Reservoir Sedimentation Hazard and Mitigation Measures towards Sustainability in Tunisia
Activity No. : N-W-TN-2

Presentation of AnnAGNPS Model

November 2023, Tunis, Tunisia

Presentation of the AnnAGNPS model used for the WES Technical Assistance Activity in Tunisia

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This Project is funded by the European Union

Introduction

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2 – Soil Erosion (Sheet &Rill and Gully)

3 – AnnAGNPS model

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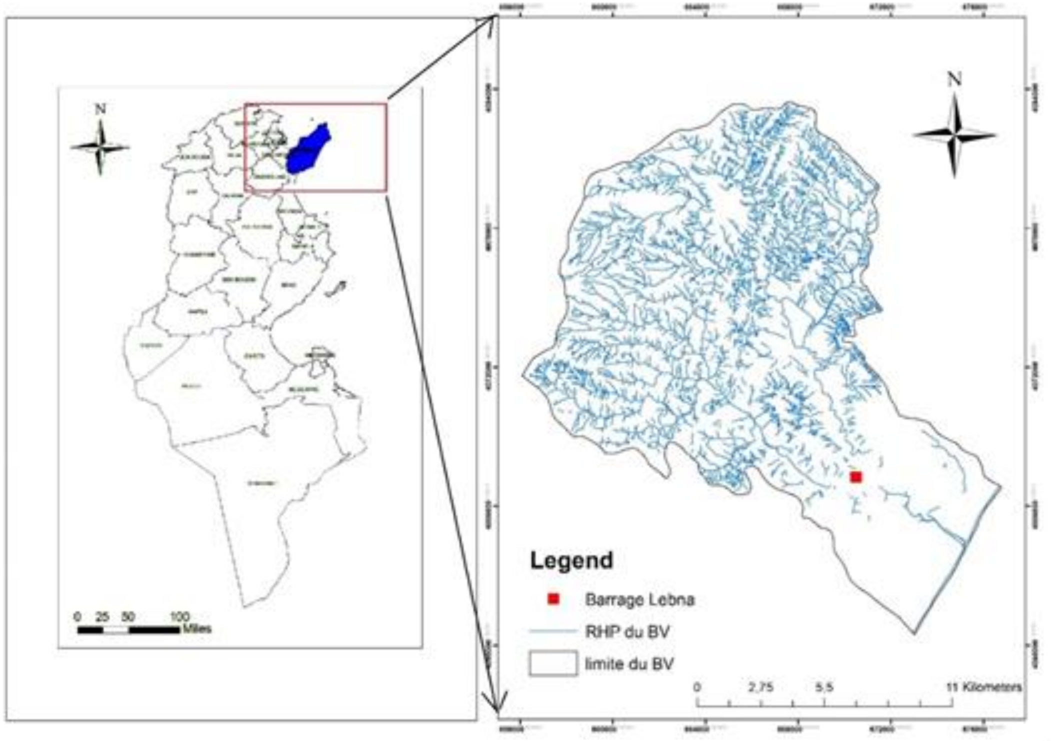
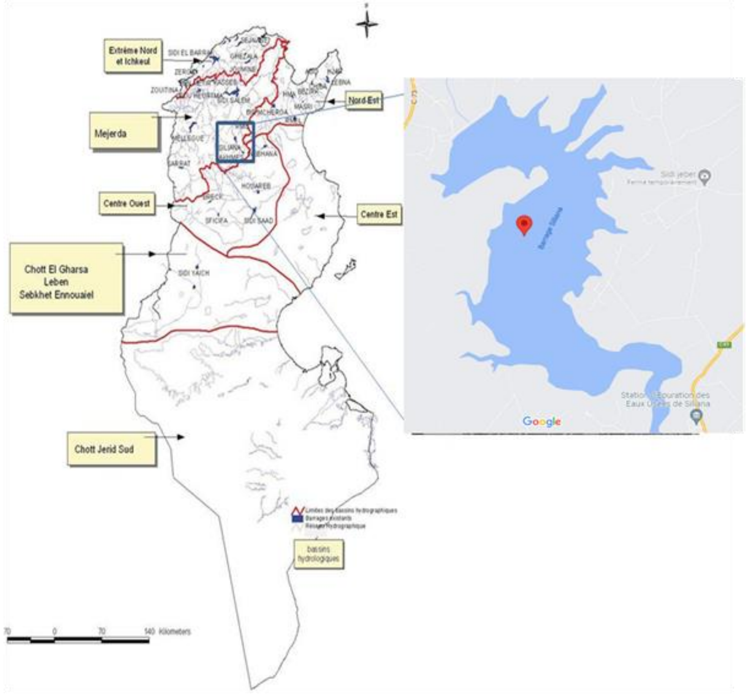
General information

- The Siliana dam is located in the northwest / central region of the country and regulates the inflow of Siliana wadi which is a tributary on the right bank of Medjerda wadi, and the Lebna dam is located in the region of Cap Bon (Northeast of the country).





General Information

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- The Lebna dam serves an irrigated perimeter of 1,200 ha and supplies raw water to the SONEDE treatment station. Current silt volume is 23% for the Lebna dam.
- The Siliana dam serves an irrigated perimeter of 4,400 ha and helps protect against flooding in the lower Medjerda valley. Current silt volume is 52% of the initial storage capacity for the Siliana dam.

General Information

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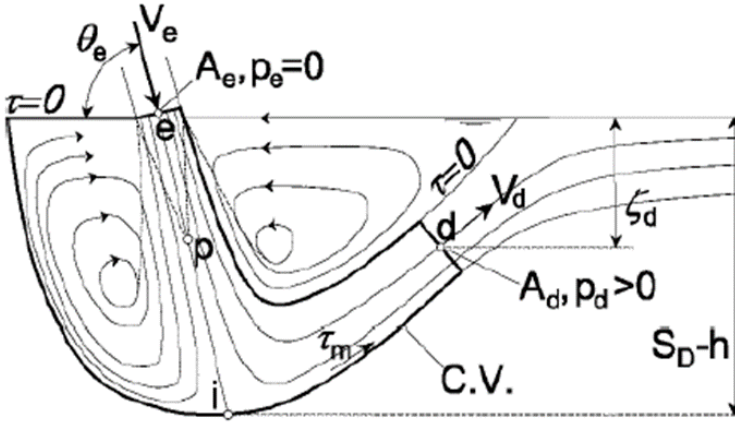
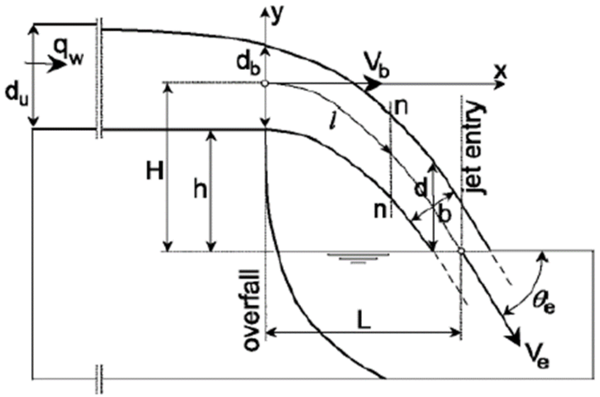
- The visit of the two dams Lebna and Siliana clearly shows that gully erosion is the main cause of the erosion of the catchments and the siltation of the two dams.

