MICROZONATION FOR RAINFALL AND SEISMICLY INDUCED LANDSLIDE

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SciNet NatHaz Prevention

Black Sea CROSS BORDER COOPERATION

APPLIED METHODS

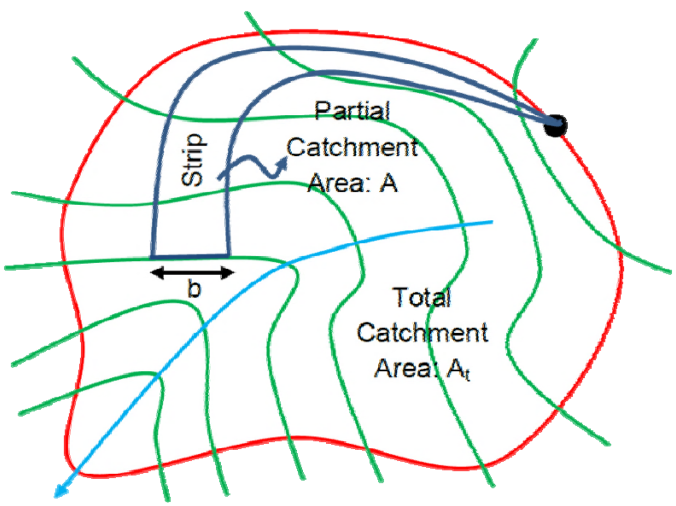
- Montgomery and Dietrich Method (1994):
  - ✓Topography is the main important factor.
- Mora and Vahrson Method (1994):
  - ✓Emprical relationship based on the case studies.
- FEMA Methodology:
  - ✓ Landslide susceptibility using topographical and geotechnical aspects
- Siyahi and Ansal (1993):
  - ✓ Pseudo – static evaluation of slope stability using seismicity

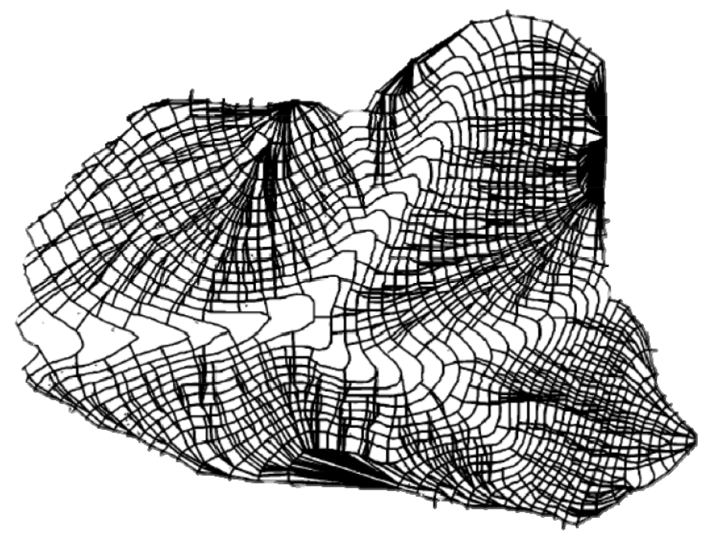
Montgomery and Dietrich Methodology (1994):

1. Topographial maps
2. Extraction of the DEM using SAGA
3. The use of DEM for extraction of slope angle map
4. The use of the DEM for extraction of catchment are map

Montgomery and Dietrich Methodology (1994):

- **Catchment area** is an area of the closed figure formed by the contour portion at the given point of the topographic surface and two flow lines coming from upslope to the ends of the contour portion.





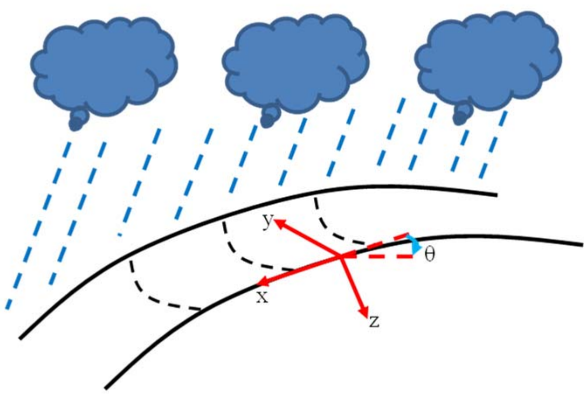
Efflux = Q_0

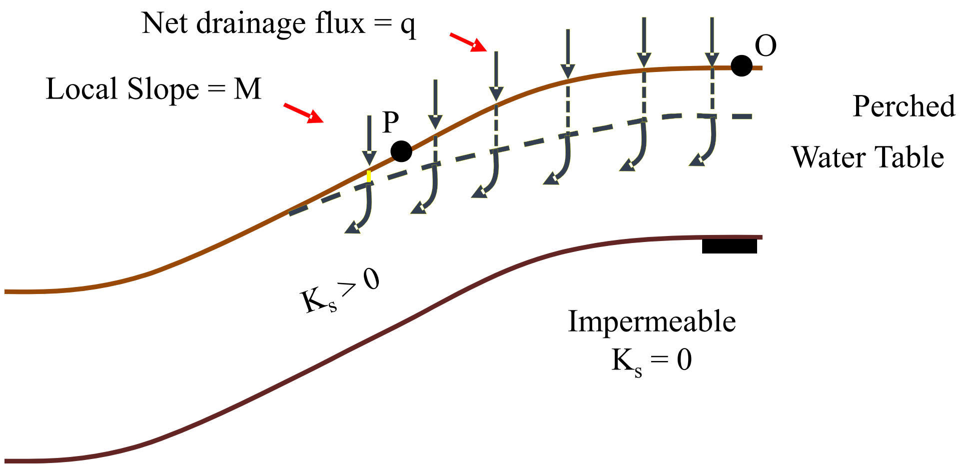
- Tekirdag Region – DEM
- Application of the Papatheodorou and Tzanou (2014) model on Tekirdağ Region using QGIS

Montgomery and Dietrich Methodology (1994):

- Areas are defined as convergent or divergent topographical structures,
- Estimation of soil capability for conducting infiltrated rain water,
- Definition of Wetness index $$W = \frac{I_z A}{bT\sin\theta}$$
- Factor of safety

$$FoS = \left(\frac{\tan\varphi}{\tan\theta}\right)\left[1 - W\left(\frac{\gamma_w}{\gamma_{sat}}\right)\right]$$





Where I_z, **A/b**, T, θ denote the net rainfall rate, **specific cathment area**, the soil transmissivity at saturation (K_h.z.cosθ) and slope angle, respectively and φ is residual shear strength angle, γ_{sat} is the saturated unit weight of soil.

(Montgomery & Dietrich, 1994)

$$W = \frac{I_z A}{bT\sin\theta}$$

I_z, A/b, T, θ denote the net rainfall rate, specific catchment area

$$W = \frac{K\sin\theta h\cos\theta}{K\sin\theta z\cos\theta} = \frac{h}{z}$$

where h and z are groundwater table height and soil depth,

For infinite slope safety factor:

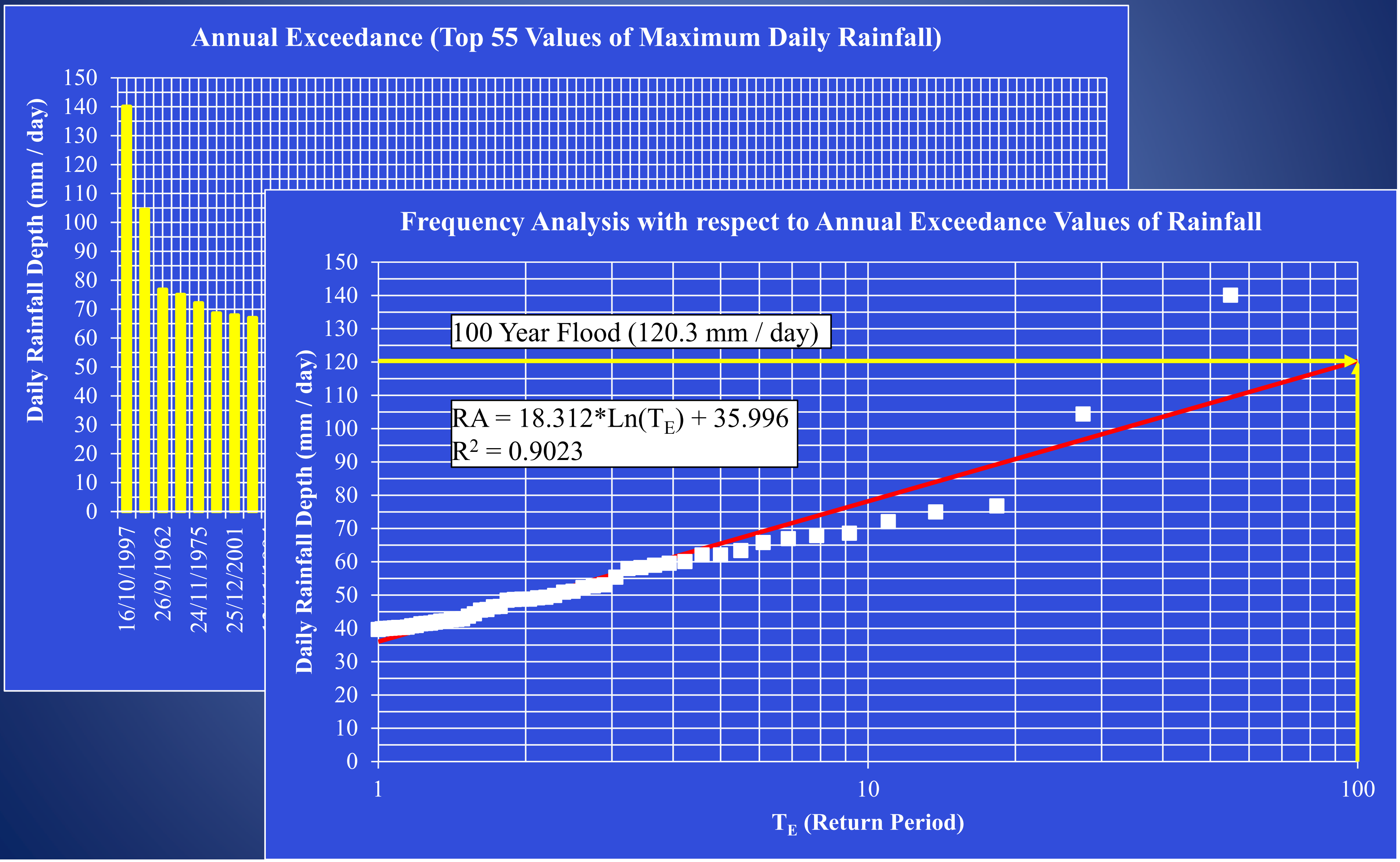
$$FoS = \frac{c + (z\gamma_{sat} - h\gamma_w)\cos^2\theta\tan\phi}{z\gamma_{sat}\cos\theta\sin\theta}$$

