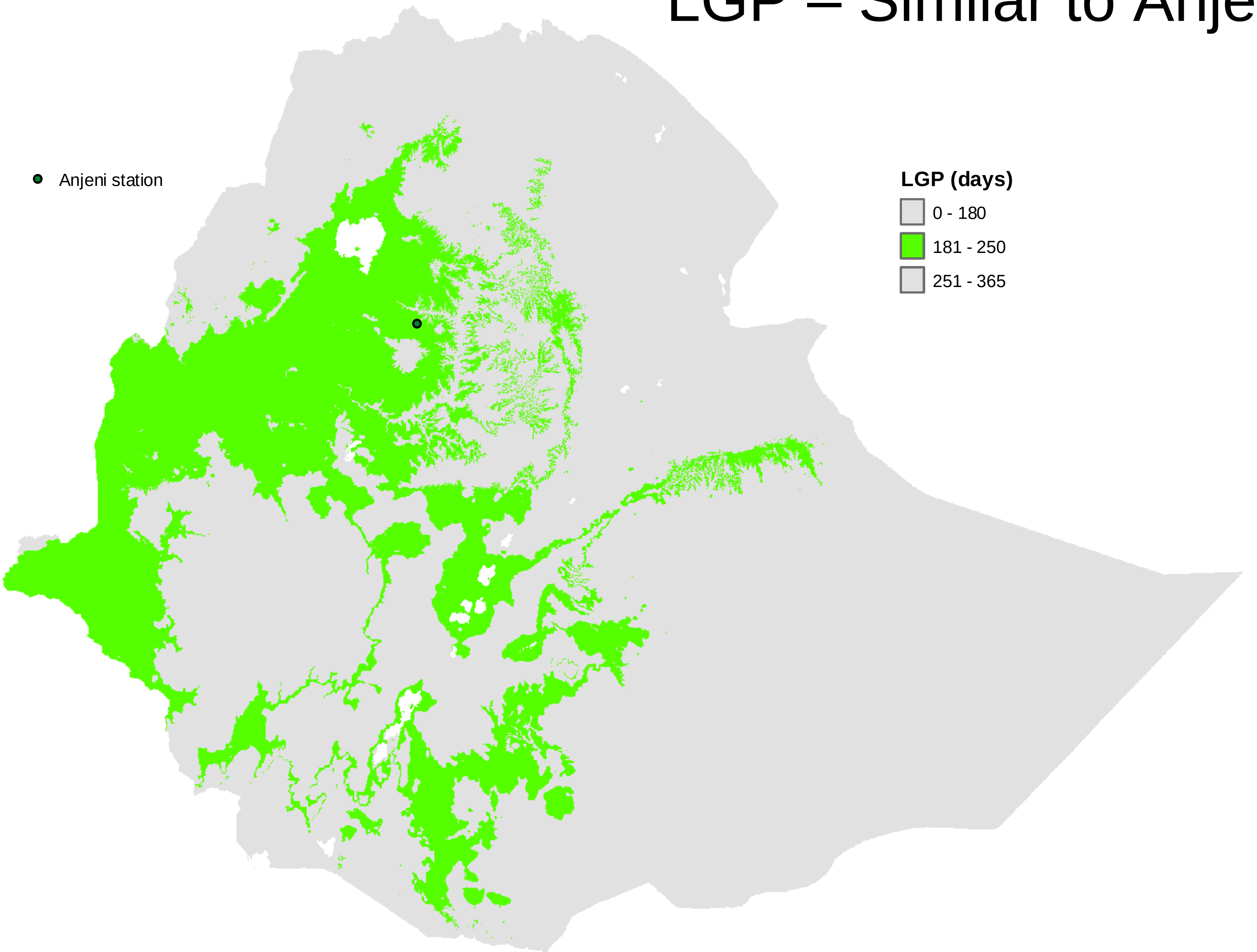
Altitudinal belts – Similar to Anjeni



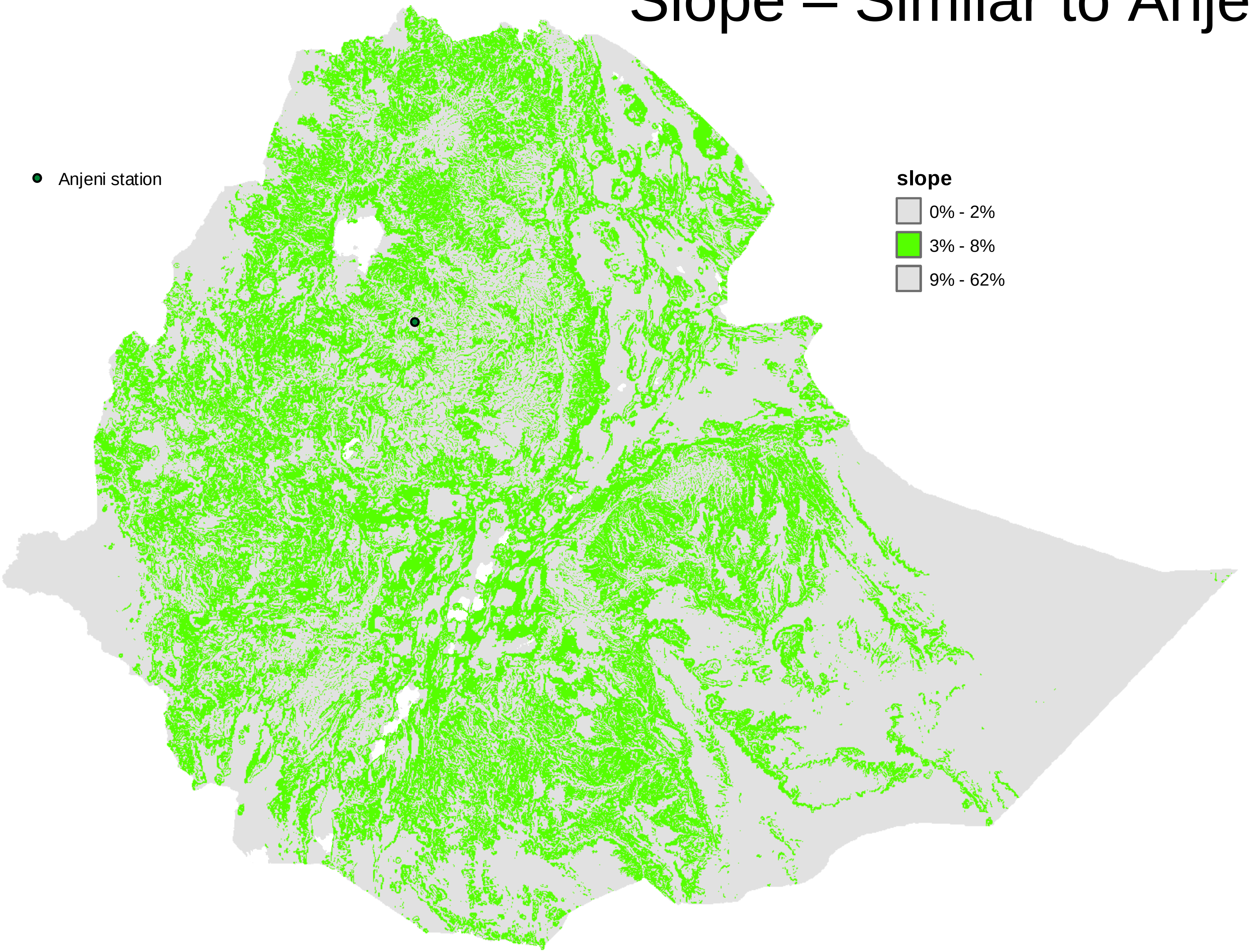
Annual rainfall – Similar to Anjeni



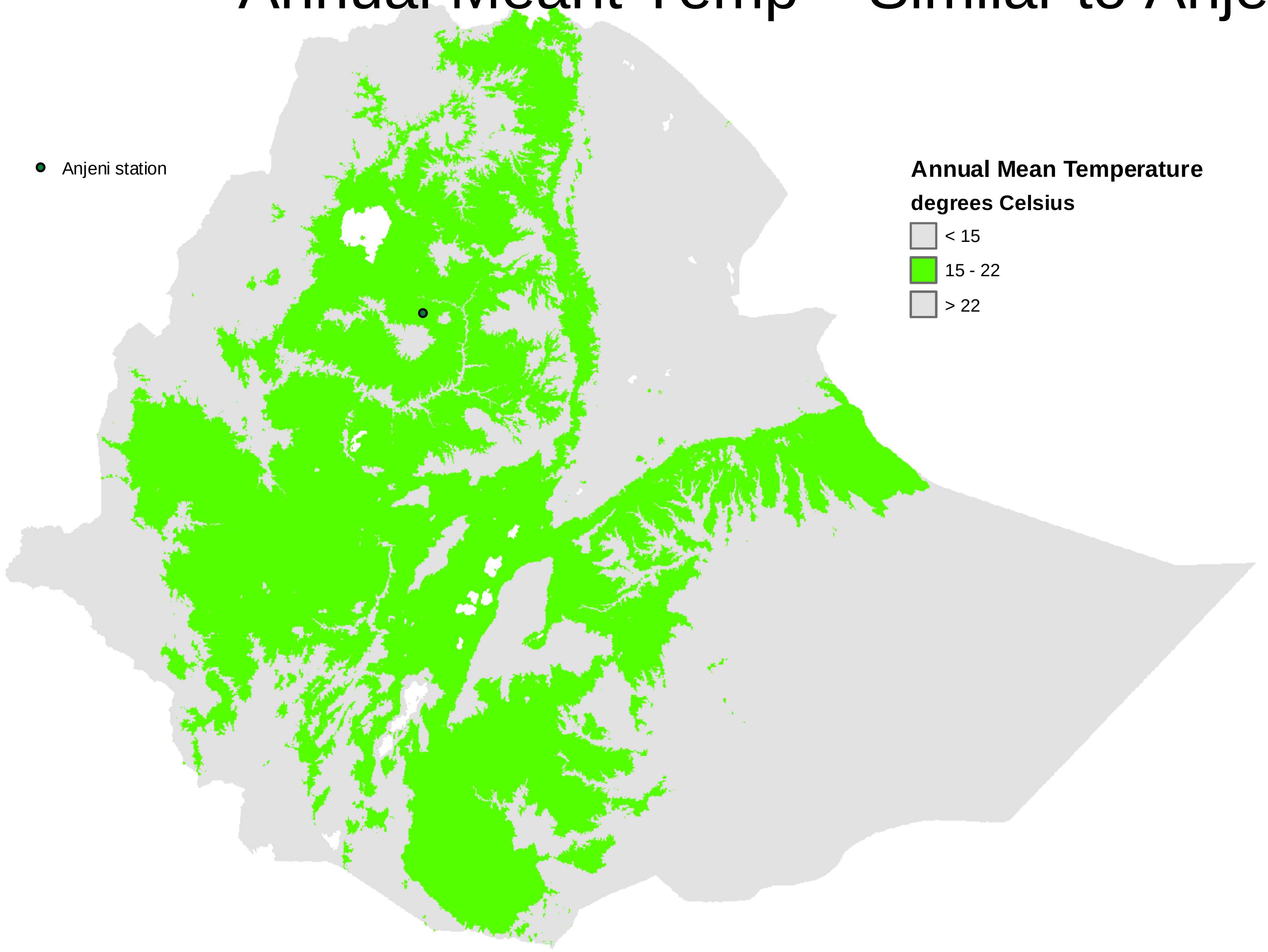
LGP – Similar to Anjeni



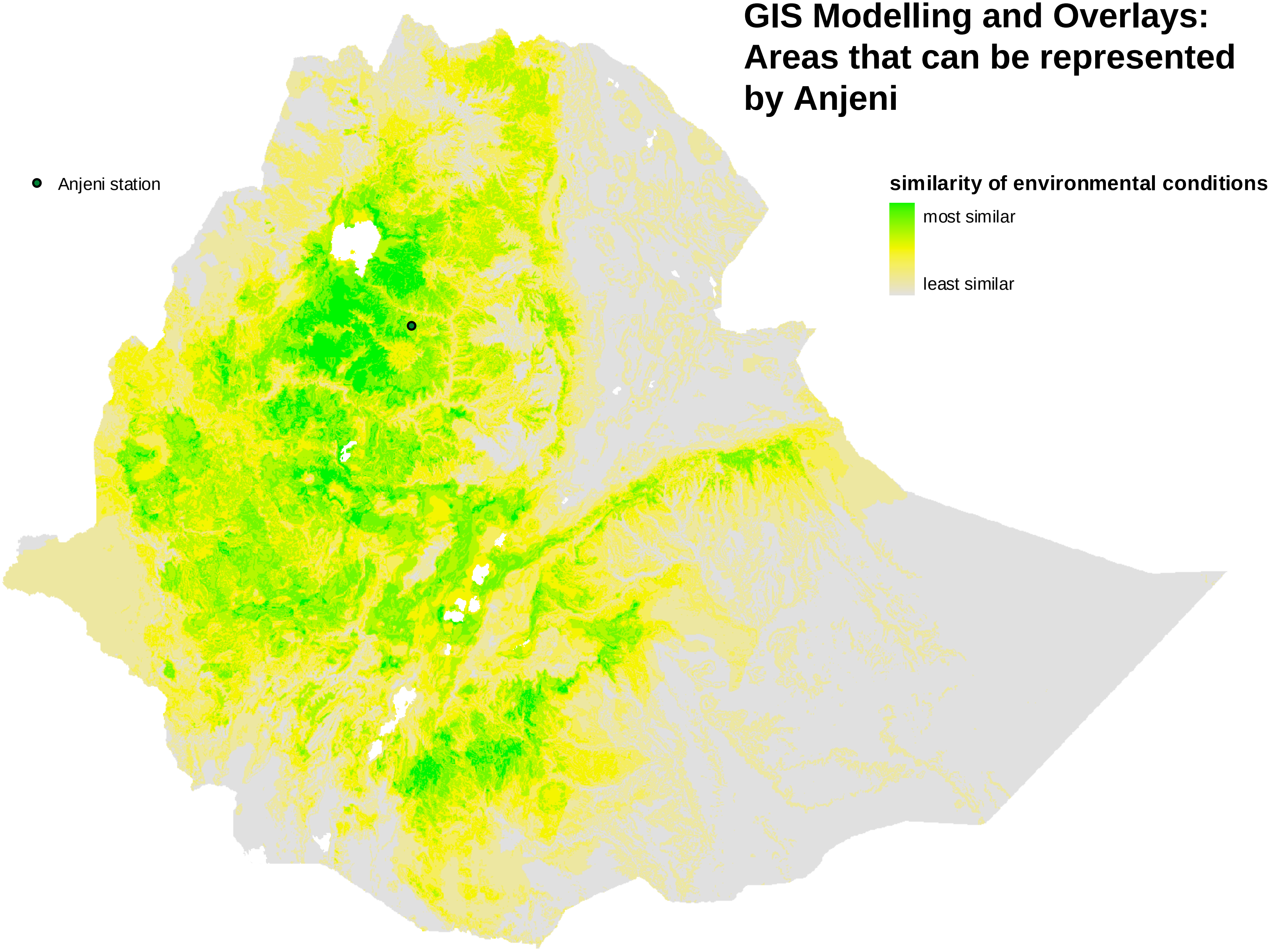
Slope – Similar to Anjeni

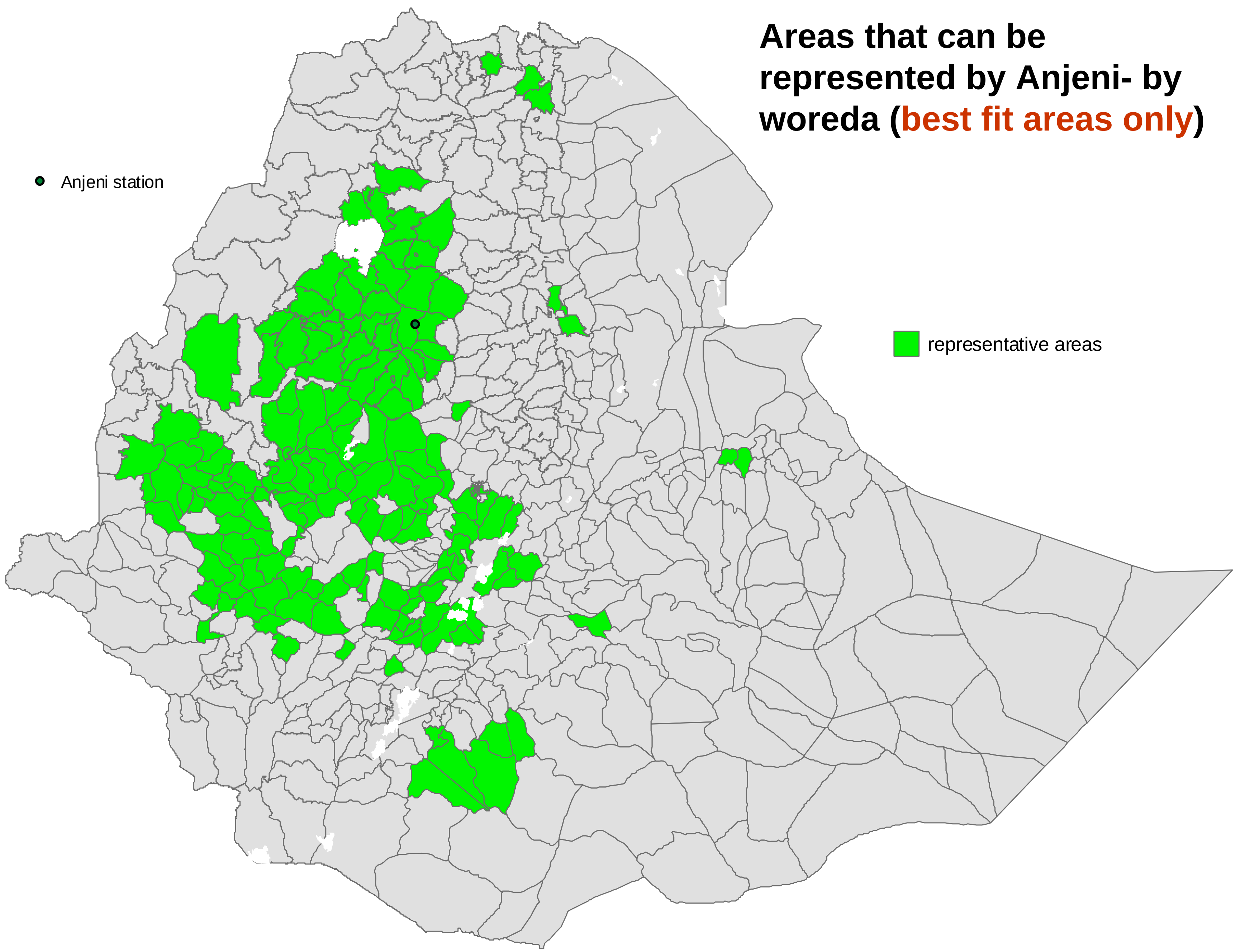


Annual Meant Temp – Similar to Anjeni



GIS Modelling and Overlays: Areas that can be represented by Anjeni

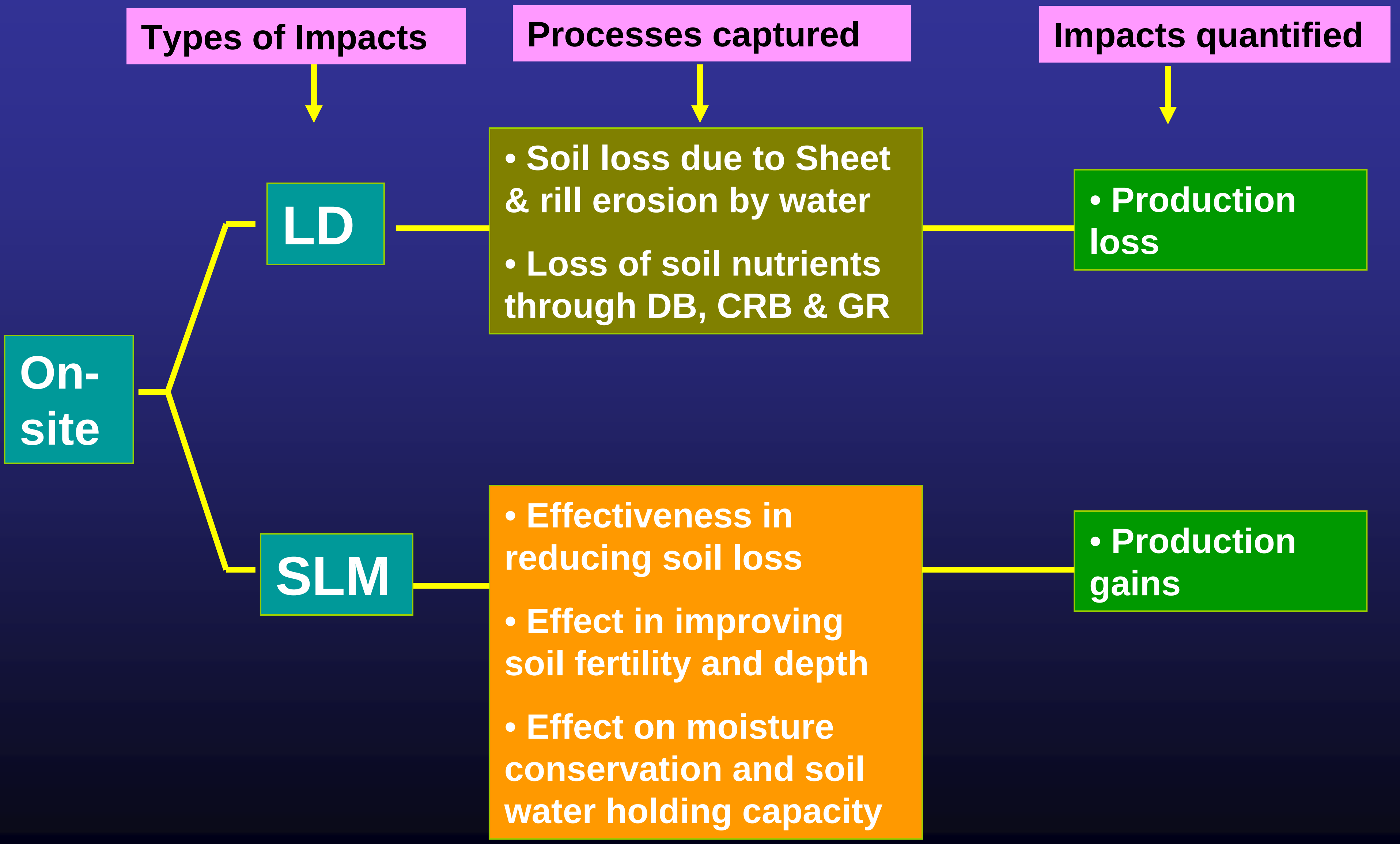




