



## Training on Roads for Water and Resilience



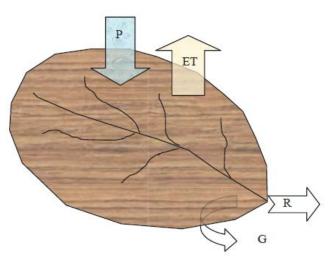
REMOTE SENSING AND GIS TOOLS FOR RAINWATER HARVESTING AND RECHARGE ESTIMATION UNDER DATA SCARCE CONDITIONS

# Most are the most sought parameters for WH

- runoff,
- evapotranspiration and
- recharge

Water Balance drainage basin $(P-E) A - Q = \frac{\Delta S}{\Delta t}$ Water Balance drainage basinWater Balance water solar as a result of humanA = I, + Ig - DWater Balance water as a result of humanA = I, + Ig - DIn which: P = precipitation on the ground surfaceE = evapotranspiration from the ground surfaceA = net water consumption due to water useR = runoff from land to oceanIs = intake of water from surface runoffIe = intake of groundwater

D = drainage of waste water

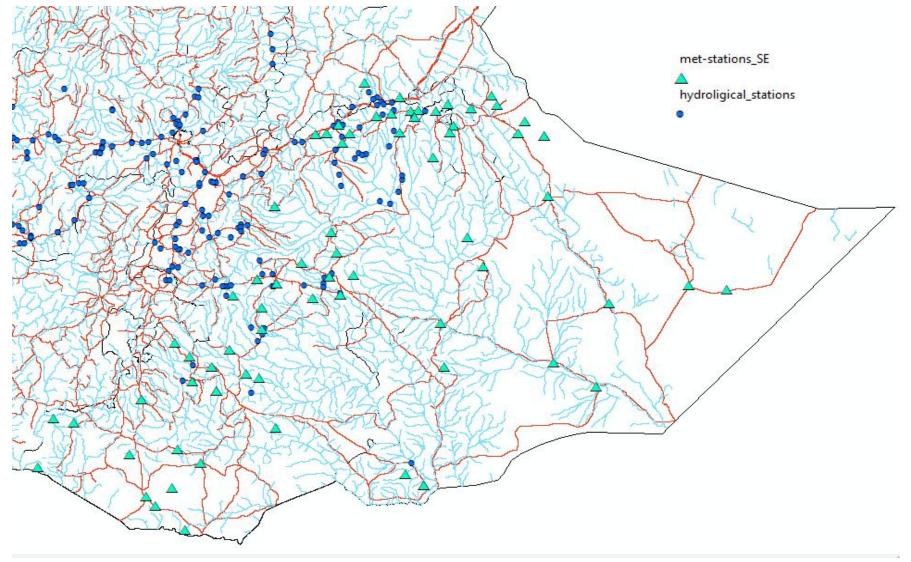


**Catchment Water Balance** 

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

Where P- precipitation, R – runoff, G – groundwater runoff, ET – evapotranspiration,  $\Delta$ S – storage change in catchment

## 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
  - o 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

- o Image processing
- Modeling

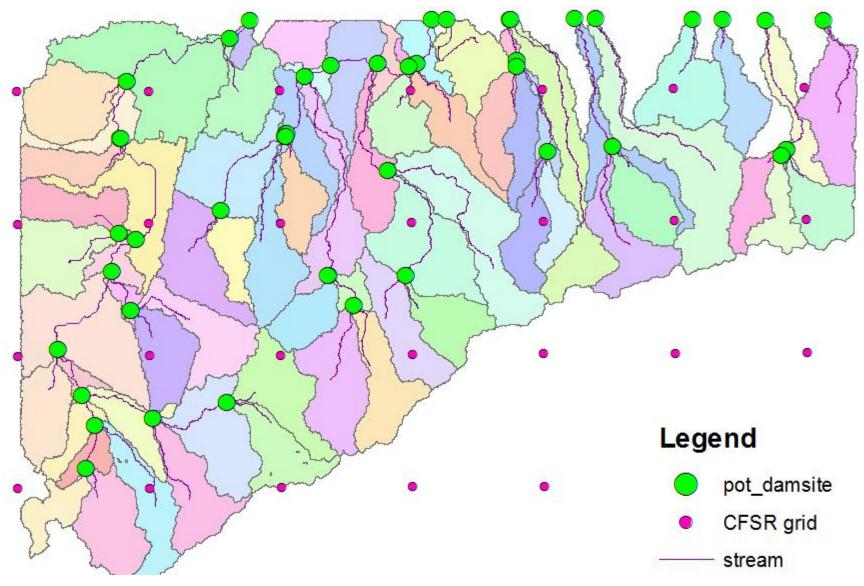
#### Data type

- 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

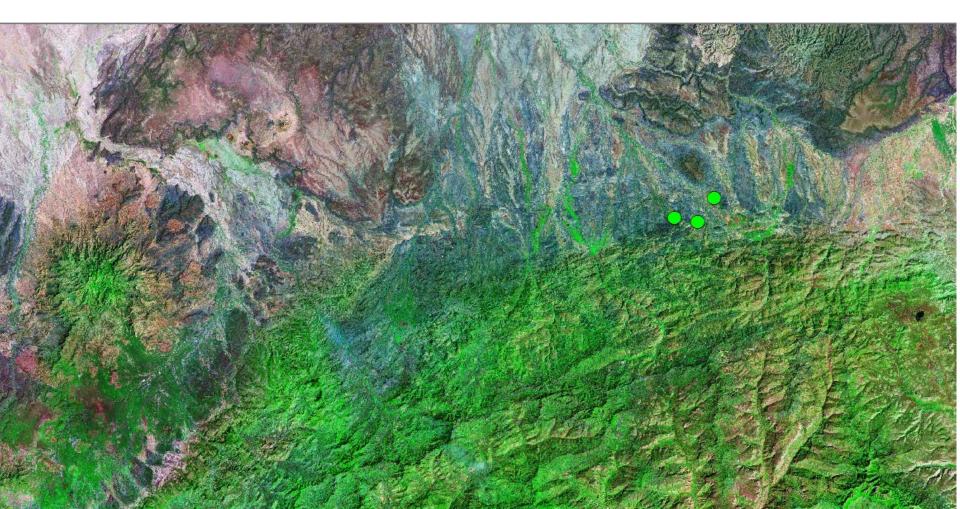


## Required data type

- for both 'Bega' and 'Kiremt' seasons
  - o Landuse/Landcover
  - Precipitation
  - Potential Evapotranspiration
  - Wind speed
  - Temperature
  - Groundwater depth
  - $\circ$  Soil
  - Slope Topography
  - Parameters
    - Landuse/Landcover parameters
    - Soil coefficient
    - Runoff coefficient

