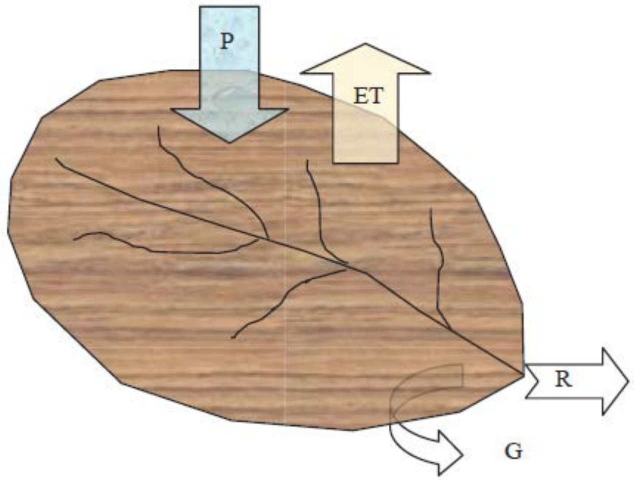
Training on

Roads for Water and Resilience

REMOTE SENSING AND GIS TOOLS FOR RAINWATER HARVESTING AND RECHARGE ESTIMATION UNDER DATA SCARCE CONDITIONS

Most are the most sought parameters for WH

- **runoff,**
- **evapotranspiration and**
- **recharge**



Catchment Water Balance

$$P - R - G - ET = \Delta S$$

Where P- precipitation, R – runoff, G – groundwater runoff, ET – evapotranspiration, ΔS – storage change in catchment

Water Balance drainage basin

$$(P - E)A - Q = \frac{\Delta S}{\Delta t}$$

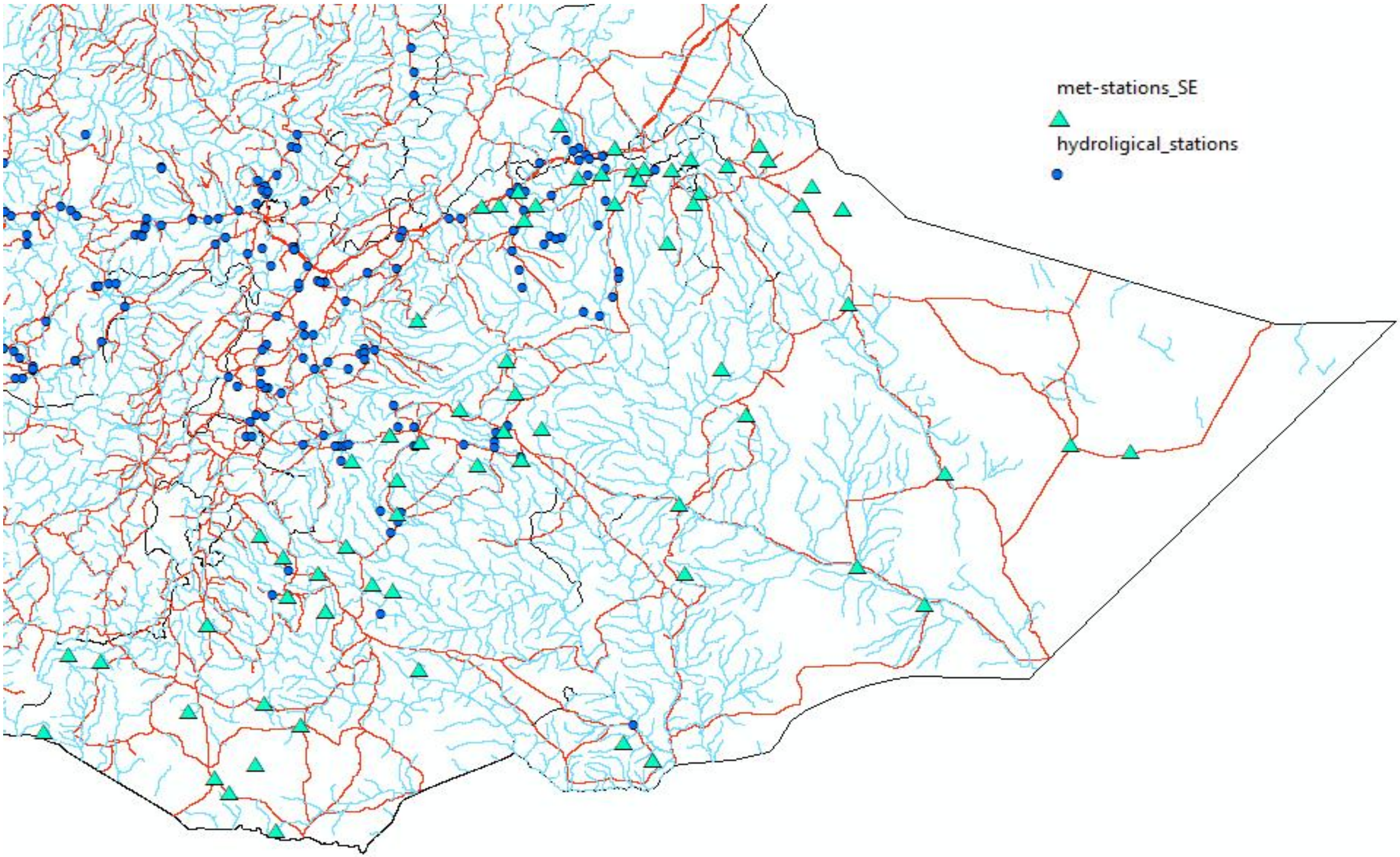
Water Balance as a result of human interference

$$P = E + A + R$$

$$A = I_s + I_g - D$$

In which:
P = precipitation on the ground surface
E = evapotranspiration from the ground surface
A = net water consumption due to water use
R = runoff from land to ocean
I_s = intake of water from surface runoff
I_g = intake of groundwater
D = drainage of waste water

Are they available & reliable for use where WH is most needed?



What is the possible way-out?

- Oral sources – ask elderlies about the local situation
  - Difficult to qualify and quantify
  - Less spatial and temporal reliance, particularly in understanding the overall hydrodynamics
- Remote sensing data sources
  - Require conducive data capturing facilities
  - Need expertise to acquire, analyze and process data and customize models
  - Require calibration, validation has to pass through pilot phase

What sort of data is available?

- Rainfall and temperature d data-
  - METEOSAT (high spatial resolution)
  - STAR Satellite Rainfall Estimates
  - CMORPH
  - Special Sensor Microwave /Image (SSM/I) – since 1978
  - Operational Hydro-Estimator (HE) Satellite -since 2002- every 15mnt
  - Tropical Rainfall Measuring Mission (TRMM) – since Nov 1997 but ended on April 15,2015

What sort of data is available?

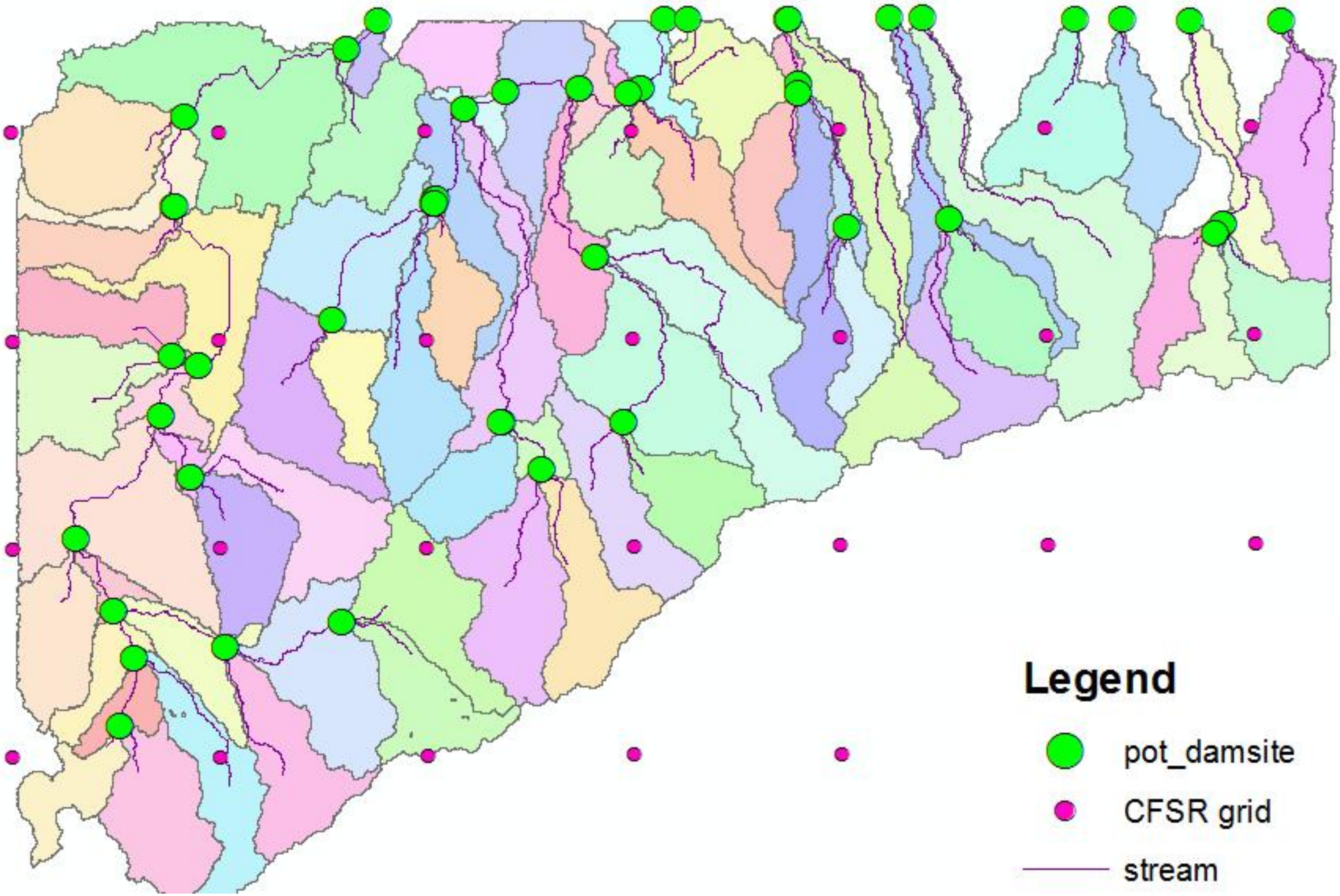
- Global Estimates & Predictions
  - National Center for Environmental Predication (NCEP)
- Combined system of observed and satellite estimates
- Moisture Estimate –
  - Gravity Recovery and Climate Experiment (GRACE)- since March 2002
  - GPR, , ..
- Image
  - Optical
    - Landsat- since 1972
    - Radar

Optional RO, ET & RE Estimation method

using RS and hybrid data

- **Objective**
  - To estimate runoff, evapotranspiration and recharge to implement water harvesting project in specific data scarce watershed
- **Method**
  - Image processing
  - Modeling
- **Data type**
  - Estimated and predicted data for hydro-metreological parameters
  - Optical and Radar images to generate land use and topographic features
- **Software**
  - MS Office, Image processing and GIS softwar

Target watershed delineation
from SRTM30M V3

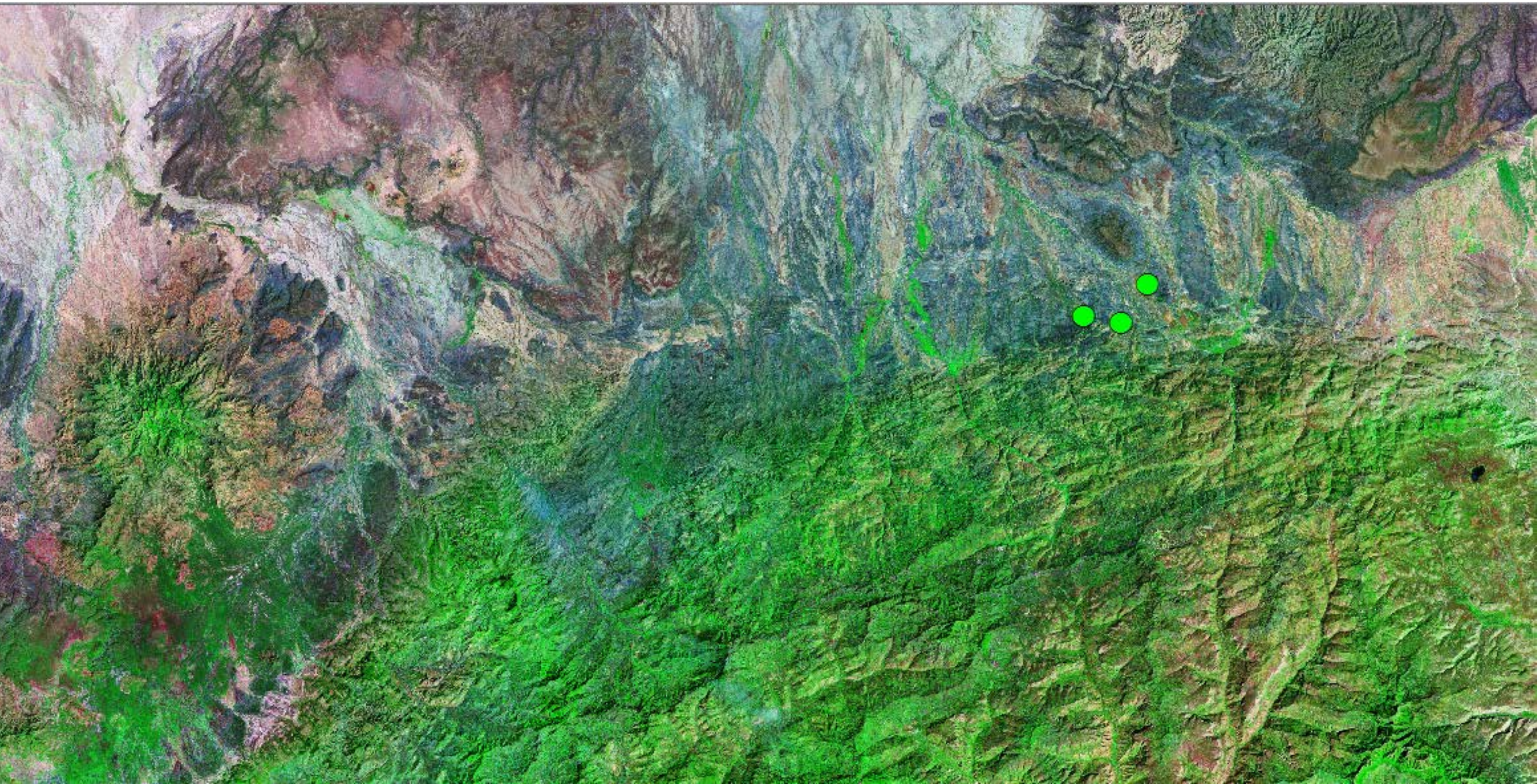


Required data type

- for both ‘Bega’ and ‘Kiremt’ seasons
  - Landuse/Landcover
  - Precipitation
  - Potential Evapotranspiration
  - Wind speed
  - Temperature
  - Groundwater depth
  - Soil
  - Slope Topography
  - Parameters
    - Landuse/Landcover parameters
    - Soil coefficient
    - Runoff coefficient

