Green Roads for Water Training in Sudan

Wad Madani, 15-20 January 2023

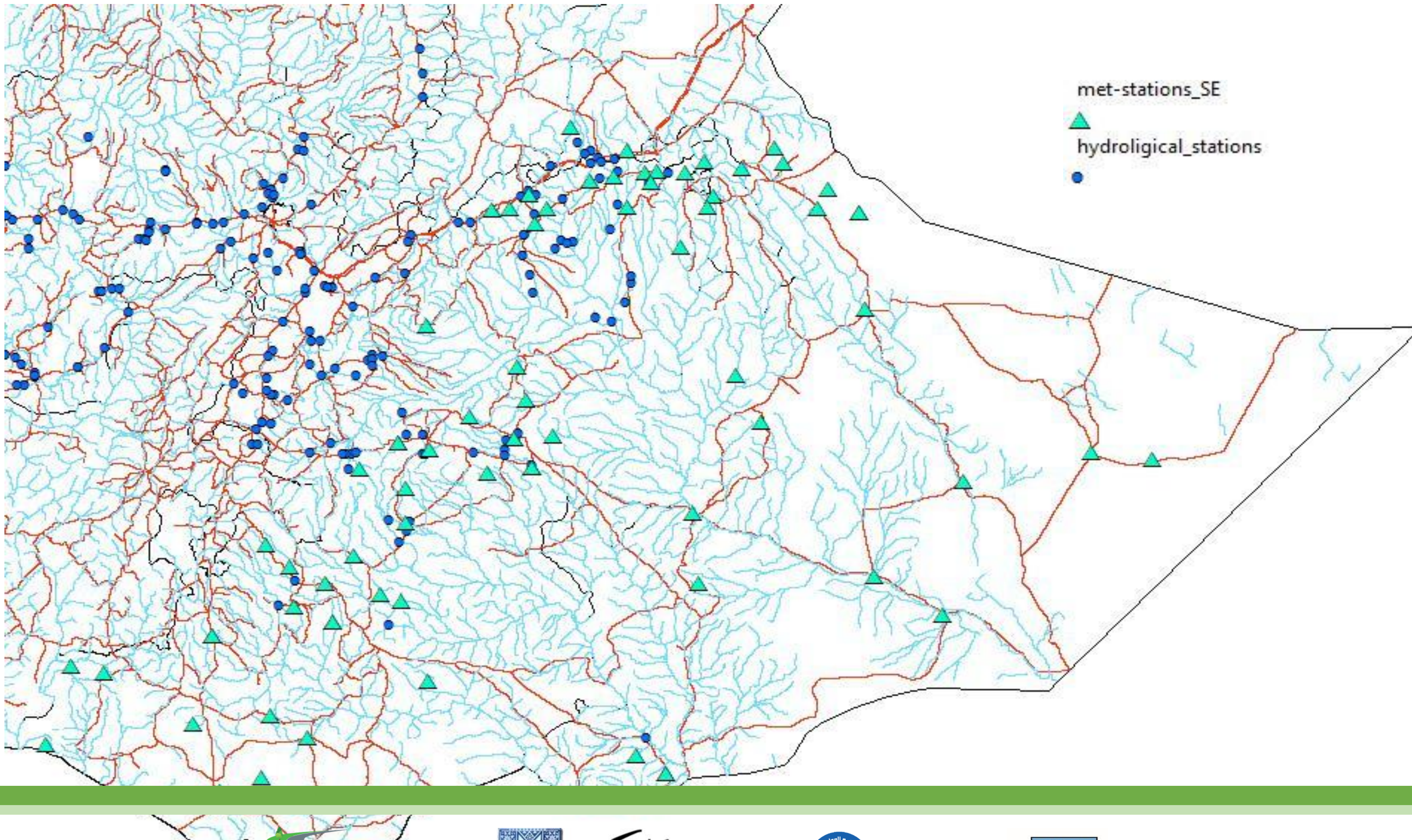
Remote Sensing Methods

Remote Sensing for Rainwater Harvesting and Recharge Estimation under Data Scarce Conditions

Most are the most sought parameters for WH

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

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-
  - Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)
  - 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?

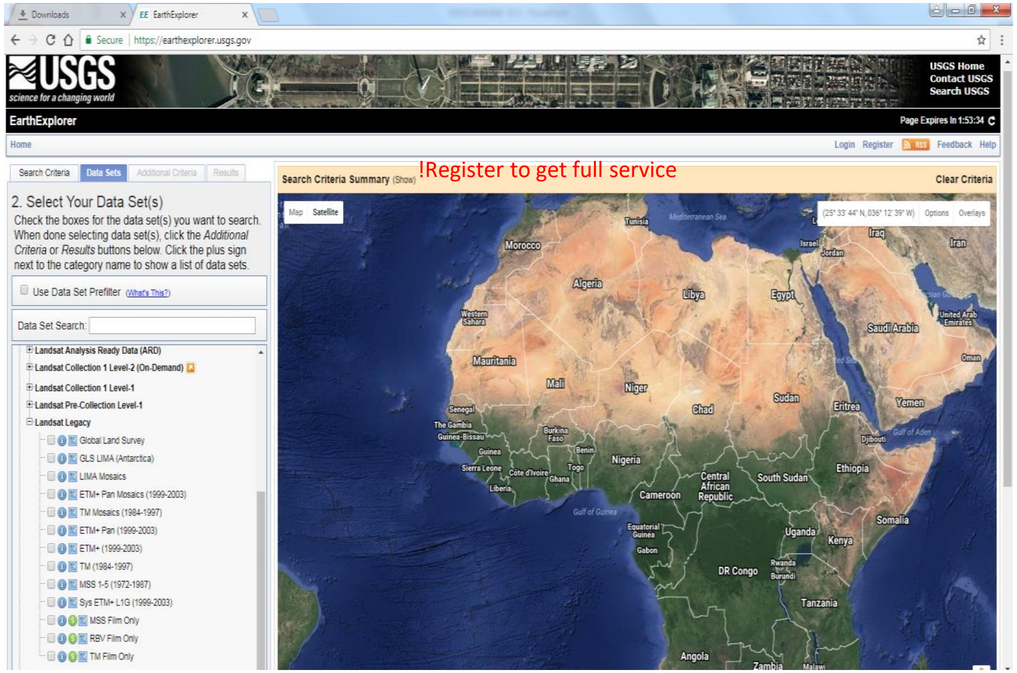
- Global Estimates & Predictions
  - National Center for Environmental Predication (NCEP)
- Combined system of observed and satellite estimates
- Moisture Estimate –
  - Gravity Recovery and Climate Experiment (GRACE)- since March 2002
  - GPR, , ..
- Image
  - Optical
    - Landsat- since 1972
    -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

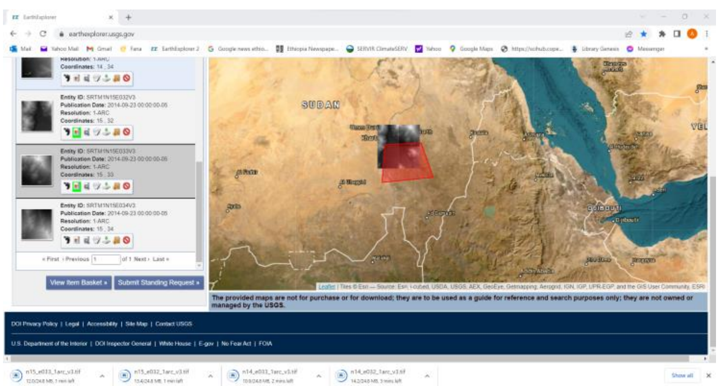
Acquiring data

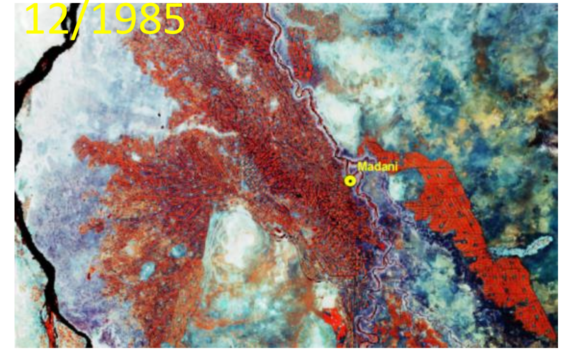
Low and high spatial, temporal resolution multi-spectral and RADAR satellite images, digital terrain models and satellite rainfall estimates are required for such data-scarce watersheds. The following links are some of the online data sources

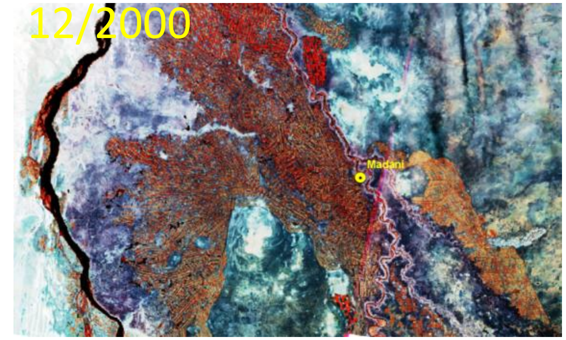
https://earthexplorer.usgs.gov/
https://scihub.copernicus.eu/dhus/#/home
https://climateserv.servirglobal.net/
https://search.asf.alaska.edu/

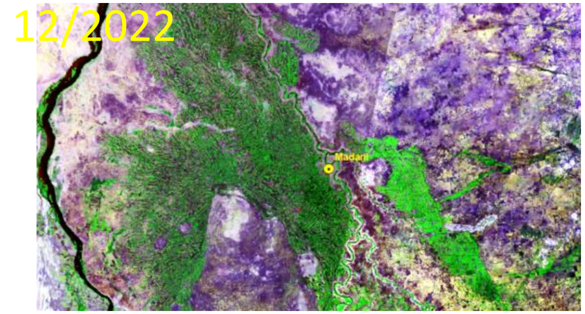
Satellite image and Digital Terrain Models