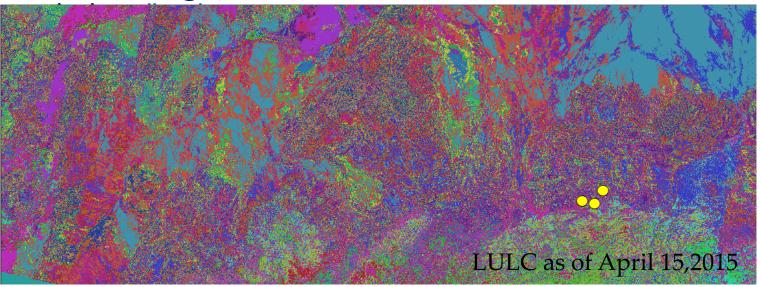
## Landsat Image

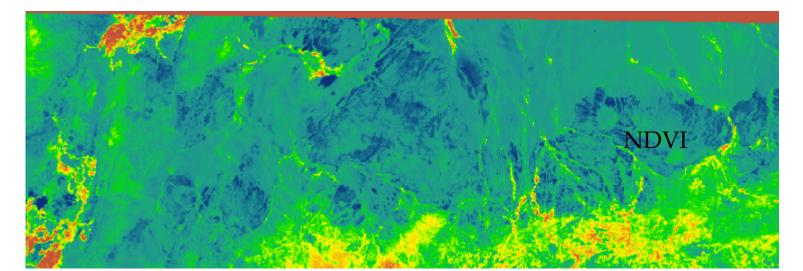
#### To generate Landuse/Landcover



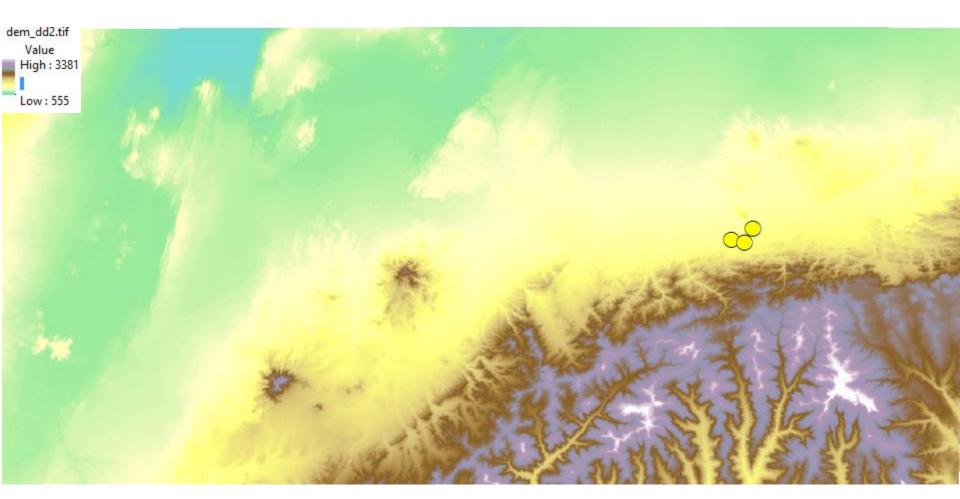
### Preparing required data input Landuse/Landcover

Can be generated from recent Landsat 8 data-

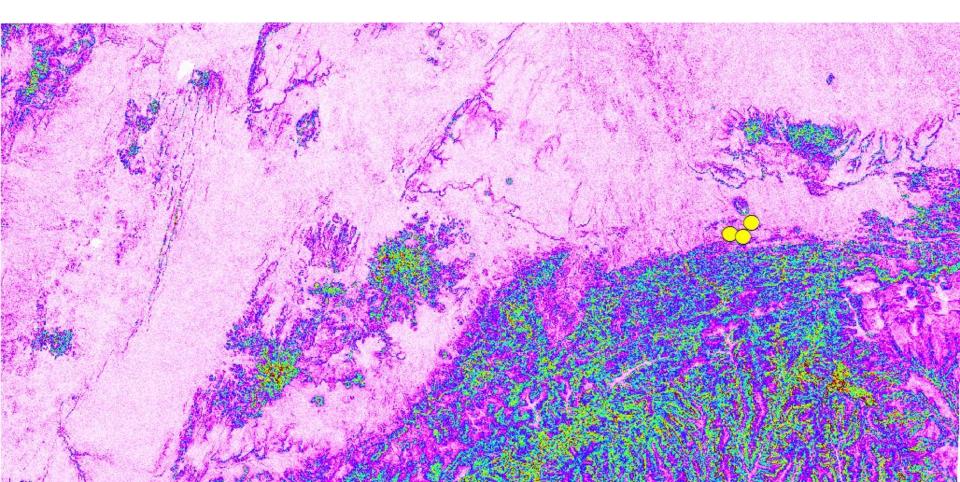




## Preparing required data input... Topography- from SRTM30M V3



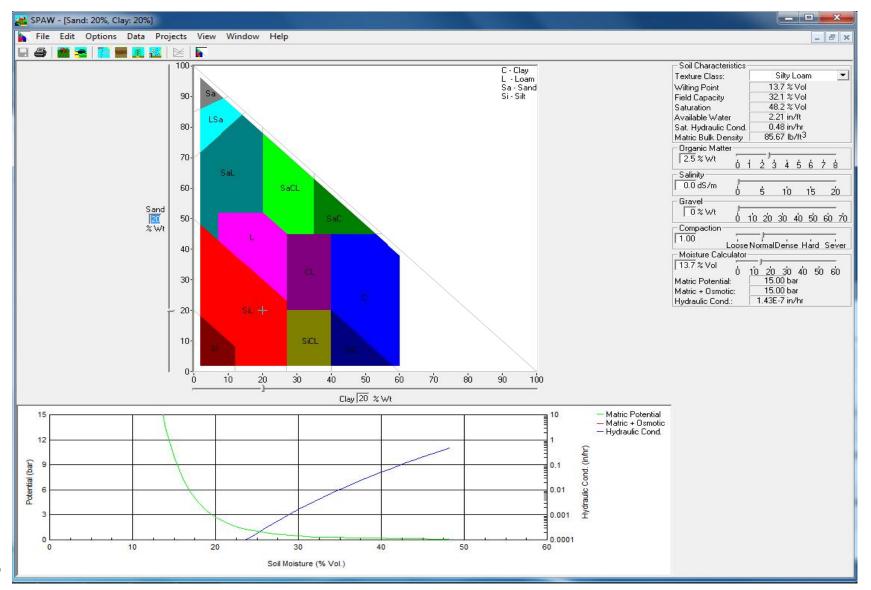
## Preparing required data input... Slope - from SRTM30M V3



## 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



## 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 subso
Α	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	
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
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
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
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
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
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
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
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
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
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	
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	
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	1
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	1
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	
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	
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	(
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	
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	
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	
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	1
В	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	1
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	1
BC 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	1
BC 3	15.3	19.3		25.7	66.3	55	5.6	5.6	1.77	0.93	0.24	0.12	47	48	15.9	
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	1.
BD 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	1.
BD 3	27.8	24.2		37	44.4	38.8	4.6	5	2.62	0.57	0.21	0.04	12	11	20.1	1
BE	36.4	41.7		32.1	26.4	26.3	6.9	7.1	1.07	0.51	0.18	0.04	88	88	20.7	
BE 1	84.5	78.3		7.6	10.4	15.4	6.7	6.6		0.2			65	66		

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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
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
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
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
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
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	
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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	1
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	1
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	
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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	
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	
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	
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	1
В	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	1
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	1
BC 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	1
BC 3	15.3	19.3		25.7	66.3	55	5.6	5.6	1.77	0.93	0.24	0.12	47	48	15.9	
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BE	36.4	41.7		32.1	26.4	26.3	6.9	7.1	1.07	0.51	0.18	0.04	88	88	20.7	
BE 1	84.5	78.3		7.6	10.4	15.4	6.7	6.6		0.2			65	66		

1	VALUE	COUNT	Abreviation	Red	Green	Blue
5	5		5 = Ap - Plinthic Acrisols	204	113	67
6	6	65229	6 = Ao - Orthic Acrisols	224	148	110
7	8		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 = QI - 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		115	76	(
19	21	5540		105	86	48
20	22	12012	22 = CI - Luvic Chernozems	97	84	59
21	23	1728	23 = X - XEROSOLS	138	138	(
22	24	14288	24 = Xh - Haplic Xerosols	168	168	(
23	25			176	176	97
24	26	and the second sec	26 = XI - Luvic Xerosols	199	199	117
25	27			204	204	
26	29	al laite	and the second	115		1
27	30	35086	30 = Bd - Dystric Cambisols	115	63	34
28	31	39807		115	1	
29	32			115		
30	33			161		
31	34			140		
32	35			115		
33	36			115		
34	37			115		
35	38	and the second sec		0		
36	39			38		
37	40			0		
38	40	Contraction of the second s	and the second	135		

## 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**

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#### Data acquisition

You

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🔛 Apps 📋 Imported From Firef...