Gully Erosion

Ephemeral gullies are defined as small channels eroded by concentrated flow that can be easily filled by normal tillage, only to reform again in the same location by additional runoff events (Soil Science Society of America, 2008).

Recent studies indicate that ephemeral gully erosion may be a significant form of erosion and source of sediment on cropland in the U.S. (averaging around 40% of the sediment delivered to the edge of the field in some documented studies).





Gully Erosion

Within the literature, several conclusions may be drawn concerning gully erosion:

Subsurface flow can potentially cause gully erosion in addition to surface flow. The interactions between these mechanisms are not fully understood at this time. Subsurface flow erosion processes and technology for prediction should be top research priority in the future.

• In many cases, the primary source of sediment at the catchment or catchment size is gully erosion. In contrast to interrill and rill erosion, gully erosion frequently connects field ditches and streams that carry eroded silt downstream, frequently causing problems with water quality and sedimentation.

In summary, erosion is the detachment and movement of soil by water, wind, ice, tillage, or gravity. The processes of erosion in gullies are due to:

• Hydraulic shear by overland flow on the rim and on the vertical sidewalls,

• The impact of splash from the plunge pool at the foot of the headwall and the vortex erosion in the pool,

• Mass wasting of the walls due to the development of tension and desiccation cracks,

Sheet and Rill Erosion (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) is an upgrade of USLE that is land use independent. It can be used on cropland, disturbed forestland, rangeland, construction sites, mined land, reclaimed land, military training grounds, landfills, waste disposal sites, and other lands where rainfall and its associated overland flow cause soil erosion. RUSLE was first introduced in the USDA Soil and Water Conservation Service in 1993. RUSLE maintains the same empirically based equation as USLE to compute sheet and rill erosion as follows: A=EI*K*LS*C*P where A is computed soil loss, EI is the rainfall-runoff erosivity factor, K is a soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is a cover management factor, and P is a supporting practices factor.

The major changes compared to USLE are in the values given for erosion as modified by vegetative cover and better calculations of the slope (LS) factors, as well as more advanced computerization. RUSLE gives more credit to the ability of surface residues to reduce erosion, as well as residues incorporated in the soil near the soil surface. Where USLE assumed that runoff was uniform over the catchment, RUSLE takes better into account that some runoff is channeled into rills and gullies. RUSLE also captures better than USLE that long rains can saturate the soil, leading to reduced intake and greater erosional runoff. In contrast with USLE, RUSLE can handle converging and diverging terrain and considers areas with net sedimentation.

An additional change incorporated in the RUSLE is to account for rock fragments on and in the soil. Rock fragments on the soil surface are treated like mulch in the C-factor, while K is adjusted for rock in the soil profile to account for rock effects on permeability and, in turn, runoff.

Sheet and Rill Erosion (RUSLE)

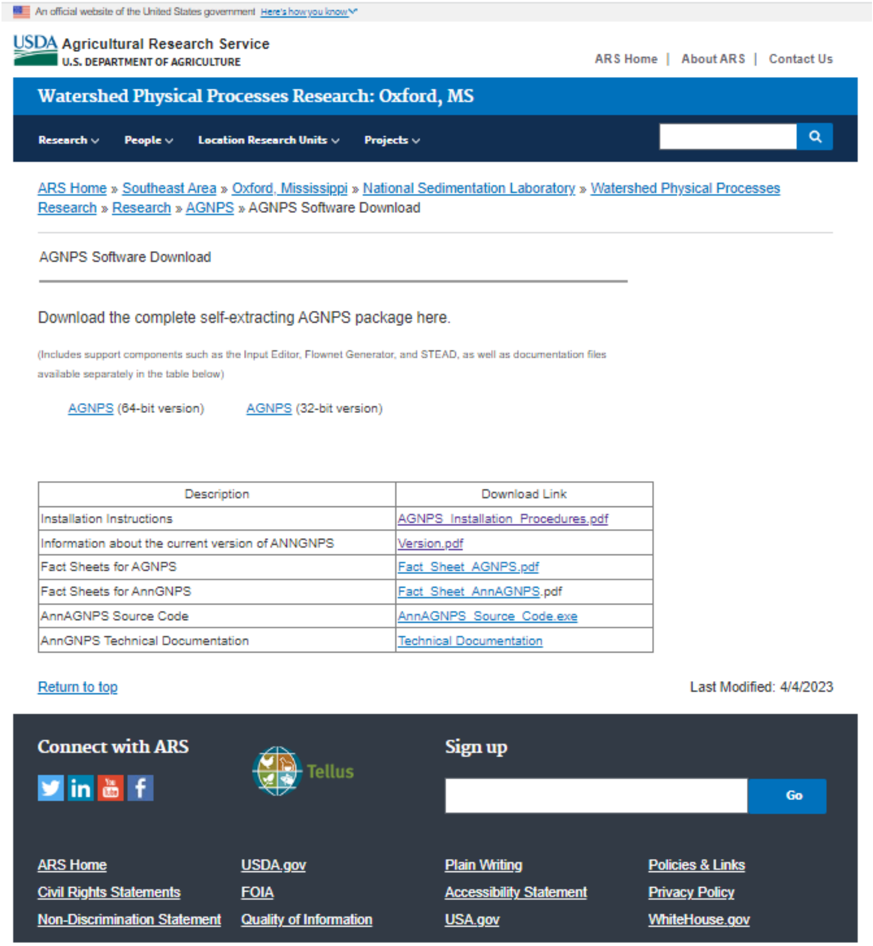
During the data preparation pre-processing step, RUSLE technology within AnnAGNPS calculates the LS, C, and P factors for each cell in the watershed and a K factor for each soil in the watershed.
The RUSLE factors,EI LS, C, P, and sediment delivery ratio are retrieved from previously entered or calculated data, then the product of EI, LS, K, C and P is computed to determine the total potential erosion. This product is then compared to the amount of thawed soil available for erosion and the lesser of the two quantities is then multiplied by the sediment delivery ratio to determine the amount of sediment delivered to the edge of the field. The sediment delivered into to the edge of the field is broken into five particle size classes: clay, silt, sand, large aggregate, and small aggregate. The large and small aggregate amounts are assumed to immediately break down into its constituent parts of sand, silt and clay once it leaves the edge of the field and becomes a part of the watercourse, therefore the amount that is sand, silt and clay in the large aggregate is added to the amount of sand, silt, and clay leaving the field as well as the amounts that are silt and clay in the small aggregates.