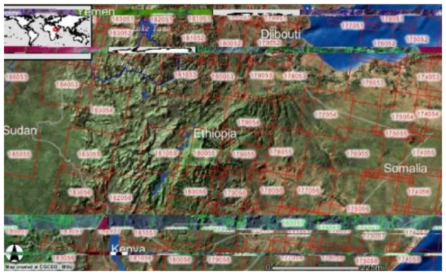


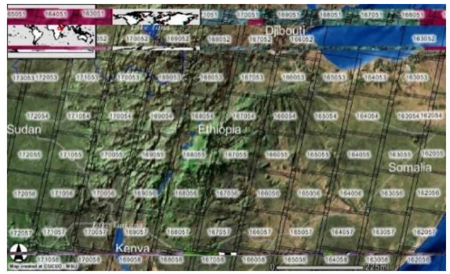
GREEN ROADS FOR WATER

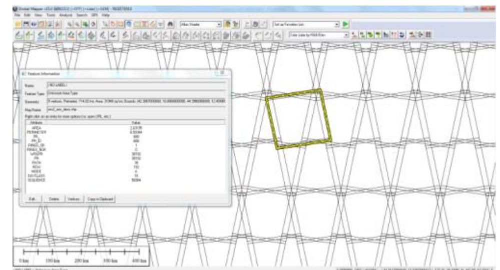
META

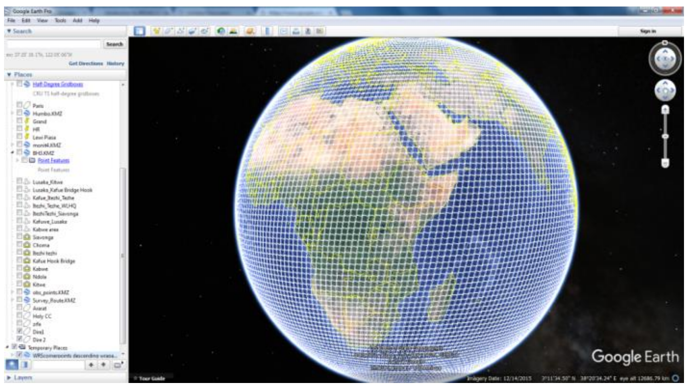
HRC SUDAN

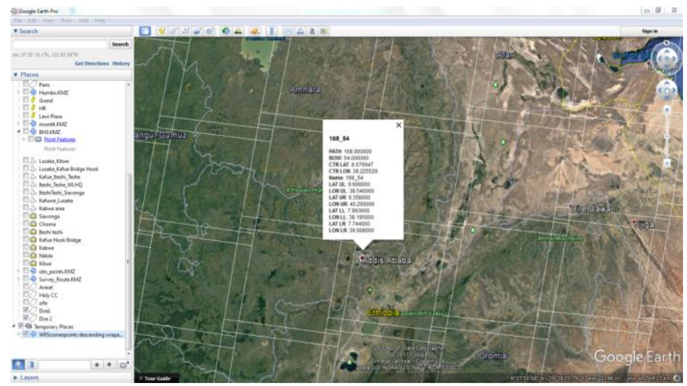
Use Path/Row Shapefile on a map or Path/Row kml on Google Earth
to find path and row of your geographic area of interest.







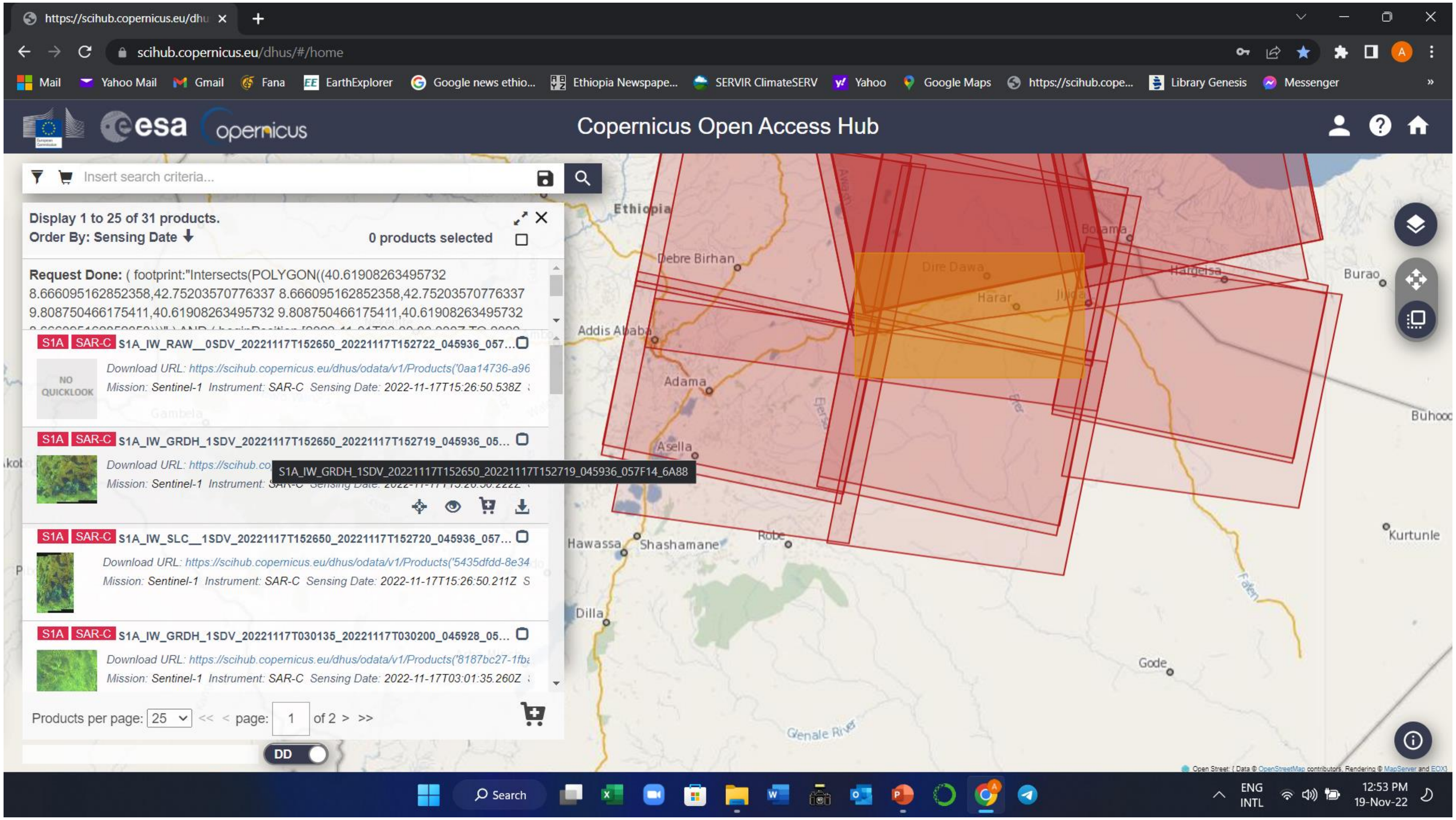




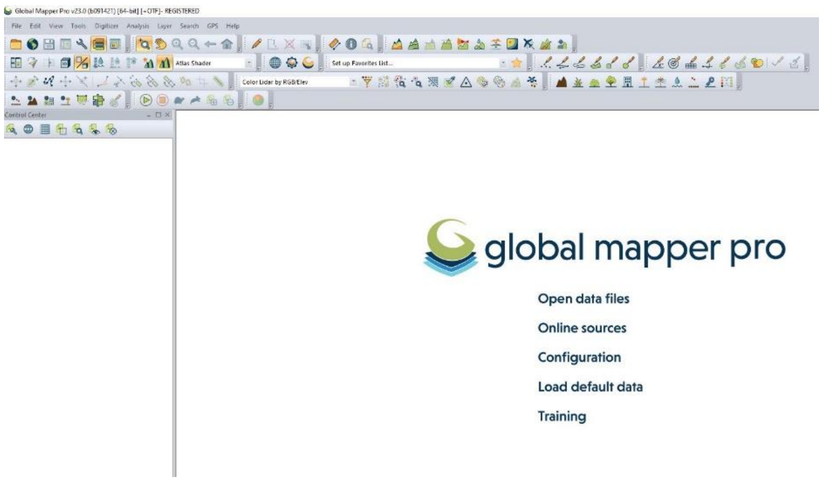
Sentinel Images and many other important products

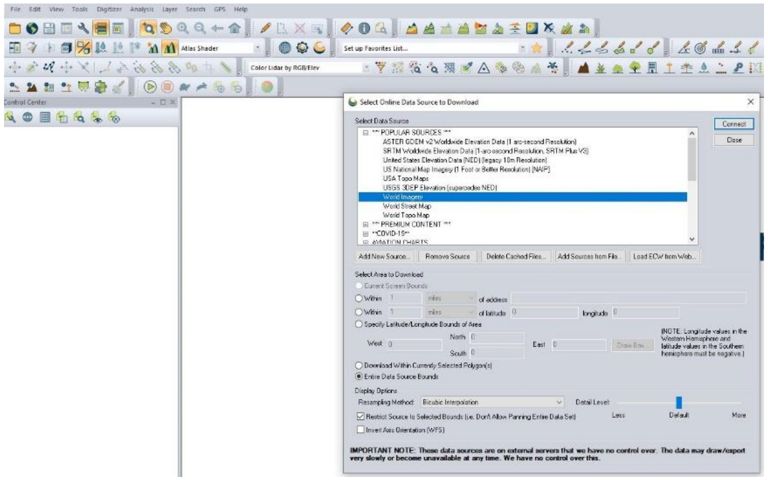
https://scihub.copernicus.eu/dhus/#/home