#### **Global Weather Data for SWAT**

The National Centers for Environmental Prediction (NCEP) <u>Climate Forecast System Reanalysis (CFSR)</u> was completed over the 36-year period of 1979 through 2014. The CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period. The current CFSR will be extended as an operational, real time product into the future.

This website allows you to download daily CFSR data (precipitation, wind, relative humidity, and solar) in SWAT file format for a given location and time period. For more information about CFSR data, please visit our <u>publications page</u>.

#### 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.



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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.



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	

07/31/2014

End Date

#### 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)

Vind (m/s)

Solar (MJ/m<sup>2</sup>)

Relative Humidity (fraction)

#### 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.

Em	ail Address	
Co	nfirm Email Address	
	Generate SWAT Files	
	Generate CSV File	

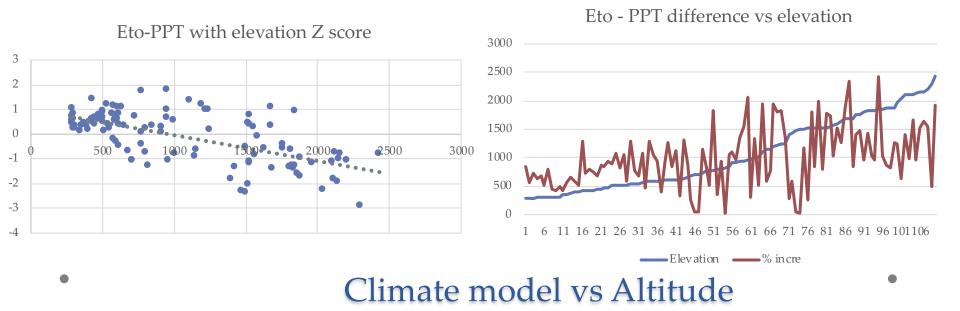


## Climate Parameters- CFSR...

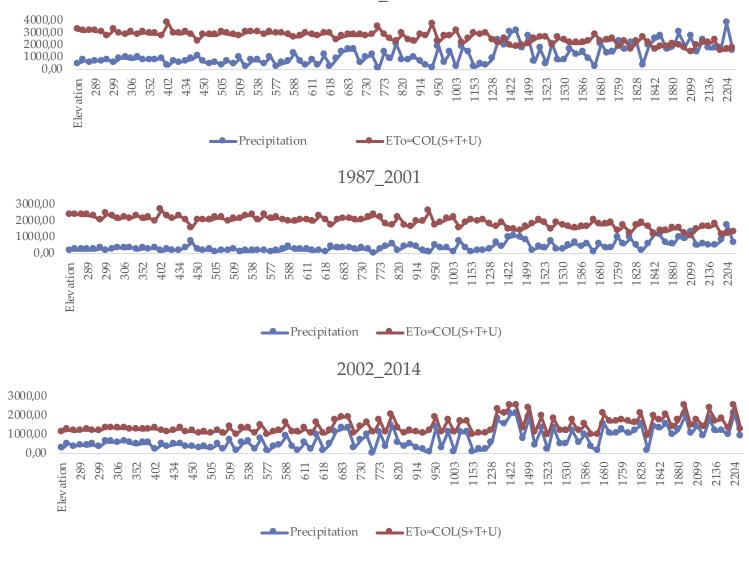
Checking data quality

#### Model parameters

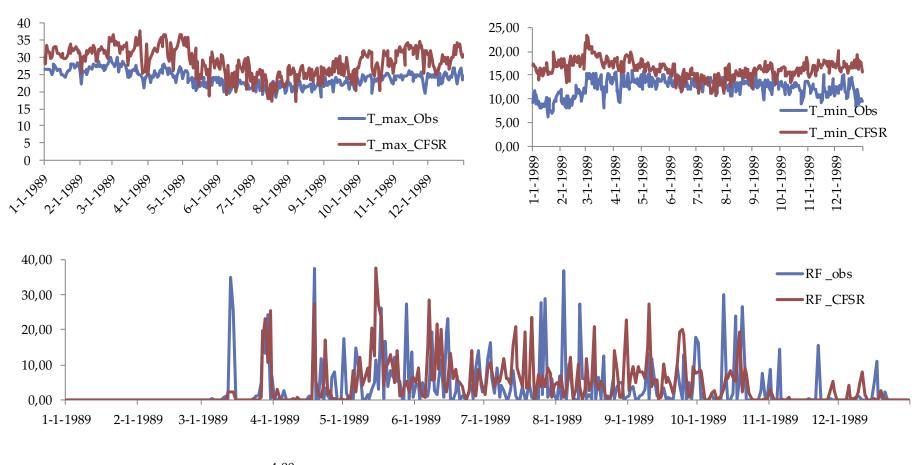
- High PET values
  - Net vs total radiation ?
  - No bias corrected data for eth.?