ANNAGNPS MODEL

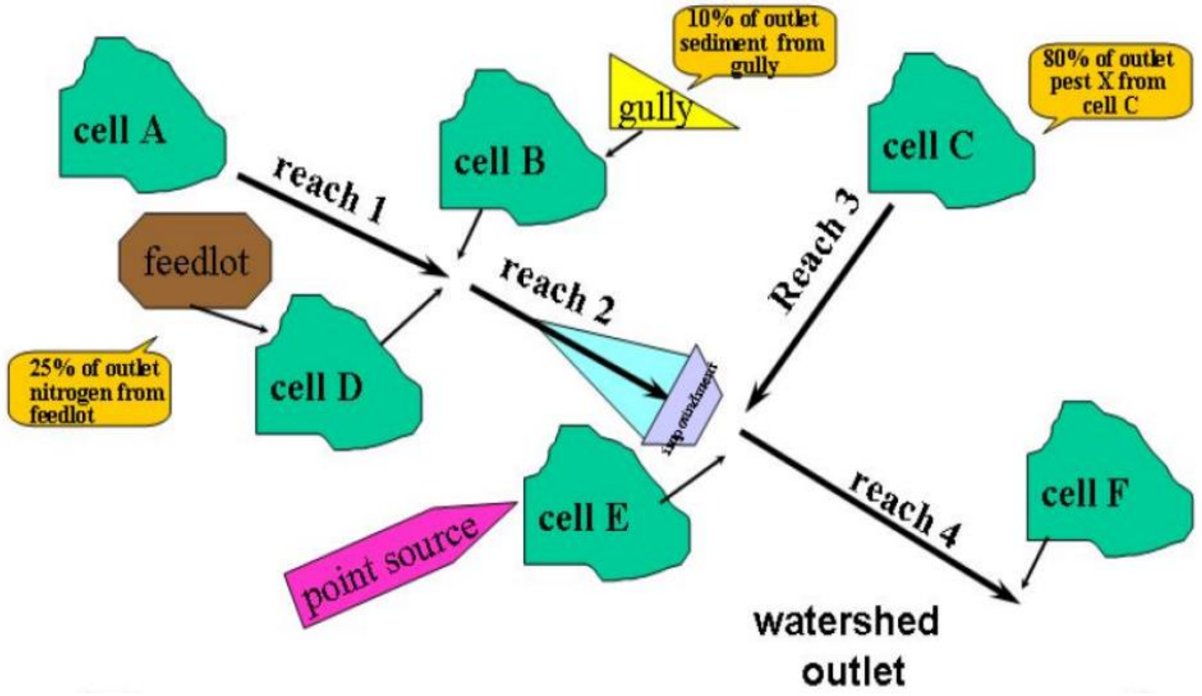
The AGNPS model was developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS). This event-based model was developed to analyze and provide estimates of runoff water quality from agricultural watersheds. This is the continuous version is Annualized Agricultural Non Point Source model (AnnAGNPS). The latest enhanced version AnnAGNPS v5.51.a.008_2019.12.11 is available through the internet web address: https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/research/agnps/agnps-software-download/

Project Developement (Download)

https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/annagnps-pollutant-loading-model/



ANNAGNPS MODEL



ANNAGNPS MODEL

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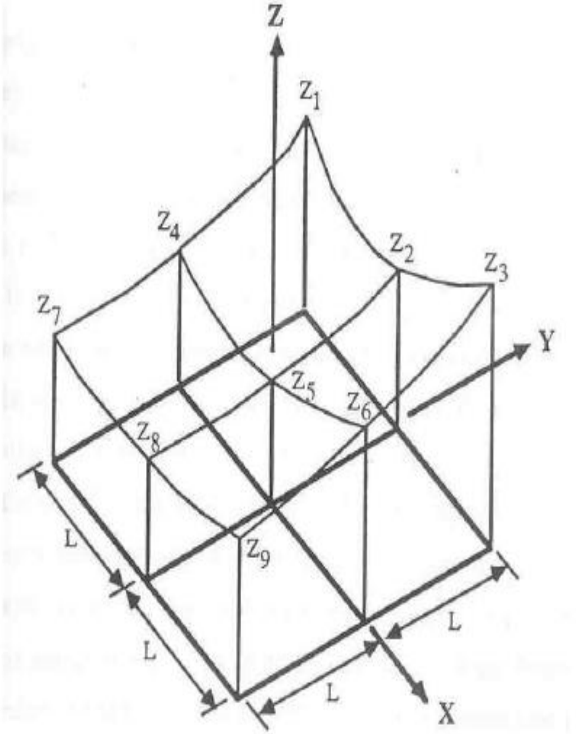
Figure 3: 3x3 altitude sub-matrix used by Zevenbergen (1989) to derive topographic parameters from digital elevation grids.