Landsat Image

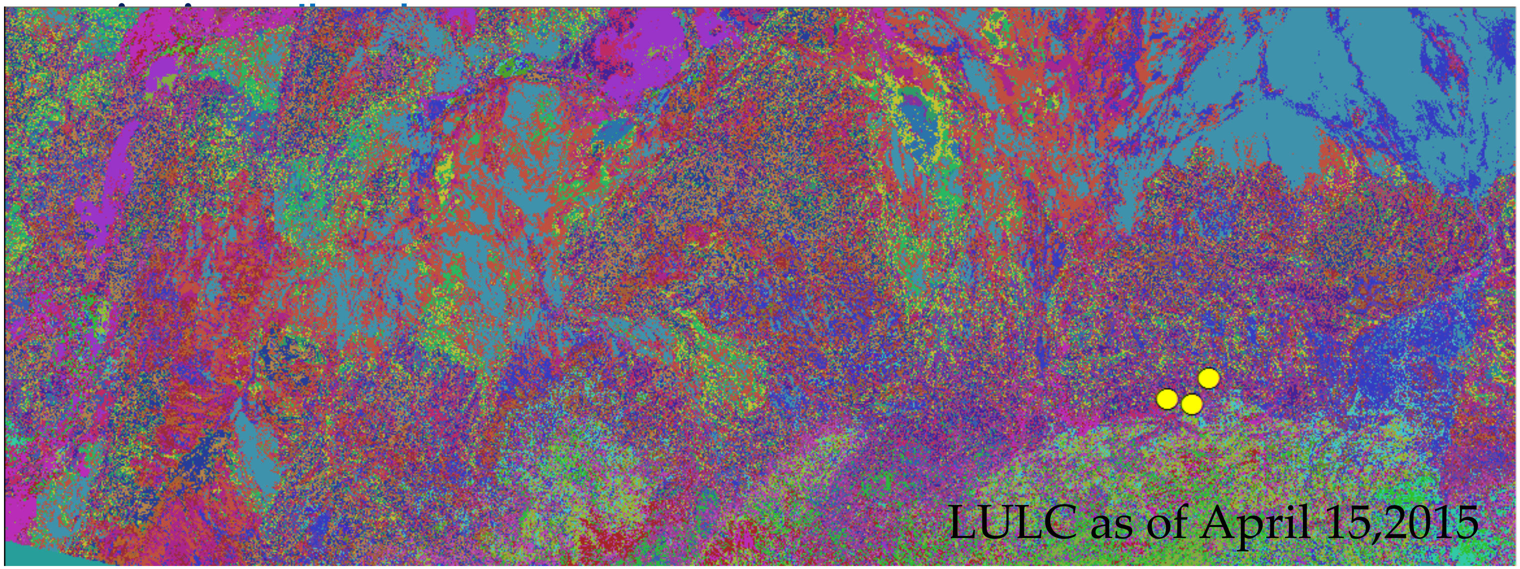
To generate Landuse/Landcover

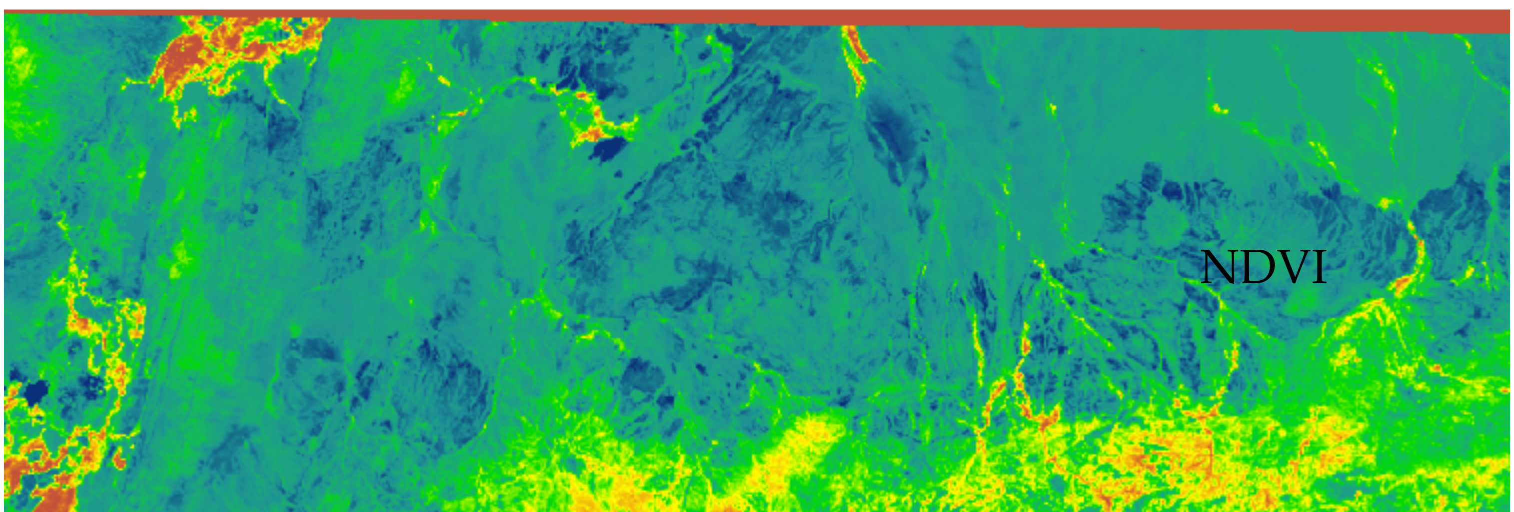


Preparing required data input

Landuse/Landcover

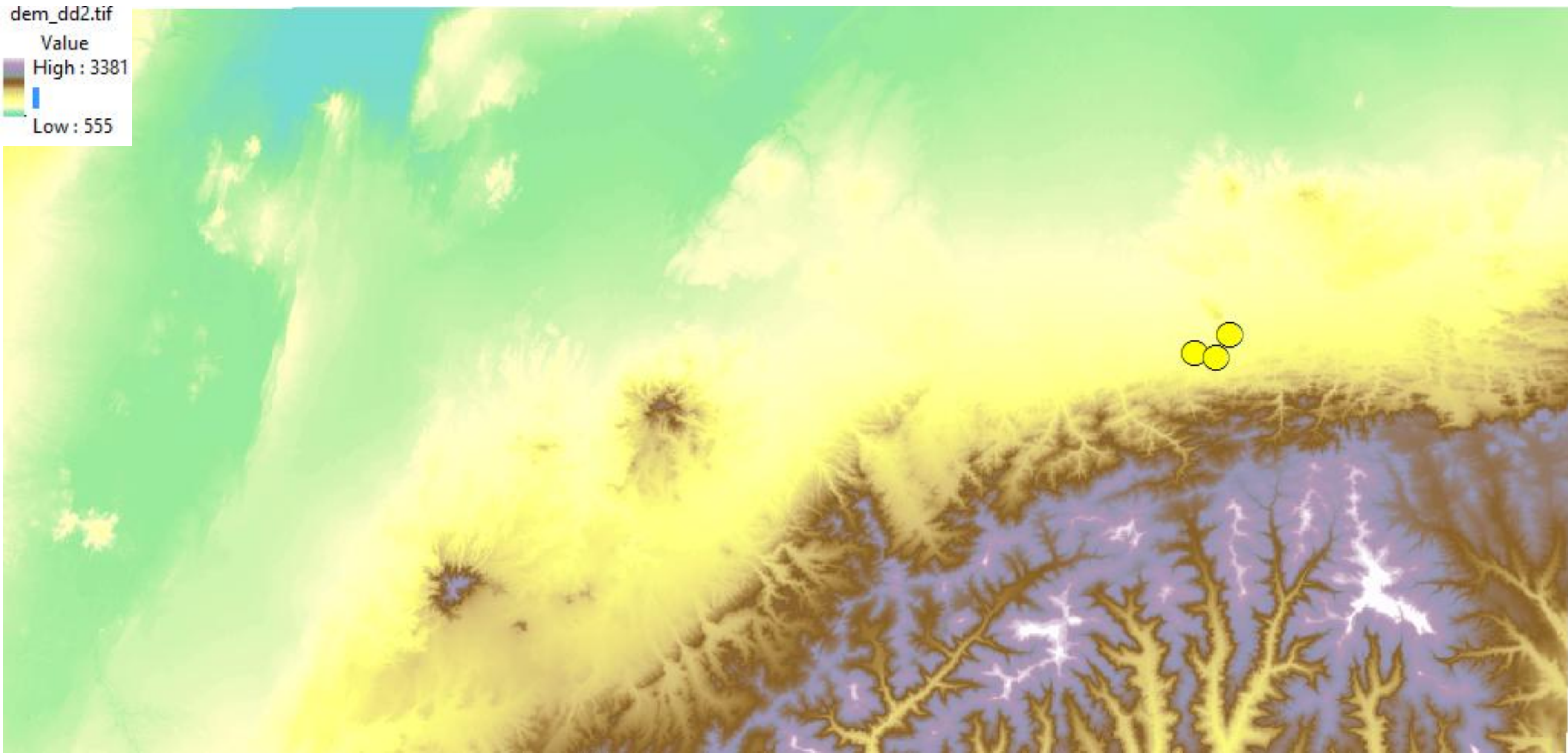
- **Can be generated from recent Landsat 8 data-**





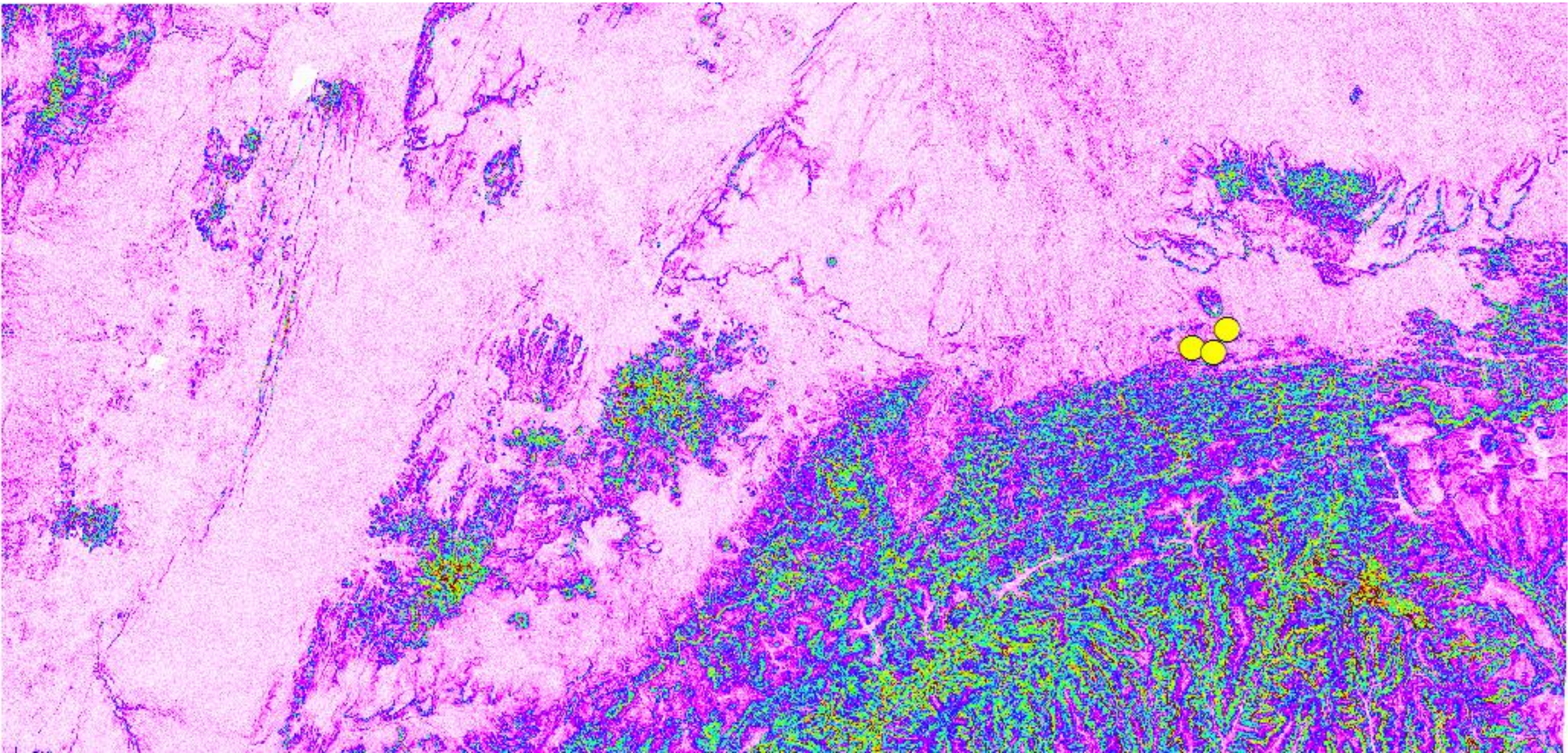
Preparing required data input…

Topography- from SRTM30M V3



Preparing required data input…

Slope - from SRTM30M V3

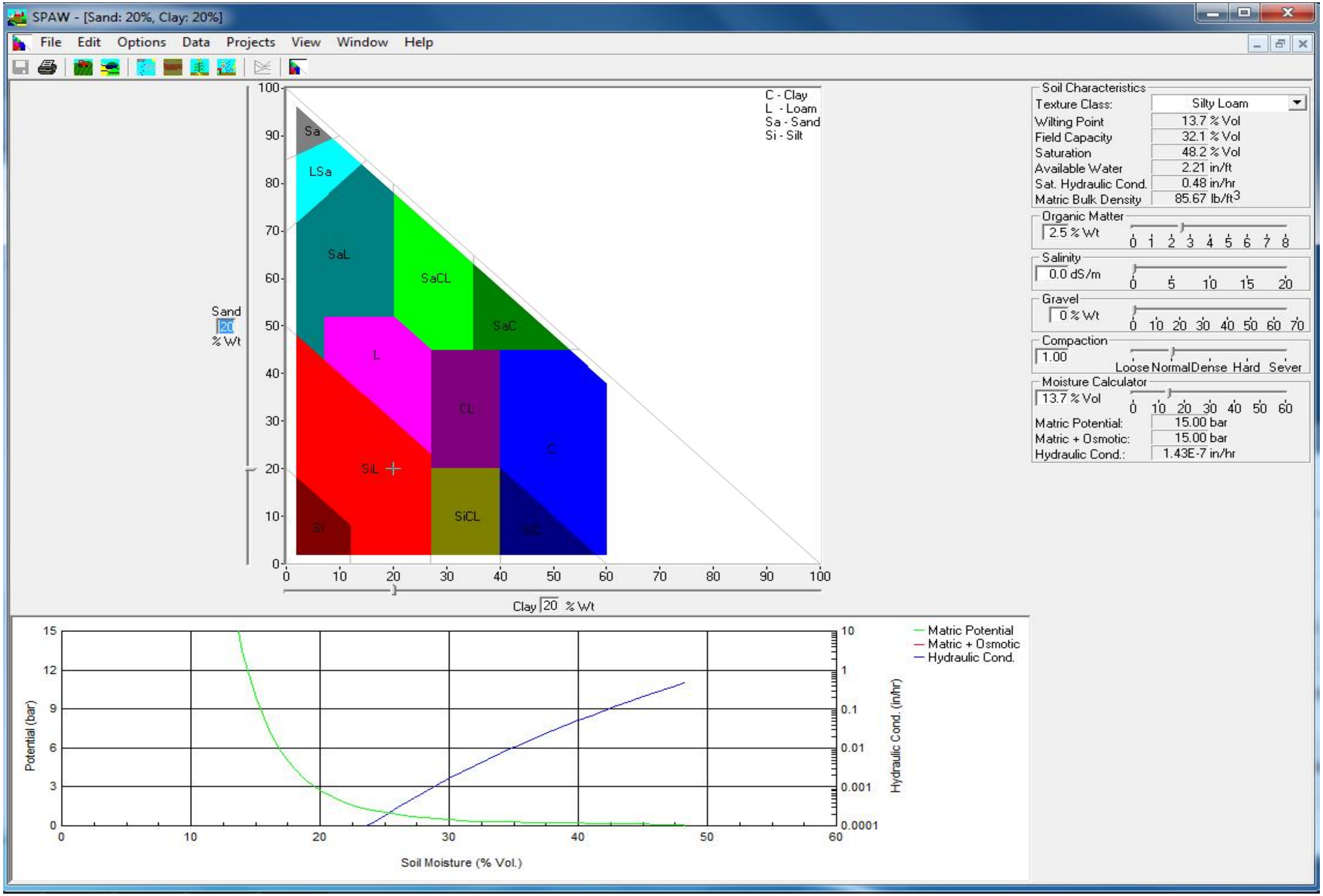


Preparing required data input…

- Groundwater depth
  - Estimates deduced from interpretation of satellite images for geology, hydrogeology and climate parameters generated from CFSR data
  - Observation of existing wells, springs will help to validate

Preparing required data input…

Soil- in USDA soil class



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Required data type

Hydro-meteorological parameters :

- Precipitation
- Potential Evapotranspiration
- Wind speed
- Temperature
- Groundwater depth
- Parameters
    - Landuse/Landcover parameters
    - Soil coefficient
    - Runoff coefficient

Where and why we need RS data in puts?

	sand % topsoil	sand % subsoil	silt % topsoil	silt % subsoil	clay % topsoil	clay % subsoil	pH2O topsoil	pH2O subsoil	OC % topsoil	OC % subsoil	N % topsoil	N % subsoil	BS % topsoil	BS % subsoil	CEC topsoil	CEC subsoil
A	53.3	44.3	17.2	17.1	29.5	38.6	5.2	5.2	1.74	0.63	0.17	0.08	37	29	8.7	8
AF	61.7	52.5	14.4	12.9	23.9	34.6	5.4	5.3	0.91	0.34	0.12	0.06	43	34	7.8	6.9
AF 1	81.1	75.5	8.7	8.9	10.2	15.6	5.7	5.5	0.35	0.2	0.07	0.03	47	43	4.4	4.6
AF 2	61.7	44.5	14.3	10.8	24	44.7	5.1	5.2	1.05	0.37	0.11	0.03	37	28	9.6	7.2
AF 3	21.3	13.1	25.7	24.4	52.9	62.3	5	4.9	1.85	0.58	0.15	0.1	42	23	12.5	11.1
AG	40.9	36.8	27.2	29.7	32.1	33.4	5.1	4.9	2.26	0.34	0.11	0.03	22	16	11.2	9.8
AG 1	89.3	72.5	7.2	9.5	3.5	17.9	5.5	5.1	-1	-1	0.02	-1	55	34	1.2	2.5
AG 2	9.6	15.8	75.2	64.7	15.3	19.6	4.4	4.2	3.07	0.25	0.14	0.03	8	15	12.5	11.8
AG 3	35.2	32	17.9	24.8	47.2	43.2	5.2	5.1	1.99	0.38	0.18	-1	16	11	14.1	11.6
AH	31.3	27.1	24.8	25.1	43.8	47.8	5	5.4	3.34	1.49	0.29	0.14	20	16	18	17.9
AH 1	72.8	71.9	14.6	10.6	12.6	17.4	5	5	1.58	0.9	0.28	0.12	6	5	28.4	28
AH 2	52.4	45.4	27.9	33	19.6	21.5	5.1	5.7	4.46	1.95	0.36	0.17	4	6	7.3	1.9
AH 3	9.2	7.4	26.1	22.2	64.8	70.4	5	5.3	2.88	1.25	0.25	0.13	27	21	18.1	19.4
AO	53.6	43.4	15.8	16	30.6	40.6	5.1	5.2	2.25	0.75	0.18	0.07	39	32	7.6	7.5
AO 1	82.3	68.1	8.6	11.4	9.2	20.5	5	5.1	0.3	0.21	0.06	0.02	41	41	4.1	5.4
AO 2	51	41.3	21.6	17.2	27.4	41.5	5.3	5	1.73	0.73	0.13	0.08	53	34	7.7	7.8
AO 3	33	28.9	14.2	15.5	52.9	55.6	5.2	5.4	1.84	0.89	0.12	0.07	31	28	8.6	6.8
AP	57	46.2	15.6	17.1	27.1	36.8	5.3	5	1.09	0.26	0.09	0.03	31	17	6	5.7
AP 1	80	65.1	12	14.6	7.8	20.3	5.6	5	0.69	0.2	0.05	0.02	40	19	3	3.2
AP 2	58.7	45.4	16.3	17.4	25	37.1	5.8	5.6	0.87	-1	0.07	-1	28	20	6	6.8
AP 3	10.4	8.8	22.7	22	66.7	69.6	4.5	4.6	2.91	0.49	0.23	0.05	17	13	12.1	10.2
B	60.4	60	17	16.6	22.5	23.4	6.9	7.2	1.17	0.57	0.25	0.12	79	80	14.2	12.7
BC	40.1	41.8	21.5	22.7	38.4	35.5	5.7	5.8	1.44	0.74	0.17	0.09	67	68	15.7	18.9
BC 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
BC 2	56.7	56.8	23.6	20.6	19.8	22.5	5.8	5.9	1.22	0.61	0.13	0.08	81	82	15.6	18.1
BC 3	15.3	19.3	18.5	25.7	66.3	55	5.6	5.6	1.77	0.93	0.24	0.12	47	48	15.9	20
BD	32.7	29.8	30.3	37.6	37.1	32.3	4.9	5.3	3.28	0.87	0.23	0.05	16	20	19.1	14.1
BD 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
BD 2	39.9	38.2	34.1	38.4	26	22.7	5.4	5.8	4.26	1.33	0.29	0.06	23	33	17.6	14.4
BD 3	27.8	24.2	27.8	37	44.4	38.8	4.6	5	2.62	0.57	0.21	0.04	12	11	20.1	13.8
BE	36.4	41.7	37.2	32.1	26.4	26.3	6.9	7.1	1.07	0.51	0.18	0.04	88	88	20.7	19.9
BE 1	84.5	78.3	6.1	7.6	10.4	15.4	6.7	6.6	0.2	0.2	-1	-1	65	66	8.9	12.5