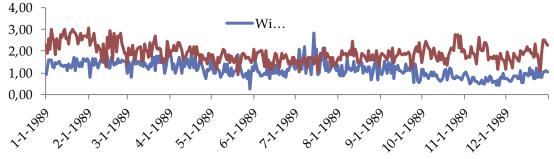
1979\_1986



#### PPT vs PET vs Altitude







#### **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	

#### Hydrological Inputs- data preparation

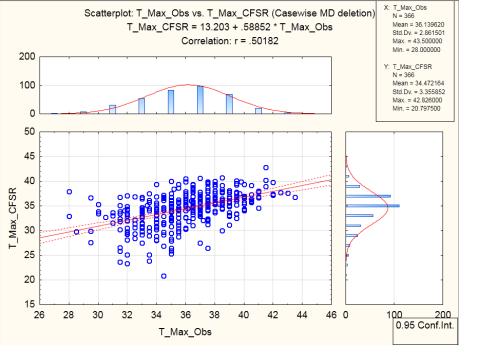
																						_		
Date	Longitude	Latitude	Elevation M	ax Temp I	Min Temp	Precipita Wind	Relative H	Solar	ETo=COL(S	427	1	Longitude								Relative H		Date	Date	Date
1/1/1979	35	5.464	611	31.383	19.783	0 2.735787	0.290037	23.72215	9.710326	2		35	5.464	611	31.2232	19.1561	6.00386	273.9181	2.97718	0.45519	21.7318	1/1/1979	1/1/1979	6/1/1979
1/2/1979	35	5.464	611	31	16.985	0 2.668442	0.320819	25.29653	8.026906													2/1/1979	2/1/1979	7/1/1979
1/3/1979	35	5.464	611	30.758	17.235	0 3.296837	0.32758	25.39254	8.966562													3/1/1979	3/1/1979	8/1/1979
1/4/1979	35	5.464	611	31.321	17.651	0 3.237821	0.344166	25.41156	9.286115													4/1/1979	4/1/1979	9/1/1979
1/5/1979	35	5.464	611	31.406	16.013	0 2.740741	0.311086	25.47776	10.13427													5/1/1979	5/1/1979	6/1/1980
1/6/1979	35	5.464	611	31.288	17.745	0 3.076374	4 0.385202	25.19365	10.08871													6/1/1979	10/1/1979	7/1/1980
1/7/1979	35	5.464	611	30.173	18.478		0.492735															7/1/1979	11/1/1979	8/1/1980
1/8/1979	35	5.464	611	30.885	18.203	0 2.763151	0.494266	20.98727	7.716868													8/1/1979	12/1/1979	9/1/1980
1/9/1979	35	5.464	611	31.145	18.753	0 3.064657	7 0.460182	25.10364	7.93713													9/1/1979	1/1/1980	6/1/1981
1/10/1979	35	5.464	611	31.367	17.933	0 2.844268	8 0.461025	25.18954	9.684293													10/1/1979	2/1/1980	7/1/1981
1/11/1979	35	5.464	611	30.516	19.572	0 3.370039	9 0.469463	21.72134	9.436641													11/1/1979	3/1/1980	8/1/1981
1/12/1979	35	5.464	611	31.189	19.502	0 3.679965	5 0.467845	21.31138	8.709952													12/1/1979	4/1/1980	9/1/1981
1/13/1979	35	5.464	611	31.021	19.003	0.73128 4.446189	9 0.514871	24.35187	7.881042													1/1/1980	5/1/1980	6/1/1982
1/14/1979	35	5.464	611	30.513	19.377	0.4137 4.737021	0.519585	25.24224	8.701655													2/1/1980	10/1/1980	7/1/1982
1/15/1979	35	5.464	611	30.958	18.486	0 3.649688	8 0.504547	25.35379	7.826445													3/1/1980	11/1/1980	8/1/1982
1/16/1979	35	5.464	611	30.241	19.075	0 3.323296	5 0.500077	22.87125	8.427795													4/1/1980	12/1/1980	9/1/1982
1/17/1979	35	5.464	611	31.525	18.784	0 3.709304	4 0.474055	23.8923	9.145345													5/1/1980	1/1/1981	6/1/1983
1/18/1979	35	5.464	611	31.332	19.703	0 4.939034	4 0.466442	25.58053	8.969924													6/1/1980	2/1/1981	7/1/1983
1/19/1979	35	5.464	611	30.911	18.819	0 4.438907	0.469934	25.81695	8.613946													7/1/1980	3/1/1981	8/1/1983
1/20/1979	35	5.464	611	30.359	19.226	0 2.567966	5 0.47894	16.73443	7.997378													8/1/1980	4/1/1981	9/1/1983
1/21/1979	35	5.464	611	32.499	18.324	0 2.887463	3 0.438824	25.69894	9.227998													9/1/1980	5/1/1981	6/1/1984
1/22/1979	35	5.464	611	33.033	19.758	0.02747 2.553209	9 0.484182	17.89829	9.600792													10/1/1980	10/1/1981	7/1/1984
1/23/1979	35	5.464	611	30.282	19.683	0 2.370437	0.509276	18.14467	8.587088													11/1/1980	11/1/1981	8/1/1984
1/24/1979	35	5.464	611	31.495	19.24	1.48144 2.040861	0.538267	16.34974	8.422683													12/1/1980	12/1/1981	9/1/1984
1/25/1979	35	5.464	611	30.849	20.599	0.23003 2.625281	0.472244	18.33857	8.813943													1/1/1981	1/1/1982	6/1/1985
1/26/1979	35	5.464	611	33.453	22.683	0.81625 2.337977	0.471419	13.52818	8.958149													2/1/1981	2/1/1982	7/1/1985
1/27/1979	35	5.464	611	29.926	19.662	0.06866 2.288558	8 0.548273	14.80168	9.071268													3/1/1981	3/1/1982	8/1/1985
1/28/1979	35	5.464	611	33.146	20.268	0.17338 1.834961	0.461287	20.82459	9.512069													4/1/1981	4/1/1982	9/1/1985
1/29/1979	35	5.464	611	31.482	22.116	0.89436 1.387491	1 0.461033	13.41968	9.450799													5/1/1981	5/1/1982	6/1/1986
1/30/1979	35	5.464	611	30.931	21.35	0.79308 1.763124	4 0.492289	19.95058	9.182311													6/1/1981	10/1/1982	7/1/1986
1/31/1979	35	5.464	611	31.531	19.831	0.37422 1.451384	4 0.480827	17.12666	7.153163													7/1/1981	11/1/1982	8/1/1986
2/1/1979	35	5.464	611	30.447	19.243	3.84693 1.757523	0.563054	14.6421	7.309069	33	32	35	5.464	611	32.4336	21.3156	23.0644	262.3806	2.60436	0.43303	17.7426	8/1/1981	12/1/1982	9/1/1986
2/2/1979	35	5.464	611	29.89	19.903	0.96302 2.176204	4 0.509777	15.95351	7.49382													9/1/1981	1/1/1983	6/1/1987
2/3/1979	35	5.464	611	32.502	19.775	0 2.364039	9 0.454603	17.58809	8.599167													10/1/1981	2/1/1983	7/1/1987

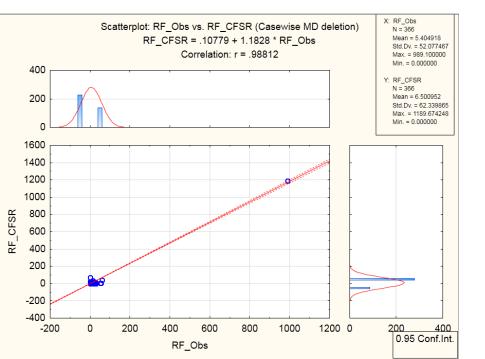
#### \* Seasonal average for every grid from daily estimates

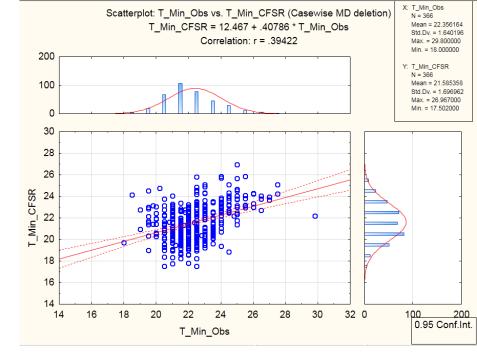
\* Eto calculated using
 \* Penman-Monteith Equation