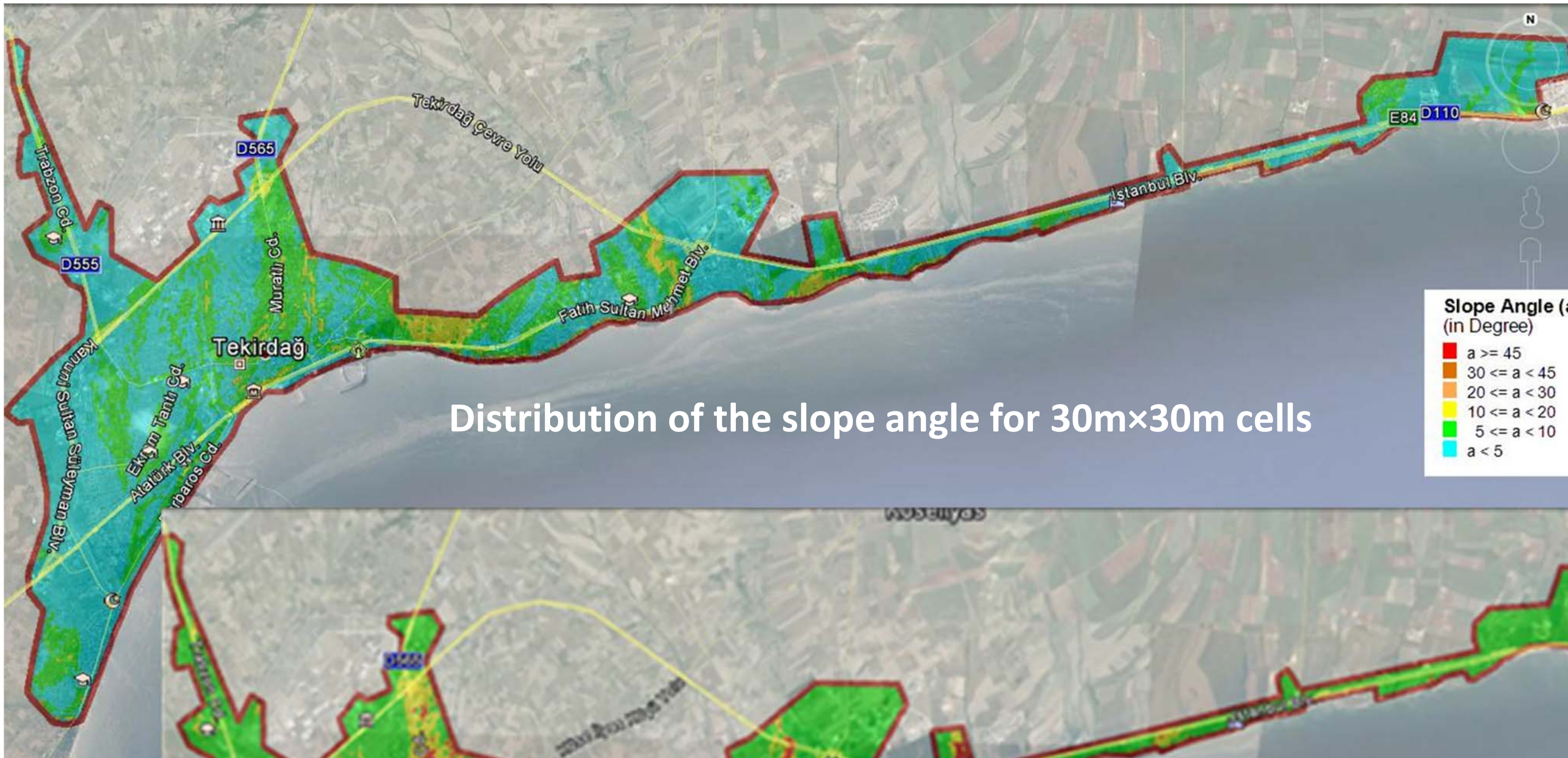
Assuming c=0 and inserting wetness index, safety factor:

$$FoS = \frac{\tan\phi}{\tan\theta}\left[1 - W\left(\frac{\gamma_w}{\gamma_{sat}}\right)\right]$$

Rainfall Hazard Determination

Annual Exceedance (Top N Maximum Daily Rainfall)

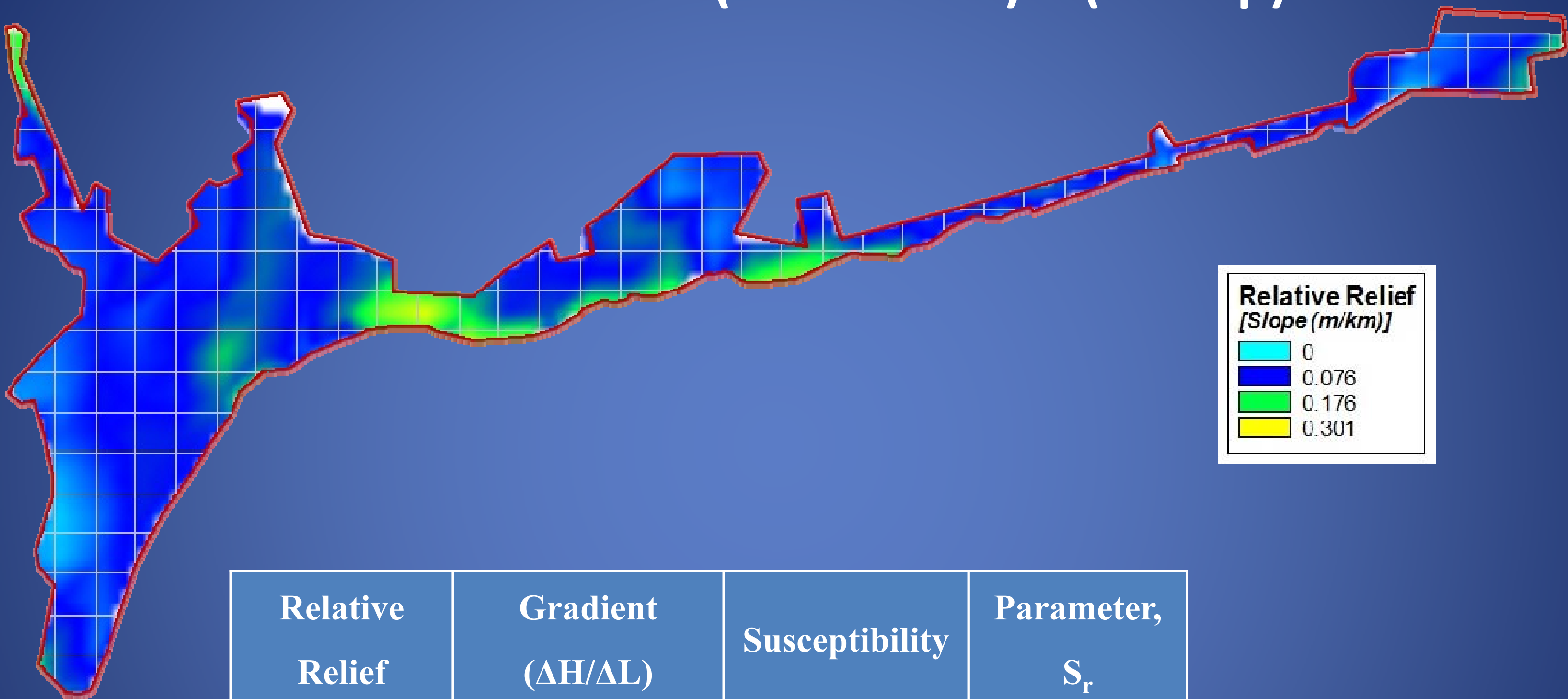



Distribution of the slope angle for 30m×30m cells
Slope Angle (a)
(in Degree)
a >= 45
30 <= a < 45
20 <= a < 30
10 <= a < 20
5 <= a < 10
a < 5
Tekirdağ
D565
D555
D110
E84
Trabzon Cd.
Tekirdağ Çevre Yolu
Muratlı Cd.
Fatih Sultan Mehmet Blv.
İstanbul Blv.
Kanuni Sultan Süleyman Blv.
Atatürk Blv.
Barbaros Cd.