Where and why we need RS data in puts?

	sand % topsoil	sand % subsoil	silt % topsoil	silt % subsoil	clay % topsoil	clay % subsoil	pH2O topsoil	pH2O subsoil	OC % topsoil	OC % subsoil	N % topsoil	N % subsoil	BS % topsoil	BS % subsoil	CEC topsoil	CEC subsoil
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AF	61.7	52.5	14.4	12.9	23.9	34.6	5.4	5.3	0.91	0.34	0.12	0.06	43	34	7.8	6.9
AF 1	81.1	75.5	8.7	8.9	10.2	15.6	5.7	5.5	0.35	0.2	0.07	0.03	47	43	4.4	4.6
AF 2	61.7	44.5	14.3	10.8	24	44.7	5.1	5.2	1.05	0.37	0.11	0.03	37	28	9.6	7.2
AF 3	21.3	13.1	25.7	24.4	52.9	62.3	5	4.9	1.85	0.58	0.15	0.1	42	23	12.5	11.1
AG	40.9	36.8	27.2	29.7	32.1	33.4	5.1	4.9	2.26	0.34	0.11	0.03	22	16	11.2	9.8
AG 1	89.3	72.5	7.2	9.5	3.5	17.9	5.5	5.1	-1	-1	0.02	-1	55	34	1.2	2.5
AG 2	9.6	15.8	75.2	64.7	15.3	19.6	4.4	4.2	3.07	0.25	0.14	0.03	8	15	12.5	11.8
AG 3	35.2	32	17.9	24.8	47.2	43.2	5.2	5.1	1.99	0.38	0.18	-1	16	11	14.1	11.6
AH	31.3	27.1	24.8	25.1	43.8	47.8	5	5.4	3.34	1.49	0.29	0.14	20	16	18	17.9
AH 1	72.8	71.9	14.6	10.6	12.6	17.4	5	5	1.58	0.9	0.28	0.12	6	5	28.4	28
AH 2	52.4	45.4	27.9	33	19.6	21.5	5.1	5.7	4.46	1.95	0.36	0.17	4	6	7.3	1.9
AH 3	9.2	7.4	26.1	22.2	64.8	70.4	5	5.3	2.88	1.25	0.25	0.13	27	21	18.1	19.4
AO	53.6	43.4	15.8	16	30.6	40.6	5.1	5.2	2.25	0.75	0.18	0.07	39	32	7.6	7.5
AO 1	82.3	68.1	8.6	11.4	9.2	20.5	5	5.1	0.3	0.21	0.06	0.02	41	41	4.1	5.4
AO 2	51	41.3	21.6	17.2	27.4	41.5	5.3	5	1.73	0.73	0.13	0.08	53	34	7.7	7.8
AO 3	33	28.9	14.2	15.5	52.9	55.6	5.2	5.4	1.84	0.89	0.12	0.07	31	28	8.6	6.8
AP	57	46.2	15.6	17.1	27.1	36.8	5.3	5	1.09	0.26	0.09	0.03	31	17	6	5.7
AP 1	80	65.1	12	14.6	7.8	20.3	5.6	5	0.69	0.2	0.05	0.02	40	19	3	3.2
AP 2	58.7	45.4	16.3	17.4	25	37.1	5.8	5.6	0.87	-1	0.07	-1	28	20	6	6.8
AP 3	10.4	8.8	22.7	22	66.7	69.6	4.5	4.6	2.91	0.49	0.23	0.05	17	13	12.1	10.2
B	60.4	60	17	16.6	22.5	23.4	6.9	7.2	1.17	0.57	0.25	0.12	79	80	14.2	12.7
BC	40.1	41.8	21.5	22.7	38.4	35.5	5.7	5.8	1.44	0.74	0.17	0.09	67	68	15.7	18.9
BC 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
BC 2	56.7	56.8	23.6	20.6	19.8	22.5	5.8	5.9	1.22	0.61	0.13	0.08	81	82	15.6	18.1
BC 3	15.3	19.3	18.5	25.7	66.3	55	5.6	5.6	1.77	0.93	0.24	0.12	47	48	15.9	20
BD	32.7	29.8	30.3	37.6	37.1	32.3	4.9	5.3	3.28	0.87	0.23	0.05	16	20	19.1	14.1
BD 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
BD 2	39.9	38.2	34.1	38.4	26	22.7	5.4	5.8	4.26	1.33	0.29	0.06	23	33	17.6	14.4
BD 3	27.8	24.2	27.8	37	44.4	38.8	4.6	5	2.62	0.57	0.21	0.04	12	11	20.1	13.8
BE	36.4	41.7	37.2	32.1	26.4	26.3	6.9	7.1	1.07	0.51	0.18	0.04	88	88	20.7	19.9
BE 1	84.5	78.3	6.1	7.6	10.4	15.4	6.7	6.6	0.2	0.2	-1	-1	65	66	8.9	12.5

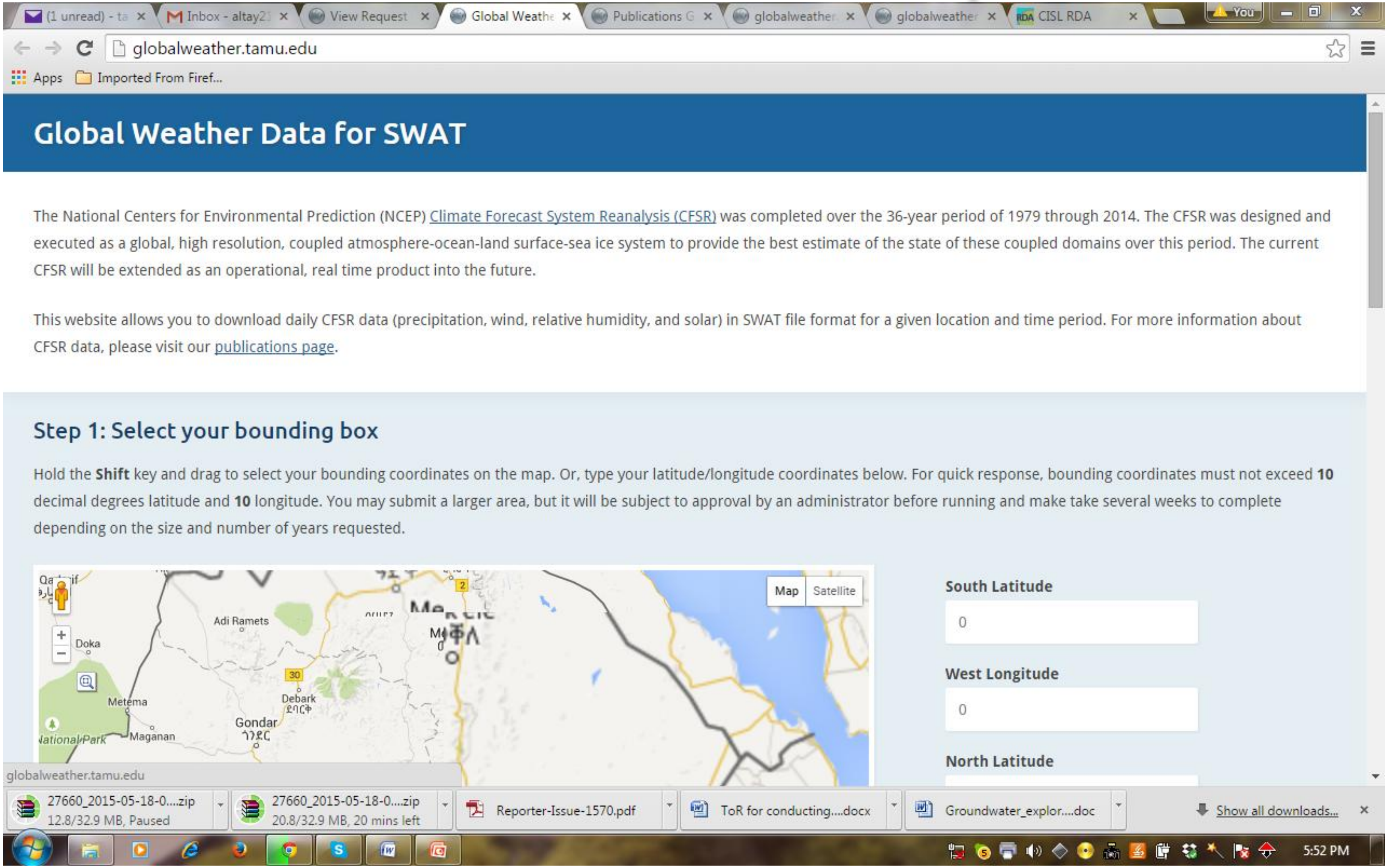
1	VALUE	COUNT	Abreviation	Red	Green	Blue
5	5	11164	5 = Ap - Plinthic Acrisols	204	113	67
6	6	65229	6 = Ao - Orthic Acrisols	224	148	110
7	8	3462	8 = To - Ochric Andosols	38	73	97
8	9	2522	9 = Th - Humic Andosols	60	99	125
9	10	1176	10 = Tm - Mollic Andosols	86	136	163
10	11	8221	11 = Tv - Vitric Andosols	109	144	163
11	13	2672	13 = Qa - Albic Arenosols	232	123	123
12	14	37523	14 = Qc - Cambic Arenosols	255	161	161
13	15	34739	15 = Qf - Ferralic Arenosols	255	190	190
14	16	9760	16 = Ql - Luvic Arenosols	255	222	222
15	17	6835	17 = E - RENDZINAS	166	143	96
16	18	3068	18 = C - CHERNOZEMS	128	107	66
17	19	1361	19 = Cg - Glossic Chernozems	115	92	47
18	20	18335	20 = Ch - Haplic Chernozems	115	76	0
19	21	5540	21 = Ck - Calcic Chernozems	105	86	48
20	22	12012	22 = Cl - Luvic Chernozems	97	84	59
21	23	1728	23 = X - XEROSOLS	138	138	0
22	24	14288	24 = Xh - Haplic Xerosols	168	168	0
23	25	31631	25 = Xk - Calcic Xerosols	176	176	97
24	26	15808	26 = Xl - Luvic Xerosols	199	199	117
25	27	793	27 = Xy - Gypsic Xerosols	204	204	133
26	29	9549	29 = Bc - Chromic Cambisols	115	50	15
27	30	35086	30 = Bd - Dystric Cambisols	115	63	34
28	31	39807	31 = Be - Eutric Cambisols	115	72	34
29	32	3942	32 = Bg - Gleyic Cambisols	115	85	40
30	33	2840	33 = Bf - Ferralic Cambisols	161	117	117
31	34	7092	34 = Bh - Humic Cambisols	140	86	86
32	35	11573	35 = Bk - Calcic Cambisols	115	69	69
33	36	3003	36 = Bv - Vertic Cambisols	115	41	41
34	37	65391	37 = Bx - Gelic Cambisols	115	0	0
35	38	1414	38 = J - FLUVISOLS	0	168	132
36	39	11728	39 = Jc - Calcaric Fluvisols	38	191	158
37	40	8325	40 = Jd - Dystric Fluvisols	0	230	169
38	41	26541	41 = Je - Eutric Fluvisols	135	230	204

Climate Parameters- CFSR

- **Hourly data Climate Forecast System Reanalysis (CFSR) is available since 1979 to June, 2014)**
  - Ground, upper air balloon, aircraft and satellite observation are assimilated in this estimate
  - High horizontal resolution ~ 47km @ the equator
  - Provide many variables
    - Maximum temperature
    - Minimum temperature
    - Precipitation
    - Wind speed
    - Relative humidity and
    - Solar radiation

Climate Parameters- CFSR

Data acquisition



Step 1: Select your bounding box

Hold the **Shift** key and drag to select your bounding coordinates on the map. Or, type your latitude/longitude coordinates below. For quick response, bounding coordinates must not exceed **10** decimal degrees latitude and **10** longitude. You may submit a larger area, but it will be subject to approval by an administrator before running and make take several weeks to complete depending on the size and number of years requested.

South Latitude

0

West Longitude

0

North Latitude

0

East Longitude

0

Step 2: Define your time period for collecting data

Please select a start date no earlier than **1/1/1979** and an end date no later than **7/31/2014**.

Start Date

01/01/1979

End Date

07/31/2014

Starting Hour of Day

Hourly data is stored in the database and aggregated to daily based on the starting hour defined below.
For example, if you select 6:00 AM, your day on Jan. 1 is defined from this time until 6:00 AM the following day.

12:00 AM

Step 3: Select what data to collect

- ☑ Temperature (°C)
- ☑ Precipitation (mm)
- ☑ Wind (m/s)
- ☑ Relative Humidity (fraction)
- ☑ Solar (MJ/m^2)

Step 4: How should we deliver your data?

Depending on the size of your region, it may take several hours to compile your data.
We will email you with a link to download a zip file containing your data when it is complete.

Email Address

Confirm Email Address

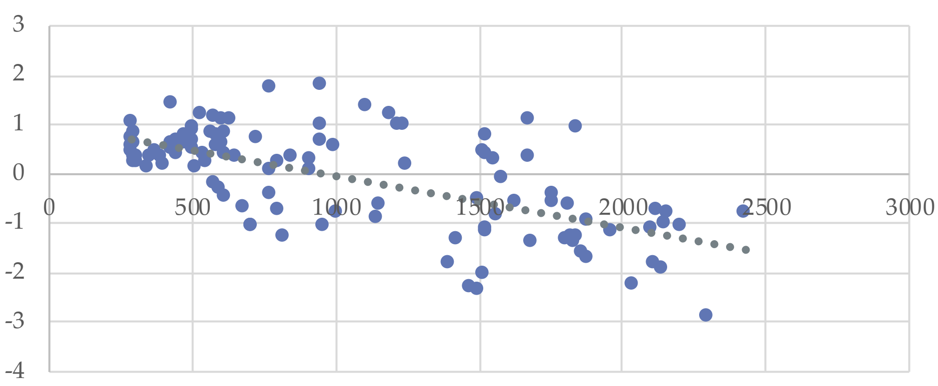
- ☑ **Generate SWAT Files**
- ☑ **Generate CSV File**

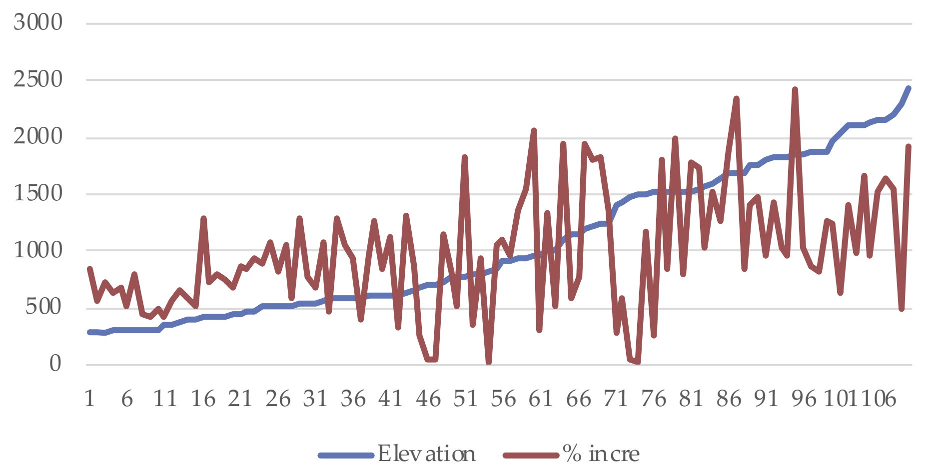
SUBMIT REQUEST

Climate Parameters- CFSR…

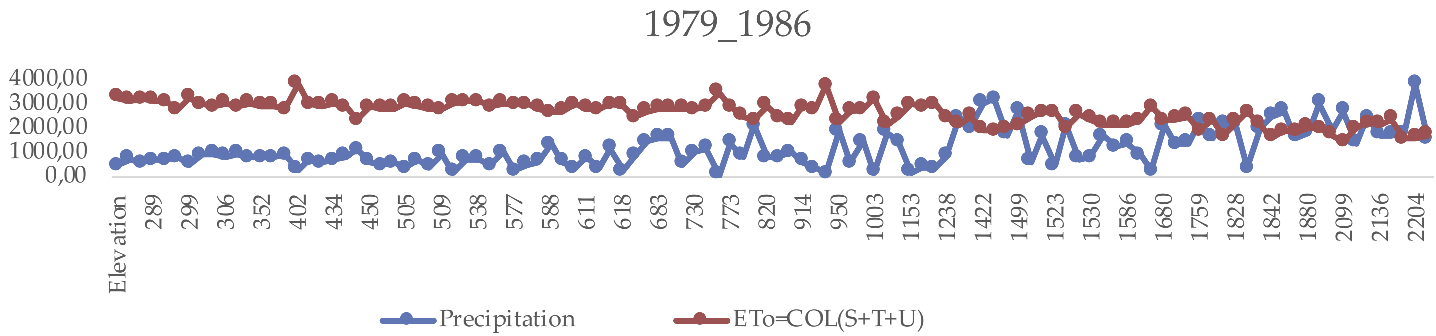
Checking data quality

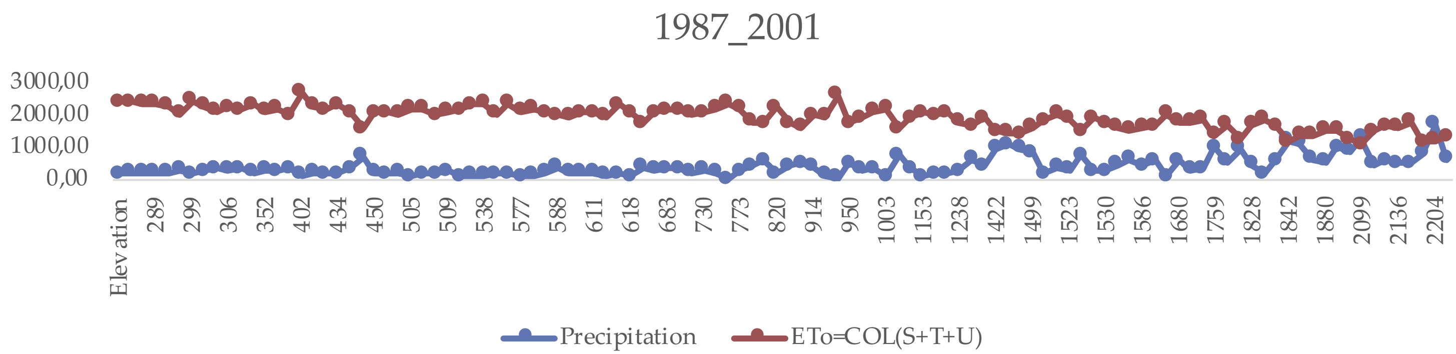
- **Model parameters**
  - **High PET values**
    - **Net vs total radiation ?**
    - **No bias corrected data for eth.?**