CTI = A * S * PLANC
Where:
A = upstream drainage area (m2);
S = local slope (m/m), which together with upstream area
PLANC = planform curvature (m/100), a measure of the landscape convergence
(negative for spurs and positive for swales

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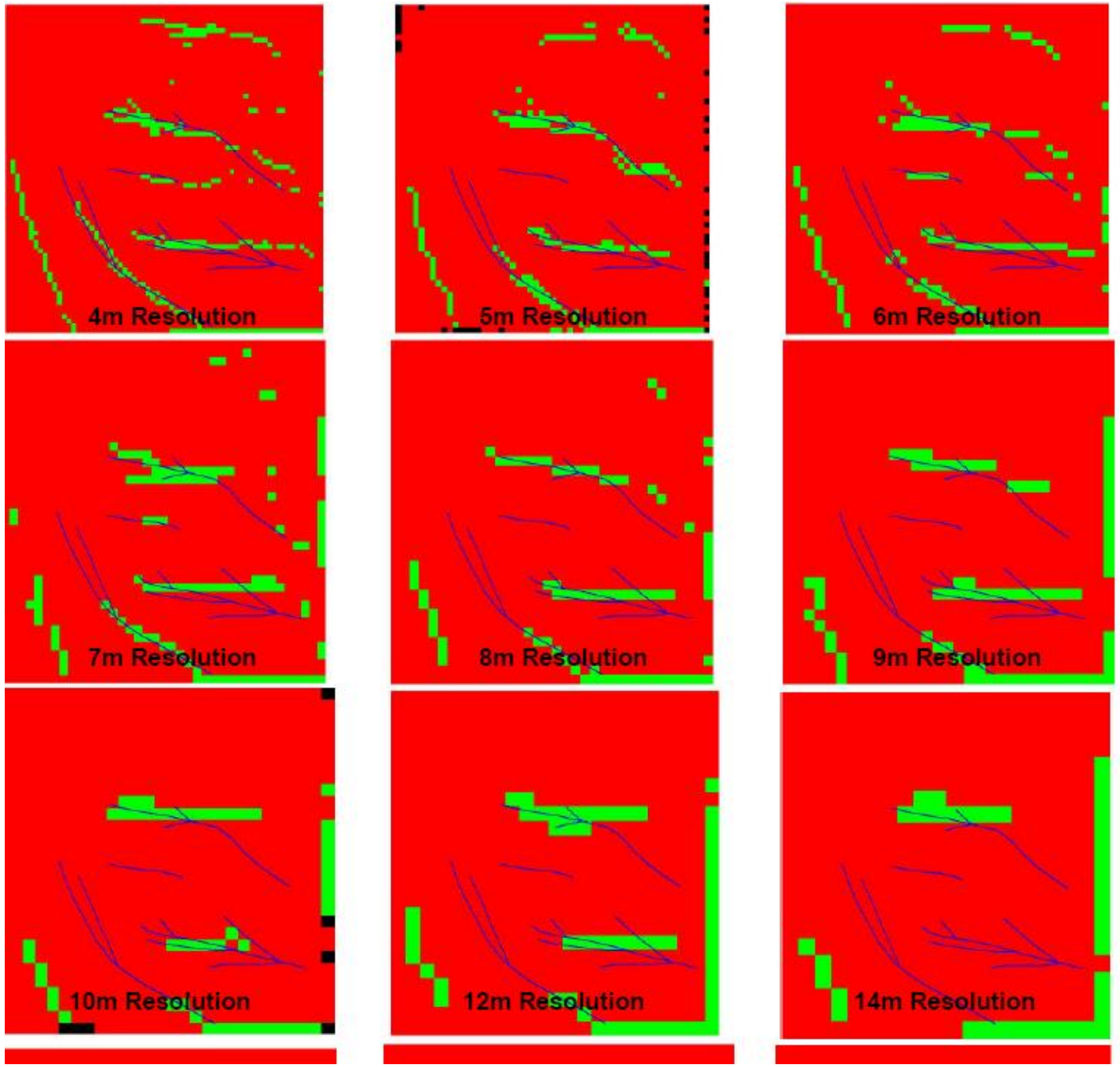

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ANNAGNPS MODEL RAINFALL RUNOFF MODEL

Land cover description	Hydrological soil group: A	B	C	D
Urban and built-up land	73	82	88	90
Dryland cropland and pasture	71	80	86	86
Irrigated cropland and pasture	64	74	81	84
Cropland/grassland mosaic	63	73	82	87
Cropland/woodland mosaic	51	68	78	82
Grassland	60	76	81	89
Shrubland	48	62	73	78
Savanna	44	65	77	82
Deciduous broadleaf forest	55	66	74	79
Evergreen broadleaf forest	55	66	74	79
Water bodies	100	100	100	100
Herbaceous wetland	100	100	100	100
Wooded wetland	100	100	100	100
Barren or sparsely vegetated	75	80	85	90

The runoff curve number (also called a curve number or simply CN) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. The curve number method was developed by the USDA Natural Resources Conservation Service— the number is still popularly known as a "SCS runoff curve number" in the literature. The runoff curve number was developed from an empirical analysis of runoff from small catchments and hillslope plots monitored by the USDA. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

ANNAGNPS MODEL RAINFALL RUNOFF MODEL

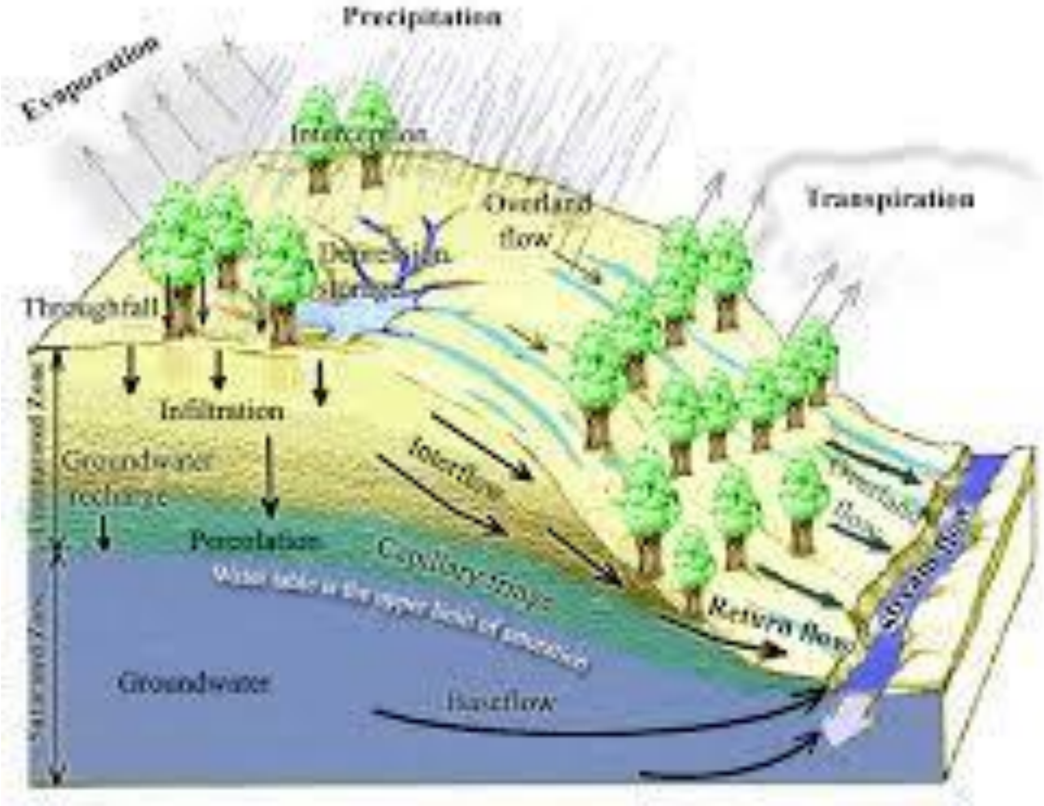
Group A: (low runoff potential): Soils with high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well-drained sands and gravels. These soils have a high rate of water transmission (final infiltration rate greater than 0.30 in (7.6 mm) per hour).