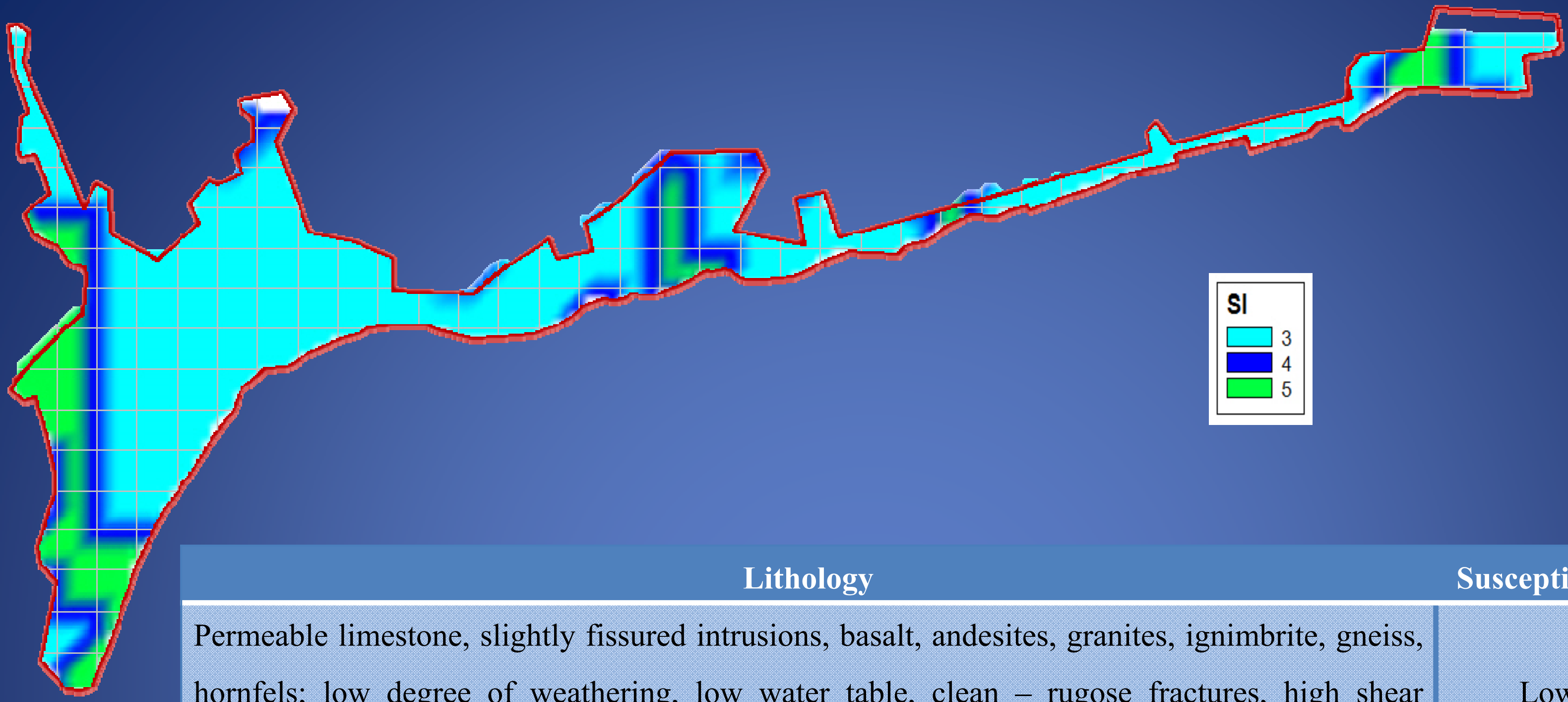

Factor Of Safety (FOS)
(Montgomery & Dietrich, 1994
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Tekirdağ
D555
Google earth

Mora and Vahrson Method (1994)

HI = SUSC * TRIG = (Sr * Sl * Sh) * (Ts + Tp)



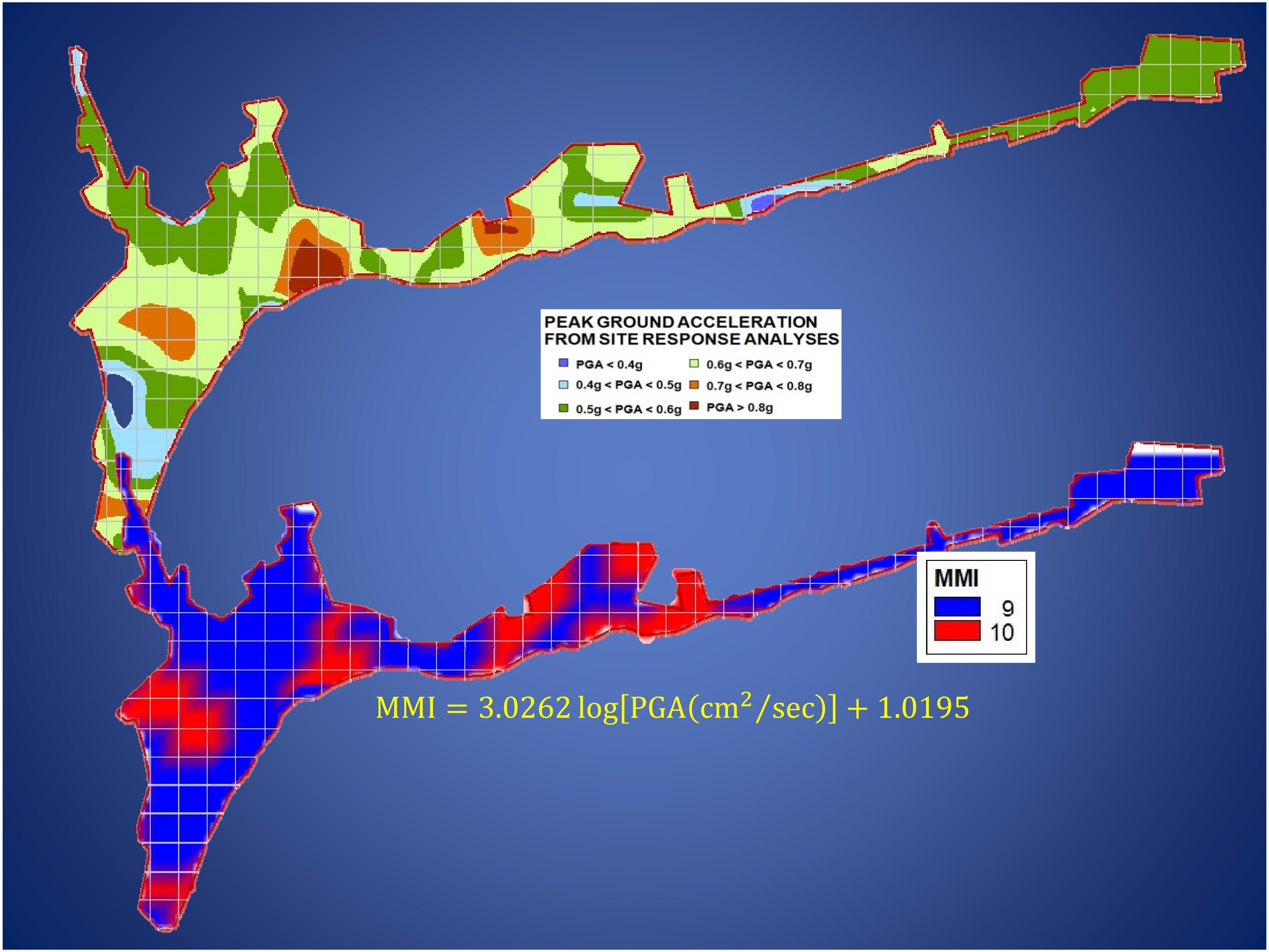
Relative Relief	Gradient (ΔH/ΔL)	Susceptibility	Parameter, S_r
0 – 75m/km²	0 – 0.075	Very Low	0
76 – 175	0.076 – 0.175	Low	1
176 – 300	0.176 – 0.3	Moderate	2
301 – 500	0.301 – 0.5	Medium	3
501 – 800	0.501 – 0.8	High	4
> 800	> 0.8	Very High	5



Lithology	Susceptibility	Value, S_l
Permeable limestone, slightly fissured intrusions, basalt, andesites, granites, ignimbrite, gneiss, hornfels; low degree of weathering, low water table, clean – rugose fractures, high shear strength rocks	Low	1
High degree of weathering of above mentioned lithologies and of hard massive clastic sedimentary rocks; low shear strength; shearable structures	Moderate	2
Considerably weathered sedimentary, intrusive, metamorphic, volcanic rocks, compacted sandy regolithic soils, considerable fracturing, fluctuating water tables, compacted colluvium and alluvium	Medium	3
Considerably weathered, hydrothermally altered rocks of any kind, strongly fractures and fissured, clay filled; poorly compacted pyroclastic and fluvio – lacustrine soils, shallow water tables	High	4
Extremely altered rocks, low shear resistance alluvial, colluvial and residual soils, shallow water tables	Very high	5

Mora and Vahrson Method (1994)