#### Template developed in Excel

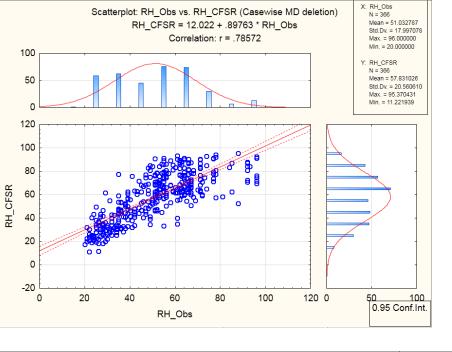
1.1	Date 1	Max Ter	Min Tei Tm									e"(Tma	eas(e'i)	z P	= 10L.3"	Y=0.665	Solar	Vind	0.405'2	140.17	900*#2*	ETo-C	L To-COL	S.T.
	1/1/1979	35.679	22.686 23										114622			0.06735		2.98088	6.3605	0.18241	27.9714	11.4628	8,254,356	
	W2/1979	35.418	22.039 20.								0.73148	150011		2		0.06735	21,7916	2.03946		0.10672	25,7067	10,4390	9 134100	
	1/3/1979	35.418	23,349 29.							27.5407		158466	118744	2	101.278	0.06735	24,7479	3.84795	6.087	0.17206	35.7804	12.2432	8.812397	
	1441979	35.605	22.464 29.					2.71964		28.0466		163047	119662	2		0.06735	24.8245	3,23903	6.2897	0.18037	29.6297	11634	8.826136	
	1/5/1979	35.523	21.427 21							25.6782		140606		2				2,62262			24,2657	111474	8.768054	
	16/1979	35.808	23.225 29		4.1269	0.23755	5.8787	2.8479	4.9833	30.6555	0.87304	1.80214	1.33759	2		0.06735	24.5645	3.41675	6.214	0.17578	30.7563	11.6204	0.597351	
	1/7/1978	34.968	24.823 29.	8955	4.2177	0.2421	5.61274	3.13453	4.37364	37.0658	1.16153	2.07985	1.62069	2		0.06735	21.727	3.71955	5.4384	0.17067	30.4256	10.6311	8.424697	
	10/1979	33,865		200.1		0.23243		3.03709	415065	09.1721		5 00005		5		0.06735	10.0091	3.3300		0.1291			8.620566	
	1/9/1979	35.63		9.894	4.21492		5.82145	3.00872		36.7725		2.14069	1.62354	2		0.06735	17.3134	3.04996	4.5079	0.17763			8.755483	
	1/10/1979	35.709	24.702 30.				5.8468	3.11198	4.47939	36.1907	1.12626	2.116	1.62112	2		0.06735	24,5319	3.32898		0.17294	28.2435	11.2033	9.596768	
	10101079	34.143			4.00429		5.00355	3.43802		37,7709	129623			2		0.06735	12 4720	0.67469			23.8455		9.070342	
	1/12/1979	33.977						3.18689	4.24987	37.1863	1,19503	1.9755	1.58029	2		0.06735	18.293	3,28805		0.17782	26,1101	9.28734	8.59772	
	M13/1979	35.886			4,29149			3.07649		38.0214		2.24476	170724	ż		0.06735	24.337		6.06362	0.16734	32.2321	11.4573	8.818533	
	914/1973	35,733	25.580 300				5.05452	3.26604		36,9559		2.16359		2		0.06735	24.0278		5.05243		43.2256	12.5519	6.00906	
	1/15/1979	35.684	25.367 30.				5.83878	3.23769		36.6018	1.18505	2.13709		2		0.06735	24.891	4.73769		0.15923	40.4192	12.3555	9.211254	
	MI6/1978	35.898	24.895 30.					3.14802	4.62782	37.6217		2.22263	170348	2			23.7418	4.01134		0.16531		11.4572	7,59689	
	W17/19/79	36.036	26,230				5.95274	3.40902	4.60000	34,5151		2.05459		5		0.06735	24.0352	4.00959	5.9395	0.15410		12,7779	7 265336	
	1/18/1979	35.96	25.681 30.							35.5929		2.10994	1.642	2		0.06735		5.55853			48.9247	13.1051	9.525499	
	11911979	35.372	25.036 20					3.17458	4.45695	35.1259		2.01589	156554	2		0.06735	25.1877	4.99979		0.15747	42.90	12.6646	80.47652	
	1/20/1979	31.411	25.445 21							39,9450		180023	153677			0.06735	9.35040	3.01961			27,2454		0.170072	
	M21/1979	35.994	25.059 30.					3,17893		35.6846	113439	2.11932		2		0.06735	17.2478	3.2042			27.8579		9,616693	
	¥22/1979	35.247	25.332 30.			0.2469		3.23097		37.262		2.12332	1.66346	2		0.06735	19.3046	3.50573		0.17071			10.09958	
	¥23/8979	35.456			4.40263		5,76595	3,45516	4.63055	37.3272		2.15227		5		0.06735	110442	2.0675		0.17345	24 507	9.5251	10.05926	
	1/24/1979	35.624				0.26557	5.81953	3.61246	4.75599	38,7637	140033			2		0.06735	3,69457	2.89651			24.7298		8.97735	
	¥25H979	36.569		1.867		0.26693	6.129	3.6	4.8645	37.8578	1.36288	2.3203	184159	2		0.06735	19.8413	3,33625		0.164	29.7728	10.1444	10.23354	
	¥26/1978	36.579		1.936	4.73761					35.675	1,29396	2.18771	174084	2		0.06735	19.0797	3.20917	5.10183	0.1648		10.0014	10.27227	
	¥27/1979	35,463	27,04 010		4.5501		5,77000	3.57372	4.6719	39,6295		2.20652		5		0.06735	17.4200	3.60741		0.16463	00.1014		31942100	
	¥28/1979	37.26			4.51592		8.38422	3.15309		38.7295		2.33755		2		0.06735	19.7033	2,43738		0.1772	21,7194		9.885603	
	V29/1979	37.286	24,299 30.				6.37322	3.03769		36.6149		2.33355	172294	2		0.06735	16.71	170761		0.18729	15.0887	7.62543	3,847211	
	¥30/1979	37.943	22.006 23						4.62463			247828		5		0.06735	217225	190251		0.10329	17.0152		9.545043	
	1/31/1979	42.4					8.37282	2.74218	5.5575			2,70971		2		0.06735	23.9264	0.8519		0.18595		9.17517	9.767184	
	2/1/1979	42.027						2.33814		316052		2.59498	1.656.97	2		0.06735	26.1566	1.50498		0.18827	16.0721	10.6605	9.856123	
	2/2/1979	41.182	22,990 321					2.00025		37.1267	104261	2.91559	19791	5		0.06735	22,4147	103265		0.17763	10.1196	9.7278	9,759824	
	2/3/1979	40.631	23.638 32					2.91969			0.97773	2.55417		2		0.06735	24,8839		7.20434	0.17671	19.577	10.6637	9.640702	
	24/1979	39.082			4.74538		7.0223		5.08076	32.8059		2.30373	1.66679	2		0.06735	22.174		6.02779	0.1673	28.477	10.9593	10.04	
	2/5/1979	09.592	23.945 01				7.29673	2.97400	5.00541	312445	0.92922	2.2540		5		0.06735	17.0000	2,34084		0.17421	24,2177		9,750062	
	2/6/1979	37.796			4.74726		6.55203	3.39096	4.97149	30.2274	1.025	1.99051		2		0.06735	25.234	3,19273				12,1428	10.4558	
	2/7/1978	38,05			4.80525		6.64269	3.42636		316729	1.09523	2,10393	1.59458	2		0.06735	24.3091	3.52194	6.41615	0.16068	35.7282	12.167	11.06628	
	2/0/1079	39.047	26,006 32				2.00913	3.52496		35,0303	112904	2.2456		5		0.06735	10.663		5.25926		26.9253		107022	
	2/9/1979	37.197	25.538 31				8.34246	3.27072		33.0045	1.07949	2.0933	1.58639	2		0.06735	25.75%	2.97448		0.17011	28.3229	11,7299	11.65905	
	2/10/1979	41.969	27.074 34			0.3037		3.59065		31.0163		2.53887	1.82476	2		0.06735	19.6344	1.59032		0.16538	18.7764	8.07915	11.53158	
	2/19/1979	36.667			4.36704	0.23961		2,76053	4.46521	30.9257	0.05371	190561		5		0.06735	13,2551	133331		0.22056	155822	6.27754	11034657	
	2/12/1979	38.272			4.76284		6.72282	3.31954	5.02118	38.2554	1,2899	2.57184		2		0.06735	23.5498	2,68816	8,4962	0.16923	24.5901	10.6575	10.38355	
	2/13/1979	37.853			4.69067			3.29584	4.83406	34.8158	116747	2,28819	171783	2	101.276		16.2217	2.65753		0.17106	26.2412	8.78101	30.49956	
	2/14/1979	37.476	25.577 31						4.05002	33,4075	10952	5.19155		5			22.4097		5.90430	0.10653	31.1465	117545	0.20325	
1	2352979	18.041	25 959 91	9745	4.74793	0.26834	6.61946	2.3492	4 99111	31 3117	101305	2.01187	153248	2	901.278	0.06735	10 2952	2 23095	5,17877	0.17413	22 9038	9 10299	10.9710	

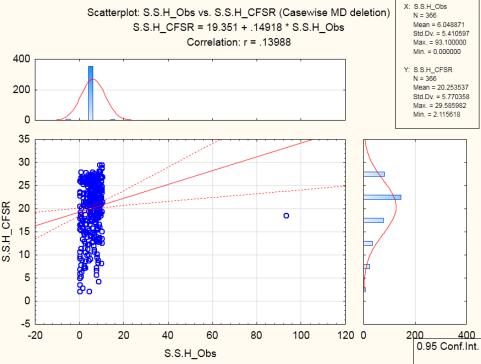


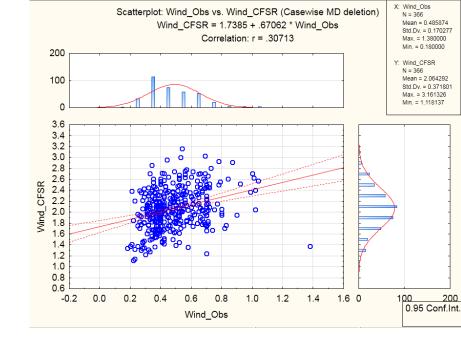




Daily, monthly estimates are poorly correlated, particularly for wind and temperature