Areas that can be represented by Anjeni- by woreda (best fit areas only)
Anjeni station
representative areas

Part V: Extrapolation

A: Model application (Eg. USLE)
to extrapolate **on-site** processes
and impacts


Types of Impacts
Processes captured
Impacts quantified
On-site
LD
SLM
• Soil loss due to Sheet & rill erosion by water
• Loss of soil nutrients through DB, CRB & GR
• Effectiveness in reducing soil loss
• Effect in improving soil fertility and depth
• Effect on moisture conservation and soil water holding capacity
• Production loss
• Production gains

Phase I: Model validation at station level

1. Quantifying Soil Loss:

- Parameter generation
  - R, K, S, L, C, P
- Model calibration
- Parameter adjustment including methods of generation
- Validate model
- Recommend options for:
  - Model response and interpretation requirements
  - procedures parameter generation
  - Options including tables, equations

Parameter generation options

- Eg. K factor

1. $$K=\frac{00021*M^{1.14}*(12-OM)+3.25*(S_{str}-2)+2.5*(S_{per}-3)}{100}$$

2. $$K = f_{csand} * f_{cl-si} * f_{org} * f_{hisand}$$

3. $$K = 7.594\left[0.0034 + 0.0405 * \exp\left(-0.5\left(\frac{\log(D_g)+1.659}{0.7101}\right)^2\right)\right]$$

4. Or use table developed based on Ethiopian experience

2. Quantifying Nutrient Loss

- We choose only three important ways of nutrient loss from the soil
  - Burning of dung
  - Burning of crop residue
  - Removal of grain
- We consider three possibilities of nutrient addition to the soil
  - Fixation
  - Weathering
  - Artificial fertilizer or manuring
- We only address two nutrients
  - N
  - P

Remark: the method can be used to include others

Procedures

- Determine nutrient content of dung, crop residue and major crops
- Set conversion coefficient - % of energy consumption covered by dung and crop residue per person, per year
- Convert this to dung and CR used
- Convert this to N & P loss from dung and CR