Group B: Soils with moderate infiltration rates when thoroughly wetted. These consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (final infiltration rate of 0.15–0.30 in (3.8–7.6 mm) per hour).

Group C: Soils with slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine textures. These soils have a slow rate of water transmission (final infiltration rate 0.05–0.15 in (1.3–3.8 mm) per hour).

Group D: (high runoff potential): Soils with very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission (final infiltration rate less than 0.05 in (1.3 mm) per hour).

ANNAGNPS MODEL RAINFALL RUNOFF MODEL



The SCS curve number technique is used within AnnAGNPS to determine the surface runoff from a field. There are parameters that are held constant throughout the simulation (clay content for each soil layer, field capacity for each soil layer, saturated hydraulic conductivity for each soil layer etc). There are also methods that are used to vary the curve number throughout the simulation as well as the curve number technique itself.

The curve number parameters S1, S3, W1, and W2 are used to vary the curve number for a given day between the dry condition curve number (CN1) and the wet condition curve number (CN3) based on soil moisture storage

ANNAGNPS MODEL RAINFALL RUNOFF MODEL

Adjustments to select curve number for soil moisture conditions.[3]

Curve Number (AMC II)	Factors to Convert Curve Number for AMC II to AMC I or III	
	AMC I (dry)	AMC III (wet)
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Runoff is affected by the soil moisture before a precipitation event, the antecedent moisture condition (AMC). A curve number, as calculated above, may also be termed AMC II or CNII, or average soil moisture. The other moisture conditions are dry, AMC I or CNI, and moist, AMC III or CNII. The curve number can be adjusted by factors to CNII, where CNI factors are less than 1 (reduce CN and potential runoff), while CNII factor are greater than 1 (increase CN and potential runoff).. Find the CN value for AMC II and multiply it by the adjustment factor based on the actual AMC to determine the adjusted curve number.

Project Development

- Installation of AnnAGNPS
- Execution of TOPAGNSPS routine and production of “basic model files”
- Development of GIS components (land use, soils) and integration of GIS information in the “basic model files”
- Preparing of the remaining csv model files
- Running the simulation with AnnAGNPS
- Parameter calibration and result verification