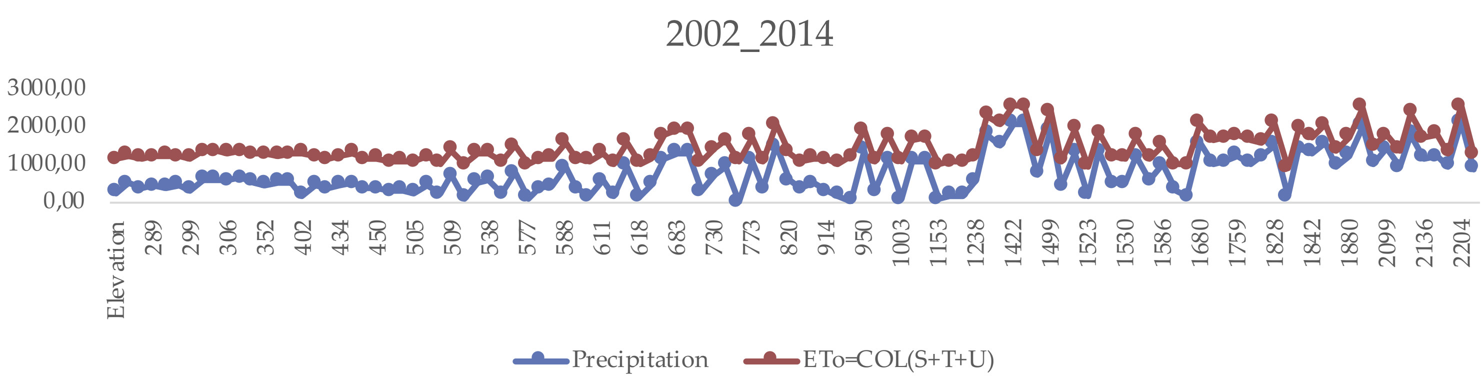




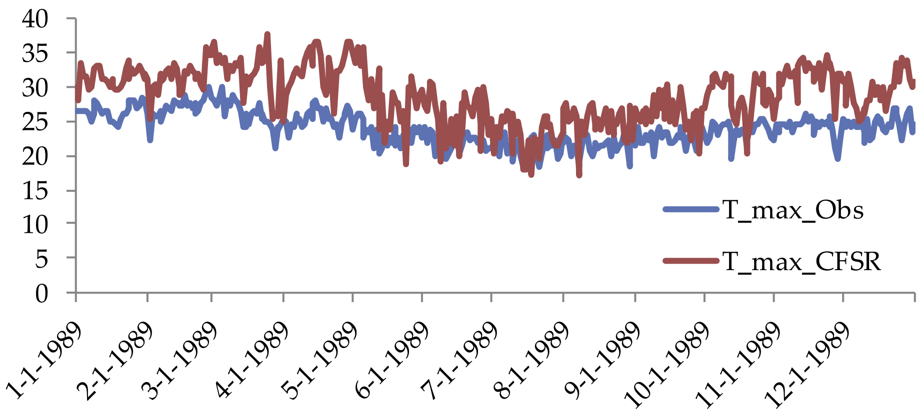
Climate model vs Altitude

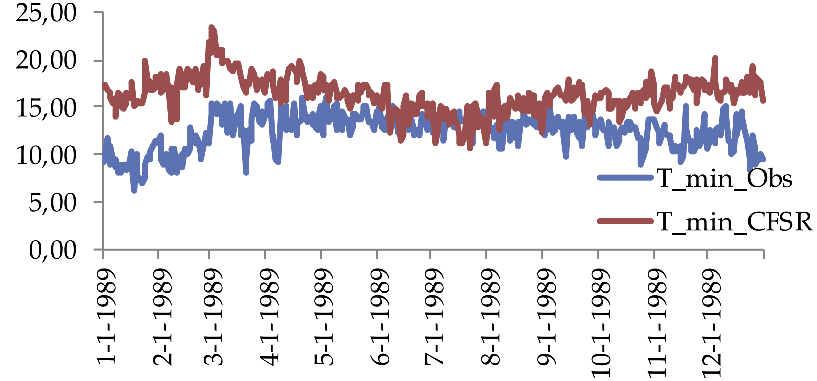


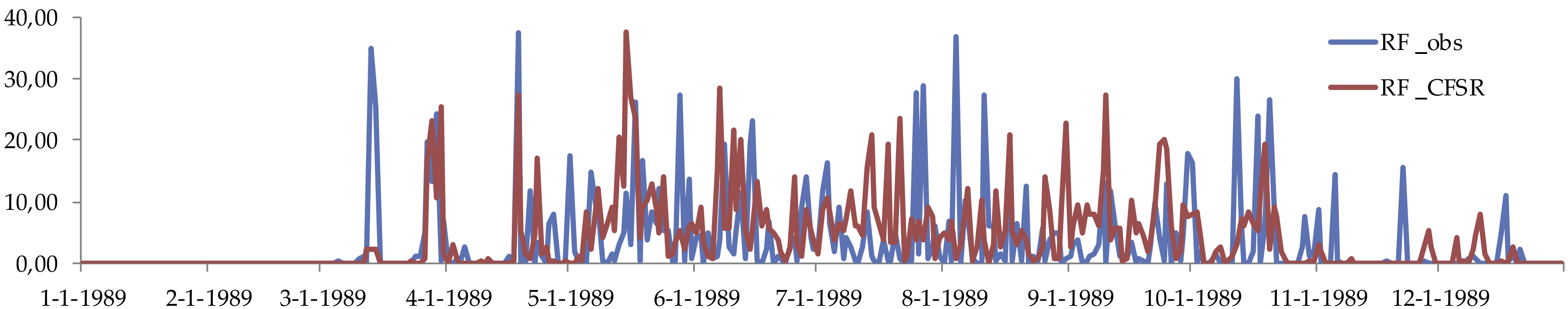




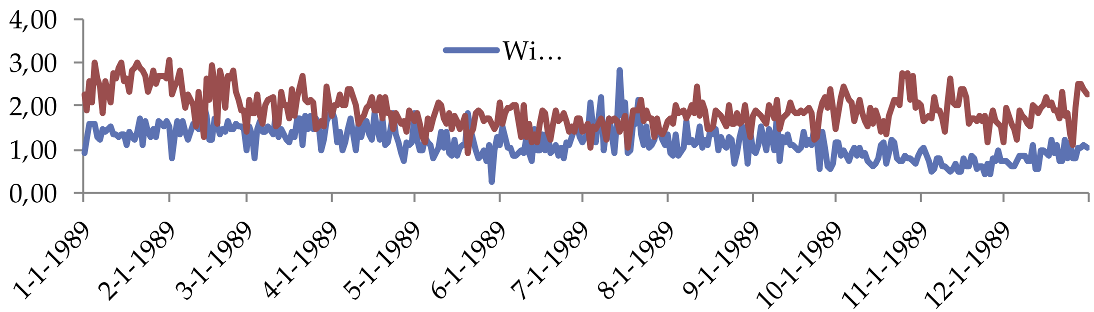
PPT vs PET vs Altitude







* Dembi Dolo Station



Observed vs CFSR

Climate Parameters- CFSR…

Checking data quality

Station	T_max_CFSR	T_min_CFSR	RF _CFSR	Wind _CFSR	RH_CFSR	S.S.H_CFSR
Dembidolo_1989	4.82	3.91	0.72	0.74		
Abobo _1980	1.95	5.53	-1.71			
Gambella 2008	-1.67	-0.77	0.55	1.58	6.80	14.20
Metu	0.13	1.70	-0.27		1.74	

Obs. Vs CFSR

Hydrological Inputs- data preparation

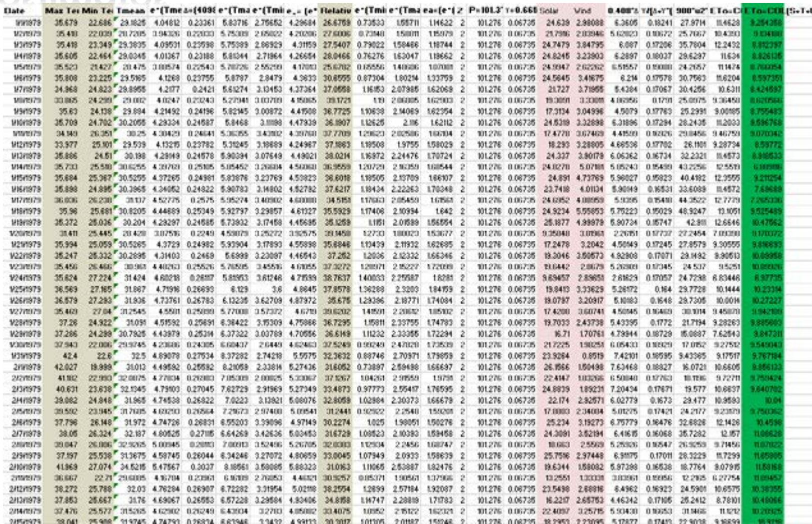
Date	Longitude	Latitude	Elevation	Max Temp	Min Temp	Precipita	Wind	Relative H	Solar	ETo=COL(S
1/1/1979	35	5.464	611	31.383	19.783	0	2.735787	0.290037	23.72215	9.710326
1/2/1979	35	5.464	611	31	16.985	0	2.668442	0.320819	25.29653	8.026906
1/3/1979	35	5.464	611	30.758	17.235	0	3.296837	0.32758	25.39254	8.966562
1/4/1979	35	5.464	611	31.321	17.651	0	3.237821	0.344166	25.41156	9.286115
1/5/1979	35	5.464	611	31.406	16.013	0	2.740741	0.311086	25.47776	10.13427
1/6/1979	35	5.464	611	31.288	17.745	0	3.076374	0.385202	25.19365	10.08871
1/7/1979	35	5.464	611	30.173	18.478	0	3.462471	0.492735	22.95287	8.676521
1/8/1979	35	5.464	611	30.885	18.203	0	2.763151	0.494266	20.98727	7.716868
1/9/1979	35	5.464	611	31.145	18.753	0	3.064657	0.460182	25.10364	7.93713
1/10/1979	35	5.464	611	31.367	17.933	0	2.844268	0.461025	25.18954	9.684293
1/11/1979	35	5.464	611	30.516	19.572	0	3.370039	0.469463	21.72134	9.436641
1/12/1979	35	5.464	611	31.189	19.502	0	3.679965	0.467845	21.31138	8.709952
1/13/1979	35	5.464	611	31.021	19.003	0.73128	4.446189	0.514871	24.35187	7.881042
1/14/1979	35	5.464	611	30.513	19.377	0.4137	4.737021	0.519585	25.24224	8.701655
1/15/1979	35	5.464	611	30.958	18.486	0	3.649688	0.504547	25.35379	7.826445
1/16/1979	35	5.464	611	30.241	19.075	0	3.323296	0.500077	22.87125	8.427795
1/17/1979	35	5.464	611	31.525	18.784	0	3.709304	0.474055	23.8923	9.145345
1/18/1979	35	5.464	611	31.332	19.703	0	4.939034	0.466442	25.58053	8.969924
1/19/1979	35	5.464	611	30.911	18.819	0	4.438907	0.469934	25.81695	8.613946
1/20/1979	35	5.464	611	30.359	19.226	0	2.567966	0.47894	16.73443	7.997378
1/21/1979	35	5.464	611	32.499	18.324	0	2.887463	0.438824	25.69894	9.227998
1/22/1979	35	5.464	611	33.033	19.758	0.02747	2.553209	0.484182	17.89829	9.600792
1/23/1979	35	5.464	611	30.282	19.683	0	2.370437	0.509276	18.14467	8.587088
1/24/1979	35	5.464	611	31.495	19.24	1.48144	2.040861	0.538267	16.34974	8.422683
1/25/1979	35	5.464	611	30.849	20.599	0.23003	2.625281	0.472244	18.33857	8.813943
1/26/1979	35	5.464	611	33.453	22.683	0.81625	2.337977	0.471419	13.52818	8.958149
1/27/1979	35	5.464	611	29.926	19.662	0.06866	2.288558	0.548273	14.80168	9.071268
1/28/1979	35	5.464	611	33.146	20.268	0.17338	1.834961	0.461287	20.82459	9.512069
1/29/1979	35	5.464	611	31.482	22.116	0.89436	1.387491	0.461033	13.41968	9.450799
1/30/1979	35	5.464	611	30.931	21.35	0.79308	1.763124	0.492289	19.95058	9.182311
1/31/1979	35	5.464	611	31.531	19.831	0.37422	1.451384	0.480827	17.12666	7.153163
2/1/1979	35	5.464	611	30.447	19.243	3.84693	1.757523	0.563054	14.6421	7.309069
2/2/1979	35	5.464	611	29.89	19.903	0.96302	2.176204	0.509777	15.95351	7.49382
2/3/1979	35	5.464	611	32.502	19.775	0	2.364039	0.454603	17.58809	8.599167

427	1	Longitude	Latitude	Elevation	Max Temp	Min Temp	Precipitati	ETo=COL(S+	Wind	Relative H	Solar
2		35	5.464	611	31.2232	19.1561	6.00386	273.9181	2.97718	0.45519	21.7318
33	32	35	5.464	611	32.4336	21.3156	23.0644	262.3806	2.60436	0.43303	17.7426

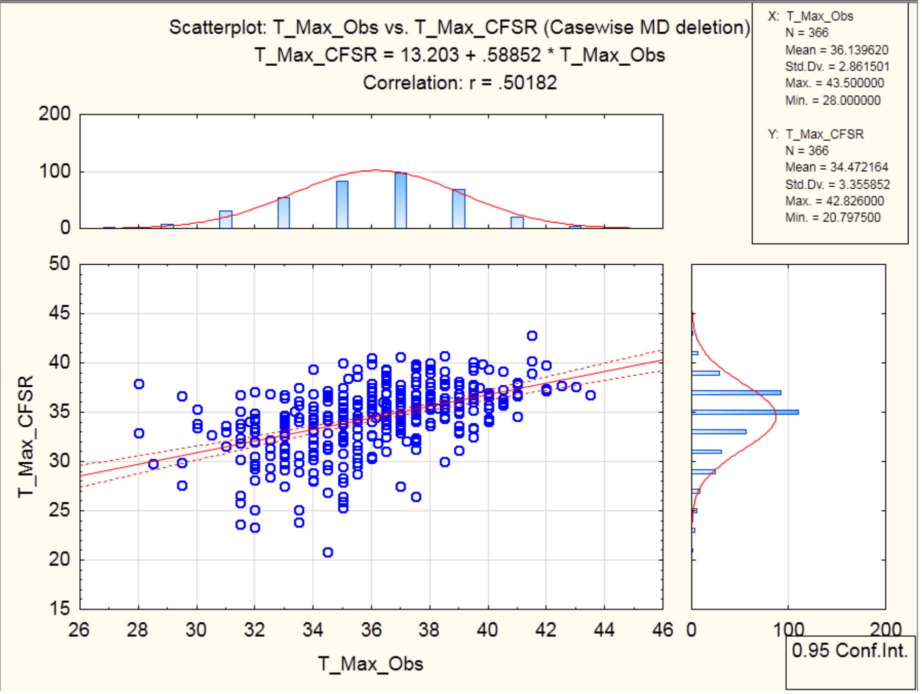
Date	Date	Date
1/1/1979	1/1/1979	6/1/1979
2/1/1979	2/1/1979	7/1/1979
3/1/1979	3/1/1979	8/1/1979
4/1/1979	4/1/1979	9/1/1979
5/1/1979	5/1/1979	6/1/1980
6/1/1979	10/1/1979	7/1/1980
7/1/1979	11/1/1979	8/1/1980
8/1/1979	12/1/1979	9/1/1980
9/1/1979	1/1/1980	6/1/1981
10/1/1979	2/1/1980	7/1/1981
11/1/1979	3/1/1980	8/1/1981
12/1/1979	4/1/1980	9/1/1981
1/1/1980	5/1/1980	6/1/1982
2/1/1980	10/1/1980	7/1/1982
3/1/1980	11/1/1980	8/1/1982
4/1/1980	12/1/1980	9/1/1982
5/1/1980	1/1/1981	6/1/1983
6/1/1980	2/1/1981	7/1/1983
7/1/1980	3/1/1981	8/1/1983
8/1/1980	4/1/1981	9/1/1983
9/1/1980	5/1/1981	6/1/1984
10/1/1980	10/1/1981	7/1/1984
11/1/1980	11/1/1981	8/1/1984
12/1/1980	12/1/1981	9/1/1984
1/1/1981	1/1/1982	6/1/1985
2/1/1981	2/1/1982	7/1/1985
3/1/1981	3/1/1982	8/1/1985
4/1/1981	4/1/1982	9/1/1985
5/1/1981	5/1/1982	6/1/1986
6/1/1981	10/1/1982	7/1/1986
7/1/1981	11/1/1982	8/1/1986
8/1/1981	12/1/1982	9/1/1986
9/1/1981	1/1/1983	6/1/1987
10/1/1981	2/1/1983	7/1/1987