Procedures cont…

- Estimate production of major crops for each zone and
- Convert this into N & P loss
- Calculate Nutrient addition by different means
- Calculate net nutrient loss:

$$\Delta N = \alpha N^{db} + N^{cb} + N^{gr} + N^{A}$$

$$\Delta P = \alpha P^{db} + P^{cb} + P^{gr} + P^{A}$$

3. Quantifying impacts of SLM practices

1. Scenario 1. Only Physical SWC measures
   – Use SCRP values
   – Adjust P factor
2. Scenario 2. Physical SWC with SF/SMM
   – Extrapolate from existing values or measure
   – Adjust P factor and may be C factor
3. Scenario 3. All best LMP
   – Extrapolate of measure
   – Adjust P factor and C factor
4. Area closure and forestry –
   – Extrapolate or measure
   – adjust P factor and C factor

Phase II: Procedures of extrapolation to Recommendation Domains (Eg)

Overlay

$$A_i = R_{aez}\left(K_i * C_i * P_i * SL_i\right)$$

- **Soil Map** → **K- Map**
- **DEM** → **SL - Map**
- **Land Use Map** → **C/P - Map**
- **Climate** → **R – Map**

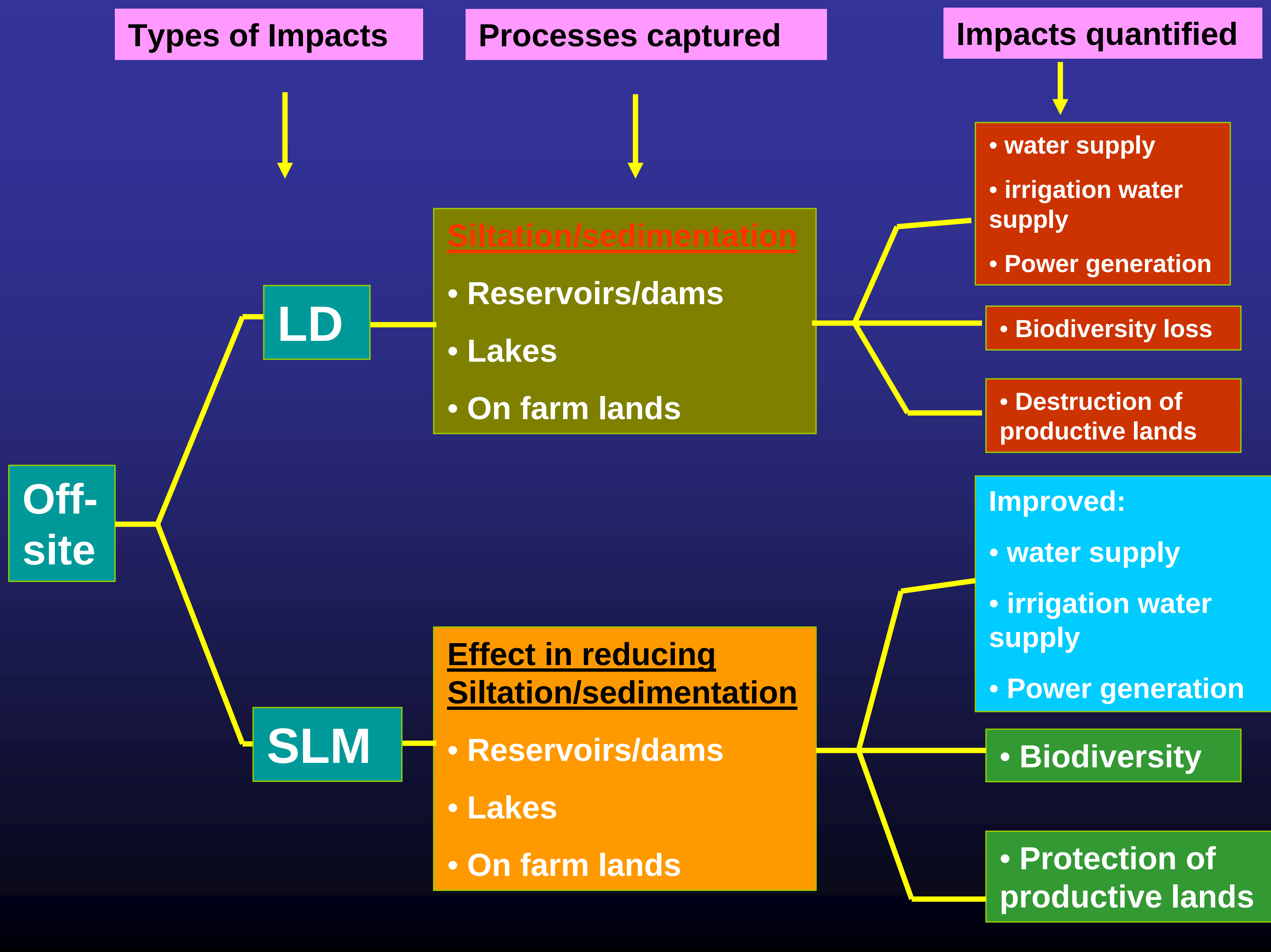
Soil Loss (Map and Data)

$$A^g = \sum_{i=1}^{n} A_i$$

$$A^n = A^g - S^f - D$$

$$\Delta S = \left(\frac{A^n}{B}\right) * 0.01$$

B: Model application (Eg. SWAT) to extrapolate **off-site** processes and impacts