Intensities (MM) T_r = 100 years	Susceptibility	Value, T_s
III	Slight	1
IV	Very low	2
V	Low	3
VI	Moderate	4
VII	Medium	5
VIII	Considerable	6
IX	Important	7
X	Strong	8
XI	Very Strong	9
XII	Extremely Strong	10



$$\mathrm{MMI} = 3.0262 \log[\mathrm{PGA}(\mathrm{cm}^2/\mathrm{sec})] + 1.0195$$

$$H_l = |S_r * S_l * S_h| * |T_s + T_p|$$

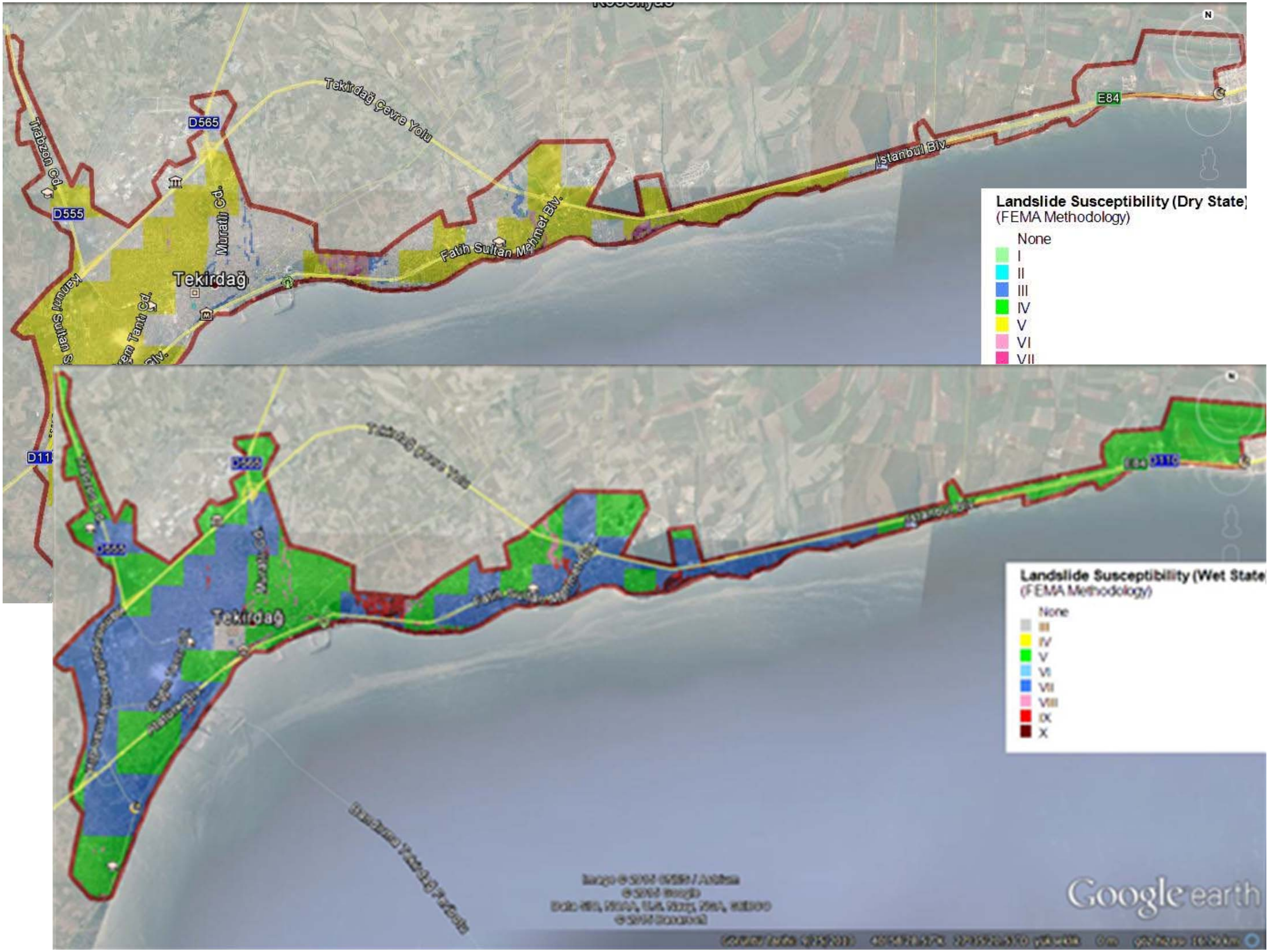
Average Monthly Precipitation (mm/month)	Assigned Value
< 125	0
125 - 250	1
250 <	2

Summation of Precipitation Averages	Susceptibility	Value, S_h
0 – 4	Very low	1
5 – 9	Low	2
10 – 14	Medium	3
15 – 19	High	4
20 – 24	Very high	5

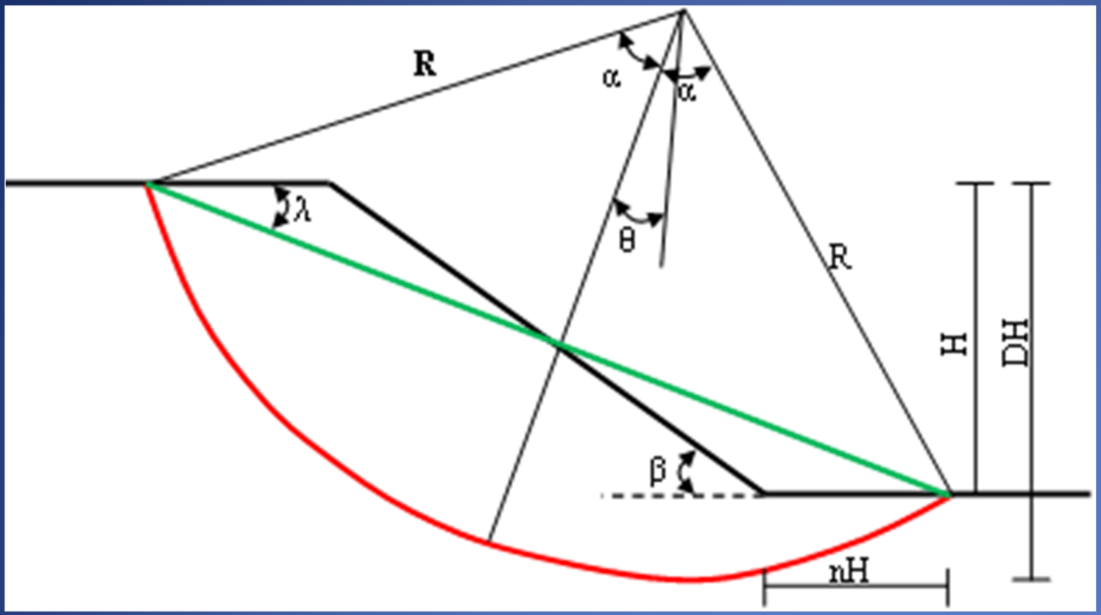
Maximum Rainfall n > 10 years: T_r = 100 years	Rainfall n<10 years; Average	Susceptibility	Value, T_p
< 100 mm	< 50 mm	Very low	1
101 – 200	51 – 90	Low	2
201 – 300	91 – 130	Medium	3
301 – 400	131 – 175	High	4
> 400	> 175	Very High	5

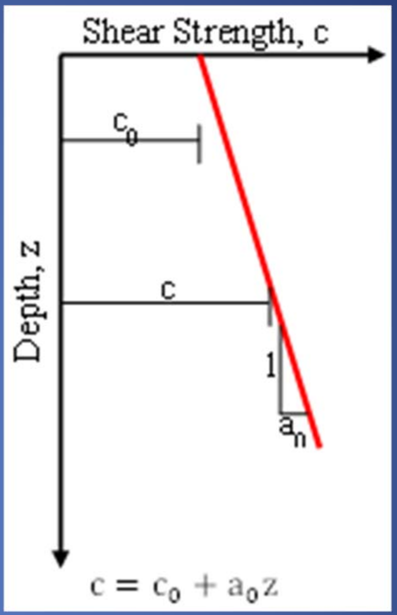
$$H_l = |S_r * S_l * S_h| * |T_s + T_p|$$

Value from Eq	Class	Susceptibility of Hazard
0 – 6	**I**	Negligible
7 – 32	II	Low
33 – 162	III	Moderate
163 – 512	IV	Medium
513 – 1250	V	High
> 1250	VI	Very High