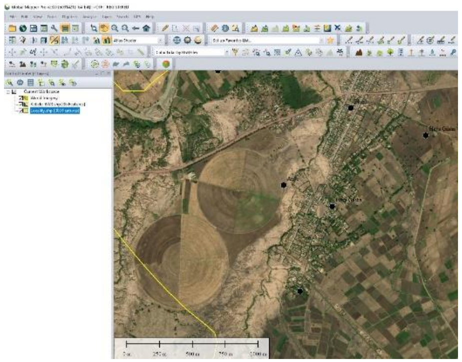
!Register to get full service



Very High Spatial Resolution Image Using Global mapper online sources

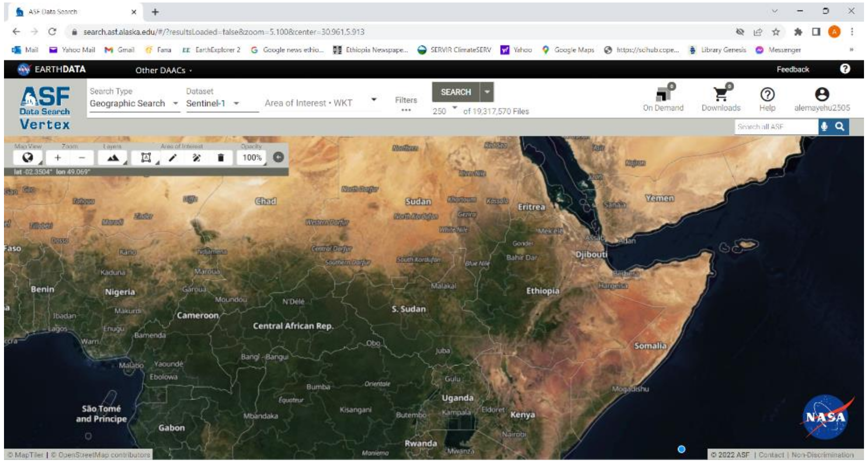


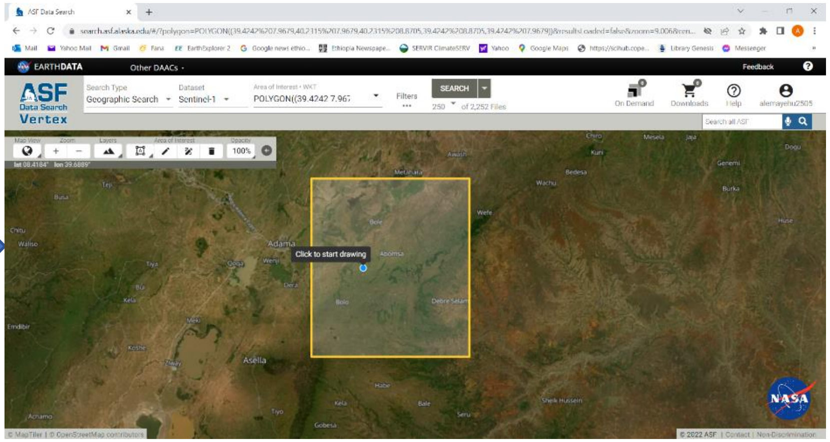


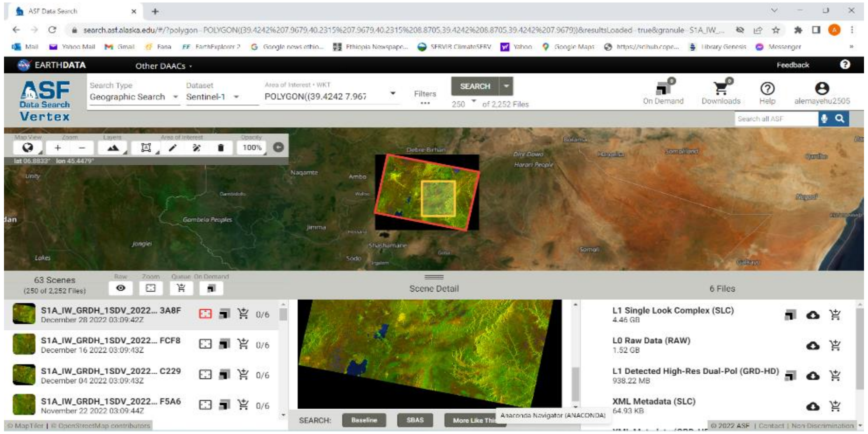


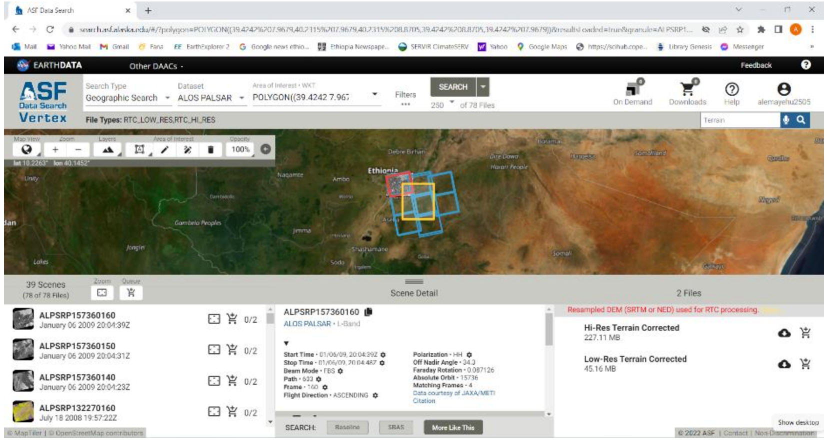
High Spatial Resolution Terrain Model, Image ASF Data Search