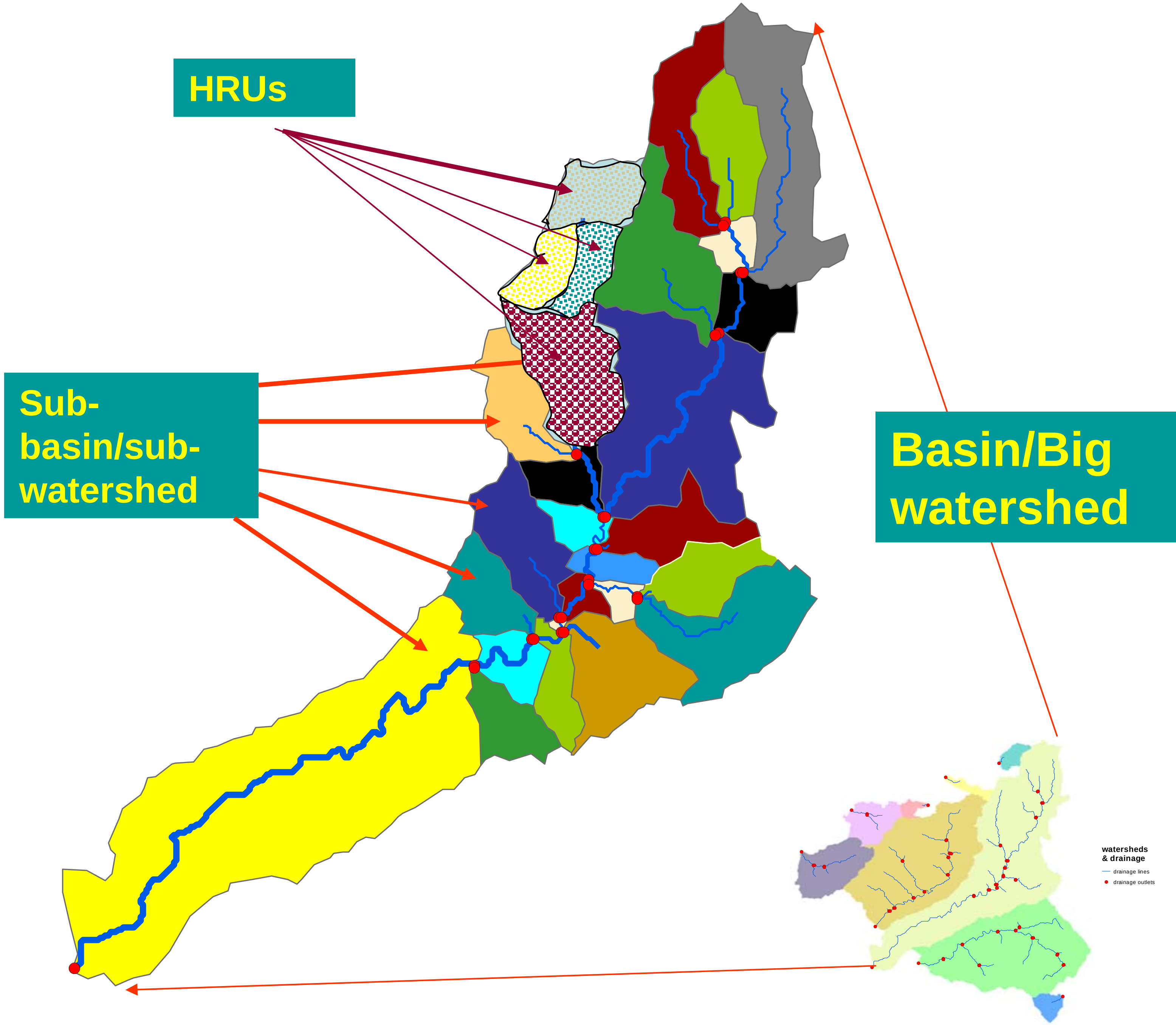
Types of Impacts
Processes captured
Impacts quantified
Off-site
LD
Siltation/sedimentation
• Reservoirs/dams
• Lakes
• On farm lands
• water supply
• irrigation water supply
• Power generation
• Biodiversity loss
• Destruction of productive lands
SLM
Effect in reducing Siltation/sedimentation
• Reservoirs/dams
• Lakes
• On farm lands
Improved:
• water supply
• irrigation water supply
• Power generation
• Biodiversity
• Protection of productive lands

1. Quantifying siltation using SWAT

- SWAT is a dynamic watershed/basin model
- Developed by USDA-ARS
- It simulates:
  - Crop growth
  - Hydrology
  - Soil erosion
  - Climate
  - Updates model parameters on a daily basis
  - It takes point sources as input
  - Impacts of land management practices
  - Point and non point pollutant
- Output:
  - Sediment yield
  - Runoff
  - Nutrient and pollutant balance
  - Etc……