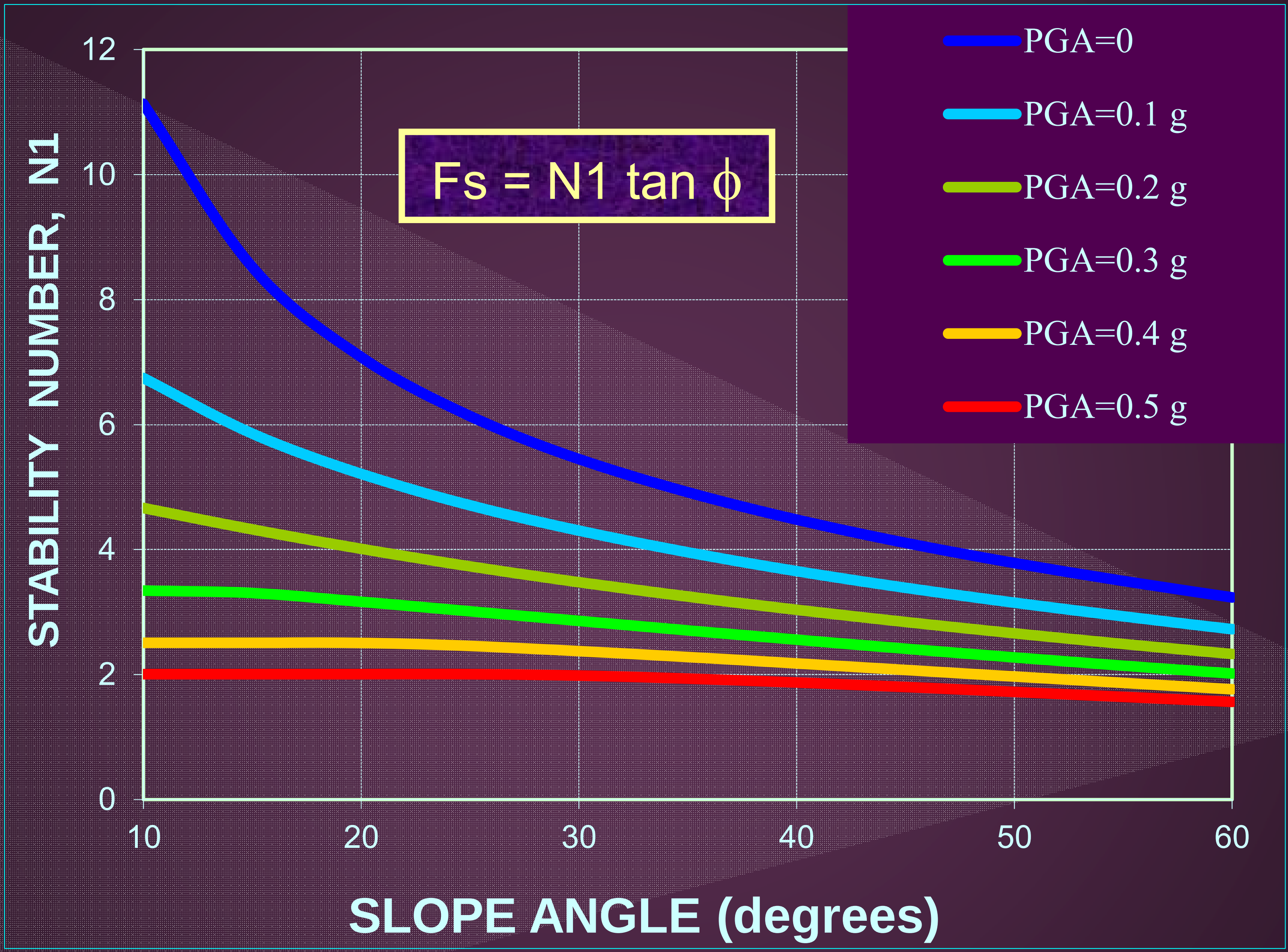

Landslide Susceptibility (Dry State)
(FEMA Methodology)
None
I
II
III
IV
V
VI
VII
Tekirdağ Çevre Yolu
D565
D555
Trabzon Cd.
Muratlı Cd.
Tekirdağ
Fatih Sultan Mehmet Blv.
İstanbul Blv.
E84
Landslide Susceptibility (Wet State)
(FEMA Methodology)
None
III
IV
V
VI
VII
VIII
IX
X
Google earth

Siyahi and Ansal (1993)

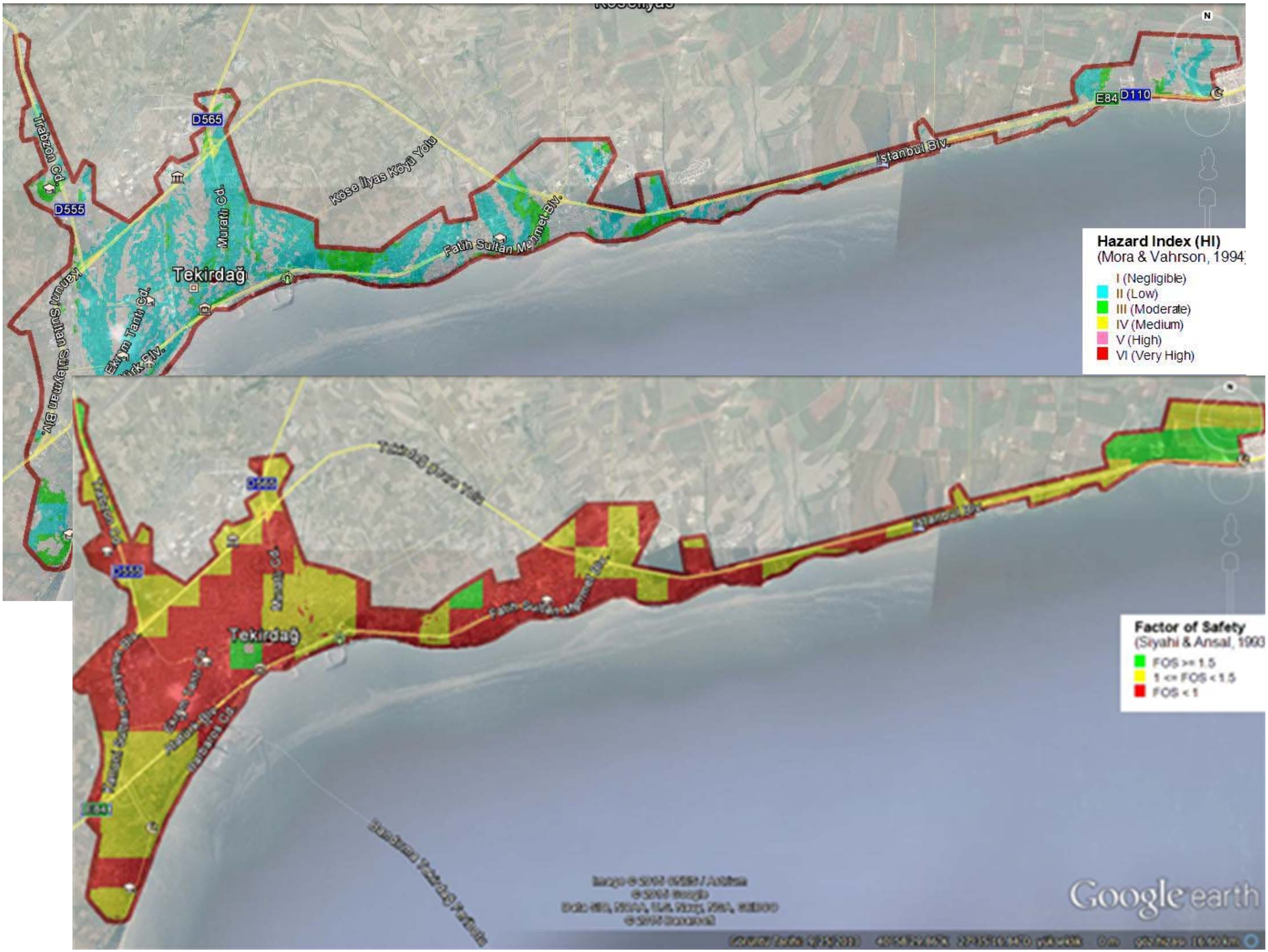




α = 50, ..., 850
β = 100, 10.50,..., 600
λ = 100,..., 550
n = 0 (toe failure presumption)
A (g) = 0.00, 0.02, ..., 1.00



LANDSLIDE HAZARD DURING EARTHQUAKES, Siyahi & Ansal, 1993

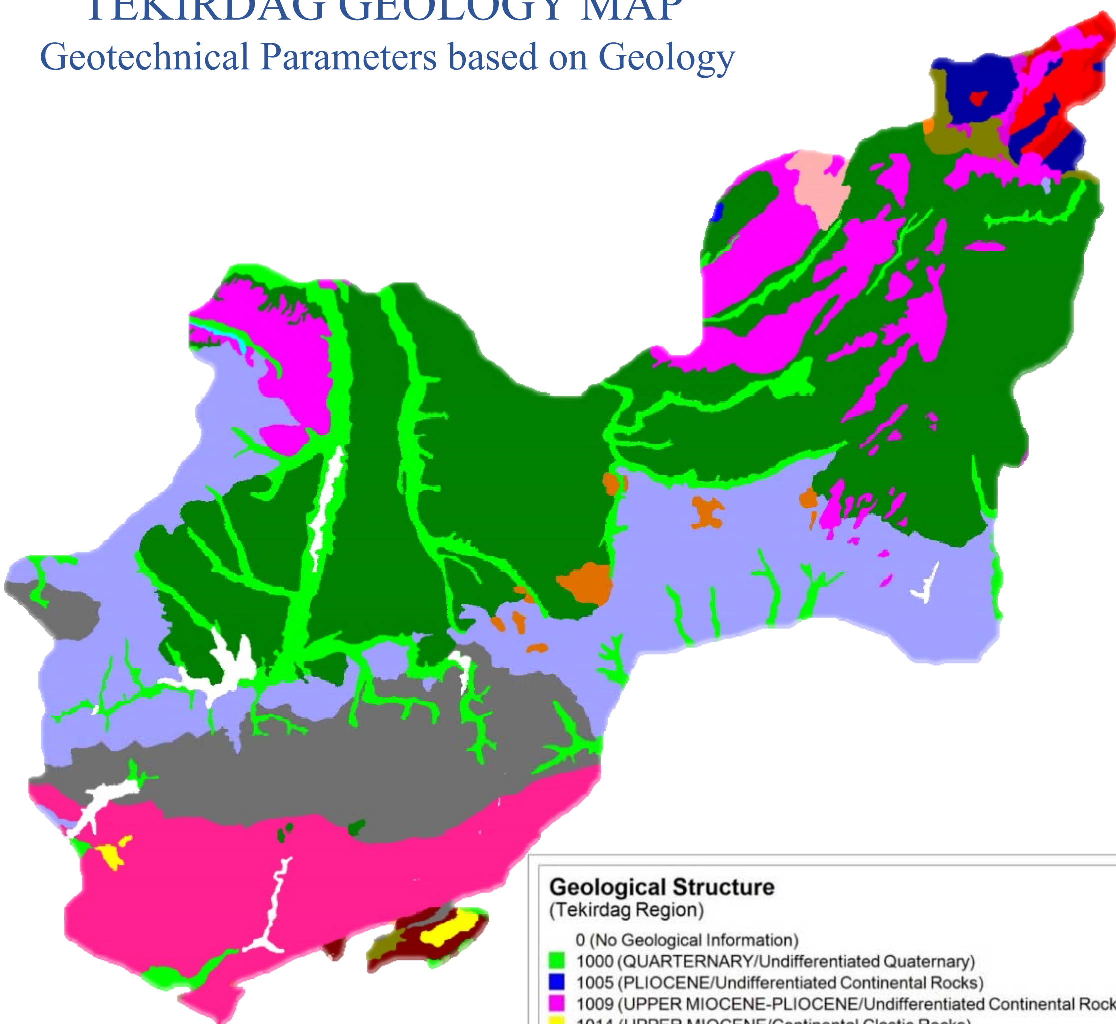


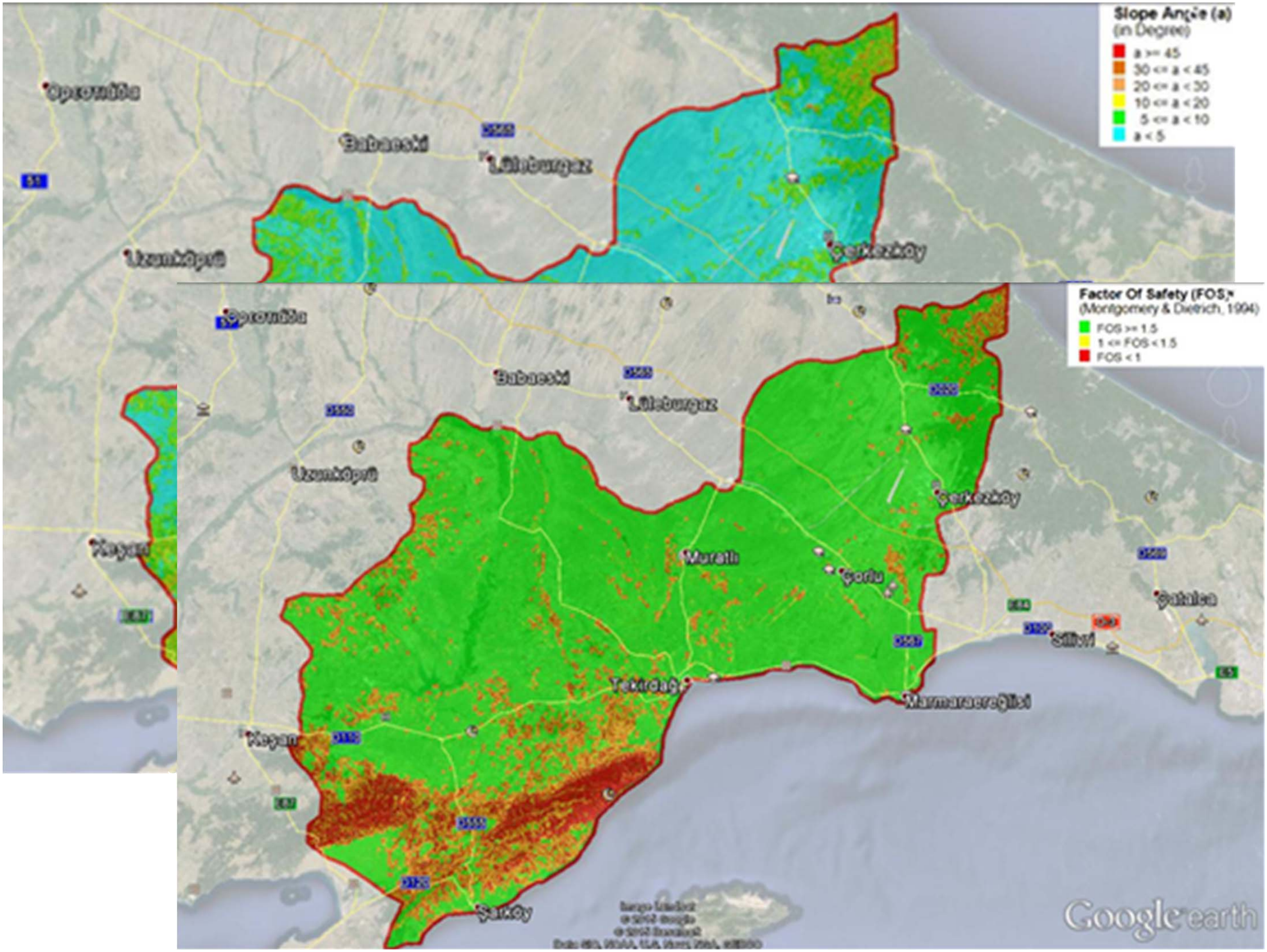
Hazard Index (HI)
(Mora & Vahrson, 1994)
I (Negligible)
II (Low)
III (Moderate)
IV (Medium)
V (High)
VI (Very High)
Tekirdağ
D565
D555
D110
E84
Trabzon Cd.
Muratlı Cd.
Köse İlyas Köyü Yolu
Fatih Sultan Mehmet Blv.
İstanbul Blv.
Kanuni Sultan Süleyman Blv.
Ekrem Tanrı Cd.
Factor of Safety
(Siyahi & Ansal, 1993)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Google earth

TEKİRDAĞ GEOLOGY MAP

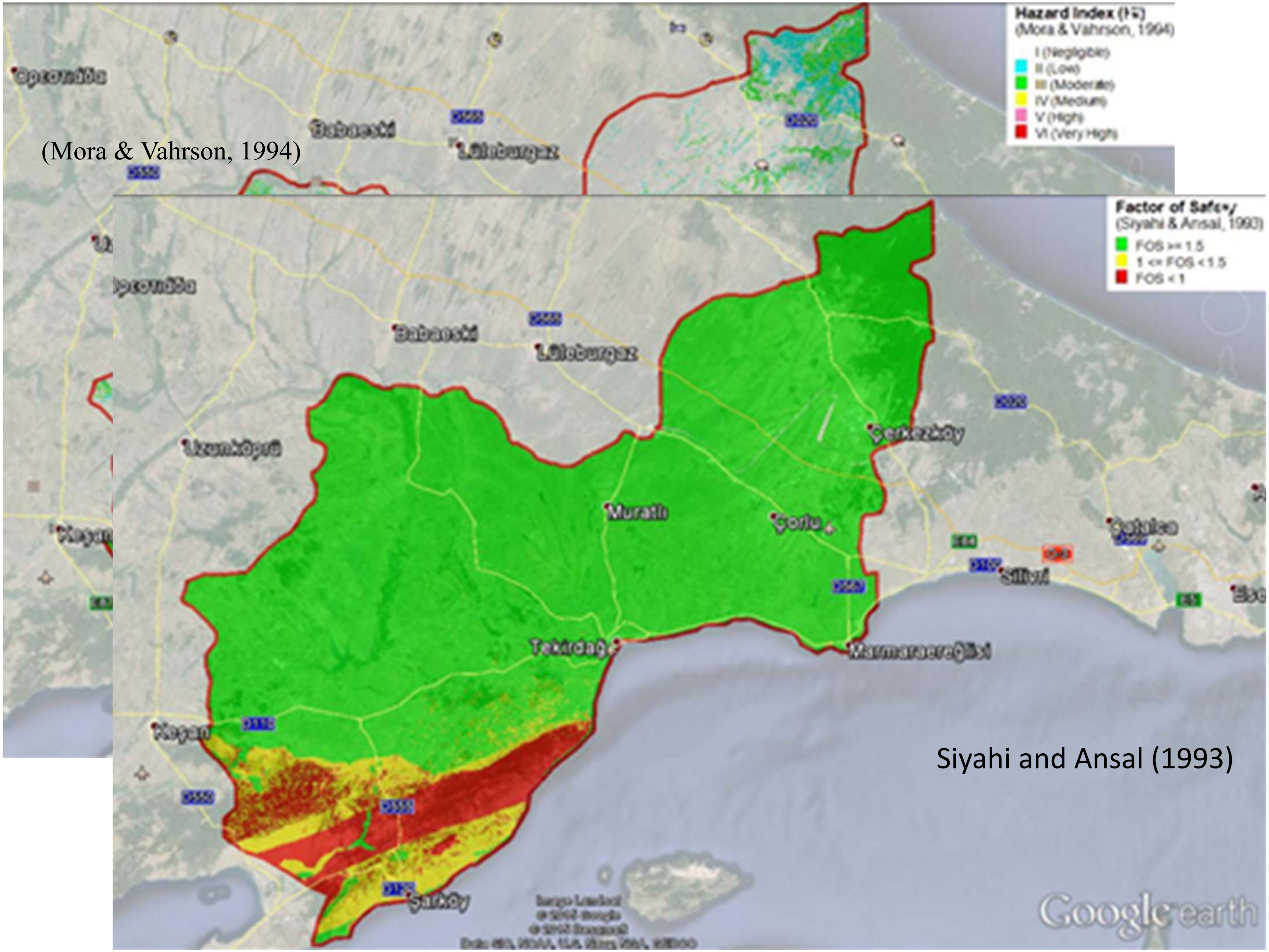
Geotechnical Parameters based on Geology

KOD	PHI	UNIT WEIGHT	KSAT (m/sec)	Z	SI
22	28	19	0.0001	1.5	4
79	35	22	0.000001	1.5	1
118	35	22	0.000001	1.5	1
119	35	22	0.000001	1.5	1
122	35	22	0.000001	1.5	1
1000	28	19	0.0001	1.5	4
1005	28	19	0.0001	1.5	4
1009	28	20	0.0001	1.5	4
1014	28	20	0.0001	1.5	4
1016	30	20	0.00003	1.5	4
1017	30	20	0.00003	1.5	4
1024	28	20	0.0001	1.5	4
1025	30	20	0.00003	1.5	4
1026	28	20	0.0001	1.5	4
1030	28	19	0.0001	1.5	4
1037	12	21	0.000001	1.5	5
1039	12	21	0.000001	1.5	5
1026_1	28	20	0.0001	1.5	4
107_2	35	22	0.000001	1.5	1
110_1	35	22	0.00001	1.5	2
110_2	35	22	0.00001	1.5	2
229_5	35	22	0.000001	1.5	1



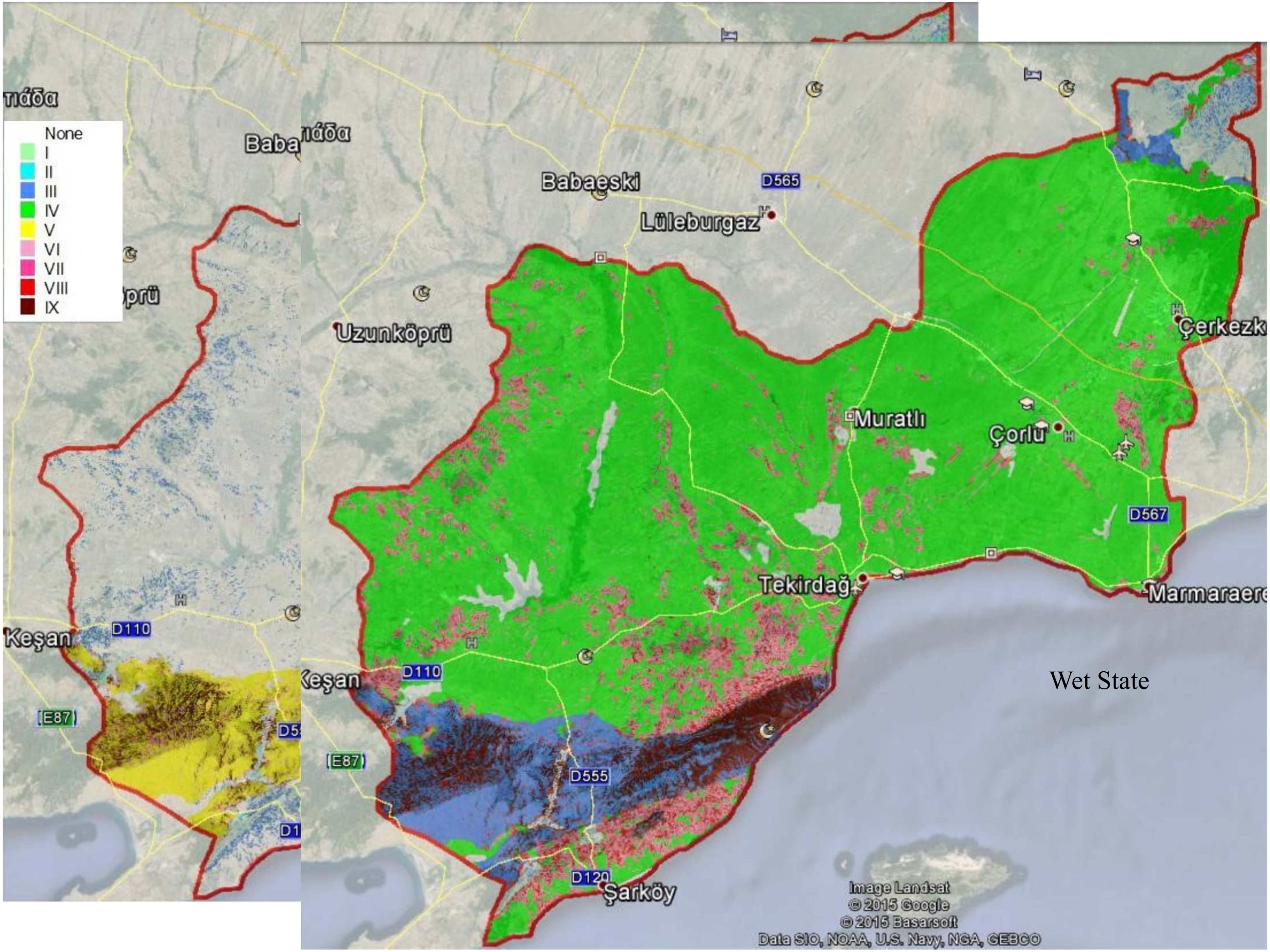


Slope Angle (a)
(in Degree)
a >= 45
30 <= a < 45
20 <= a < 30
10 <= a < 20
5 <= a < 10
a < 5
Babaeski
Lüleburgaz
Uzunköprü
Çerkezköy
Factor Of Safety (FOS)
(Montgomery & Dietrich, 1994)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Muratlı
Çorlu
Tekirdağ
Marmaraereğlisi
Silivri
Çatalca
Keşan
Şarköy
Google earth


(Mora & Vahrson, 1994)
Hazard Index (Hi)
(Mora & Vahrson, 1994)
I (Negligible)
II (Low)
III (Moderate)
IV (Medium)
V (High)
VI (Very High)
Factor of Safety
(Siyahi & Ansal, 1993)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Babaeski
Lüleburgaz
Uzunköprü
Muratlı
Çorlu
Çerkezköy
Tekirdağ
Marmaraereğlisi
Keşan
Şarköy
Silivri
Çatalca
Siyahi and Ansal (1993)
Google earth

FEMA METHODOLOGY

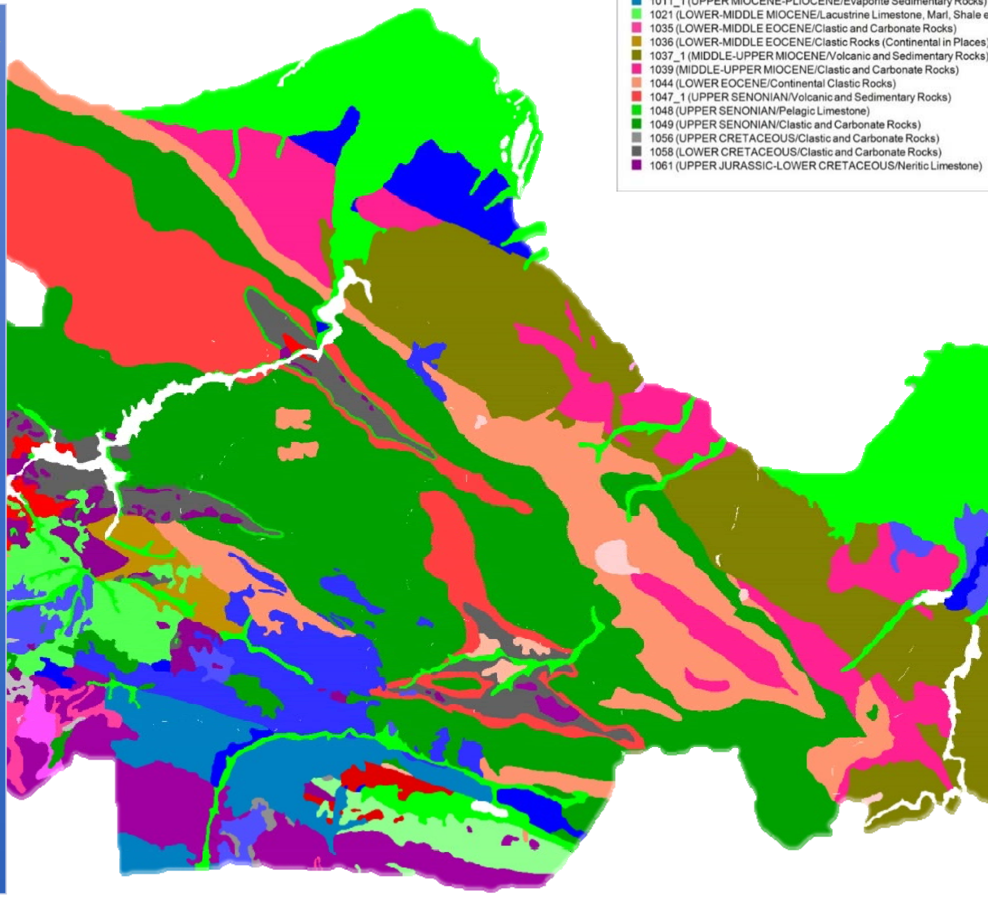
	Geologic Group	Slope Angle, degrees					
		0-10	**10-15**	**15-20**	**20-30**	**30-40**	**>40**
(a) DRY (groundwater below level of sliding)							
A	**Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^o$)**	None	None	I	II	IV	VI
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^o$)**	None	III	IV	V	VI	VII
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^o$)**	V	VI	VII	IX	IX	IX
(b) WET (groundwater level at ground surface)							
A	**Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^o$)**	None	III	VI	VII	VIII	VIII
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^o$)**	V	VIII	IX	IX	IX	X
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^o$)**	VII	IX	X	X	X	X


None
I
II
III
IV
V
VI
VII
VIII
IX
Babaeski
Lüleburgaz
D565
Uzunköprü
Muratlı
Çorlu
Çerkezk
D567
Tekirdağ
Marmaraere
Keşan
D110
E87
D555
D120
Şarköy
Wet State
Image Landsat
© 2015 Google
© 2015 Basarsoft
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