https://search.asf.alaska.edu/



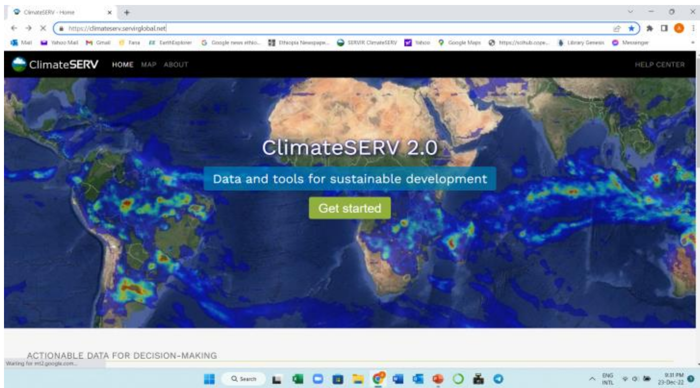


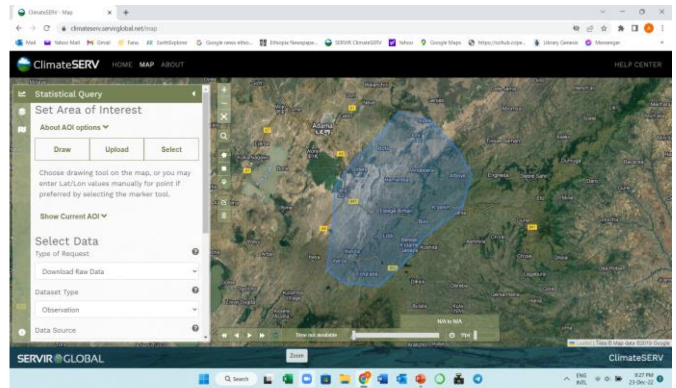


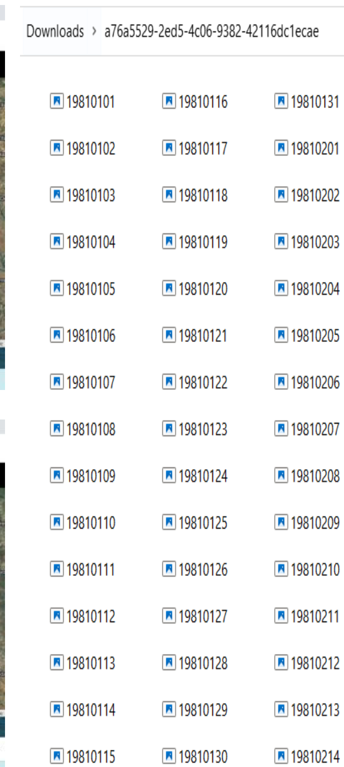


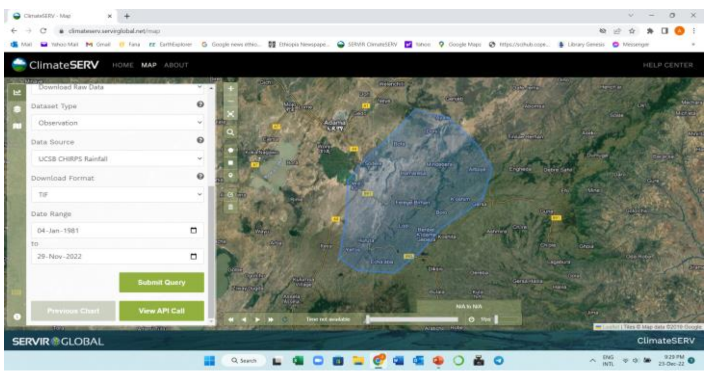
CHIRPS Rainfall

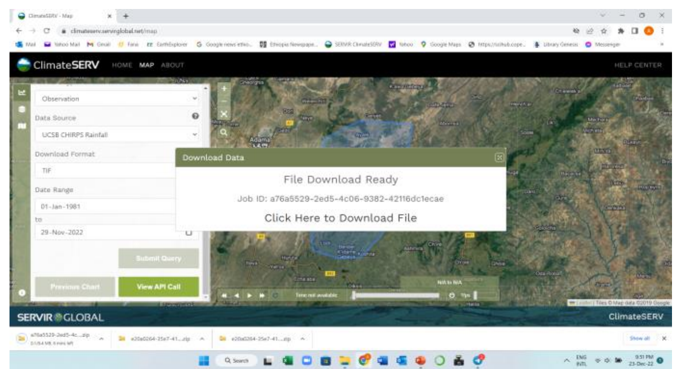
https://climateserv.servirglobal.net/











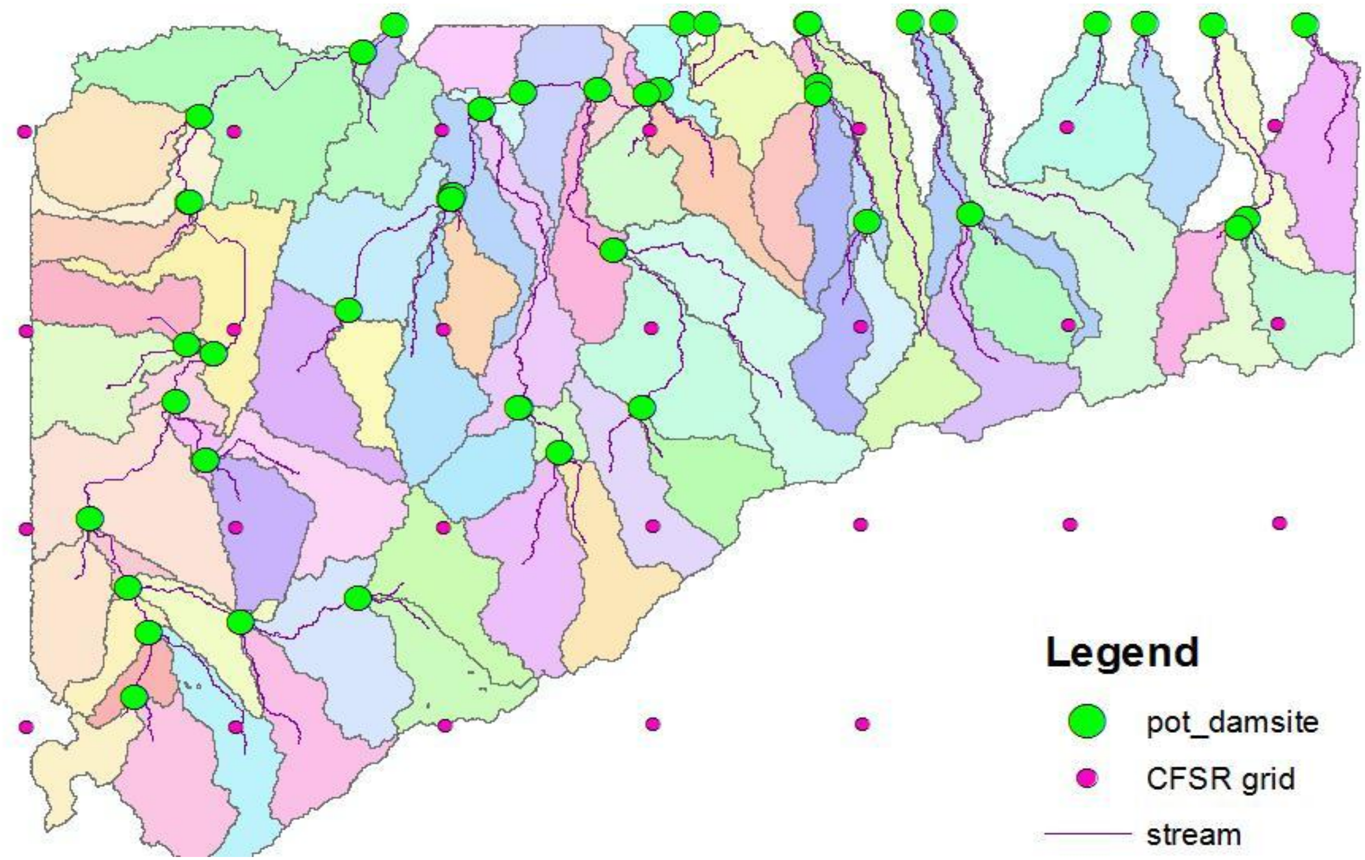
15308 files

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