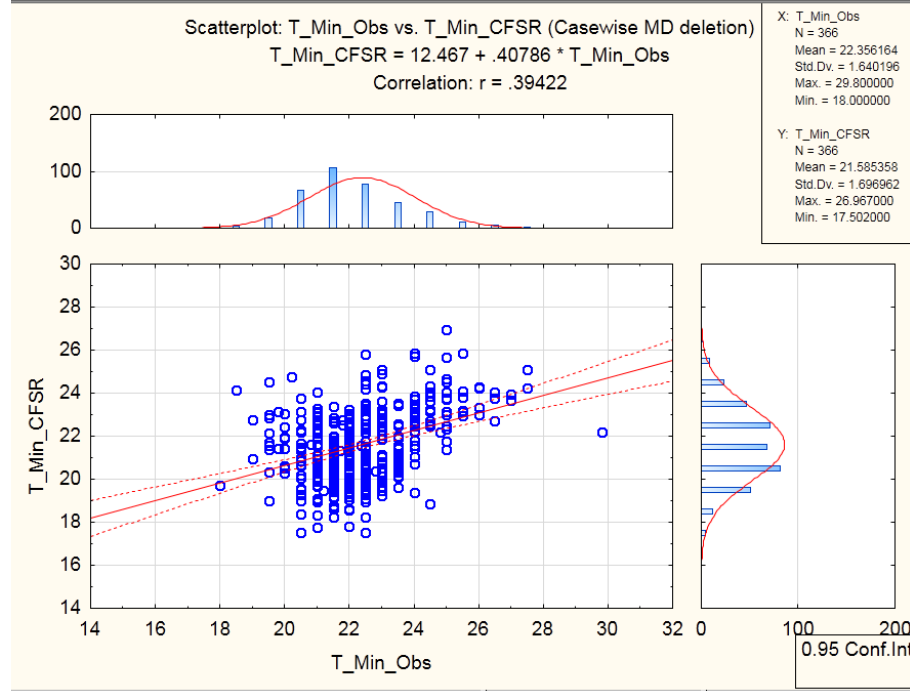
* Seasonal average for every grid
* from daily estimates

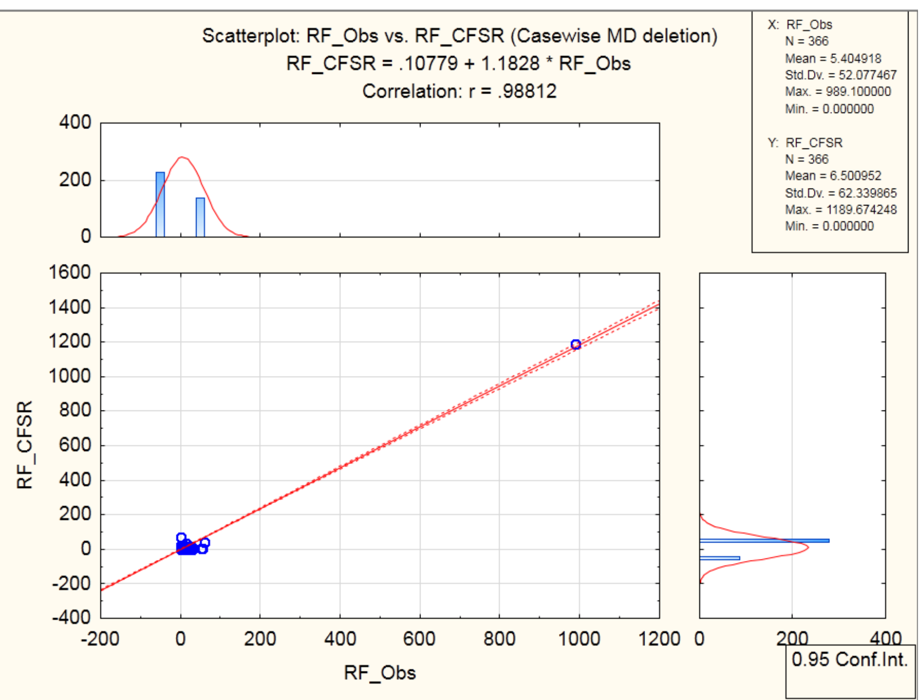
* Eto calculated using
* Penman-Monteith Equation



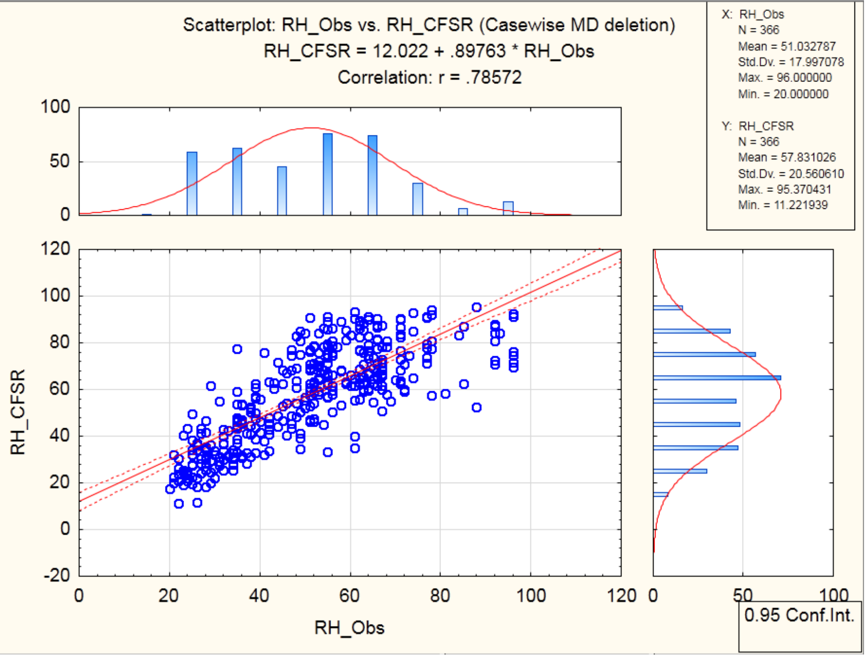
- Template developed in Excel

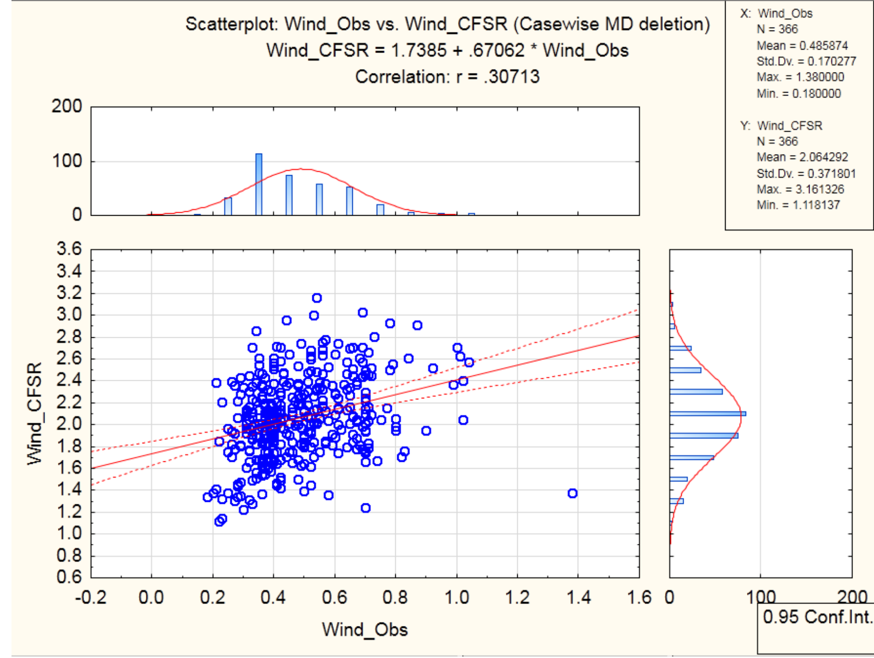


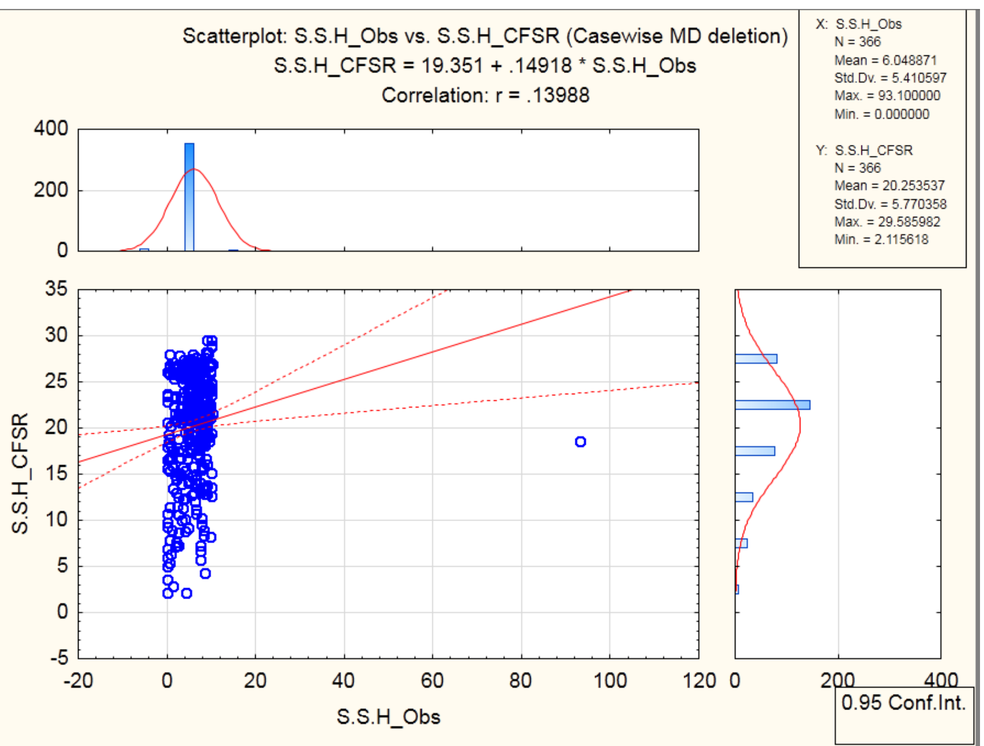




Daily, monthly estimates are poorly correlated, particularly for wind and temperature







* Correlation

RH
S.S.H
Wind

Bias correction

A second method called **"delta approach"** that corrects only the mean and which resulted in a better match was used by ***Geremew & Agizew, 2015***. The formulas used for temperature and rainfall bias correction are indicated in Equations 1 and 2. Corrections factors were computed for each month.

$$P_{bc} = P_p \times \bar{P}_o / \bar{P}_r$$

$$T_{bc} = T_p + \bar{T}_o - \bar{T}_r$$

Where,

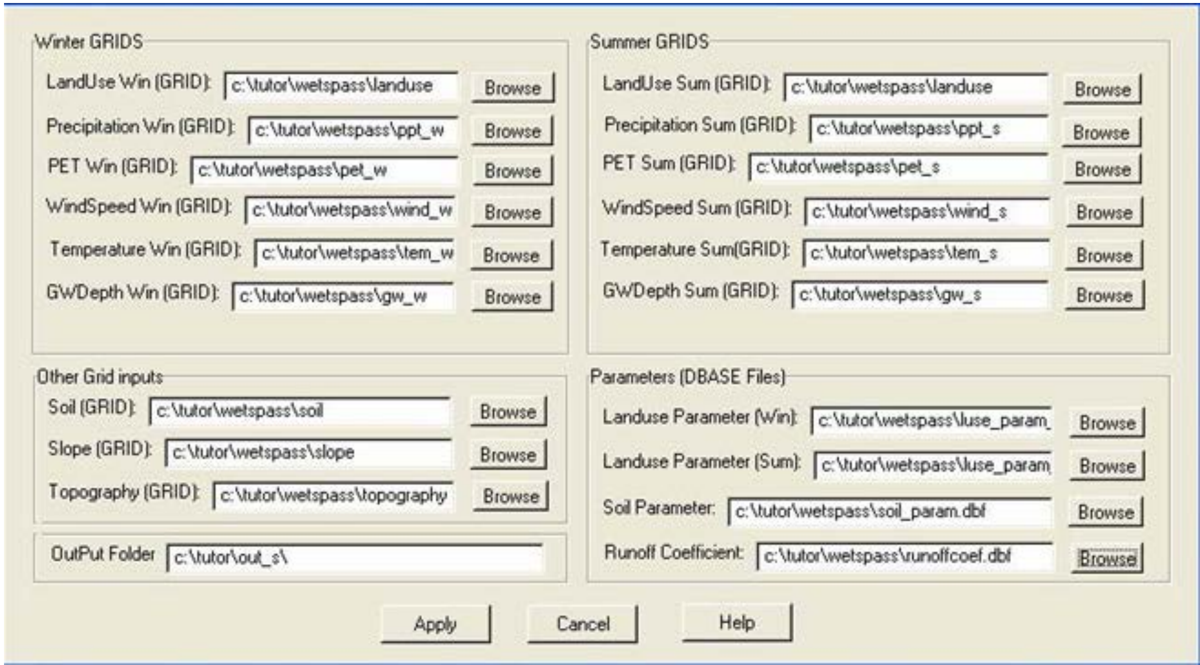
- ***Pbc*** **is Bias corrected future rainfall amount in mm;** ***Pp*** **is predicted future rainfall amount in mm;**
- ***Po*** **is mean of observed rainfall amount in mm;** ***Pr*** **is mean of computed historical rainfall during the observation period in mm.**
- ***Tbc*** **is Bias corrected future temperature in °C;**
- ***Tp*** **is predicted future temperature °C;**
- ***T o*** **is mean of observed temperature °C;**
- ***Tr*** **during the observed period in °C**

Modeling in WetSpass

- "WetSpass" an acronym for Water and Energy Transfer between Soil, Plants and Atmosphere under quasi Steady State,
- It is a GIS-based recharge estimation model by coupling surface-subsurface water balances (GIS) **(Bate- laan and De Smedt, 2001)**
- WetSpass is used for simulating yearly or seasonal averages of groundwater recharge, evapotranspiration (soil evaporation and transpiration also as separate outputs, runoff, and interception (O. and De Smedt, F., 2007)
- The groundwater recharge output from WetSpass is used as input for MODFLOW in a steady state or seasonal varying groundwater model
- The model has been applied satisfactorily in different areas in Belgium and in some parts of Ethiopia.
- The WetSpass model Batelaan, and its ArcView interface are freely available upon request)

Preparing input data …

- Parameters- provided by the Model developers but need revisit to when applying outside temperate zones
  - Landuse/Landcover parameters for *Bega* and *Kiremit*
  - Soil coefficient
  - Runoff coefficient



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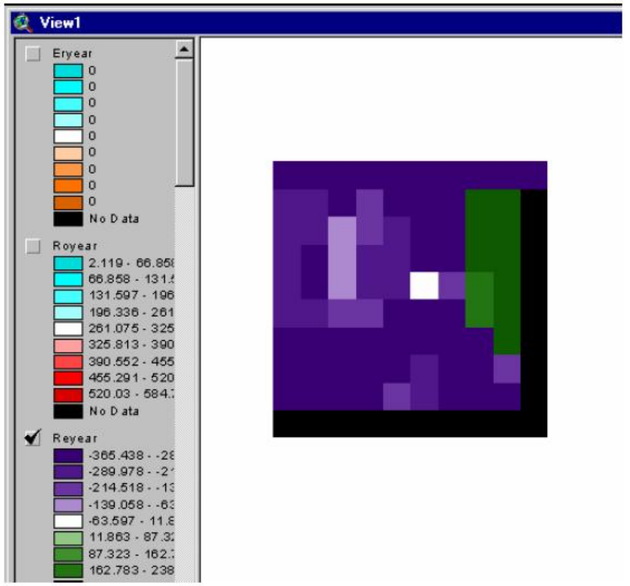
Model Outputs

WetSpass produces output files with results for winter, summer and year average periods.