## **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.

$$P_{bc} = P_p \times \frac{\overline{P}_o}{\overline{P}_r}$$

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

#### 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

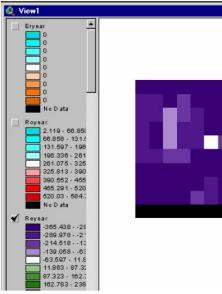
LandUse Win (GRID): c:\tutor\wetspass\landuse	Browse	LandUse Sum (GRID): c:\tutor\wetspass\landuse	Browse
Precipitation Win (GRID): c:\tutor\wetspass\ppt_w	Browse	Precipitation Sum (GRID): c:\tutor\wetspass\ppt_s	Browse
PET Win (GRID): c:\tutor\wetspass\pet_w	Browse	PET Sum (GRID): c:\tutor\wetspass\pet_s	Browse
WindSpeed Win (GRID): c:\tutor\wetspass\wind_w	Browse	WindSpeed Sum (GRID): c:\tutor\wetspass\wind_s	Browse
Temperature Win (GRID): c:\tutor\wetspass\tem_w	Browse	Temperature Sum(GRID): c:\tutor\wetspass\tem_s	Browse
GWDepth Win (GRID): c:\tutor\wetspass\gw_w	Browse	GWDepth Sum (GRID): c:\tutor\wetspass\gw_s	Browse
		Parameters (DBASE Files)	
ther Grid inputs			
	Browse		Browse
Goil (GRID): c:\tutor\wetspass\soil	Browse	Landuse Parameter (Win): [c:\tutor\wetspass\luse_param_	Browse
Soil (GRID): c:\tutor\wetspass\soil Slope (GRID): c:\tutor\wetspass\slope Topography (GRID): c:\tutor\wetspass\topography			Browse Browse

## Model Outputs

### WetSpass produces output files with results for winter,

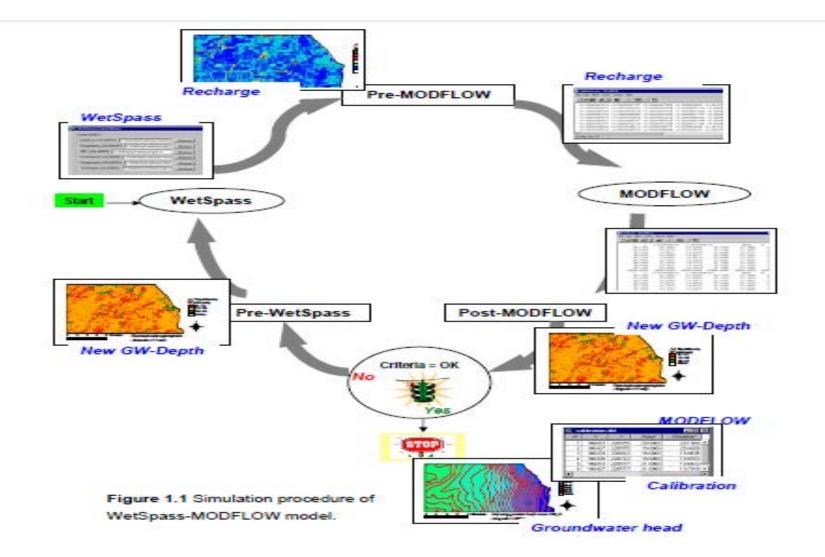
summer and year average periods.

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



<u>Winter</u>	<u>Summer Year</u>	Explanation
• Rowinter	• <b>Ro</b> summer • <b>Ro</b> year	winter, summer and yearly <b>R</b> un <b>o</b> ff
• Etwinter	• Etsummer • Etyear	winter, summer and yearly Evapotranspiration
• Inwinter	• Insummer • Inyear	winter, summer and yearly <b>In</b> terception
• <b>Tr</b> winter	• <b>Tr</b> summer • <b>Tr</b> year	winter, summer and yearly <b>Tr</b> anspiration
• Sewinter	• Sesummer • Seyear	winter, summer and yearly <b>S</b> oil <b>e</b> vaporation
• Rewinter	• <b>Re</b> summer • <b>Re</b> year	winter, summer and yearly <b>R</b> echarge
• Erwinter	• Ersummer • Eryear	winter, summer and yearly <b>Er</b> ror in water

### Process Flow in WeSpass \_MODFLOW Model



0. Batelaan and S.T. Woldeamlak, 2007

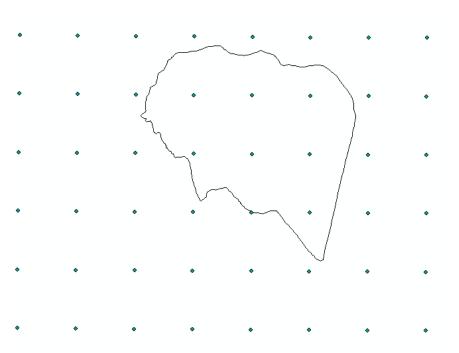
## **Defining Soil Erosion Hazard**

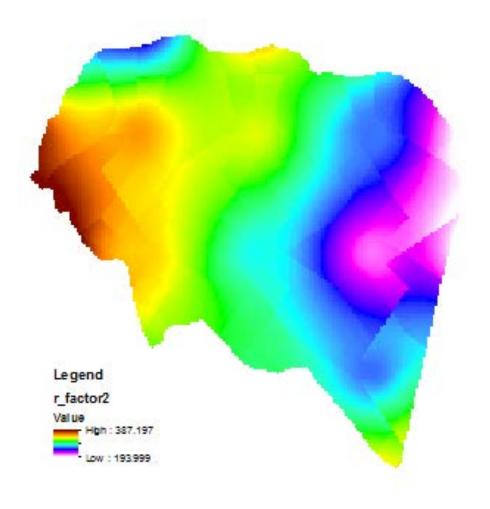
The Revised Universal Soil Loss Equation (RUSLE) was used in developing the conservation plan and land use decisions, which further, helps to estimate the potential soil loss of the study. Mathematically the equation is denoted as:

### A (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.

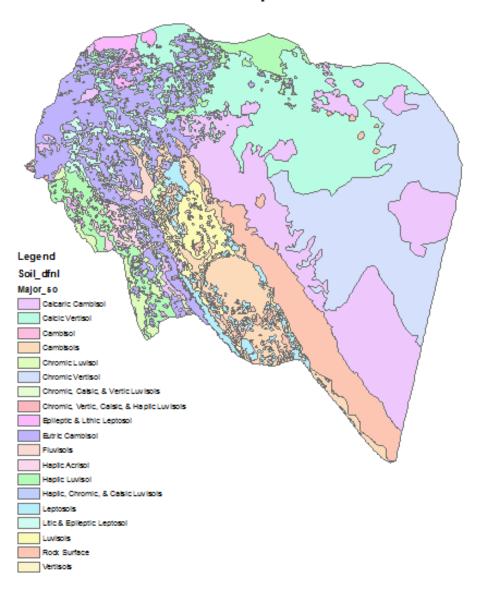
# Rainfall- observed or from bias corrected CFSR data