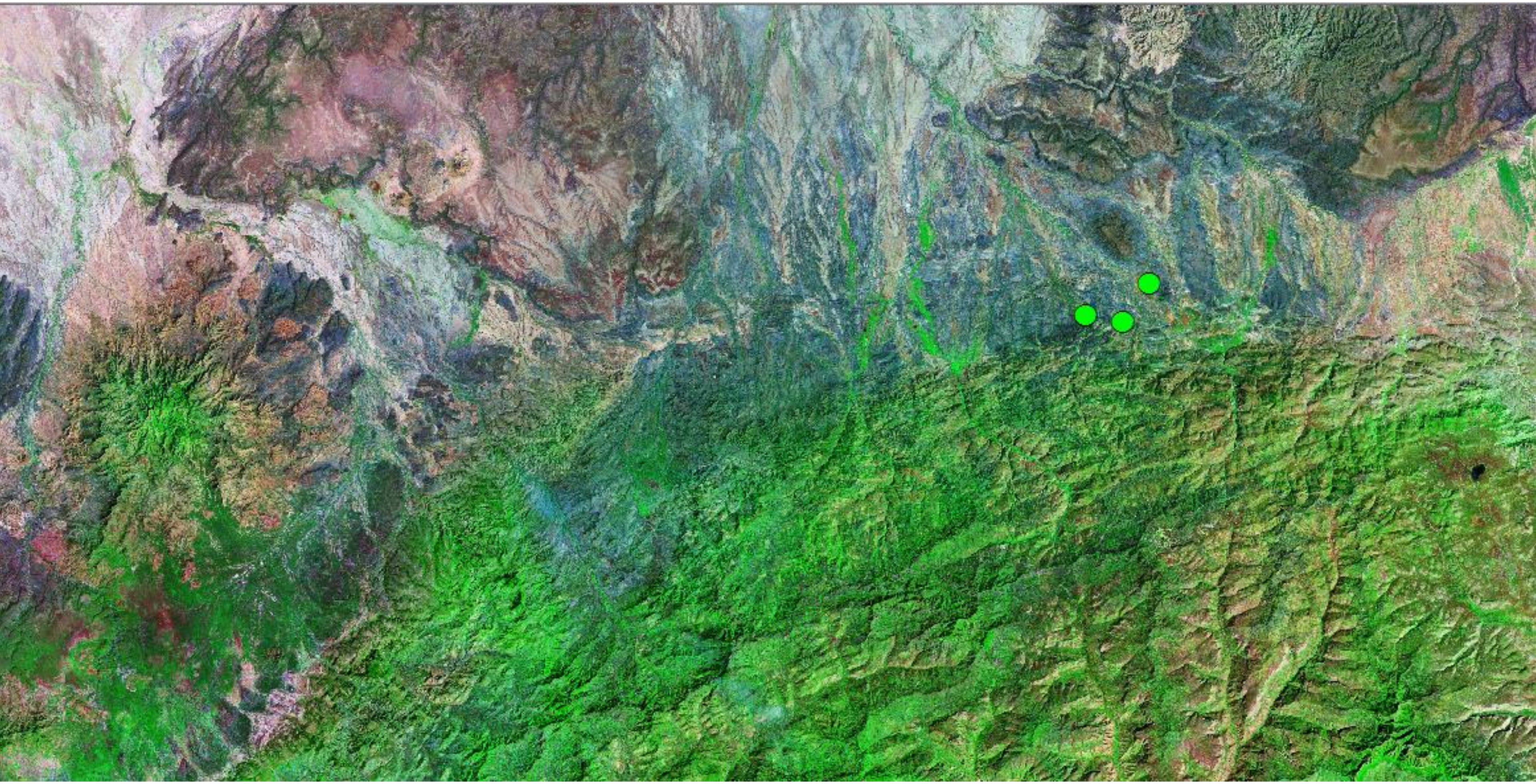


Required data type

- **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

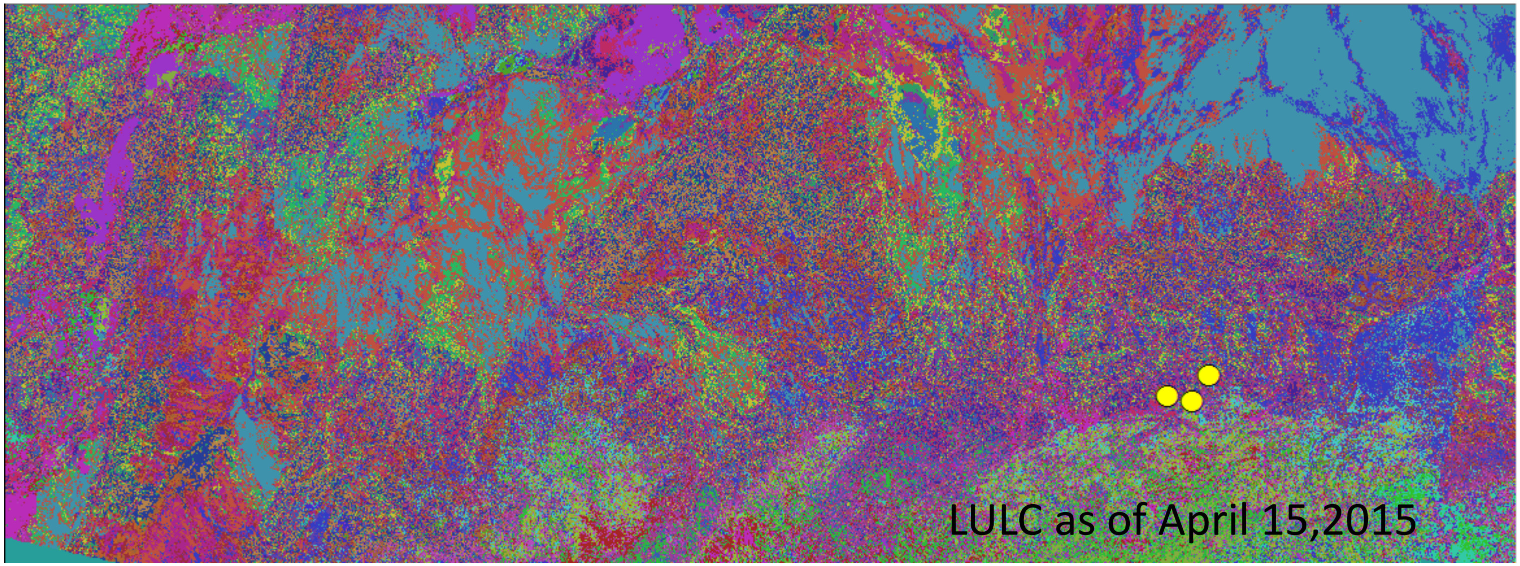
To generate Landuse/Landcover

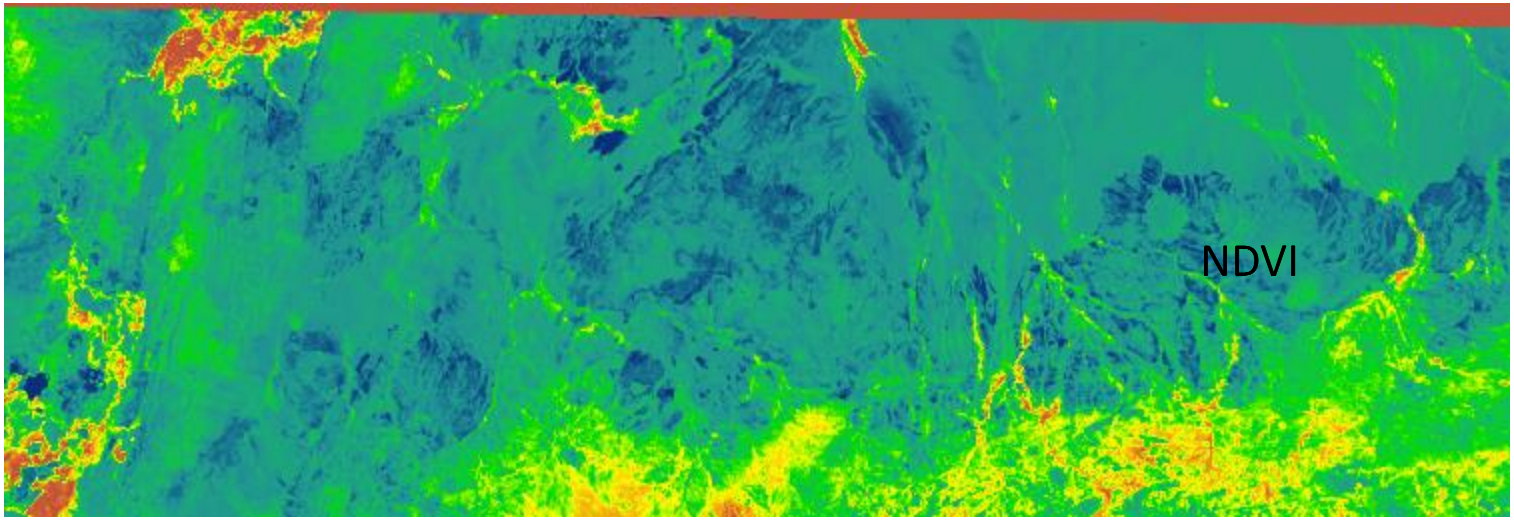


Preparing required data input

Landuse/Landcover

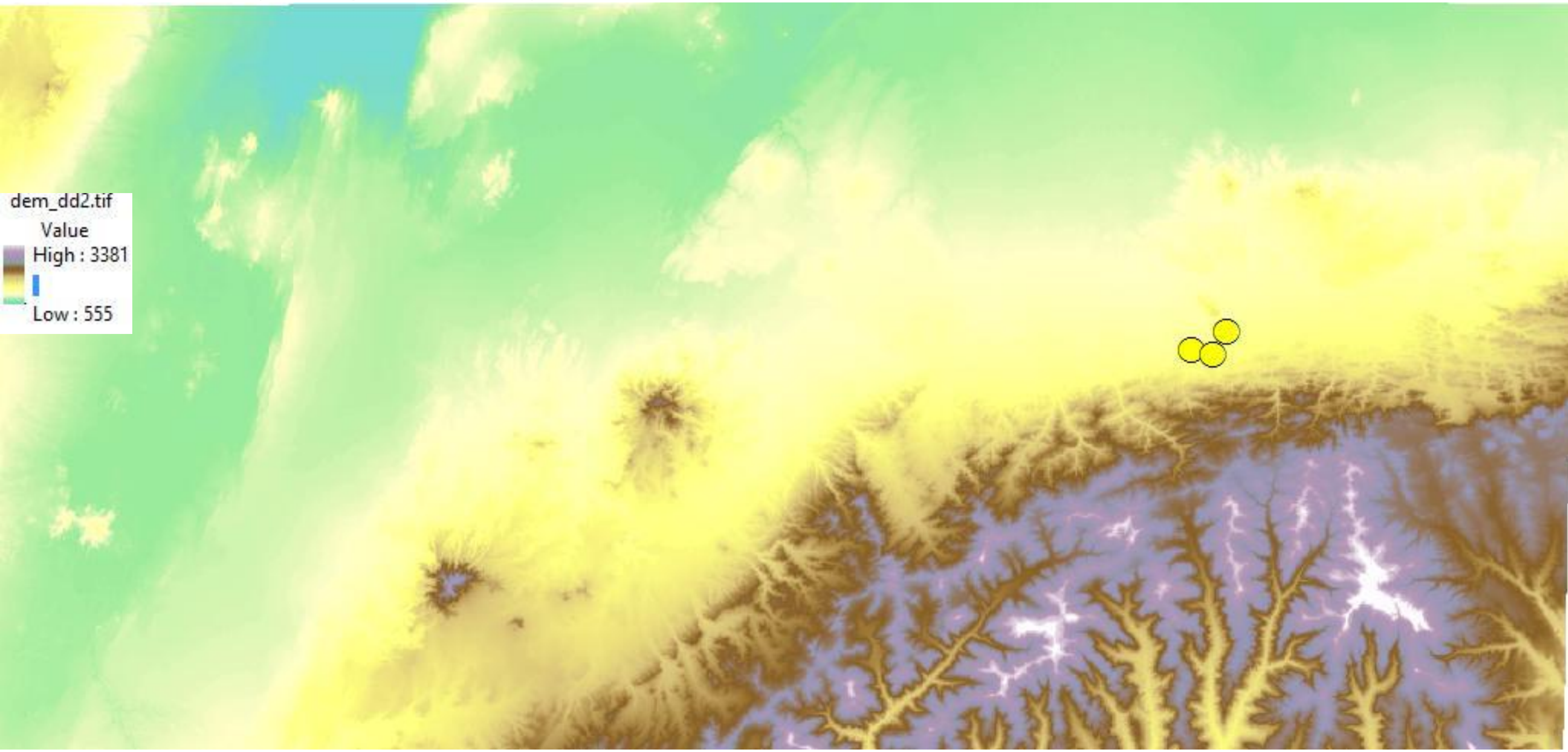
- **Can be generated from recent Landsat 8 data-** **sing in:**