- **Grid output names start with:**
- **recharge**
- **Run-off**
- **Soil evaporation**
- **Transpiration (vegetation)**
- **Interception**
- **Total evapotranspiration**



Winter	Summer	Year	Explanation
• **Ro**winter	• **Ro**summer	• **Ro**year	winter, summer and yearly **R**un**o**ff
• **Et**winter	• **Et**summer	• **Et**year	winter, summer and yearly **E**vapo**t**ranspiration
• **In**winter	• **In**summer	• **In**year	winter, summer and yearly **In**terception
• **Tr**winter	• **Tr**summer	• **Tr**year	winter, summer and yearly **Tr**anspiration
• **Se**winter	• **Se**summer	• **Se**year	winter, summer and yearly **S**oil **e**vaporation
• **Re**winter	• **Re**summer	• **Re**year	winter, summer and yearly **Re**charge
• **Er**winter	• **Er**summer	• **Er**year	winter, summer and yearly **Er**ror in water

•

Process Flow in WeSpass _MODFLOW Model

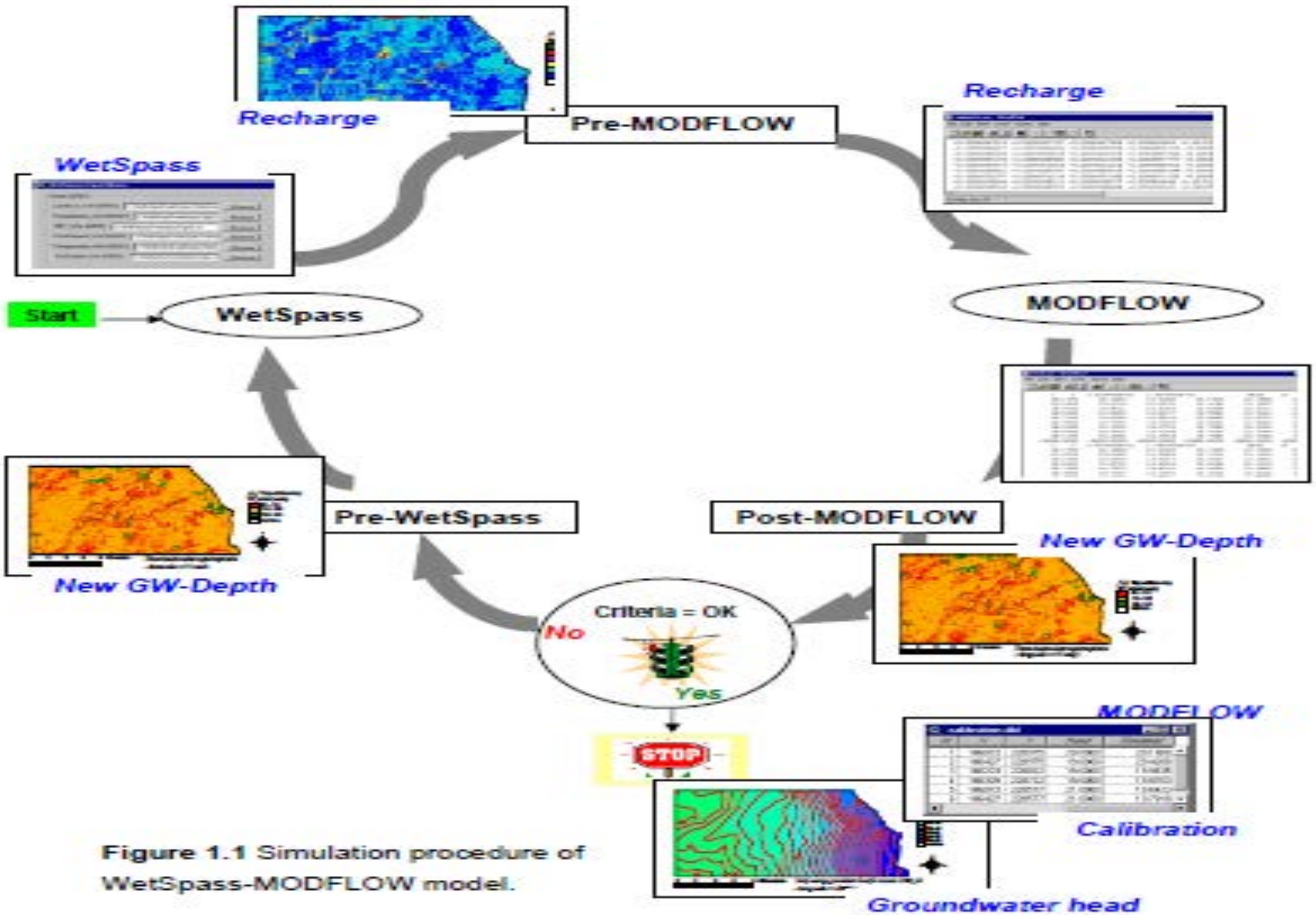


Figure 1.1 Simulation procedure of WetSpass-MODFLOW model.

0. Batelaan and S.T. Woldeamlak, 2007

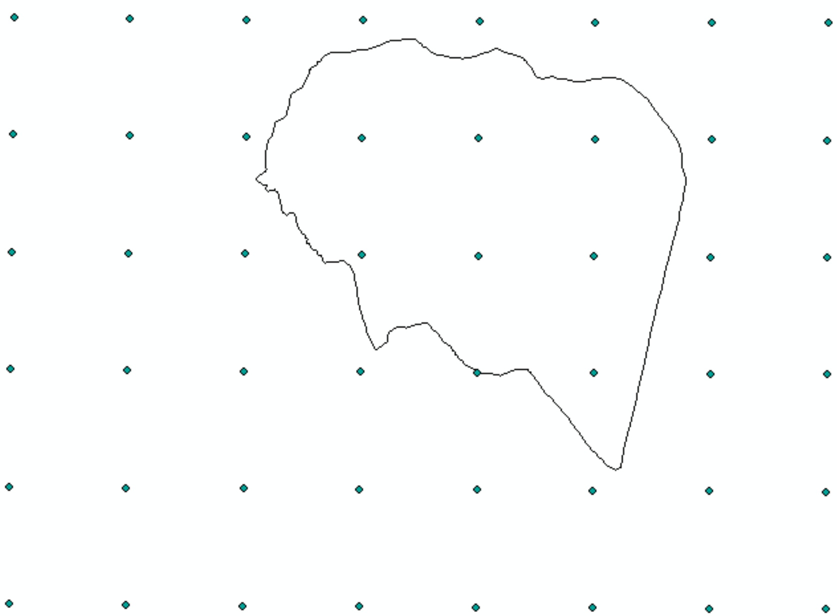
Defining Soil Erosion Hazard

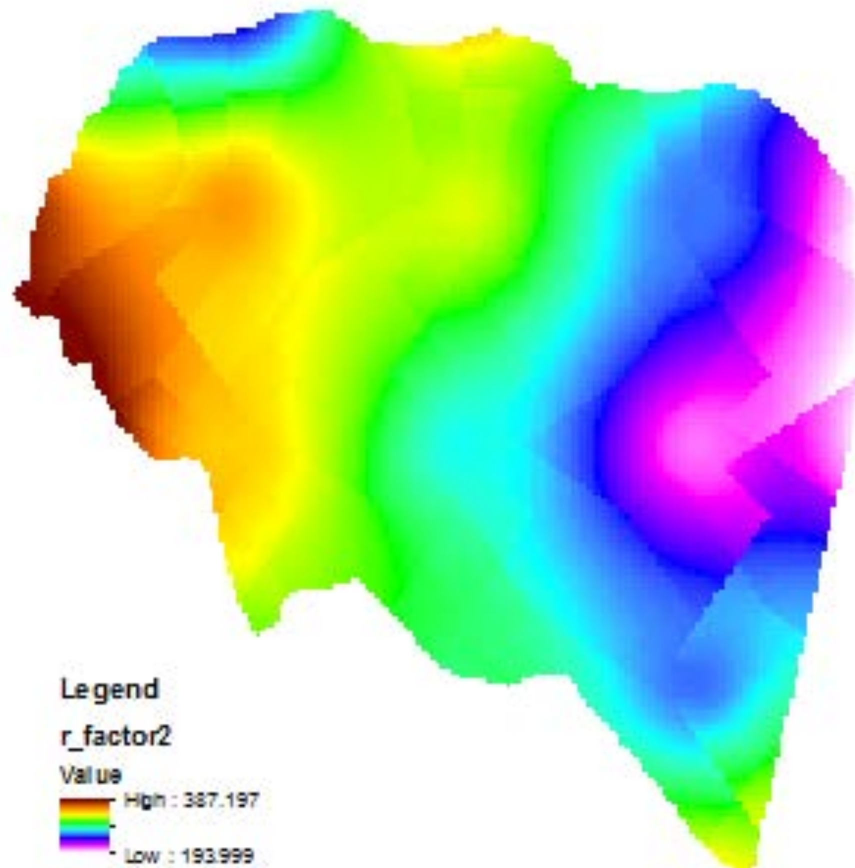
The Revised Universal Soil Loss Equation (RUSLE) was used in developing the conservation plan and land use decisions, which further, helps to estimate the potential soil loss of the study. Mathematically the equation is denoted as:

$$A \text{ (tons/ha/year)} = R * K * L * S * C * P$$

Where A is the mean annual soil loss, R is the rainfall erosivity factor, K is the soil erodability factor, L is the slope length factor, S is the slope steepness factor, C is the crop management factor and P is the erosion control practice or land management factor.

Rainfall- observed or from bias corrected CFSR data





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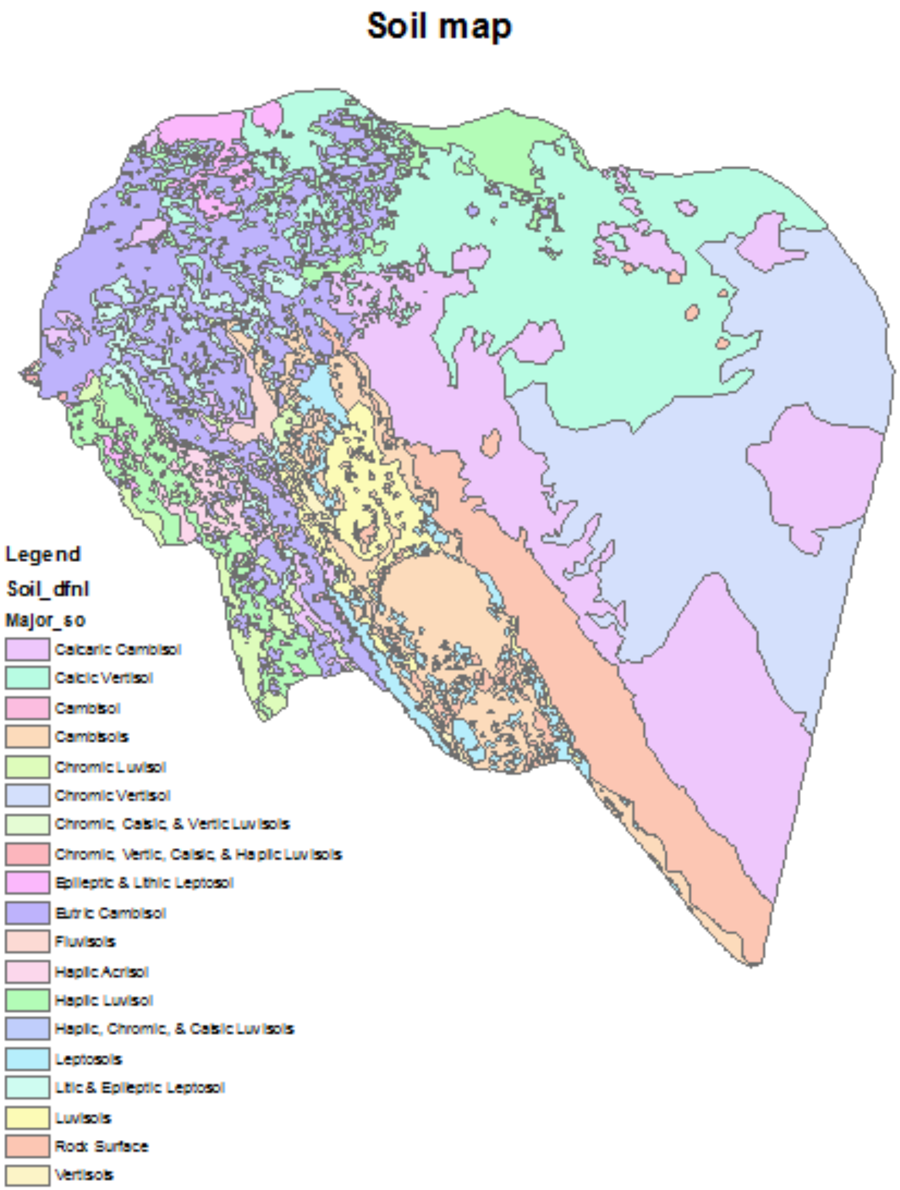
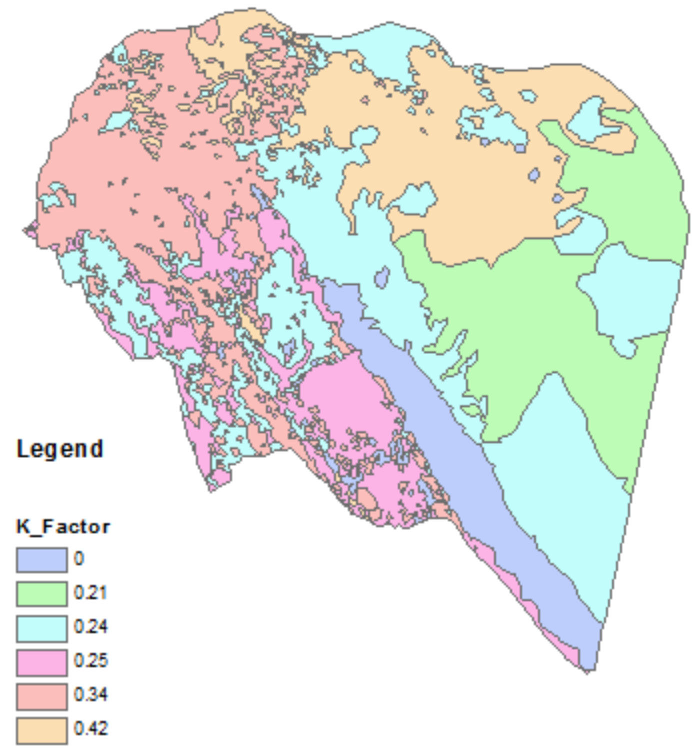
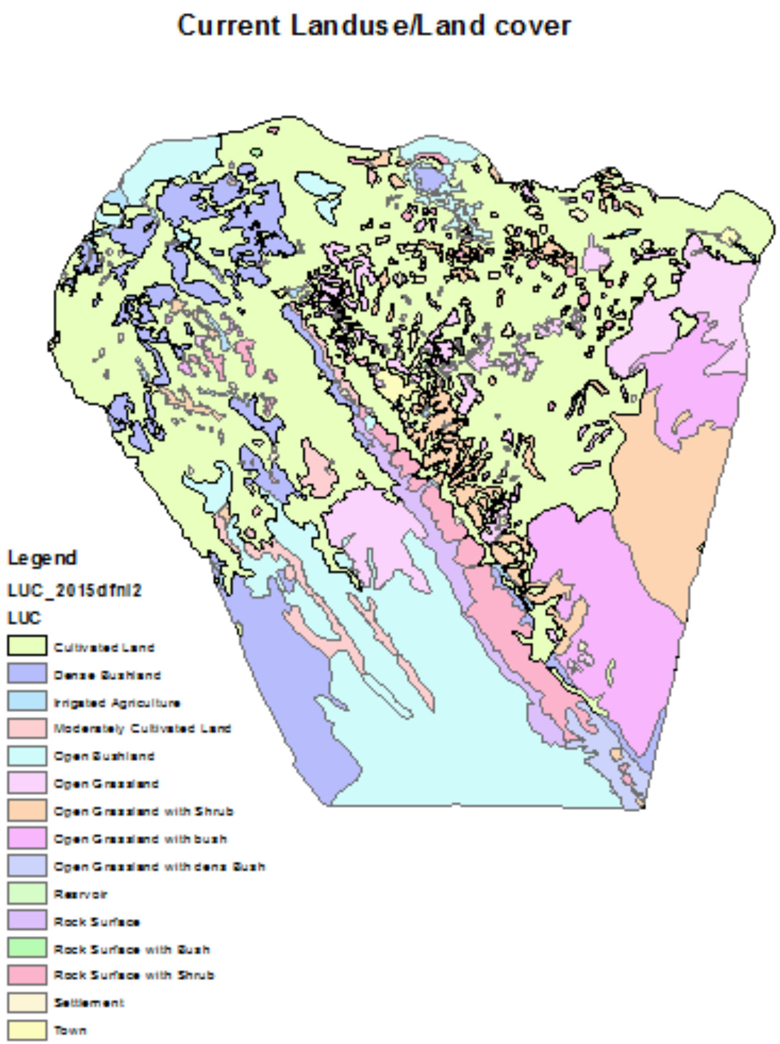
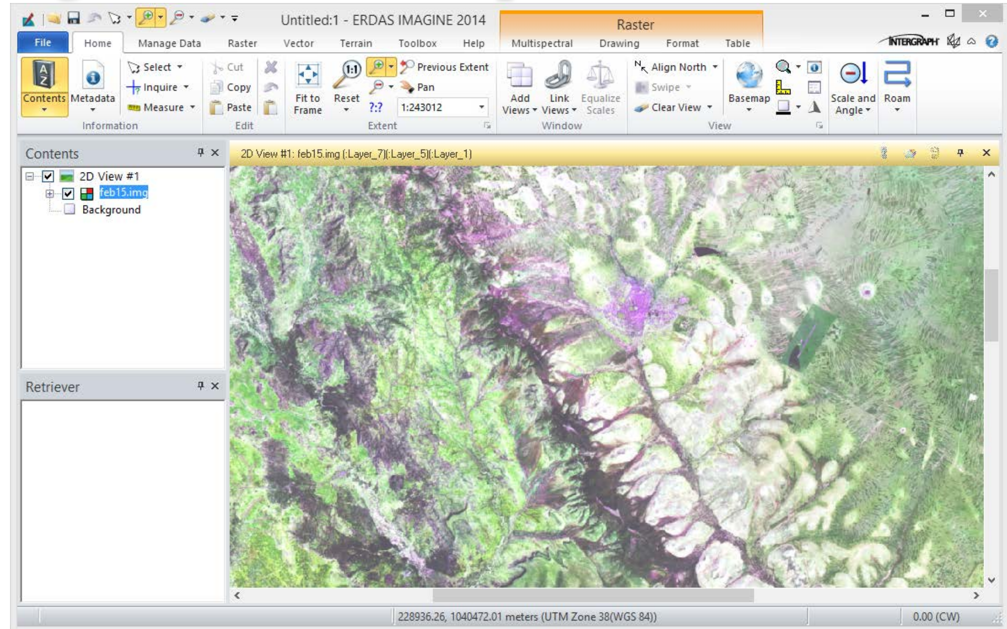
Updated soil map