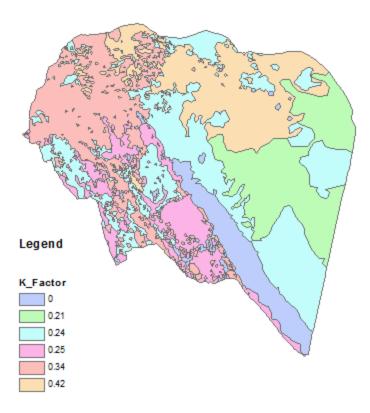




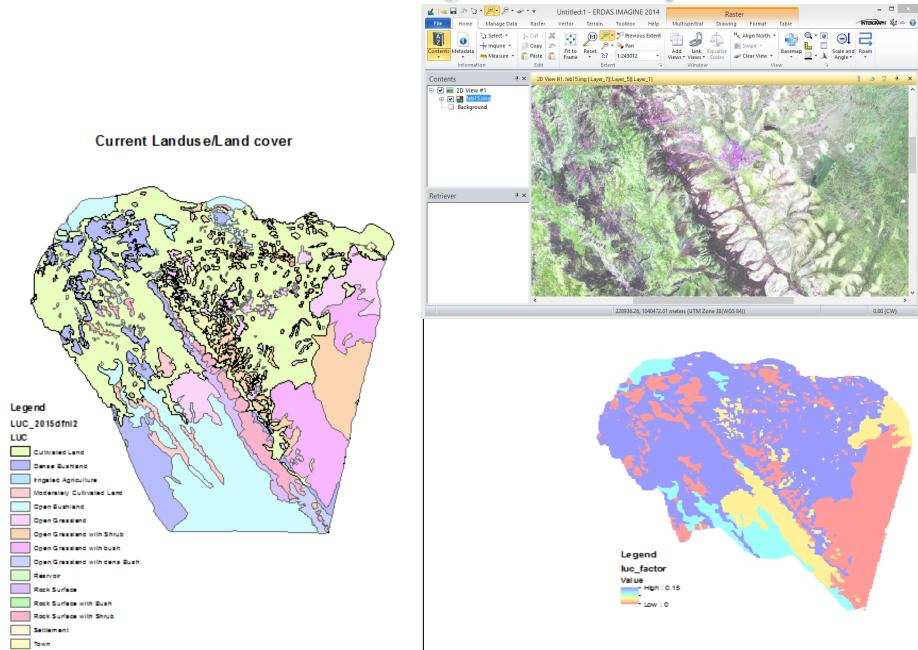
## Updated soil map

Soil map

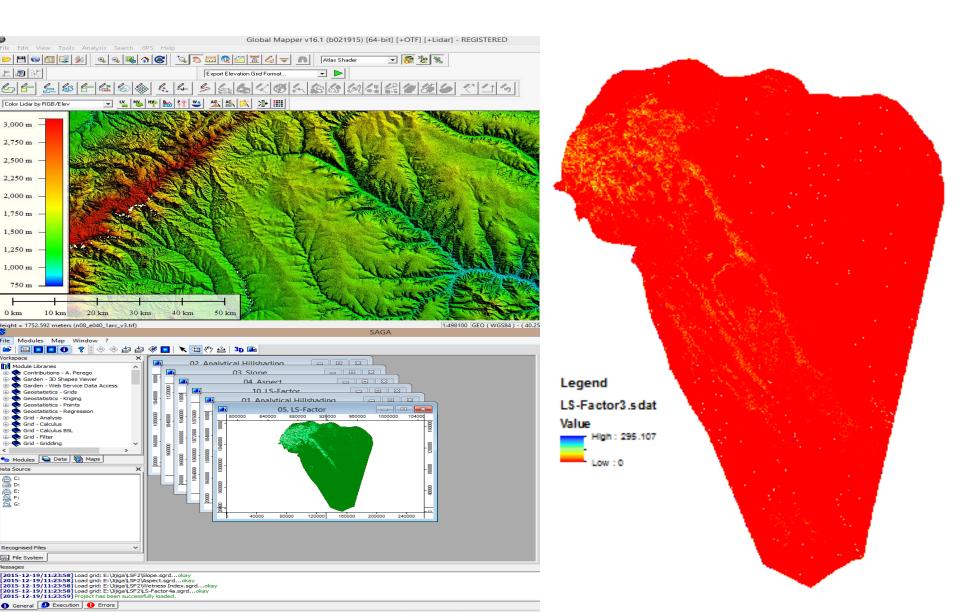




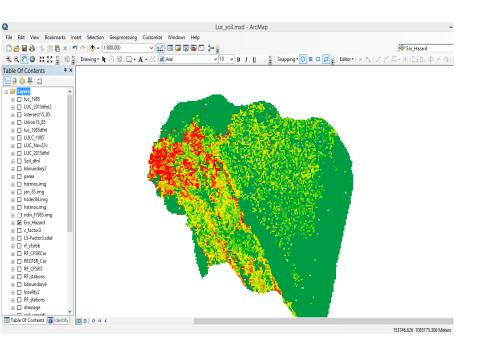
#### LUC from current images- Landsat 8/planet labs