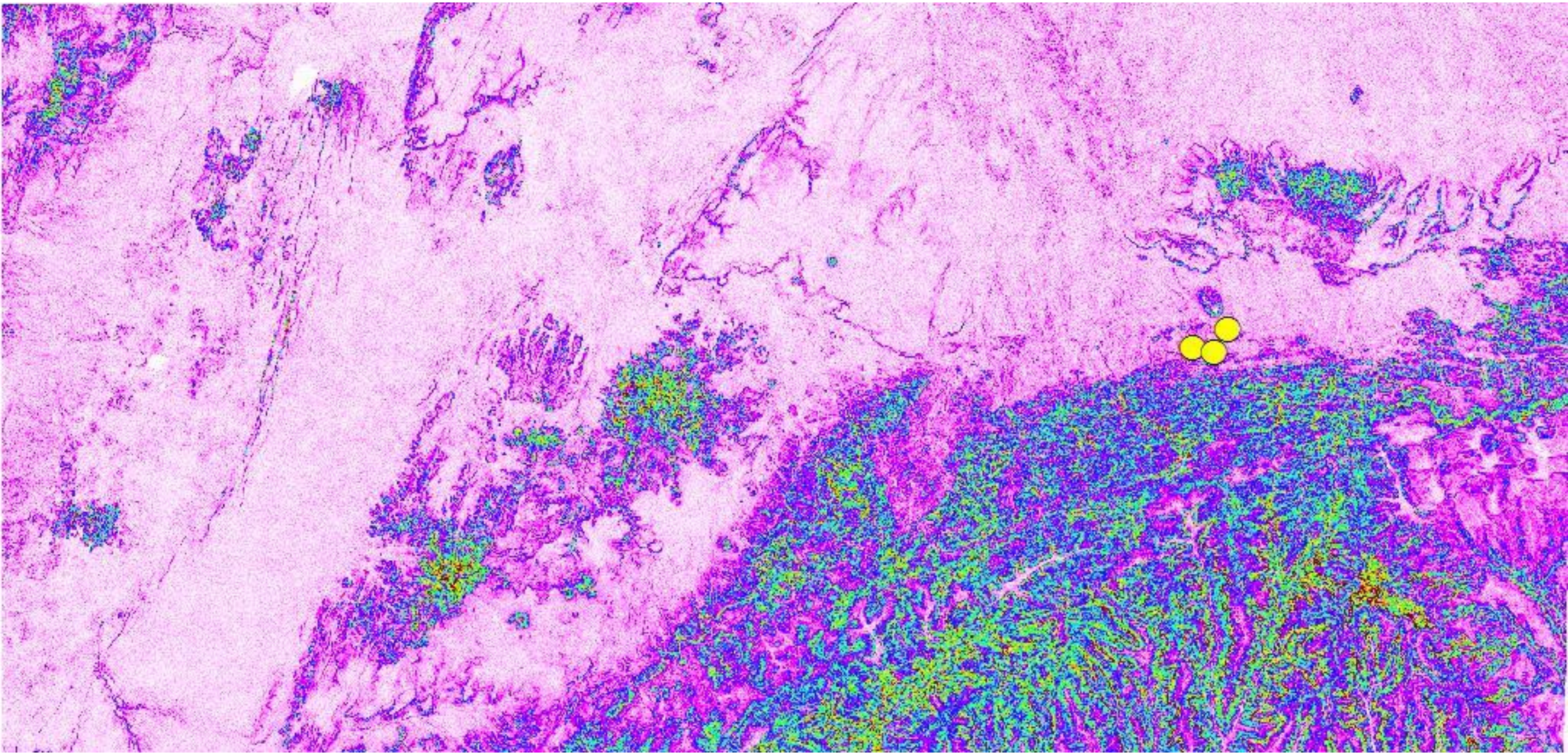
Preparing required data input…

Topography- from SRTM30M V3



Preparing required data input…

Slope - from SRTM30M V3

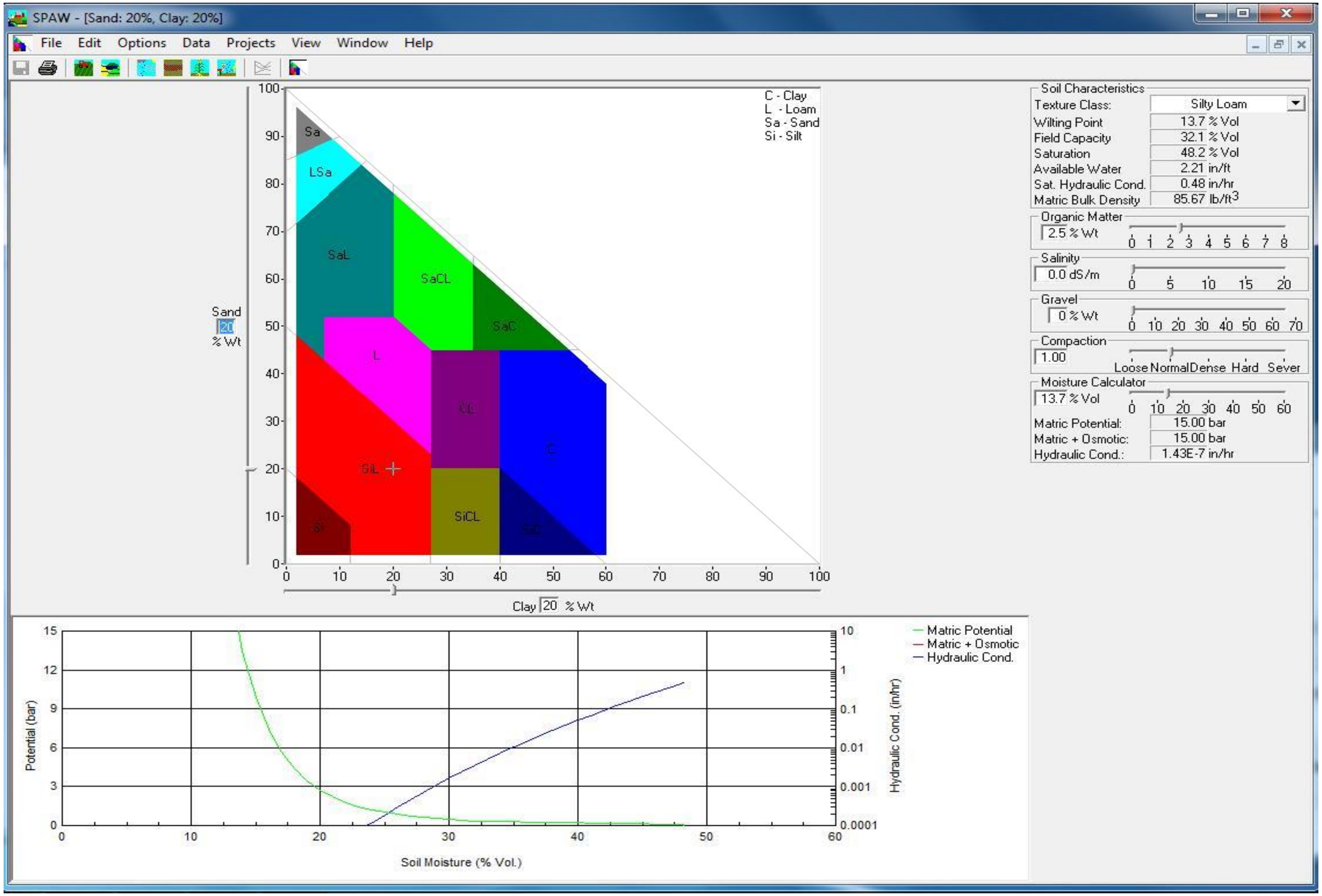


Preparing required data input…

- **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 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
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

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

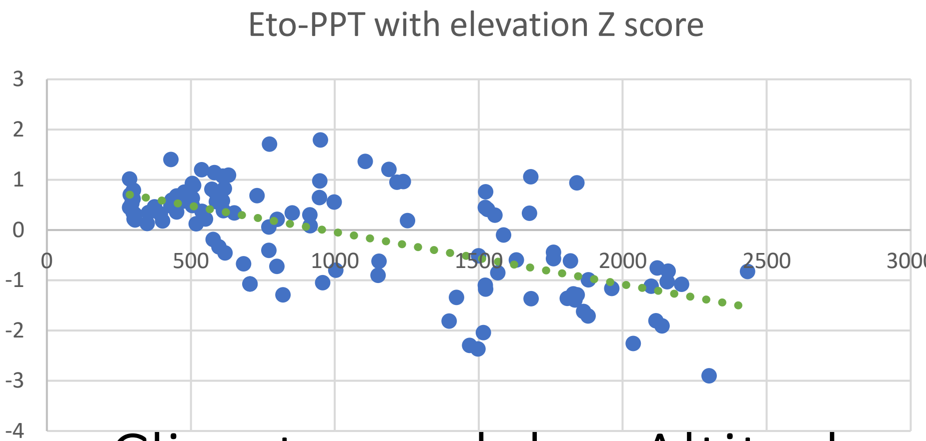
Climate Parameters- CFSR

- **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

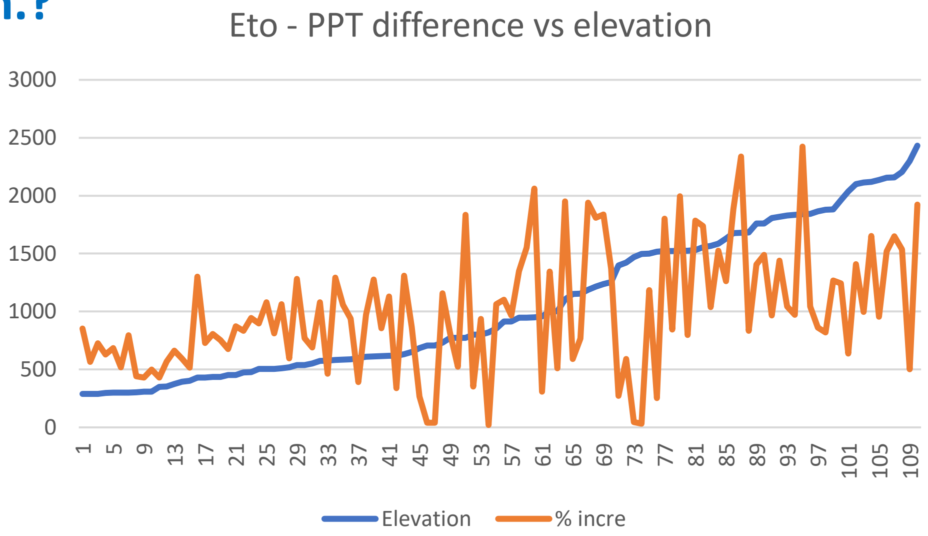
Climate Parameters- CFSR…

Checking data quality

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



Climate model vs Altitude



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**

Hydrological Inputs- data preparation

Date	Longitude	Latitude	Elevation	Max Temp	Min Temp	Precipita	Wind	Relative H	Solar	ETo=COL(
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

Date	427	1	Longitude	Latitude	Elevation	Max Temp	Min Temp	Precipitati	ETo=COL(S+	Wind	Relative H	Solar		Date	Date	Date
1/1/1979	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														2/1/1979	2/1/1979	7/1/1979
1/3/1979														3/1/1979	3/1/1979	8/1/1979
1/4/1979														4/1/1979	4/1/1979	9/1/1979
1/5/1979														5/1/1979	5/1/1979	6/1/1980
1/6/1979														6/1/1979	10/1/1979	7/1/1980
1/7/1979														7/1/1979	11/1/1979	8/1/1980
1/8/1979														8/1/1979	12/1/1979	9/1/1980
1/9/1979														9/1/1979	1/1/1980	6/1/1981
1/10/1979														10/1/1979	2/1/1980	7/1/1981
1/11/1979														11/1/1979	3/1/1980	8/1/1981
1/12/1979														12/1/1979	4/1/1980	9/1/1981
1/13/1979														1/1/1980	5/1/1980	6/1/1982
1/14/1979														2/1/1980	10/1/1980	7/1/1982
1/15/1979														3/1/1980	11/1/1980	8/1/1982
1/16/1979														4/1/1980	12/1/1980	9/1/1982
1/17/1979														5/1/1980	1/1/1981	6/1/1983
1/18/1979														6/1/1980	2/1/1981	7/1/1983
1/19/1979														7/1/1980	3/1/1981	8/1/1983
1/20/1979														8/1/1980	4/1/1981	9/1/1983
1/21/1979														9/1/1980	5/1/1981	6/1/1984
1/22/1979														10/1/1980	10/1/1981	7/1/1984
1/23/1979														11/1/1980	11/1/1981	8/1/1984
1/24/1979														12/1/1980	12/1/1981	9/1/1984
1/25/1979														1/1/1981	1/1/1982	6/1/1985
1/26/1979														2/1/1981	2/1/1982	7/1/1985
1/27/1979														3/1/1981	3/1/1982	8/1/1985
1/28/1979														4/1/1981	4/1/1982	9/1/1985
1/29/1979														5/1/1981	5/1/1982	6/1/1986
1/30/1979														6/1/1981	10/1/1982	7/1/1986
1/31/1979														7/1/1981	11/1/1982	8/1/1986
2/1/1979	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														9/1/1981	1/1/1983	6/1/1987
2/3/1979														10/1/1981	2/1/1983	7/1/1987

* Seasonal average for every grid

* from daily estimates

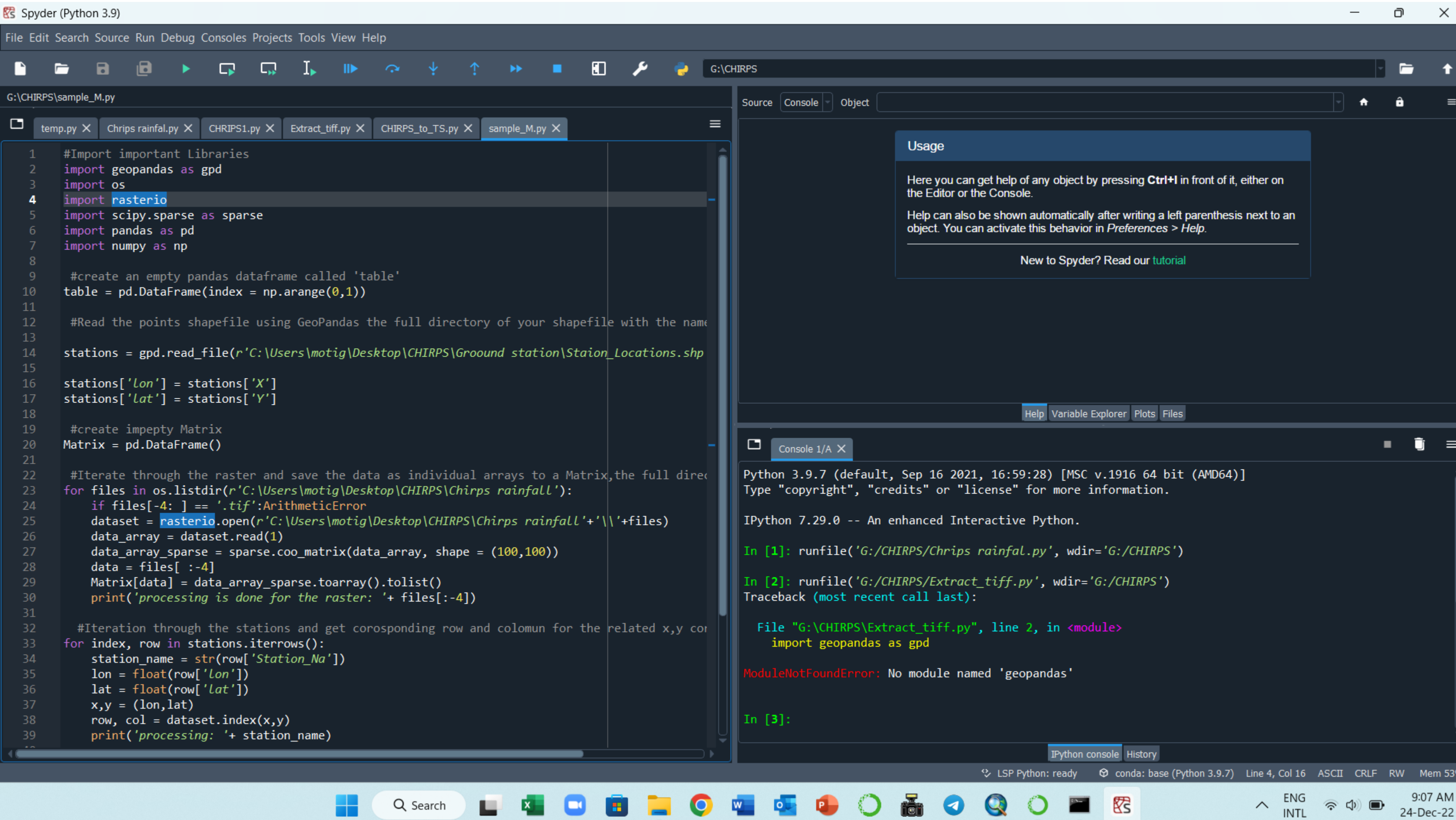
* Eto calculated using

* Penman-Monteith Equation

Template developed in Excel

Date	Max Ter	Min Tei	Tmean	e°(Tme	Δ=(4098	e°(Tma	e°(Tmi	e_s=(e°	Relativ	e°(Tmi	e°(Tma	ea=(e°(
1/1/1979	35.679	22.686	29.1825	4.04812	0.23361	5.83716	2.75652	4.29684	26.6759	0.73533	1.55711	1.14622
1/2/1979	35.418	22.039	28.7285	3.94326	0.22833	5.75389	2.65022	4.20206	27.6006	0.73148	1.58811	1.15979
1/3/1979	35.418	23.349	29.3835	4.09531	0.23598	5.75389	2.86929	4.31159	27.5407	0.79022	1.58466	1.18744
1/4/1979	35.605	22.464	29.0345	4.01367	0.23188	5.81344	2.71964	4.26654	28.0466	0.76276	1.63047	1.19662
1/5/1979	35.523	21.427	28.475	3.88574	0.22543	5.78726	2.55299	4.17013	25.6792	0.65556	1.48606	1.07081
1/6/1979	35.808	23.225	29.5165	4.1268	0.23755	5.8787	2.8479	4.3633	30.6555	0.87304	1.80214	1.33759
1/7/1979	34.968	24.823	29.8955	4.2177	0.2421	5.61274	3.13453	4.37384	37.0558	1.16153	2.07985	1.62069
1/8/1979	33.865	24.299	29.082	4.0247	0.23243	5.27941	3.03789	4.15865	39.1721	1.19	2.06805	1.62903
1/9/1979	35.63	24.138	29.884	4.21492	0.24196	5.82145	3.00872	4.41508	36.7725	1.10638	2.14069	1.62354
1/10/1979	35.709	24.702	30.2055	4.29334	0.24587	5.8468	3.11198	4.47939	36.1907	1.12625	2.116	1.62112
1/11/1979	34.149	26.351	30.25	4.30429	0.24641	5.36355	3.43182	4.39768	37.7709	1.29623	2.02586	1.66104
1/12/1979	33.977	25.101	29.539	4.13215	0.23782	5.31245	3.18689	4.24967	37.1863	1.18508	1.9755	1.58029
1/13/1979	35.886	24.51	30.198	4.29149	0.24578	5.90394	3.07649	4.49021	38.0214	1.16972	2.24476	1.70724
1/14/1979	35.733	25.518	30.6255	4.39769	0.25105	5.85452	3.26684	4.56068	36.9559	1.20729	2.16359	1.68544
1/15/1979	35.684	25.367	30.5255	4.37265	0.24981	5.83876	3.23769	4.53823	36.6018	1.18505	2.13709	1.66107
1/16/1979	35.898	24.895	30.3965	4.34052	0.24822	5.90783	3.14802	4.52792	37.6217	1.18434	2.22263	1.70348
1/17/1979	36.036	26.238	31.137	4.52775	0.2575	5.95274	3.40902	4.68088	34.5151	1.17663	2.05459	1.61561
1/18/1979	35.96	25.681	30.8205	4.44689	0.25349	5.92797	3.29857	4.61327	35.5929	1.17406	2.10994	1.642
1/19/1979	35.372	25.036	30.204	4.29297	0.24585	5.73932	3.17458	4.45695	35.1259	1.1151	2.01599	1.56554
1/20/1979	31.411	25.445	28.428	3.87516	0.2249	4.59879	3.25272	3.92575	39.1458	1.2733	1.80023	1.53677
1/21/1979	35.994	25.059	30.5265	4.3729	0.24982	5.93904	3.17893	4.55898	35.6846	1.13439	2.11932	1.62685
1/22/1979	35.247	25.332	30.2895	4.31403	0.2469	5.6999	3.23097	4.46543	37.252	1.2036	2.12332	1.66346
1/23/1979	35.456	26.466	30.961	4.48263	0.25526	5.76595	3.45516	4.61055	37.3272	1.28971	2.15227	1.72099
1/24/1979	35.624	27.224	31.424	4.60218	0.26117	5.81953	3.61246	4.71599	38.7637	1.40033	2.25587	1.8281
1/25/1979	36.569	27.165	31.867	4.71916	0.26693	6.129	3.6	4.8645	37.8578	1.36288	2.3203	1.84159
1/26/1979	36.579	27.293	31.936	4.73761	0.26783	6.13235	3.62709	4.87972	35.675	1.29396	2.18771	1.74084
1/27/1979	35.469	27.04	31.2545	4.5581	0.25899	5.77008	3.57372	4.6719	39.6202	1.41591	2.28612	1.85102
1/28/1979	37.26	24.922	31.091	4.51592	0.25691	6.36422	3.15309	4.75866	36.7295	1.15811	2.33755	1.74783
1/29/1979	37.286	24.299	30.7925	4.43979	0.25314	6.37322	3.03789	4.70556	36.6149	1.11232	2.33355	1.72294
1/30/1979	37.943	22.006	29.9745	4.23686	0.24305	6.60437	2.6449	4.62463	37.5249	0.99249	2.47828	1.73539
1/31/1979	42.4	22.6	32.5	4.89078	0.27534	8.37282	2.74218	5.5575	32.3632	0.88746	2.70971	1.79859
2/1/1979	42.027	19.999	31.013	4.49592	0.25592	8.21059	2.33814	5.27436	31.6052	0.73897	2.59498	1.66697
2/2/1979	41.182	22.993	32.0875	4.77834	0.26983	7.85309	2.80825	5.33067	37.1267	1.04261	2.91559	1.9791
2/3/1979	40.631	23.638	32.1345	4.79103	0.27045	7.62729	2.91969	5.27349	33.4873	0.97773	2.55417	1.76595
2/4/1979	39.082	24.848	31.965	4.74538	0.26822	7.0223	3.13921	5.08076	32.8059	1.02984	2.30373	1.66679
2/5/1979	39.592	23.945	31.7685	4.69293	0.26564	7.21673	2.97408	5.09541	31.2441	0.92922	2.2548	1.59201
2/6/1979	37.796	26.148	31.972	4.74726	0.26831	6.55203	3.39096	4.97149	30.2274	1.025	1.98051	1.50276
2/7/1979	38.05	26.324	32.187	4.80525	0.27115	6.64269	3.42636	5.03453	31.6729	1.08523	2.10393	1.59458
2/8/1979	39.047	26.806	32.9265	5.00945	0.28113	7.00913	3.52496	5.26705	32.0383	1.12934	2.2456	1.68747
2/9/1979	37.197	25.538	31.3675	4.58745	0.26044	6.34246	3.27072	4.80659	33.0045	1.07949	2.0933	1.58639
2/10/1979	41.969	27.074	34.5215	5.47567	0.3037	8.18561	3.58085	5.88323	31.0163	1.11065	2.53887	1.82476
2/11/1979	36.667	22.71	29.6885	4.16784	0.23961	6.16189	2.76053	4.46121	30.9257	0.85371	1.90561	1.37966
2/12/1979	38.272	25.788	32.03	4.76284	0.26907	6.72282	3.31954	5.02118	38.2554	1.2699	2.57184	1.92087
2/13/1979	37.853	25.667	31.76	4.69067	0.26553	6.57228	3.29584	4.93406	34.8158	1.14747	2.28819	1.71783
2/14/1979	37.476	25.577	31.5265	4.62902	0.26249	6.43934	3.2783	4.85882	33.4075	1.0952	2.15122	1.62321

Date	Z	P=101.3*	γ=0.665	Solar	Wind	0.408*Δ	γ/[Δ+γ*(	900*u2*	ETo=C	ETo=COL(S+T+U)
1/1/1979	2	101.276	0.06735	24.639	2.98088	6.3605	0.18241	27.9714	11.4628	9.254358
1/2/1979	2	101.276	0.06735	21.7916	2.83946	5.62823	0.18672	25.7667	10.4393	9.134188
1/3/1979	2	101.276	0.06735	24.7479	3.84795	6.087	0.17206	35.7804	12.2432	8.812397
1/4/1979	2	101.276	0.06735	24.8245	3.23903	6.2897	0.18037	29.6297	11.634	8.826135
1/5/1979	2	101.276	0.06735	24.9947	2.62262	6.51557	0.19088	24.2657	11.1474	8.766054
1/6/1979	2	101.276	0.06735	24.5645	3.41675	6.214	0.17578	30.7563	11.6204	8.597351
1/7/1979	2	101.276	0.06735	21.727	3.71955	5.4384	0.17067	30.4256	10.6311	8.424597
1/8/1979	2	101.276	0.06735	19.3091	3.33011	4.86956	0.1791	25.0975	9.36458	8.620566
1/9/1979	2	101.276	0.06735	17.3134	3.04996	4.5079	0.17763	25.2991	9.00185	8.755483
1/10/1979	2	101.276	0.06735	24.5319	3.32898	6.31896	0.17294	28.2435	11.2033	9.596768
1/11/1979	2	101.276	0.06735	17.4778	3.67469	4.41599	0.16926	29.8456	9.46759	9.070342
1/12/1979	2	101.276	0.06735	18.293	3.28805	4.66536	0.17702	26.1101	9.28734	8.59772
1/13/1979	2	101.276	0.06735	24.337	3.90179	6.06362	0.16734	32.2321	11.4573	8.918533
1/14/1979	2	101.276	0.06735	24.8278	5.07181	5.85243	0.15499	43.2256	12.5519	6.889116
1/15/1979	2	101.276	0.06735	24.891	4.73769	5.96027	0.15823	40.4182	12.3555	9.211254
1/16/1979	2	101.276	0.06735	23.7418	4.01134	5.90149	0.16531	33.6089	11.4572	7.69689
1/17/1979	2	101.276	0.06735	24.6952	4.88959	5.9395	0.15418	44.3522	12.7779	7.265336
1/18/1979	2	101.276	0.06735	24.9234	5.55853	5.75223	0.15029	48.9247	13.1051	9.525489
1/19/1979	2	101.276	0.06735	25.1877	4.99979	5.90734	0.15747	42.911	12.6646	10.47562
1/20/1979	2	101.276	0.06735	9.35848	3.81961	2.26151	0.17737	27.2454	7.09398	9.170372
1/21/1979	2	101.276	0.06735	17.2478	3.2042	4.50149	0.17245	27.8579	9.30555	9.816693
1/22/1979	2	101.276	0.06735	19.3046	3.50573	4.92908	0.17071	29.1492	9.90513	10.09958
1/23/1979	2	101.276	0.06735	19.6442	2.8679	5.26909	0.17345	24.537	9.5251	10.09926
1/24/1979	2	101.276	0.06735	9.69457	2.89651	2.61629	0.17057	24.7298	6.83446	6.97735
1/25/1979	2	101.276	0.06735	19.8413	3.33629	5.26172	0.164	29.7728	10.1444	10.23314
1/26/1979	2	101.276	0.06735	19.0797	3.20917	5.10183	0.1648	29.7305	10.0014	10.27227
1/27/1979	2	101.276	0.06735	17.4208	3.60741	4.50145	0.16469	30.1014	9.45878	9.942109
1/28/1979	2	101.276	0.06735	19.7033	2.43738	5.43395	0.1772	21.7194	9.28263	9.885603
1/29/1979	2	101.276	0.06735	16.71	1.70761	4.79944	0.18729	15.0887	7.62543	9.847311
1/30/1979	2	101.276	0.06735	21.7225	1.98251	6.05433	0.18929	17.0152	9.27512	9.549043
1/31/1979	2	101.276	0.06735	23.9264	0.8519	7.42101	0.18595	9.43365	9.17517	9.767184
2/1/1979	2	101.276	0.06735	26.1566	1.50498	7.63468	0.18827	16.0721	10.6605	9.856133
2/2/1979	2	101.276	0.06735	22.4147	1.83266	6.50848	0.17763	18.1196	9.72711	9.759424
2/3/1979	2	101.276	0.06735	24.8839	1.89231	7.20434	0.17671	19.577	10.6637	9.640702
2/4/1979	2	101.276	0.06735	22.174	2.92571	6.02779	0.1673	29.477	10.9593	10.04
2/5/1979	2	101.276	0.06735	17.8803	2.34084	5.01275	0.17421	24.2177	9.23179	9.750362
2/6/1979	2	101.276	0.06735	25.234	3.19273	6.75779	0.16476	32.6826	12.1426	10.4598
2/7/1979	2	101.276	0.06735	24.3091	3.52194	6.41615	0.16068	35.7282	12.157	11.08628
2/8/1979	2	101.276	0.06735	18.663	2.5569	5.25926	0.16547	26.9259	9.71456	11.07822
2/9/1979	2	101.276	0.06735	25.7516	2.97448	6.91175	0.17011	28.3229	11.7299	11.65805
2/10/1979	2	101.276	0.06735	19.6344	1.58082	5.97398	0.16538	18.7764	9.07915	11.58168
2/11/1979	2	101.276	0.06735	13.2551	1.33331	3.83961	0.19956	12.2165	6.27754	11.09457
2/12/1979	2	101.276	0.06735	23.5498	2.68816	6.4962	0.16923	24.5901	10.6575	10.38355
2/13/1979	2	101.276	0.06735	16.2217	2.65753	4.46342	0.17105	25.2412	8.78101	10.48066
2/14/1979	2	101.276	0.06735	22.4097	3.25715	5.93438	0.16653	31.1466	11.1212	10.28925

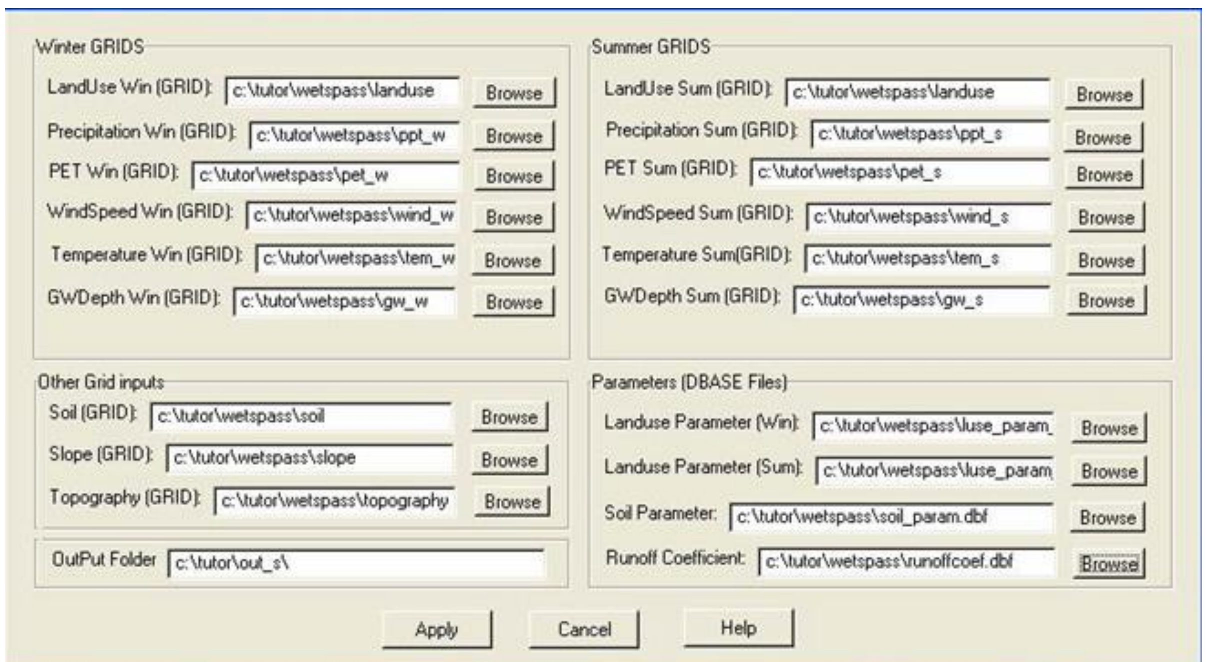

Spyder (Python 3.9)
File Edit Search Source Run Debug Consoles Projects Tools View Help
G:\CHIRPS
G:\CHIRPS\sample_M.py
temp.py
Chrips rainfal.py
CHIRPS1.py
Extract_tiff.py
CHIRPS_to_TS.py
sample_M.py
#Import important Libraries
import geopandas as gpd
import os
import rasterio
import scipy.sparse as sparse
import pandas as pd
import numpy as np
#create an empty pandas dataframe called 'table'
table = pd.DataFrame(index = np.arange(0,1))
#Read the points shapefile using GeoPandas the full directory of your shapefile with the name
stations = gpd.read_file(r'C:\Users\motig\Desktop\CHIRPS\Groound station\Staion_Locations.shp
stations['lon'] = stations['X']
stations['lat'] = stations['Y']
#create impepty Matrix
Matrix = pd.DataFrame()
#Iterate through the raster and save the data as individual arrays to a Matrix,the full direc
for files in os.listdir(r'C:\Users\motig\Desktop\CHIRPS\Chirps rainfall'):
if files[-4:] == '.tif':ArithmeticError
dataset = rasterio.open(r'C:\Users\motig\Desktop\CHIRPS\Chirps rainfall'+'\\'+files)
data_array = dataset.read(1)
data_array_sparse = sparse.coo_matrix(data_array, shape = (100,100))
data = files[:-4]
Matrix[data] = data_array_sparse.toarray().tolist()
print('processing is done for the raster: '+ files[:-4])
#Iteration through the stations and get corosponding row and colomun for the related x,y cor
for index, row in stations.iterrows():
station_name = str(row['Station_Na'])
lon = float(row['lon'])
lat = float(row['lat'])
x,y = (lon,lat)
row, col = dataset.index(x,y)
print('processing: '+ station_name)
Source Console Object
Usage
Here you can get help of any object by pressing Ctrl+I in front of it, either on the Editor or the Console.
Help can also be shown automatically after writing a left parenthesis next to an object. You can activate this behavior in Preferences > Help.
New to Spyder? Read our tutorial
Help Variable Explorer Plots Files
Console 1/A
Python 3.9.7 (default, Sep 16 2021, 16:59:28) [MSC v.1916 64 bit (AMD64)]
Type "copyright", "credits" or "license" for more information.
IPython 7.29.0 -- An enhanced Interactive Python.
In [1]: runfile('G:/CHIRPS/Chrips rainfal.py', wdir='G:/CHIRPS')
In [2]: runfile('G:/CHIRPS/Extract_tiff.py', wdir='G:/CHIRPS')
Traceback (most recent call last):
File "G:\CHIRPS\Extract_tiff.py", line 2, in <module>
import geopandas as gpd
ModuleNotFoundError: No module named 'geopandas'
In [3]:
IPython console History
LSP Python: ready conda: base (Python 3.9.7) Line 4, Col 16 ASCII CRLF RW Mem 53%
Search
ENG INTL
9:07 AM 24-Dec-22

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)

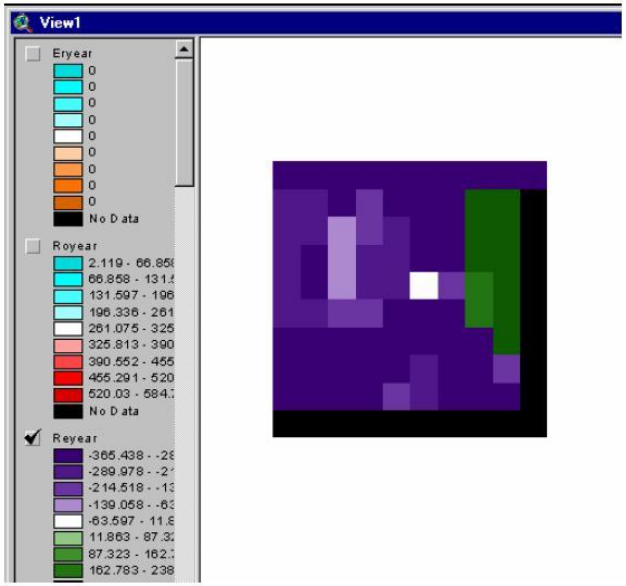
Preparing input data …

- **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**



Model Outputs

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



- **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 **Ro**noff
• **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

Thank you!

For more information visit www.roadsforwater.org
or send an email to adeligianni@metameta.nl