TOPAGNPS Development

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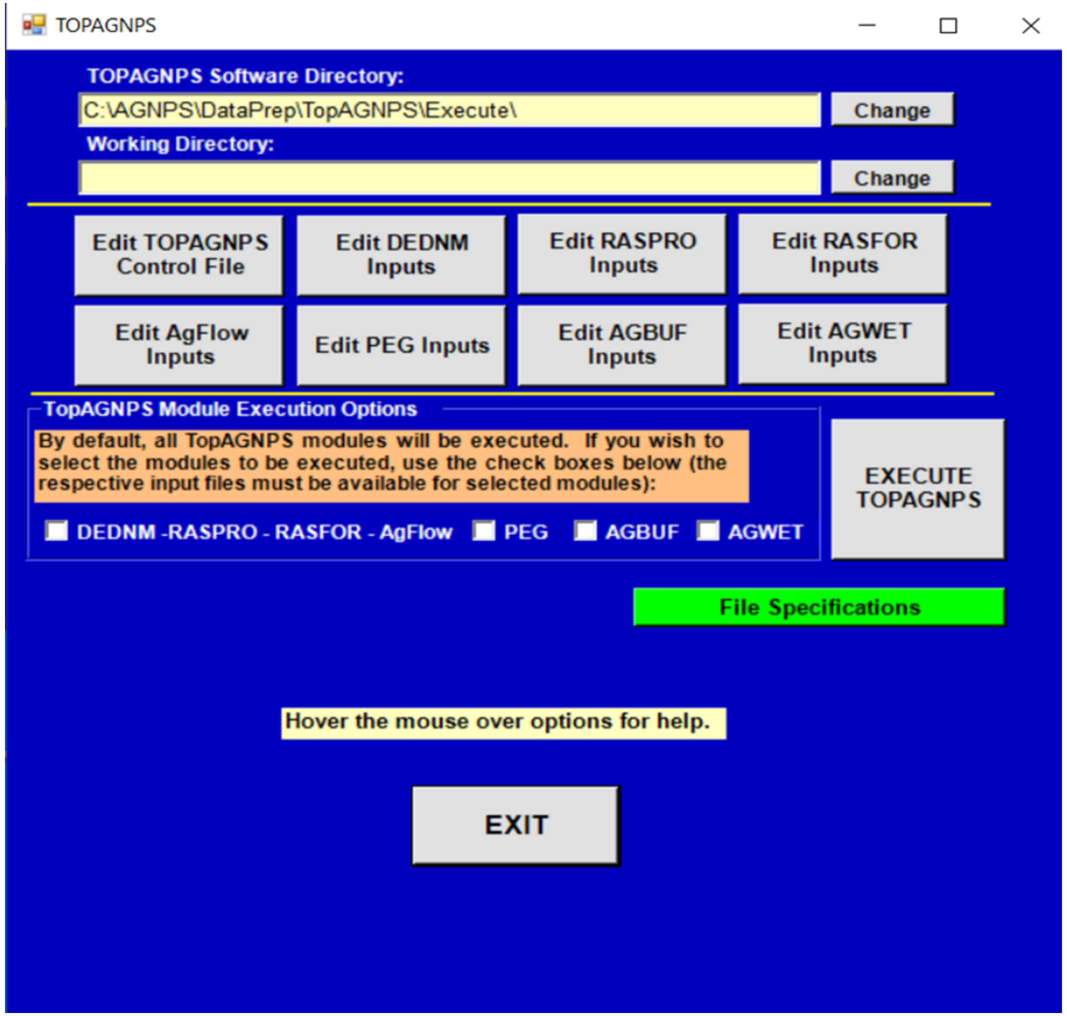
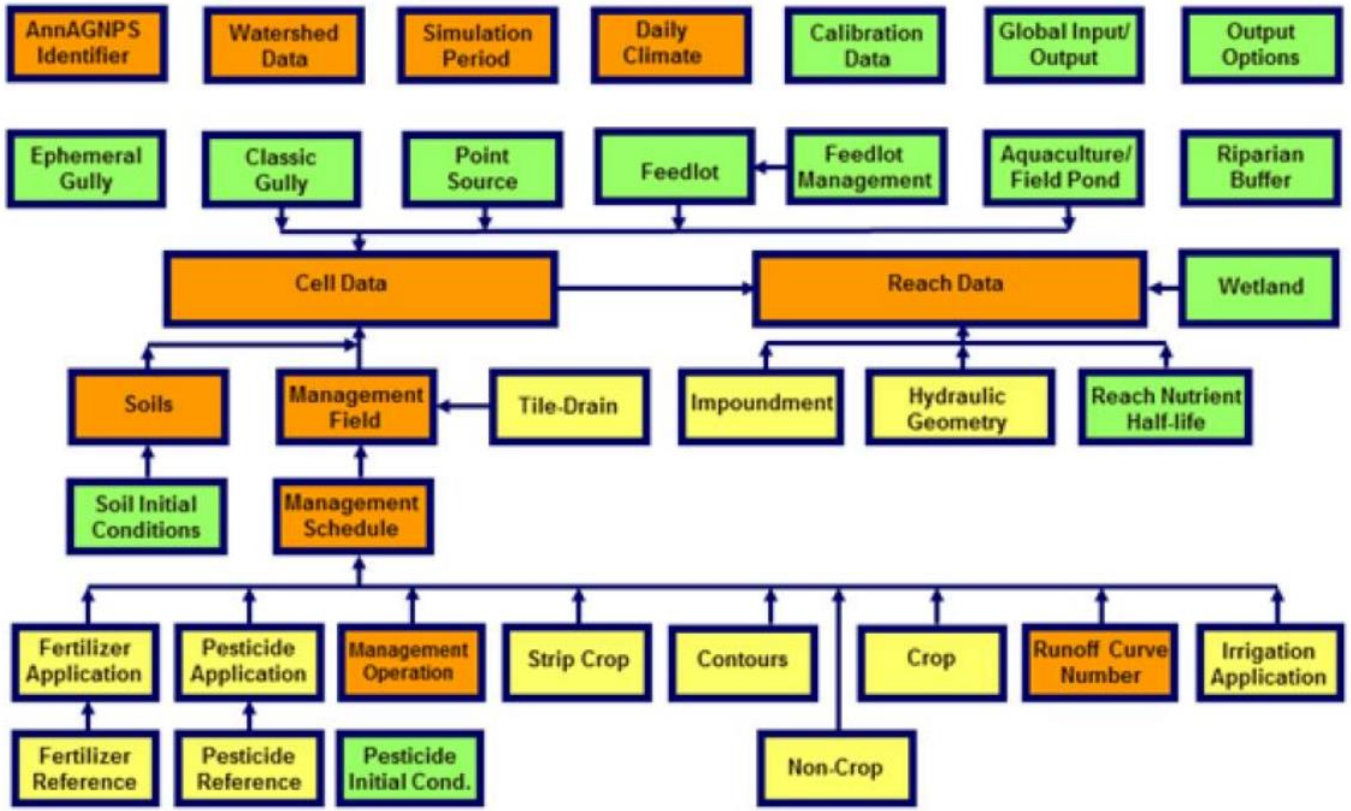


ANNAGNPS MODEL



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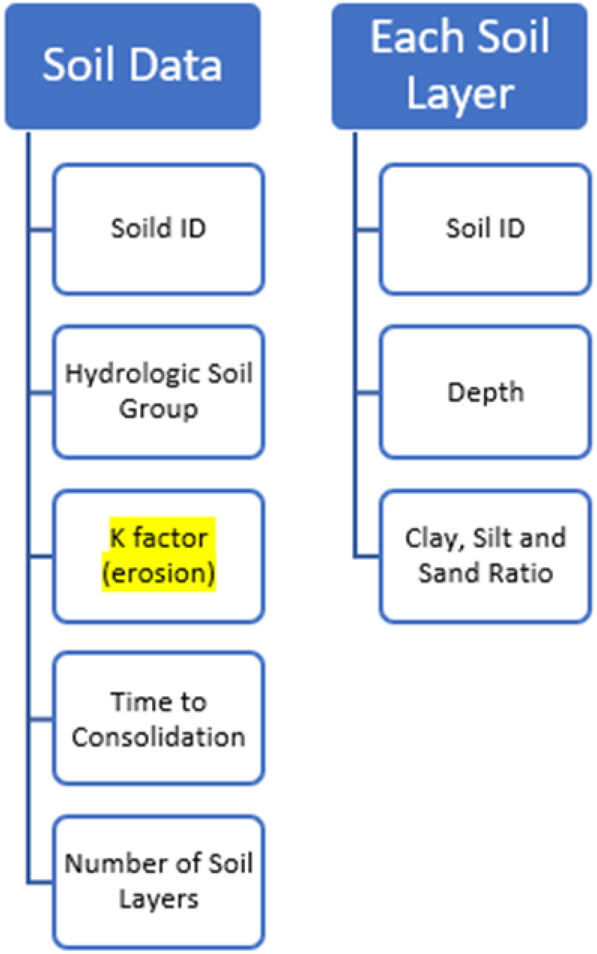

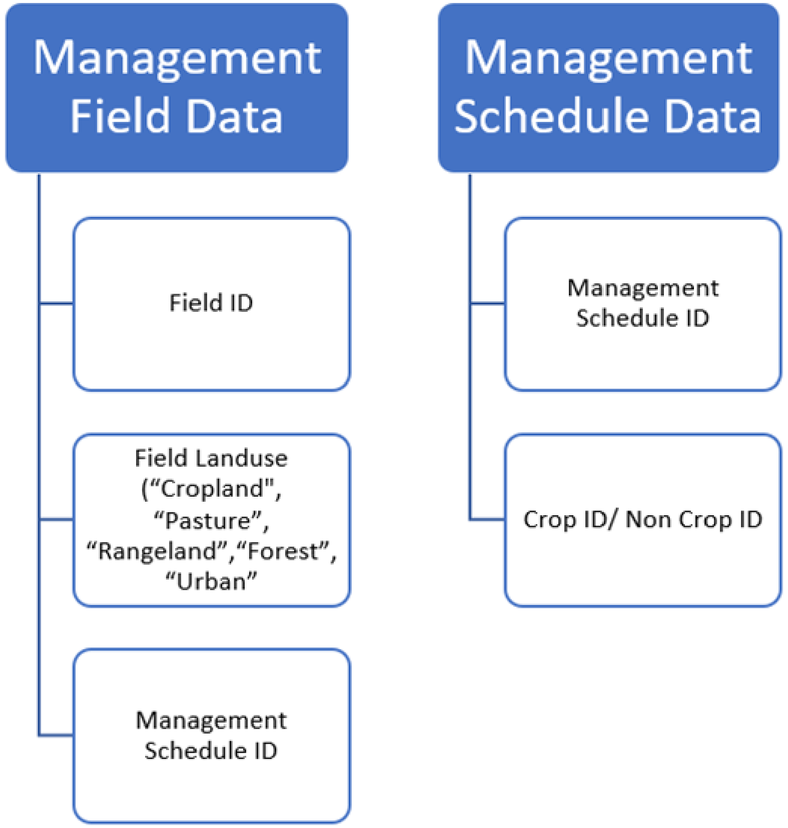

Each Field ID corresponds eventually to a Crop or Non-Crop ID.

Soil and Land Use Data Lebna

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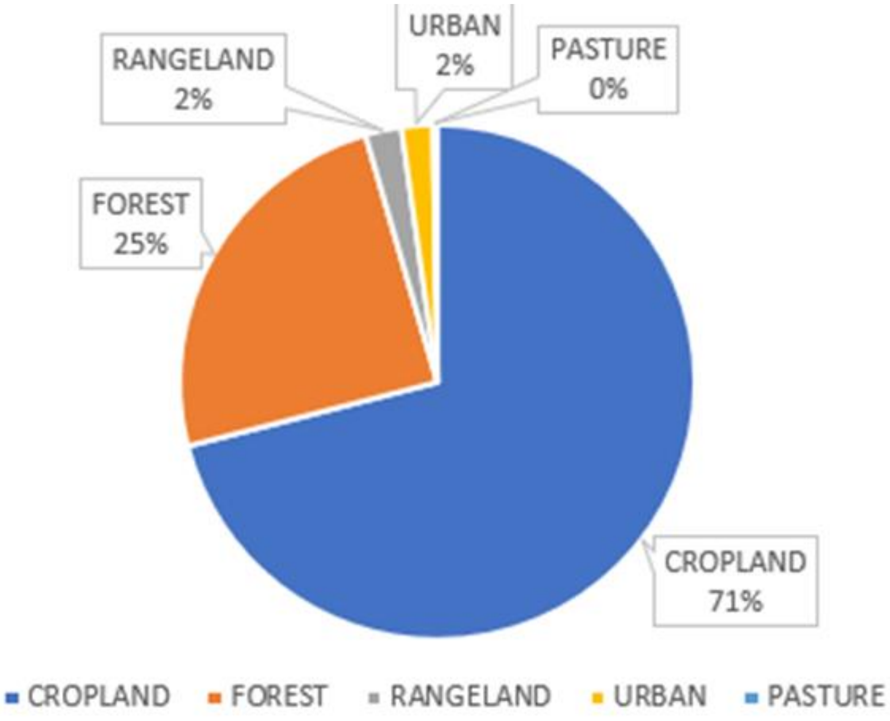