### Generated from DEM in SAGA GIS

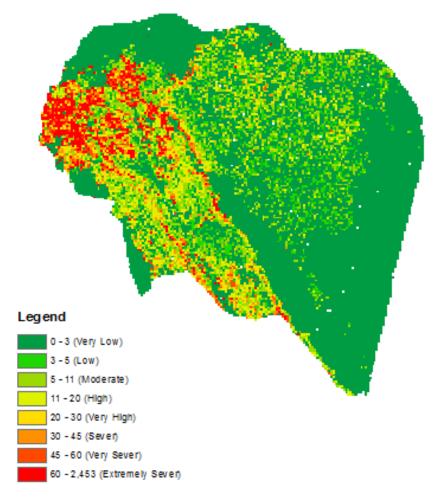


## Integration in GIS



#### Water Erosion Hazard

#### (Expressed interms of Soil loss in ton/ha/year)



# Monitoring Tools

←

× EE EarthExplorer

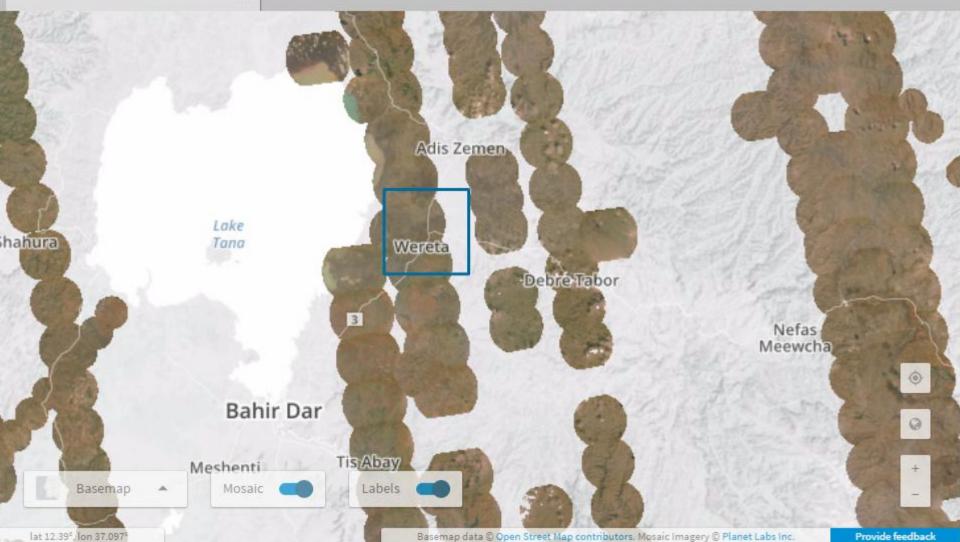
Q

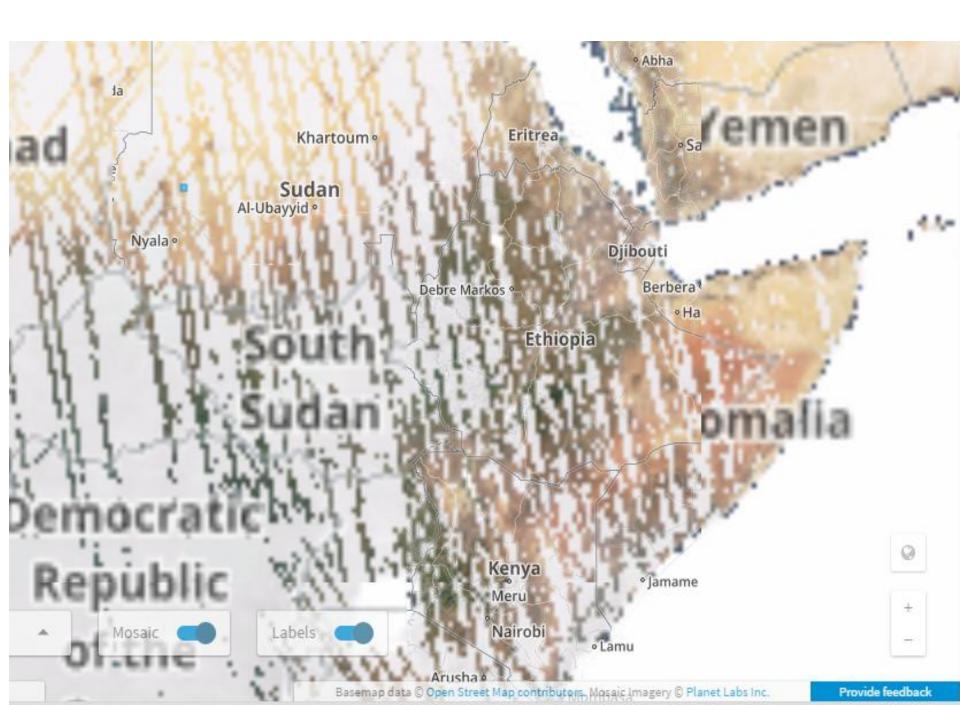
C 🔒 https://www.planet.com/mosaics/#/center/37.6982,11.9199/zoom/16/mosaic.visible/1/labels.visible/1/mosaic/color\_bala

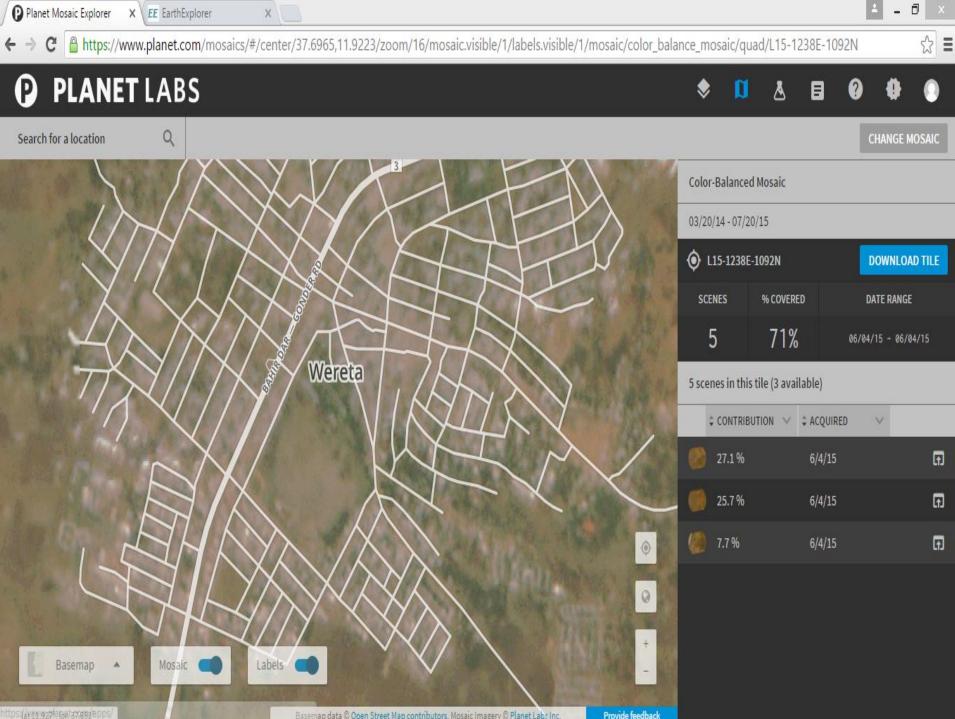
X

### PLANET LABS

Search for a location







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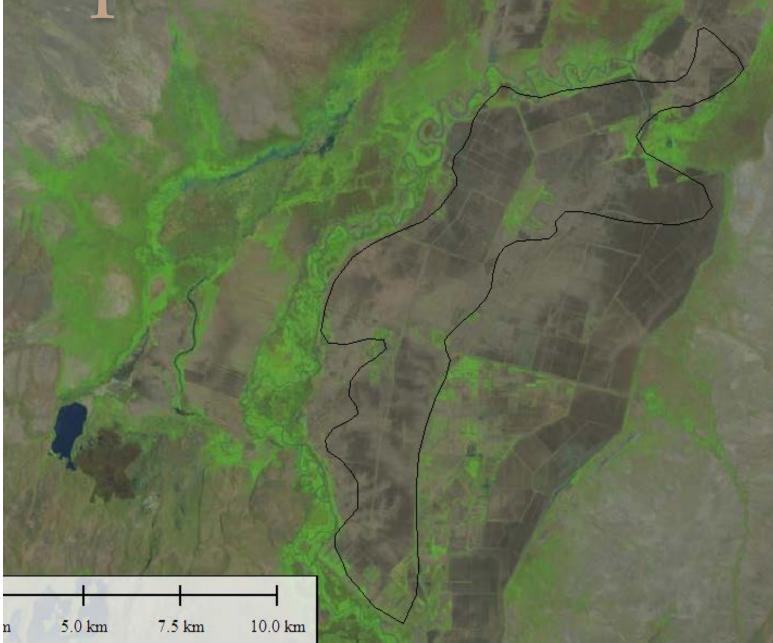
Basemap data @ Open Street Map contributors, Mosaic Imagery @ Planet Labs Inc.



#### **Before Enhancement**

#### After Enhancement

# April 2014



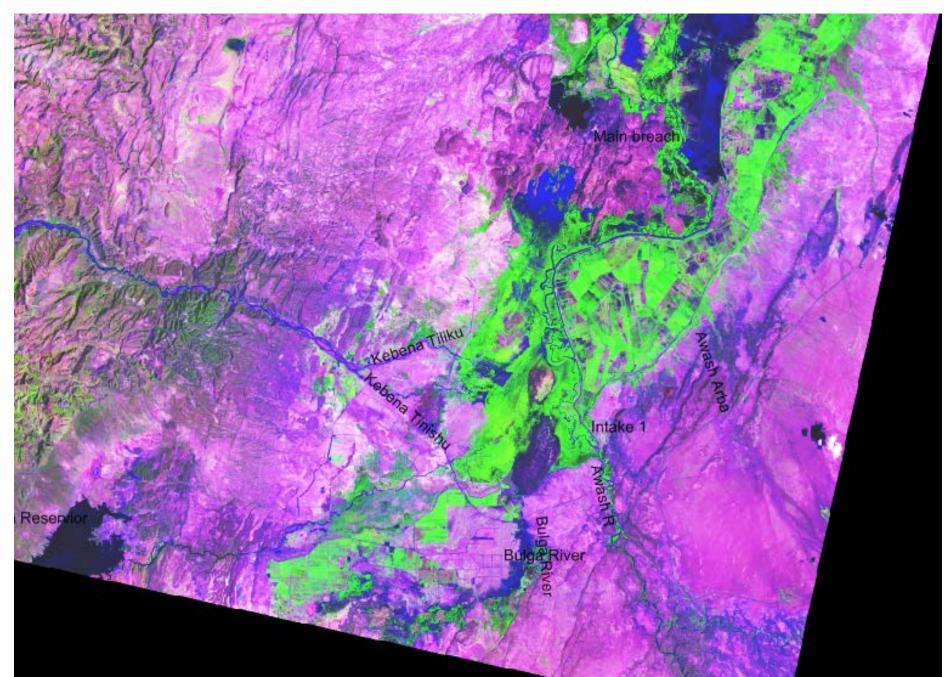
## Inundated area, Oct 17 2014

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Breach Breach Breach Breach

### rivers



#### Supported by:



