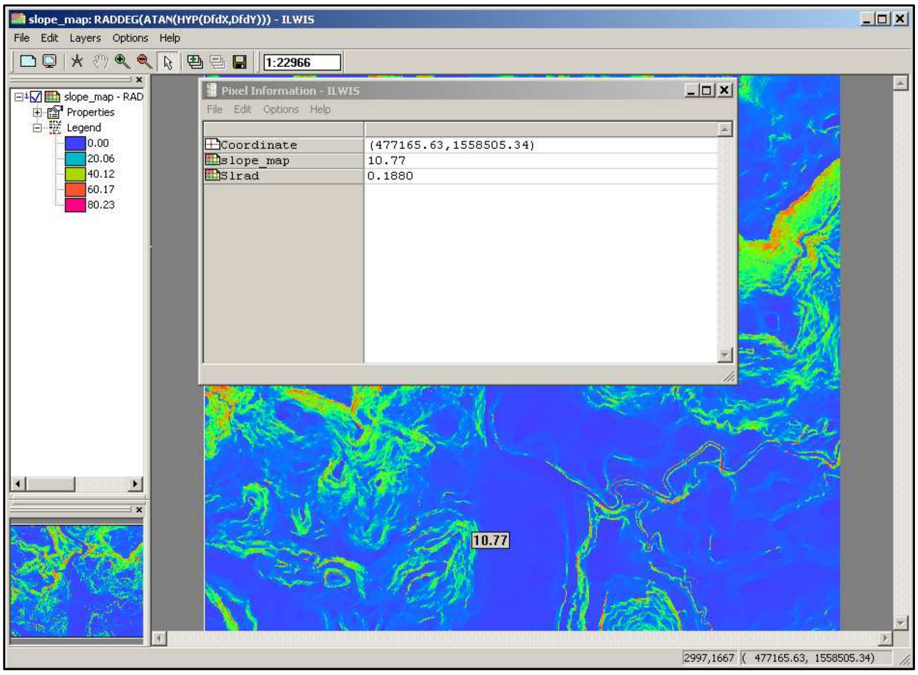
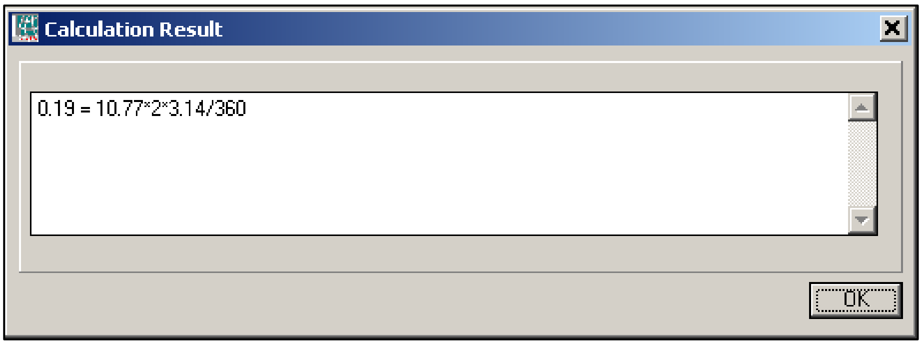
Exercise 3L2. Deterministic landslide hazard assessment

Preparation of the data

With the pixel information click in some points of the map and read the values in degree and in radians. For the example shown in the right image and you can type in the command line of ILWIS the following formula:
?10.77*2*3.14/360
And check the results with the value in radians read in the pixel information.

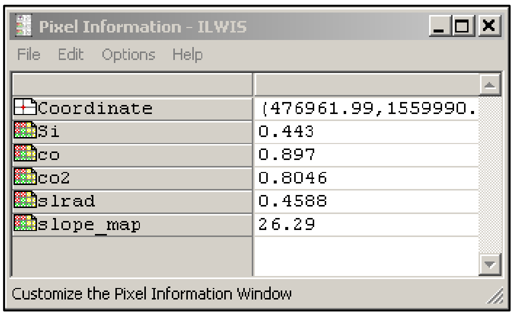


Slope_map and pixel information with Slrad

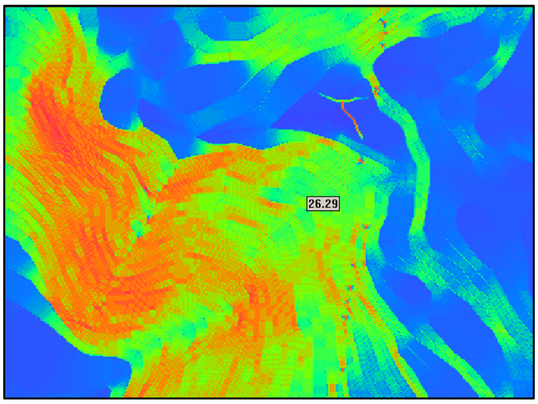


If the map is right, the value of Slrad should be the same of your check with the calculator.

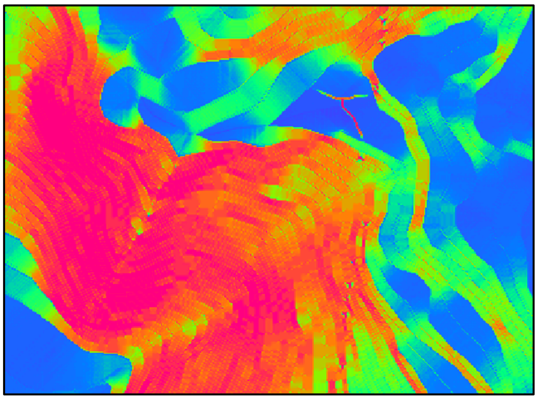
In this page you is shown how the maps Si, Co, Co2, Slrad, Slope_map should appear.



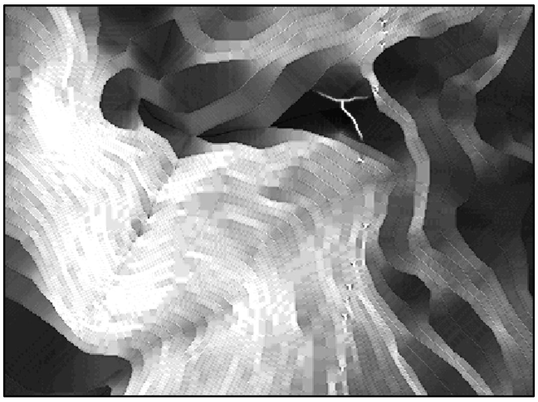
Pixel information



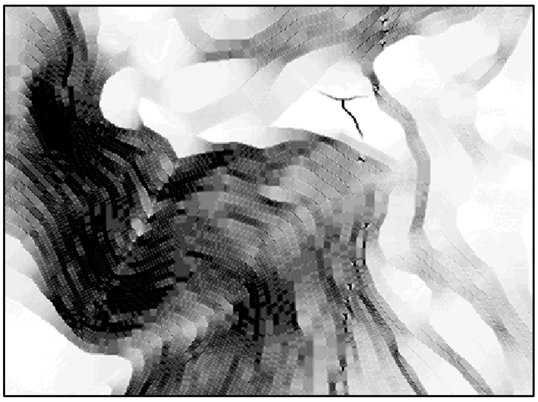
Slope_map.



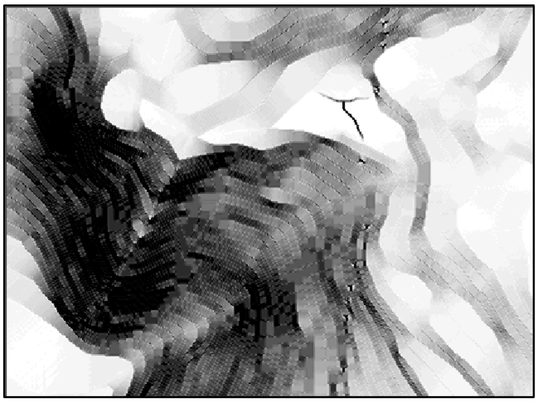
Slrad.



Si.



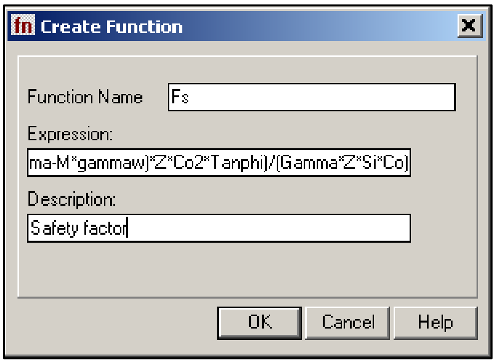
Co.

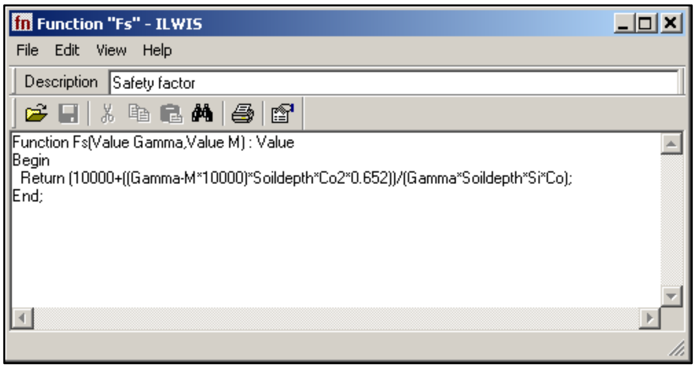


Co2

Creating a function for the infinite slope formula

The formula simplified should look like:





Dry condition

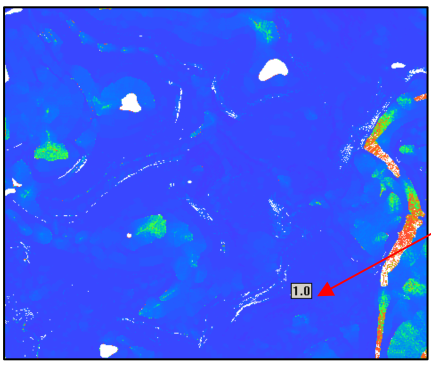
The procedure to figure out and check the value of Fdry, is here explained:

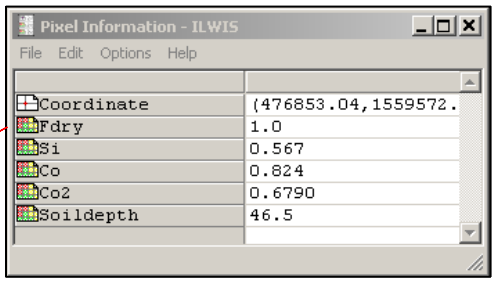
- Use this formula in the pocket calculator.

$$F = \frac{c' + (\gamma - m\gamma_w)\, z \cos^2\beta \tan\phi'}{\gamma z \sin\beta \cos\beta}$$

- In our case: $c' = 11000$
  $m = 0$
  $\gamma' = 11000$
  $\phi' = 0.625$
  F=?

- Use the pixel information to read the value of Soildepth, Co2, Co, Si and Fdry.



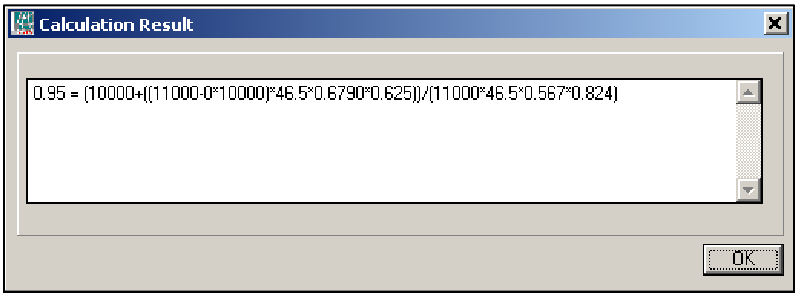


Fdry map.