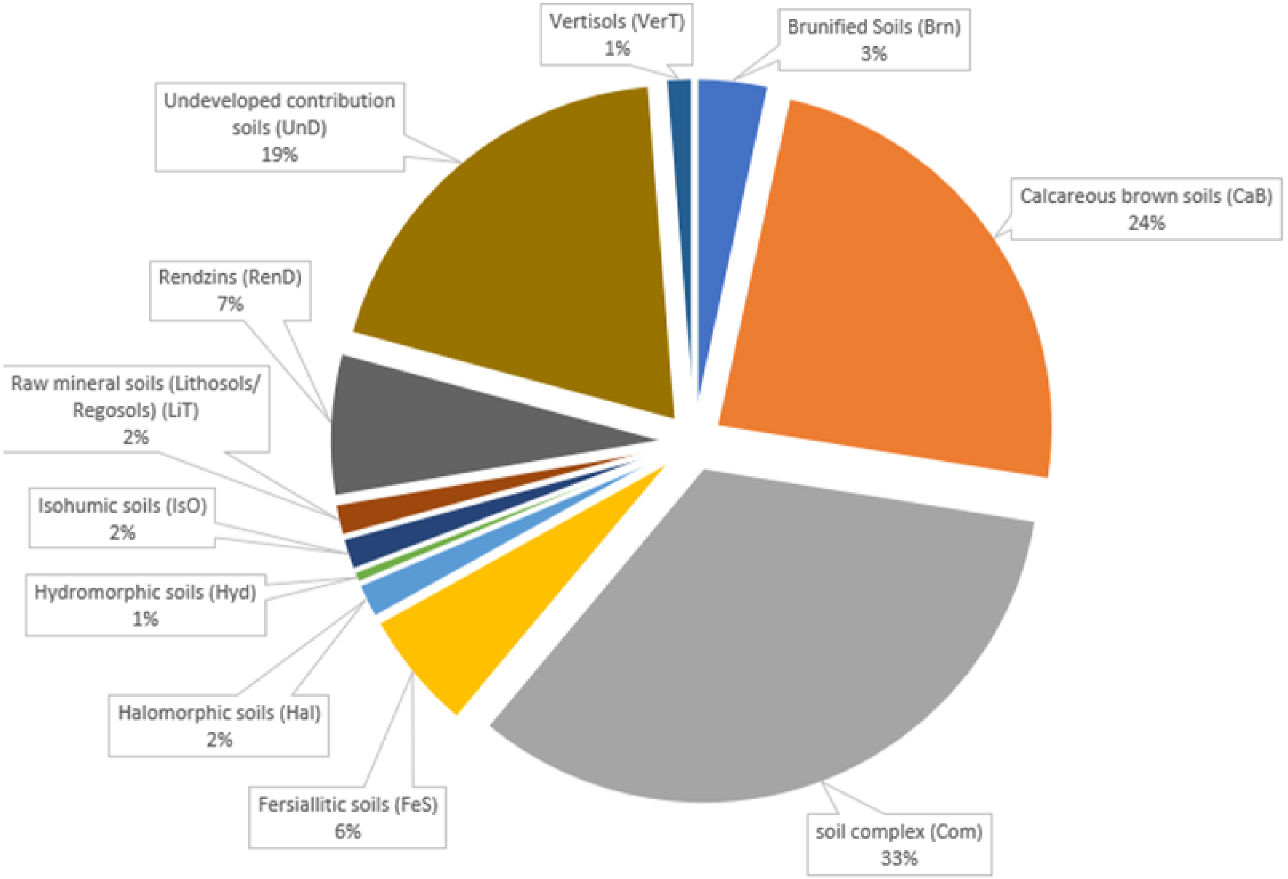

Soil and Land Use Data Siliana

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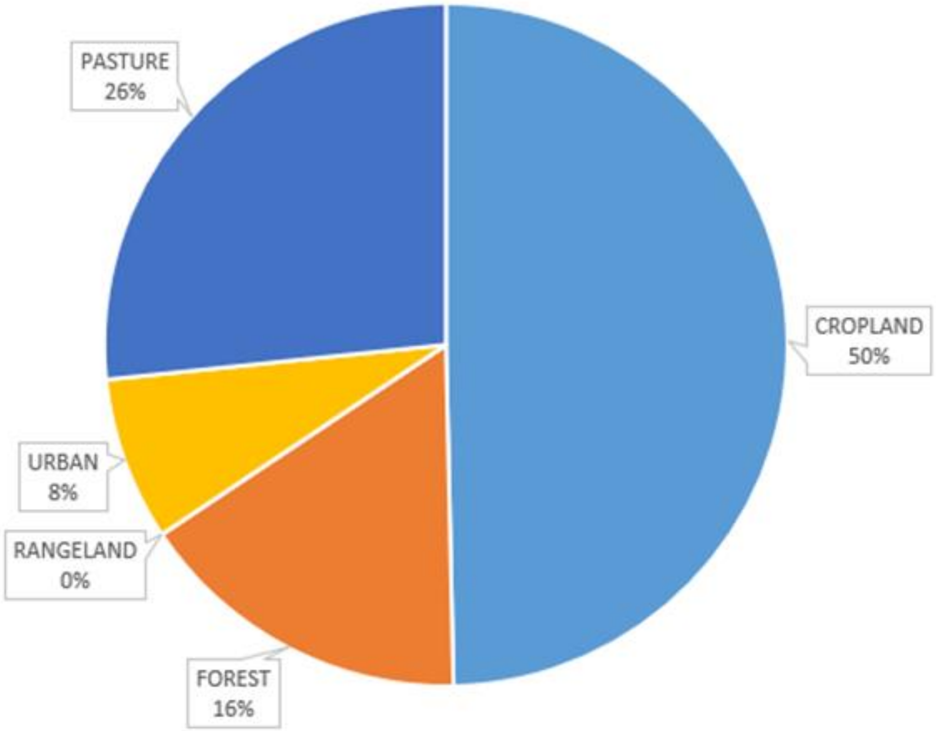

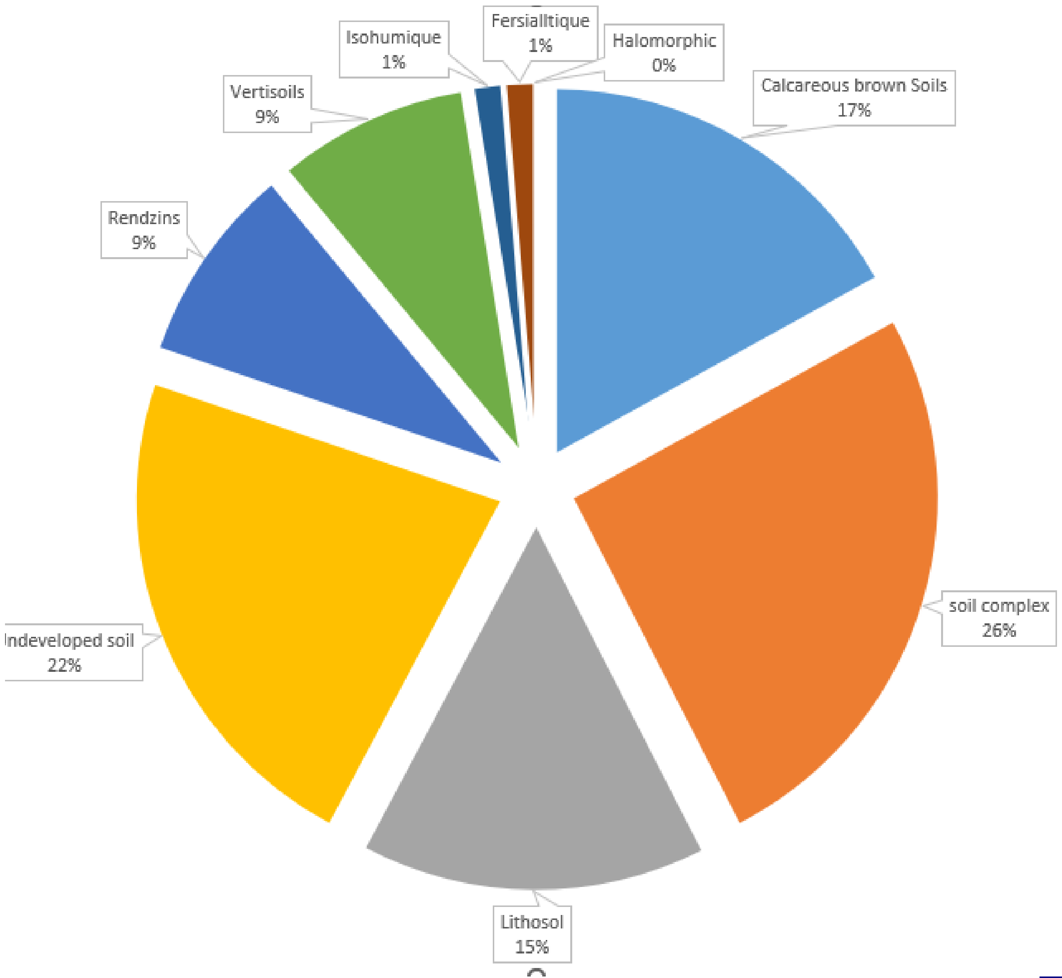

Thank you for your attention