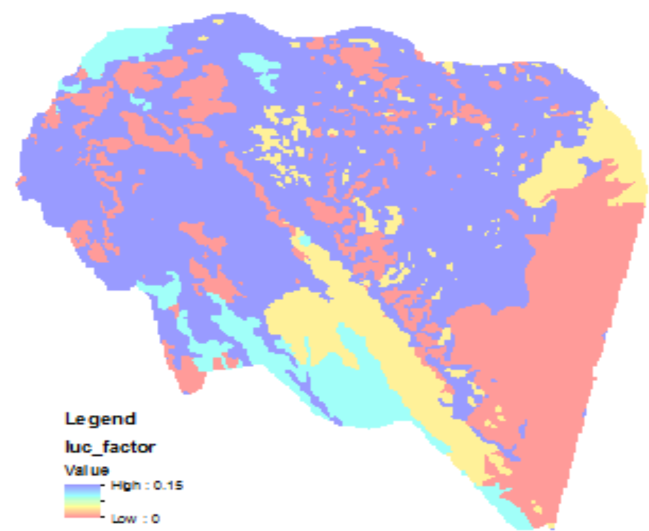




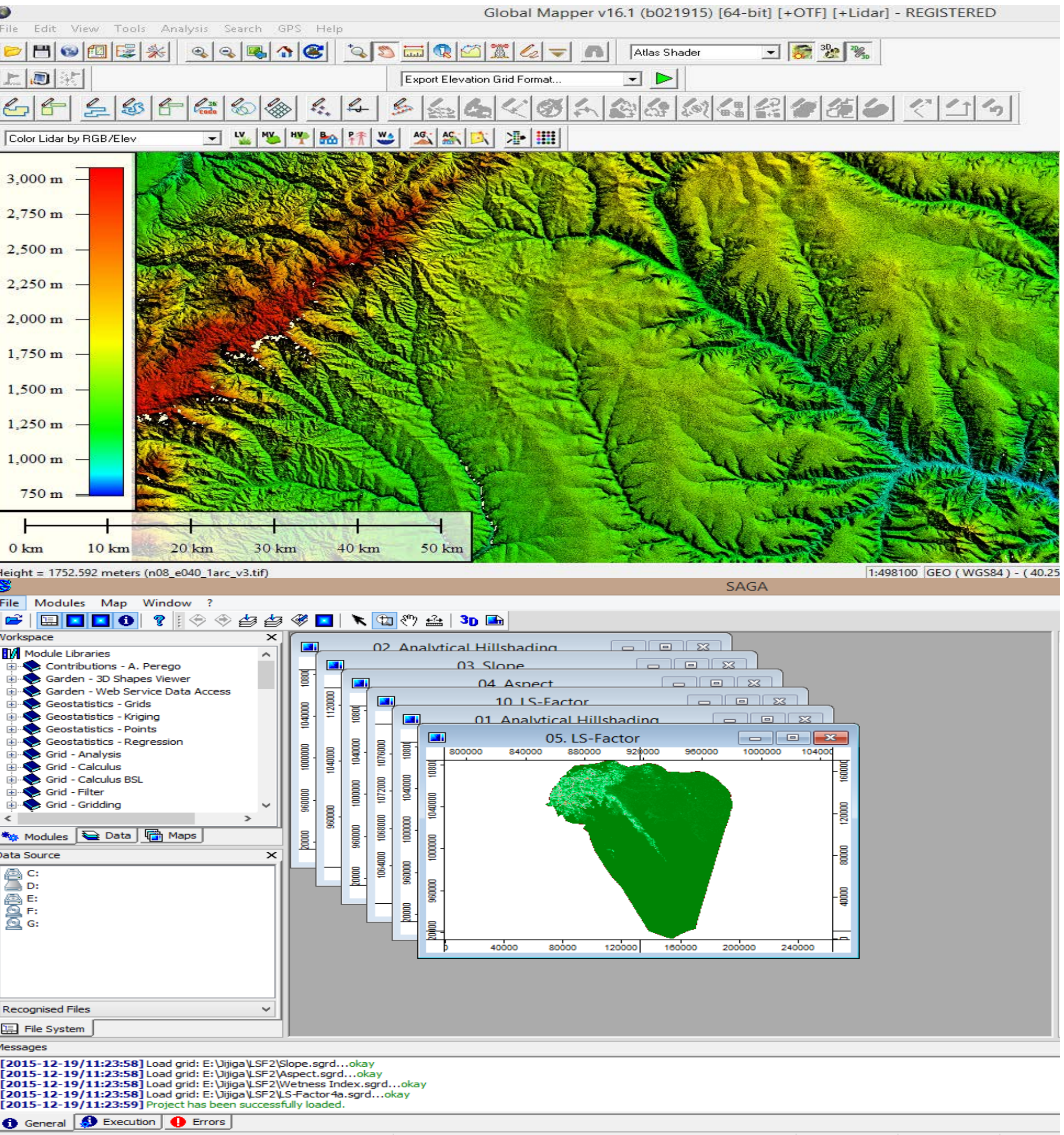
LUC from current images- Landsat 8/planet labs

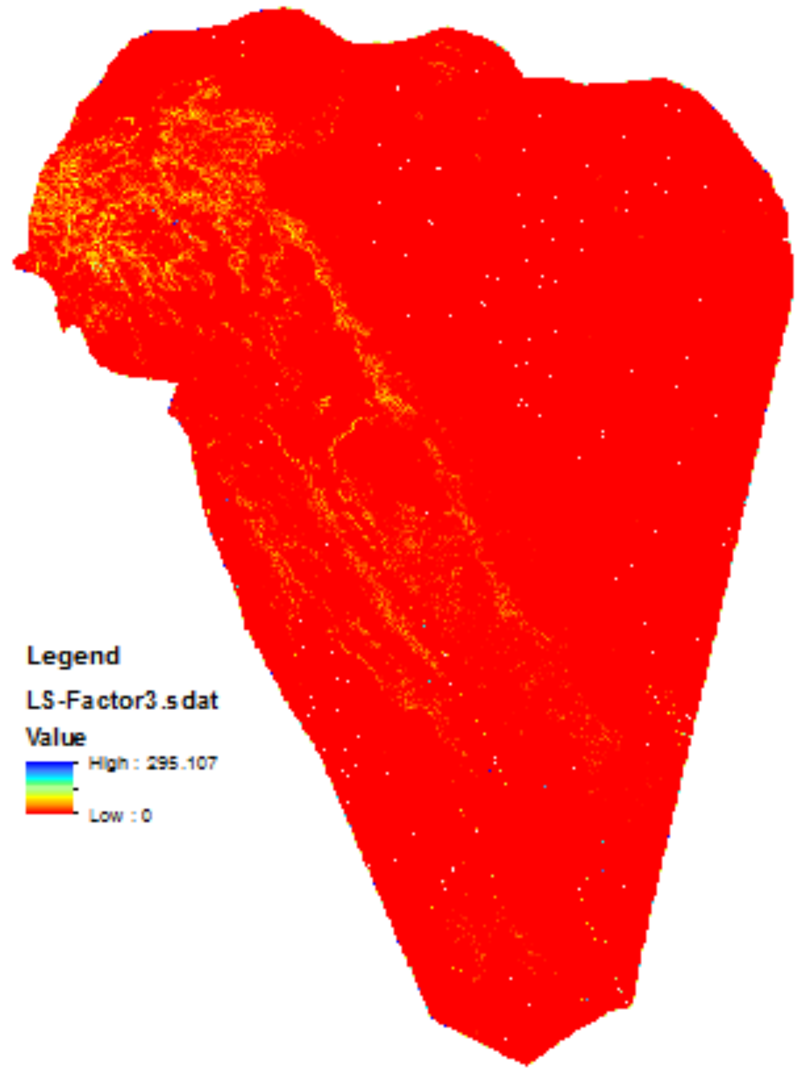




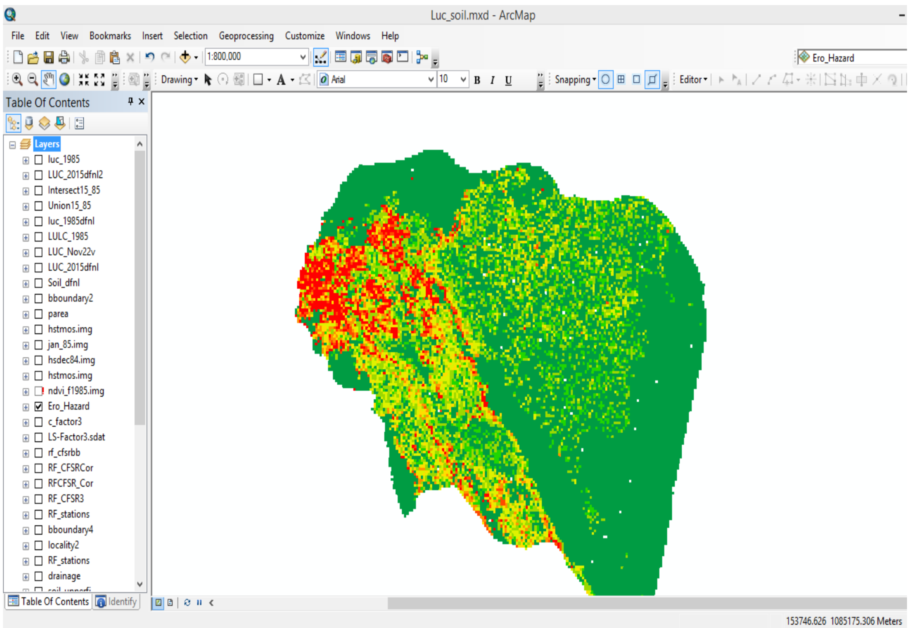


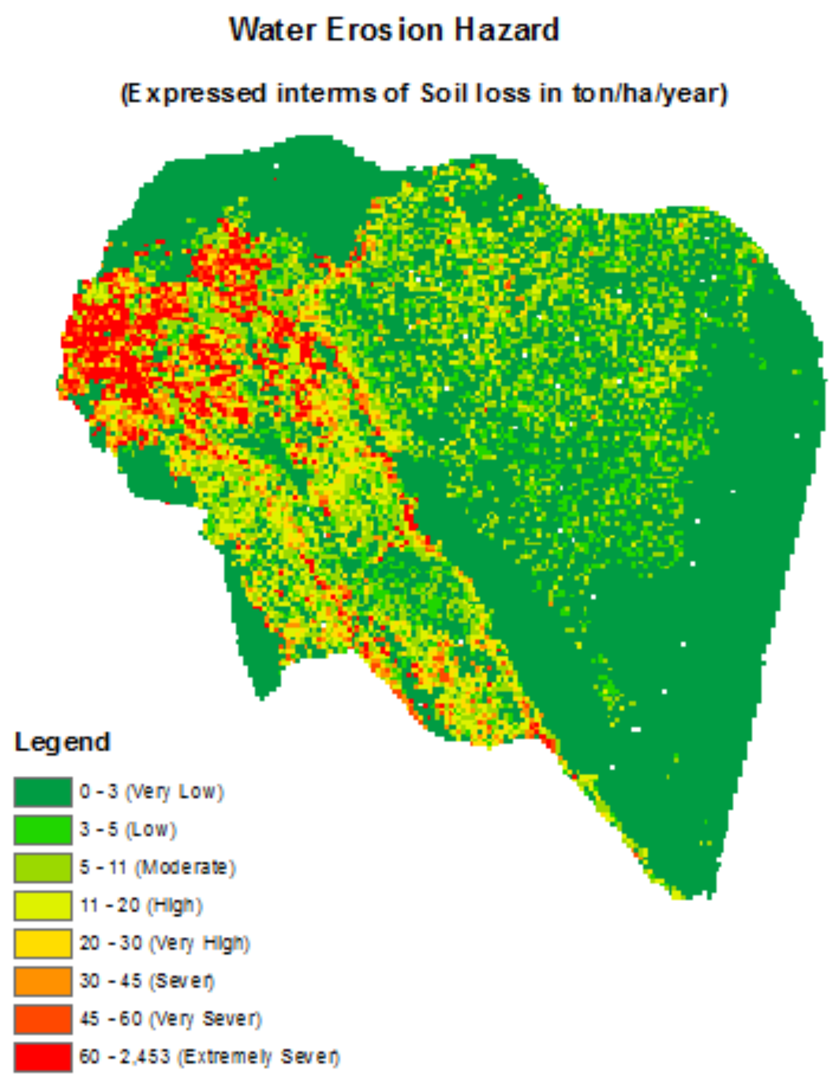
Generated from DEM in SAGA GIS





Integration in GIS





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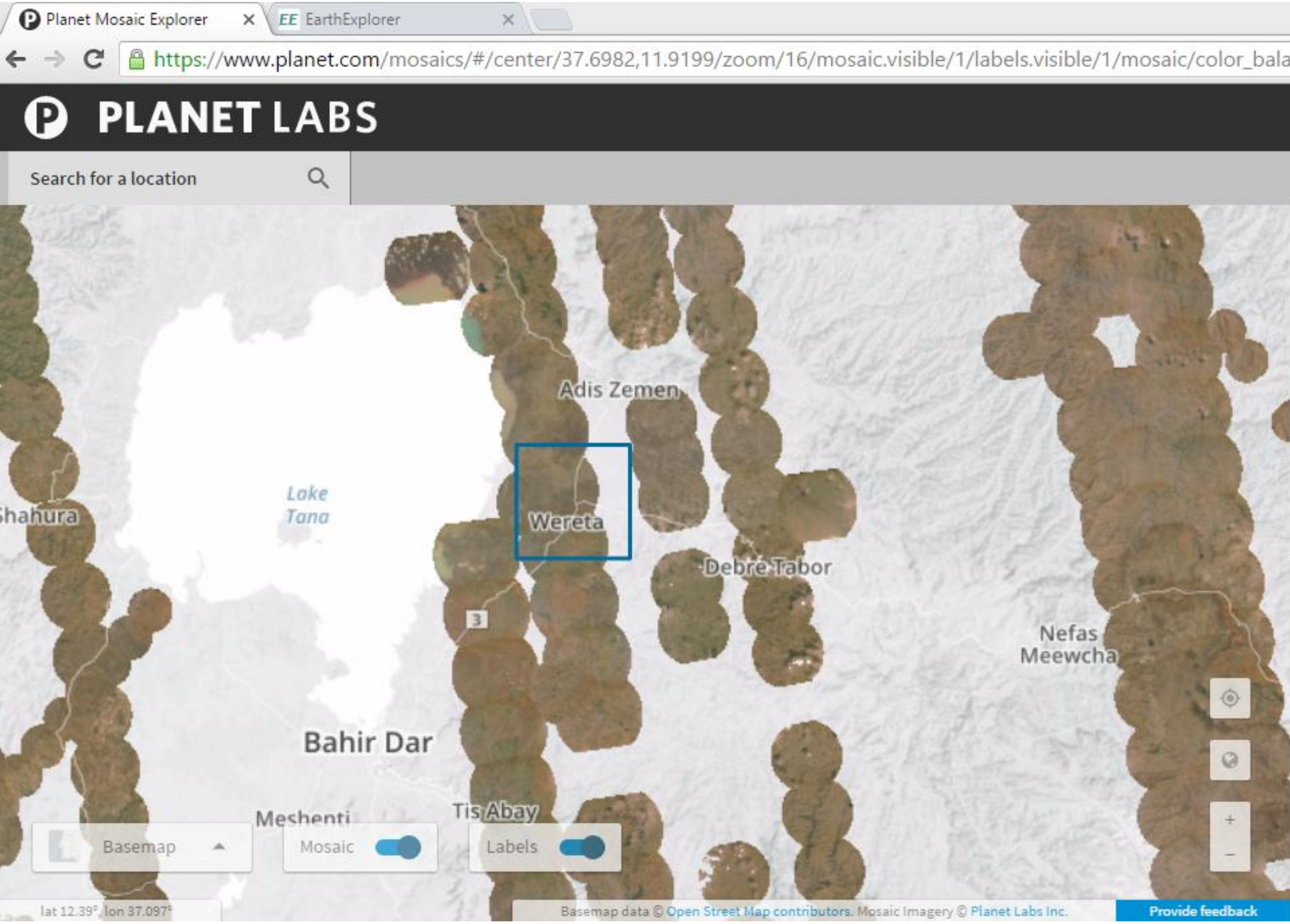
Monitoring Tools


Planet Mosaic Explorer
EarthExplorer
https://www.planet.com/mosaics/#/center/37.6982,11.9199/zoom/16/mosaic.visible/1/labels.visible/1/mosaic/color_bala
PLANET LABS
Search for a location
Adis Zemen
Lake Tana
Shahura
Wereta
Debre Tabor
Nefas Meewcha
Bahir Dar
Meshenti
Tis Abay
Basemap
Mosaic
Labels
lat 12.39°, lon 37.097°
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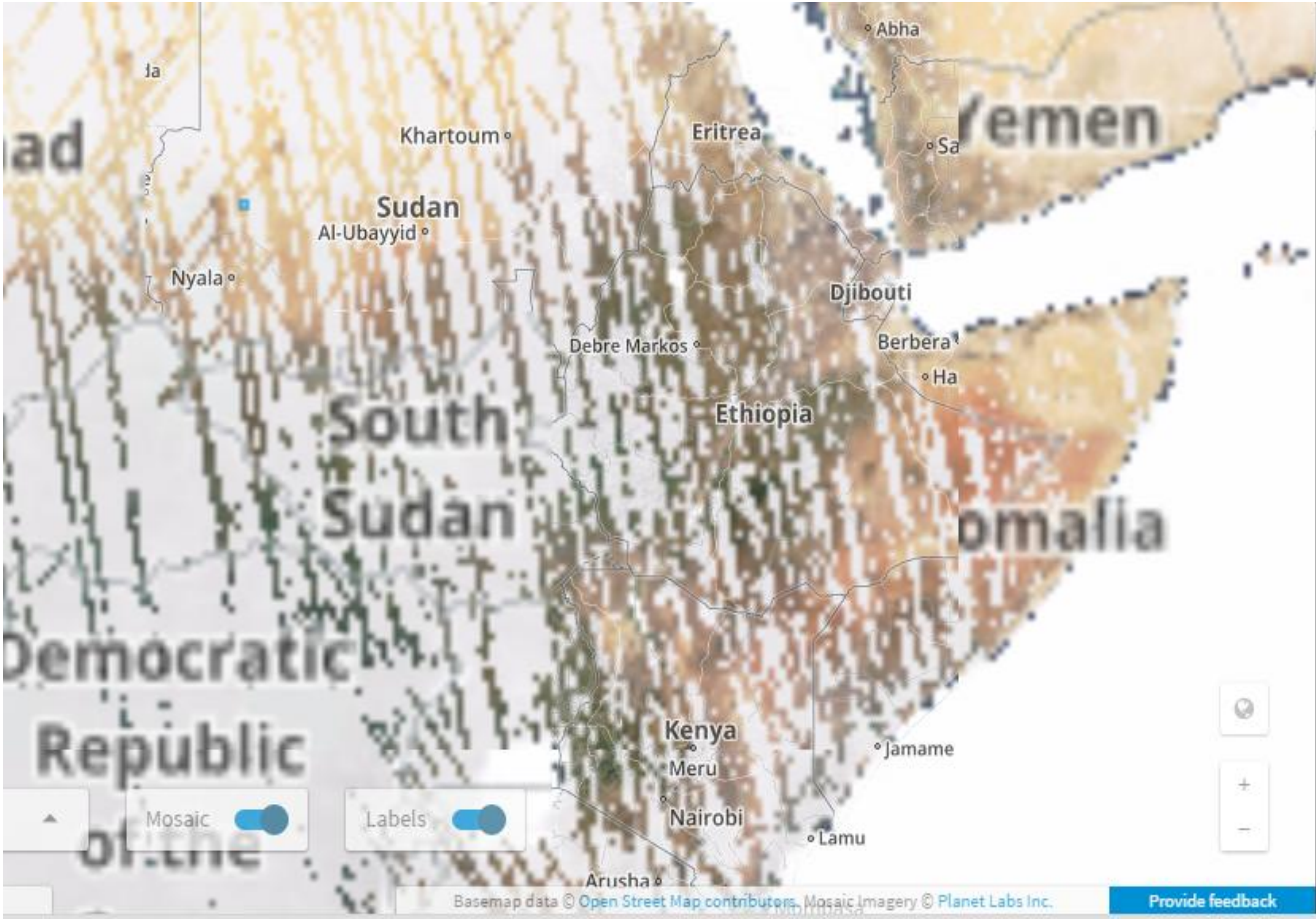
Provide feedback