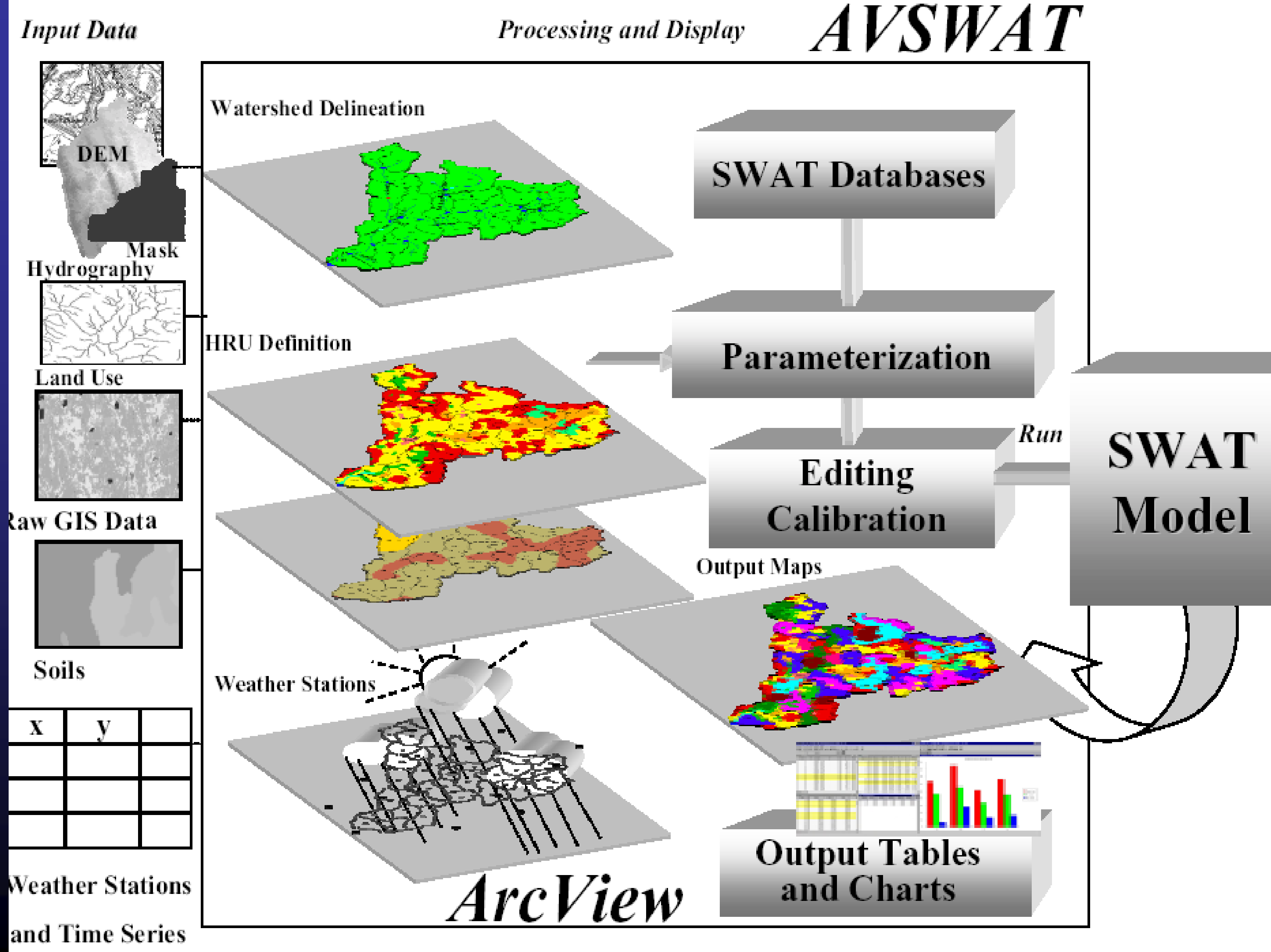
1. Quantifying siltation using SWAT cont….

- SWAT simulates at three levels
  - HRU
    - Homogenous units in terms of soil and land use
  - Sub-basin (smaller watershed)
    - Holds a number of HRU
  - Basin (bigger watershed)
    - Holds a number of sub-basins
- Has GIS interface and the model can run through GIS
- Has weather generator


HRUs
Sub-basin/sub-watershed
Basin/Big watershed
watersheds & drainage
drainage lines
drainage outlets

Procedures of using SWAT

1. Validate model using SCRP station data
   - Generate parameter
   - Conduct sensitivity analysis
   - Calibrate model
   - Adjust model parameters
   - Validate model
2. Apply model on selected basins
   - Prepare soil map and data
   - Prepare and use map and data
   - Prepare DEM
   - Map climate variables
   - Indicate point sources
   - Produce parameter – built model database
   - Run the model



Input Data
Processing and Display
AVSWAT
Watershed Delineation
DEM
Mask
Hydrography
SWAT Databases
HRU Definition
Parameterization
Land Use
Run
Editing
Calibration
SWAT
Model
Raw GIS Data
Output Maps
Soils
Weather Stations
x
y
Output Tables
and Charts
Weather Stations
and Time Series
ArcView

Conclusion

a. Build required resource database
b. Develop information on SLM scenarios
    - Develop generic values based on some observation
    - If absolutely needed establish learning sites
c. Build capacity
    - On modelling
    - Parameterization
d. Develop packages of recommendation
e. Develop feedback system among research, extension and policy makers