- Now you can type in the command line of ILWIS the formula:

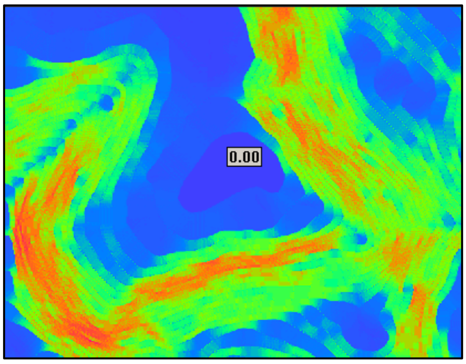
?(10000+((11000-0*10000)*46.5*0.6790*0.625))/(11000*46.5*0.567*0.824)

and read the following result:

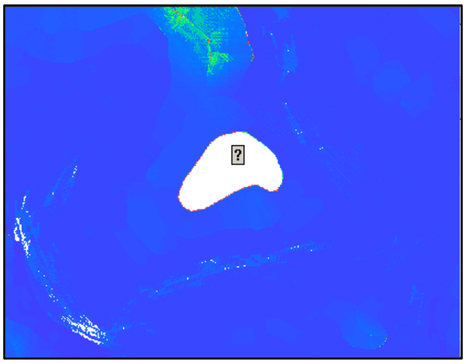


Some areas have undefined value of Fdry. This means stabil conditions and is due to the flat areas (slope=0) or to the absence of soil (soildepth=0).

In the two images below you can see the case of flat area and the correspondant Fdry value.

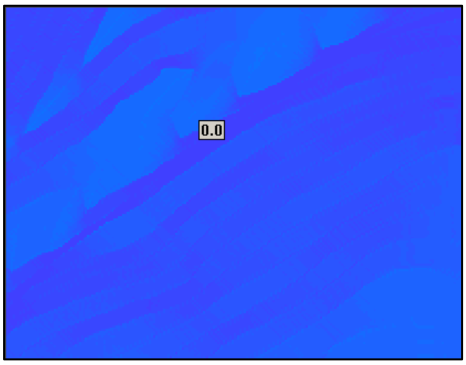


Slope_map.

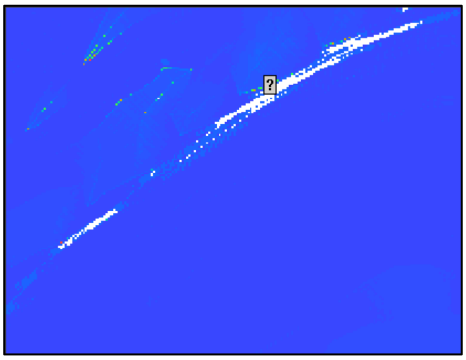


Fdry map.

In this other two images is shown the case of soil lack area and the correspondant Fdry value.

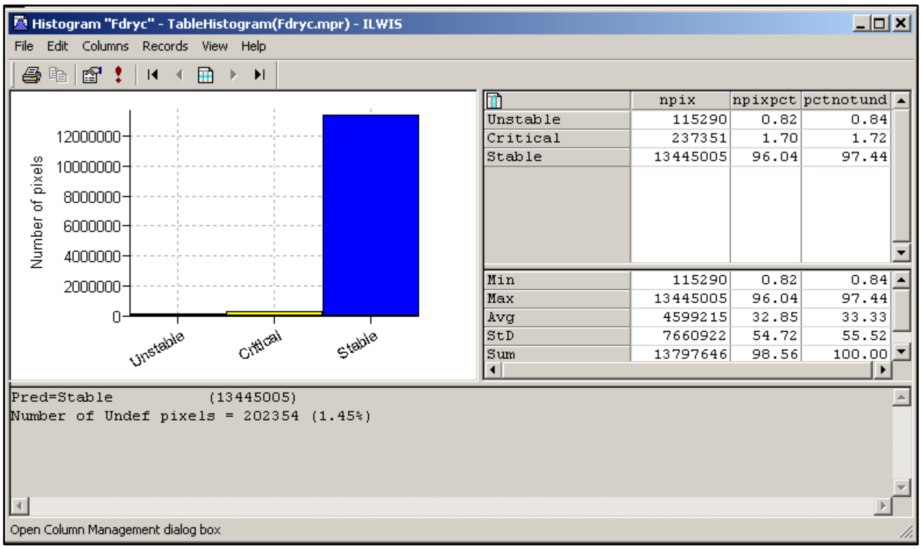


Soildepth.



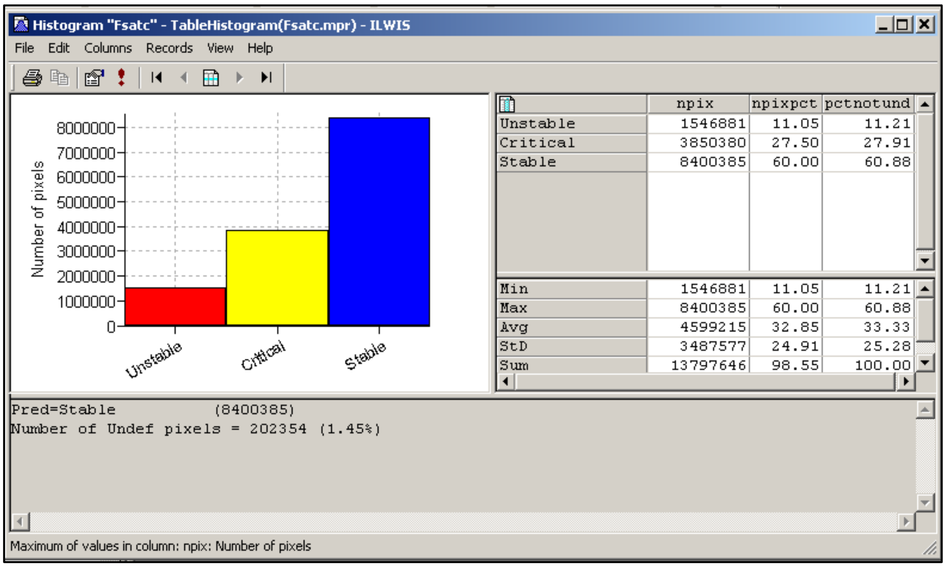
Fdry map.

After the slicing operations of Fdry using the domain “Stabil”, the histogram of Fdryc should looks as the following image.

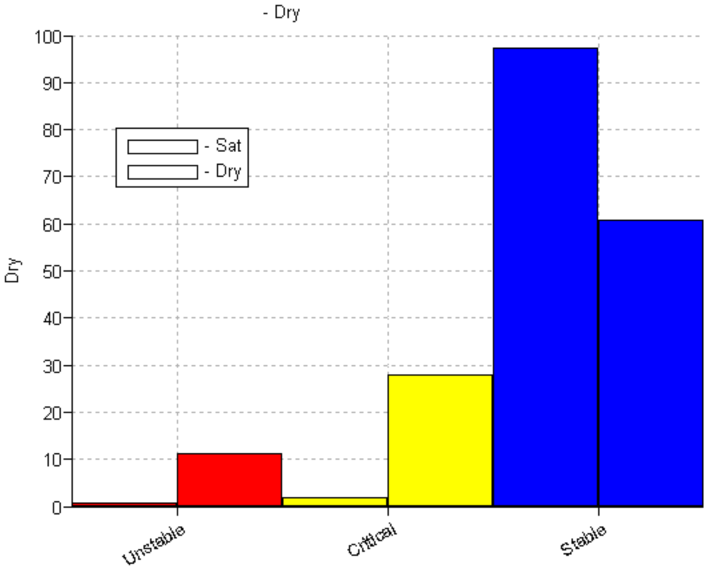


Histogram of Fdryc.

Completely saturated condition



Histogram of Fsatc.



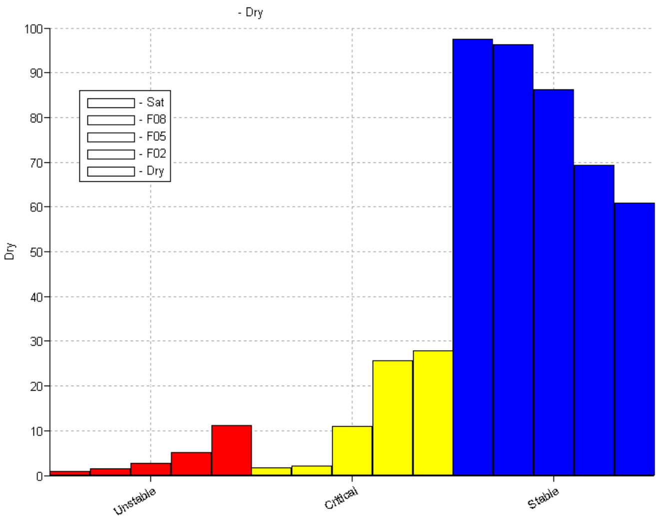
In this graph are compared the dry conditions (columns left) with the saturated conditions. As you can see the the most safe is the dry condition while with the saturated condition there is an increasing of the unstable and critical classes, to the detriment of the Stable class.

Partially saturated condition

We are now considering also partially saturated conditions. In this exemple have been calculated the scenarios with *m=0.2*, *m=0.5* and *m=0.8*.
The name of the output maps, the values of *gamma* and the relative *m* are shown in the formulas used for this example:

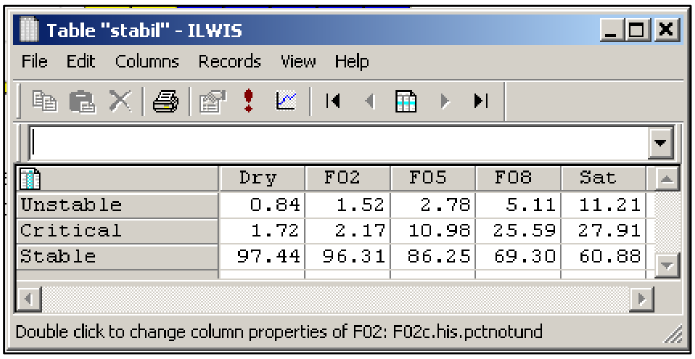
F02:=fs(12500,0.2)
F05:=fs(14000,0.5)
F08:=fs(15000,0.8)

Comparing the 5 scenario in a histogram it is possible appreciate how the general instability of the area increases with the increase of the water table.



Histograms of the complete scenario (Dry, partially and complete saturated conditions).

The results are stored in the table "stabil". Check your values.



	Dry	F02	F05	F08	Sat
Unstable	0.84	1.52	2.78	5.11	11.21
Critical	1.72	2.17	10.98	25.59	27.91
Stable	97.44	96.31	86.25	69.30	60.88

Table "stabil".

It could be useful create a table in an spreadsheet, in order to make some graphs and consideration.

	DRY	m=0.2	m=0.5	m=0.8	SATURED
UNSTABLE	0.84	1.52	2.78	5.11	11.21
CRITICAL	1.72	2.17	10.98	25.59	27.91
STABLE	97.74	96.31	86.25	69.3	60.88

Values in the different scenarios in a spreadsheet.

For experienced ILWIS users

We assume that:

The soil changes with the same boundary of the lithologycal map.

Using different values for cohesion and friction angle

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- Open the **litholgy** table. Create a new column **Cohesion**. Select the range between 0 and 100000.0.
- Decide the values of the cohesion for the suppose soil developed on top of the listed lithology.
- Add also the columns **gamma** and **phi**. Choose reasonable values.
- Create the attribute map **Cohesion**, **Gamma**, **Phi,** using the **lithology** map and the **lithology** table.
- The next step is the transform the **phi** map, from degree to radians. In the command line of ILWIS type the following formula:

phi_rad:=degrad(phi)

Check with the pixel information and with the map calculator the results. (remember: **values radians=values degree*2π/360)**

- Now that we have the phi values in radians it is possible obtain the tangent of the angle of shearing resistance. Type the formula:

tanphi:=tan(phi_rad)

- Open the function **Fs**, and copy as **Fs_param**. Now you can open the function **Fs_param** and modify it.

The formula Fs_param is:

```
Function Fs_param(Value M) : Value
Begin
  Return (cohesion+((gamma-M*10000)*Soildepth*Co2*tanphi))/(gamma*Soildepth*Si*Co);
End;
```

Now we have all the maps and value and we can evaluate the Fs.

In this example we are calculated the Fs in condition of partially saturation. You can do also for other scenario, but taking care to change the value of gamma in table lithology and creating new attribute map of gamma.

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- In the command line type the formula:

Fs_var:=Fs_param(1)

Use the range between 0 and 100. Select the somewhere georeference and a precision of 0.1

- Classify the Fs_var using the domain **stabil** *(operation, image processing, slicing)*. Call the output map **Fs_var_c.**
- Create the histogram of **Fs_var_c**. What can you conclude?

We are considering the case of cohesion,ϕ and gamma constant and satured. You can apply the same method to the previous step, or in different saturation rate scenario.

Using different failure depths

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- Create a new function modifying Fs. Call it Fs_depth.

The function Fs_depth should be:

```
Function Fs_depth(Value Gamma,Value M,Value depth) : Value
Begin
  Return (10000+((Gamma-M*10000)*depth*Co2*0.652))/(Gamma*depth*Si*Co);
End;
```

☞

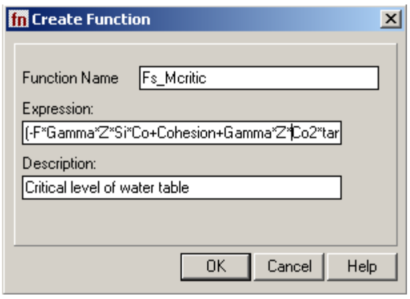
- Type the formulas:

Fs_2m:=Fs_depth(16000,1,2)
Fs_3m:=Fs_depth(16000,1,3)

Fs_5m:=Fs_depth(16000,1,5)
Fs_10m:=Fs_depth(16000,1,10)

Use the precision 0.1, the georeference somewhere and the range 0-100.

- Create the map **Fs_2m_c, Fs_3m_c, Fs_5m_c**, **Fs_10m_c**.(*Operations, image processing, slicing*, and use the domain **stabil**)
- Create also the histograms.
- What you can conclude? Try to explain how and why the depth influence the safety factor.



Finding out the critical m values

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- Create a new function called **Fs_Mcritic**, and fill with the expression: **(-F*Gamma*Z*Si*Co+Cohesion+Gamma*Z*Co2*tanphi)/(Gammaw*Z*Co2*Tanphi)**
  Description: Critical level of water table edit the formula
- Click ok, and modify the expression as this shown below.

The expression should looks like:

```
Function Fs(Value Gamma,Value M) : Value
Begin
  Return (10000+((Gamma-M*10000)*Soildepth*Co2*0.652))/(Gamma*Soildepth*Si*Co);
End;
```

We can now calculate the map of the M critical, representing the condition that determine a Safety Factor=1.

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- In the command line of ILWIS type the formula:

M_critic:=Fs_Mcritic(1,16000)

We have now the M values pixel per pixel. We can easily calculate the level of the water table, since: M= Depth to groundwater /Depth to failure surface

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- In the command line of ILWIS type the formula:

Zw_critic:=M_critic*Soildepth

Show the map and compare the map **Zw_critic** with **Soildepth.**