Abha
Yemen
Khartoum
Eritrea
Sudan
Al-Ubayyid
Nyala
Djibouti
Debre Markos
Berbera
Ethiopia
South Sudan
Democratic Republic of the
Kenya
Jamame
Meru
Nairobi
Lamu
Arusha
Mosaic
Labels
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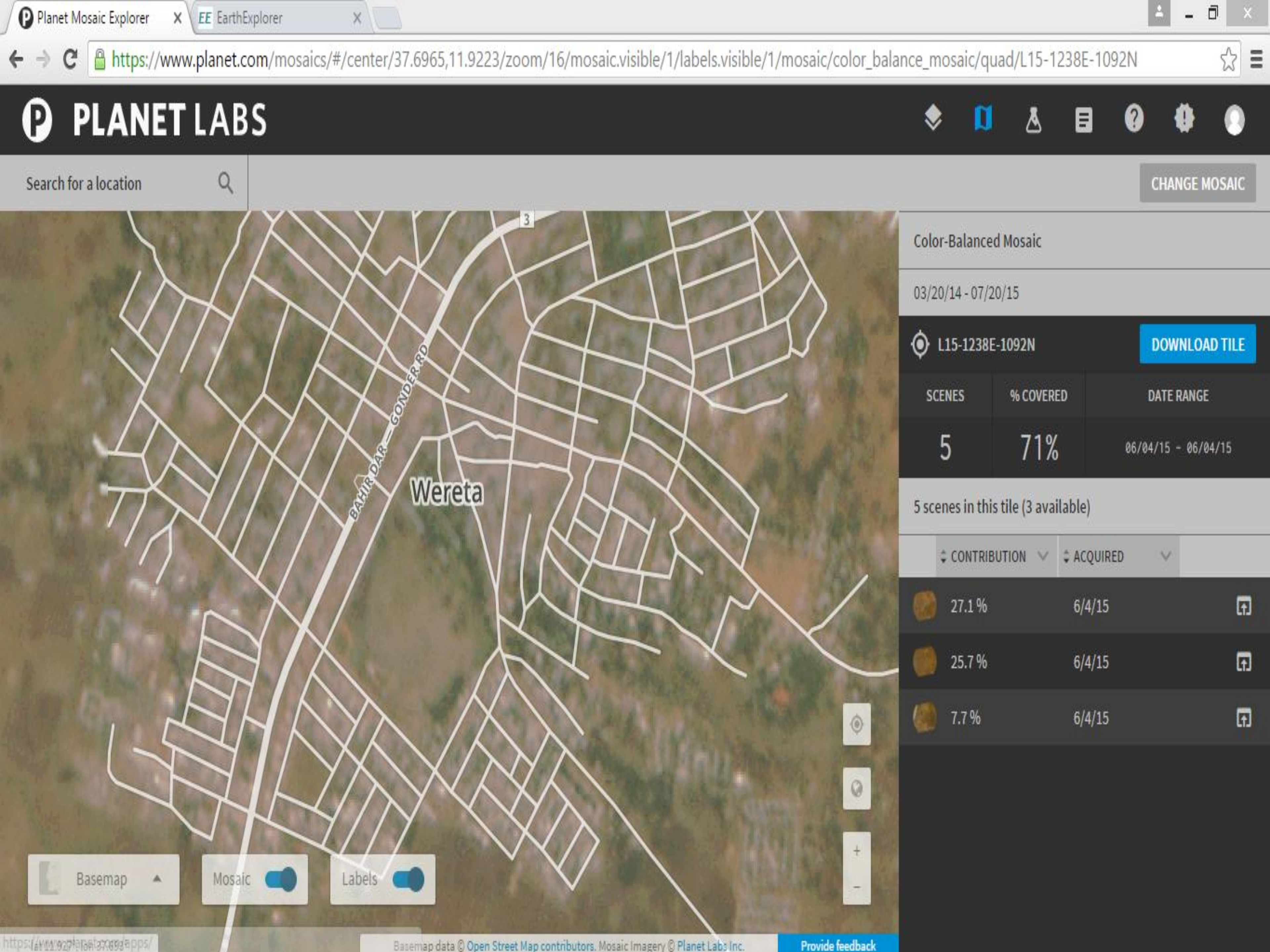
Provide feedback


Planet Mosaic Explorer
EarthExplorer
https://www.planet.com/mosaics/#/center/37.6965,11.9223/zoom/16/mosaic.visible/1/labels.visible/1/mosaic/color_balance_mosaic/quad/L15-1238E-1092N
PLANET LABS
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CHANGE MOSAIC
Color-Balanced Mosaic
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5 scenes in this tile (3 available)
CONTRIBUTION
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27.1 %
6/4/15
25.7 %
6/4/15
7.7 %
6/4/15
Wereta
BAHIR DAR — GONDER RD
3
Basemap
Mosaic
Labels
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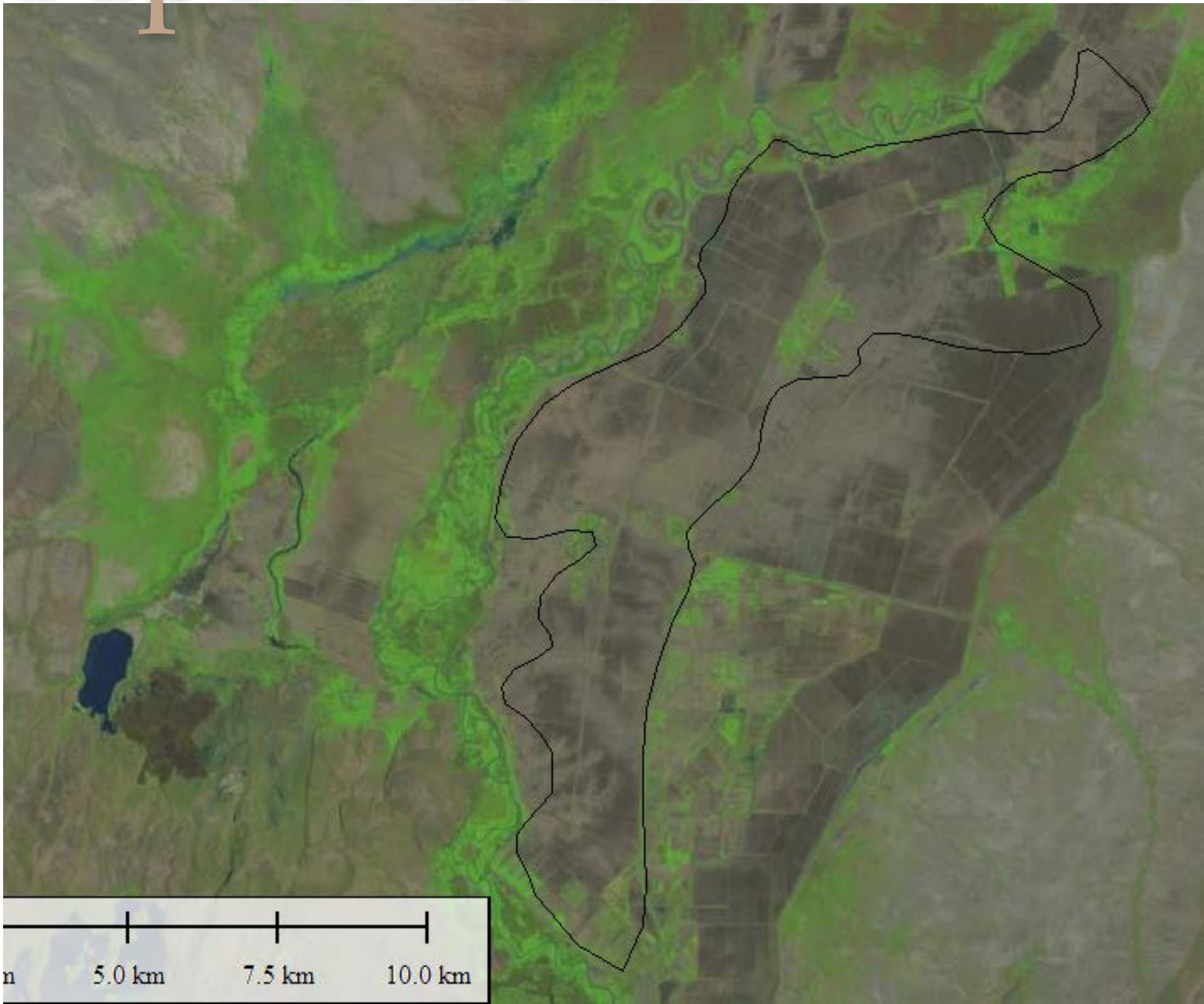
Provide feedback

Before Enhancement

After Enhancement

•

April 2014



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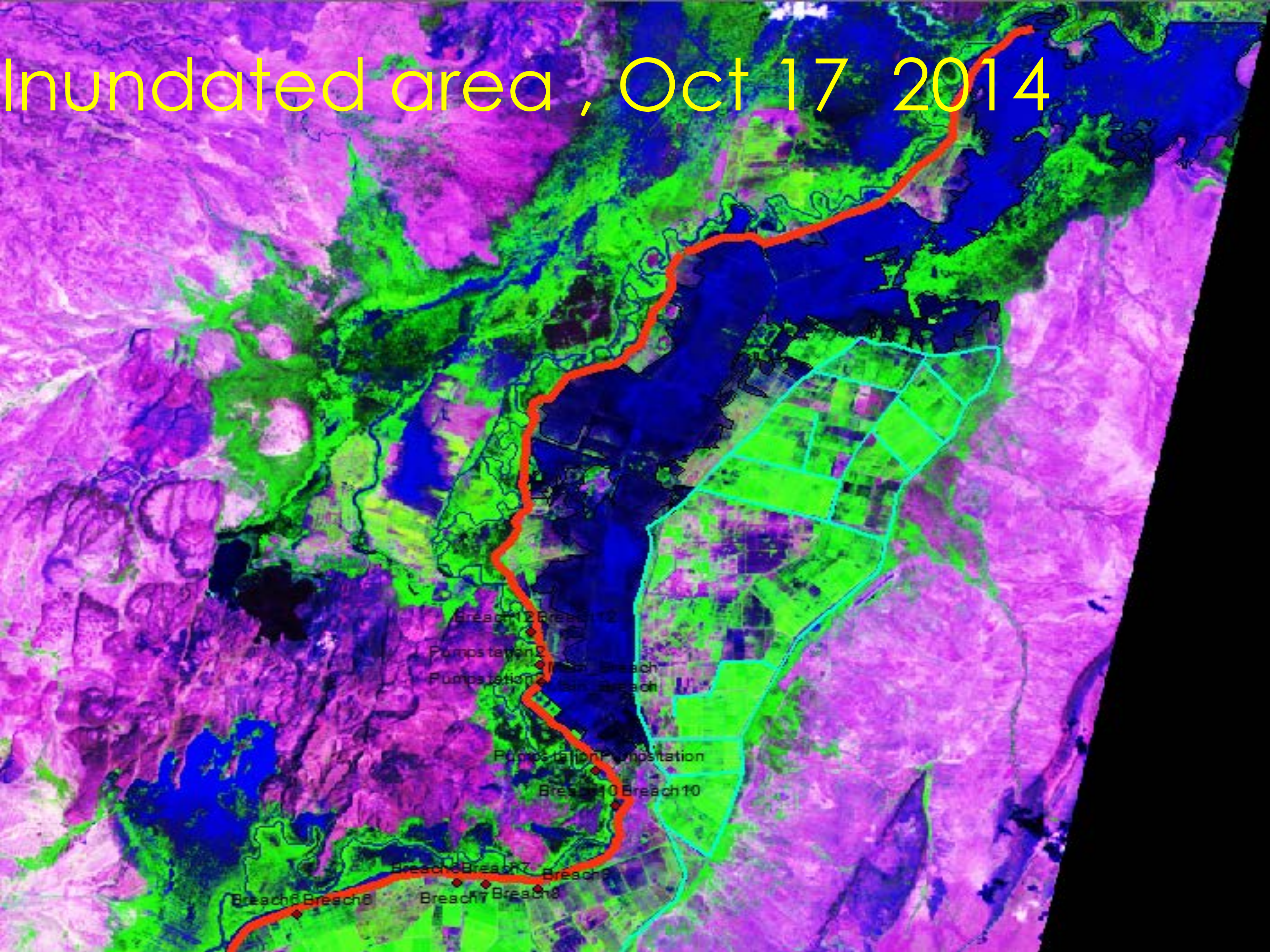
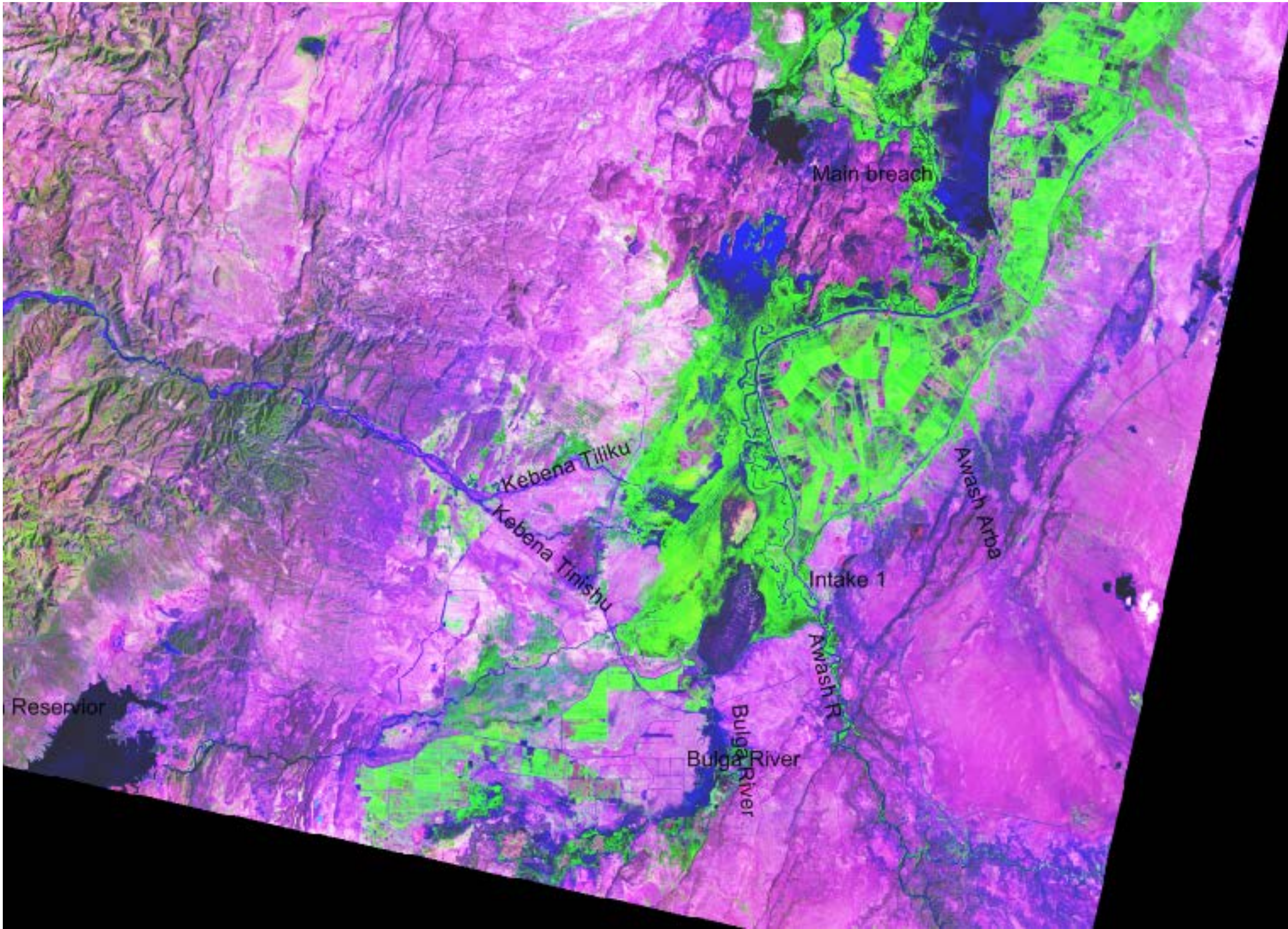
Inundated area , Oct 17 2014



rivers


Main breach
Kebena Tiliku
Kebena Tinishu
Awash Arba
Intake 1
Awash R
Reservior
Bulga River
Bulga River

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