SAMSUN GEOLOGY MAP

Geotechnical Parameters based on Geology

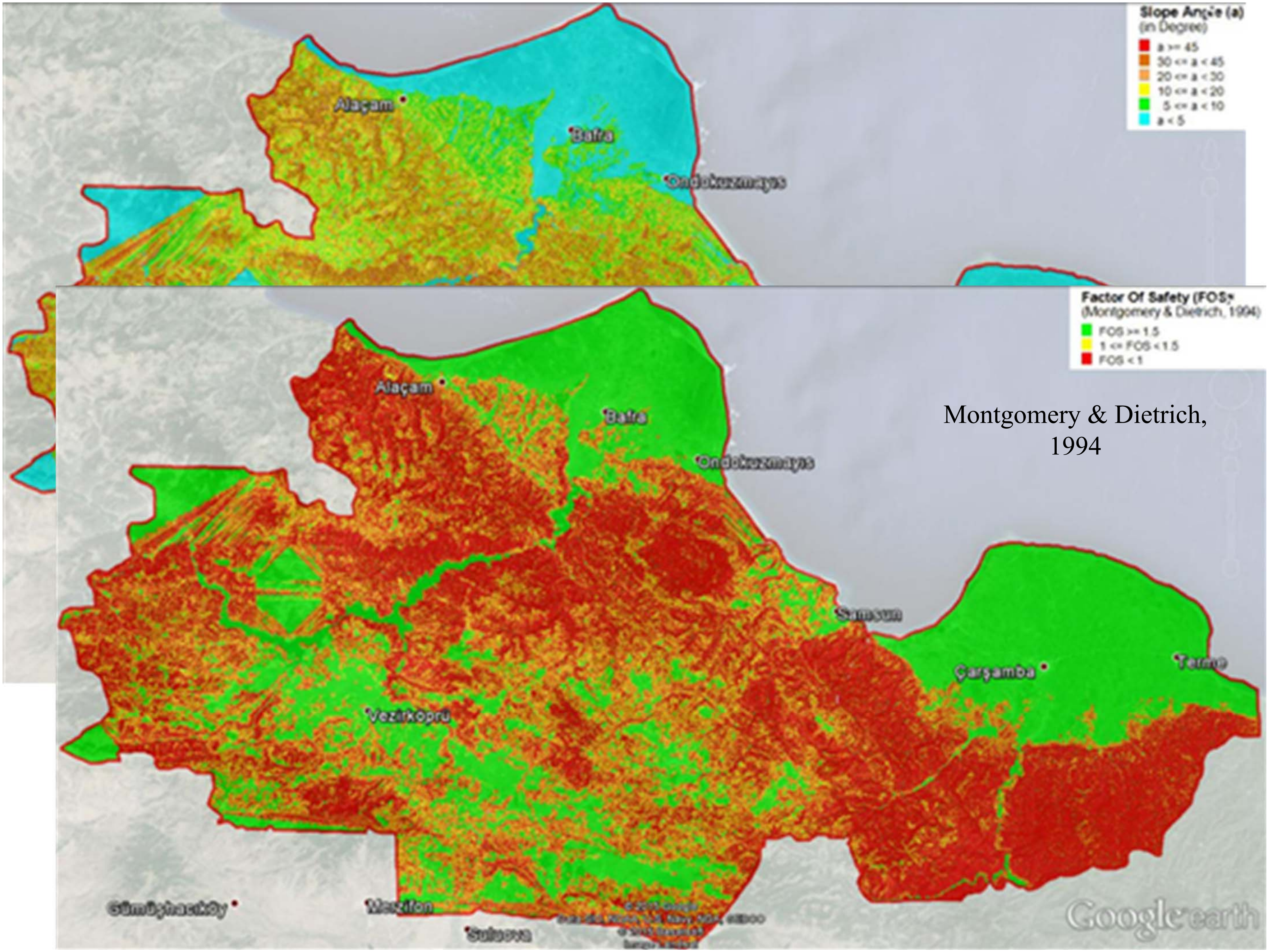
KOD	PHI	UNIT WEIGHT	KSAT (m/sec)	Z	Sl
1000	28	19	0.0001	1.5	4
1001	28	19	0.0001	1.5	4
1002	28	19	0.0001	1.5	4
1003	28	19	0.0001	1.5	4
1005	28	19	0.0001	1.5	4
1011_1	22	20	0.00001	1.5	4
1018	22	20	0.00001	1.5	4
1019	22	20	0.00001	1.5	4
102	30	20	0.00003	1.5	4
1027	25	21	0.00001	1.5	4
1036	12	21	0.000001	1.5	5
1037_1	12	21	0.000001	1.5	5
1038	12	21	0.000001	1.5	5
1039	12	21	0.000001	1.5	5
1043	30	20	0.00003	1.5	4
1043_1	30	20	0.00003	1.5	4
1044	30	20	0.00003	1.5	4
1046	30	20	0.00003	1.5	4
1047_1	30	20	0.00003	1.5	4
1049	30	20	0.00003	1.5	4
1054_1	30	20	0.00003	1.5	4
1055	30	20	0.00003	1.5	4
1058	30	20	0.00003	1.5	4
1061	35	22	0.00001	1.5	2
1062	35	22	0.00001	1.5	2
1067_1	35	22	0.00001	1.5	2
1076	22	20	0.00001	1.5	4
110	35	22	0.00001	1.5	2



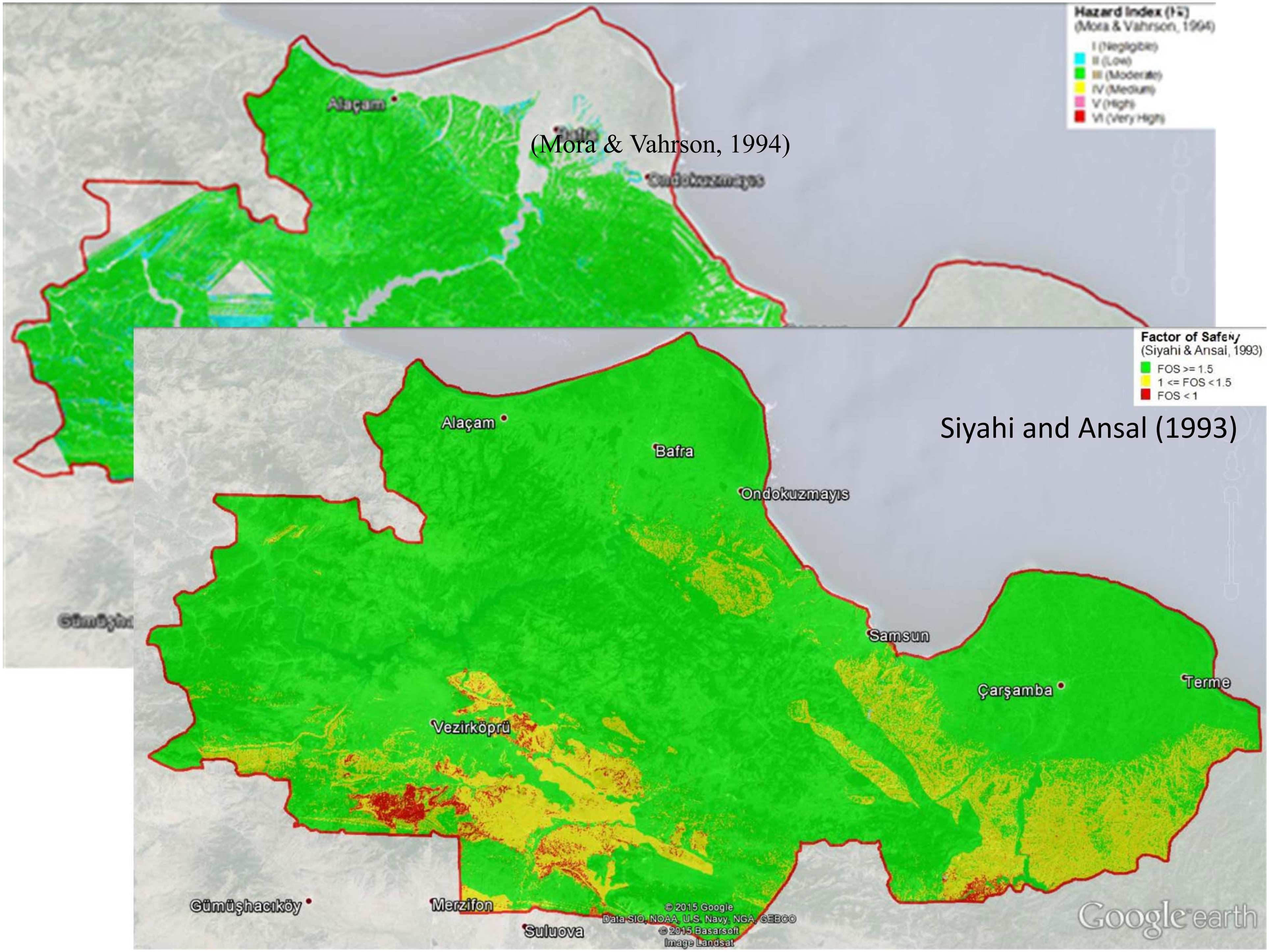
Geological Structure
(Samsun Region)

- 0 (No Geological Information)
- 1000 (QUARTERNARY/Undifferentiated Quarternary)
- 1001 (QUARTERNARY/Slope Debris and Cone of Dejection etc.)
- 1003 (QUARTERNARY/Beach and Dune)
- 1005 (PLIOCENE/Undifferentiated Continental Rocks)
- 1011_1 (UPPER MIOCENE-PLIOCENE/Evaporite Sedimentary Rocks)
- 1021 (LOWER-MIDDLE MIOCENE/Lacustrine Limestone, Marl, Shale etc.)
- 1035 (LOWER-MIDDLE EOCENE/Clastic and Carbonate Rocks)
- 1036 (LOWER-MIDDLE EOCENE/Clastic Rocks (Continental in Places))
- 1037_1 (MIDDLE-UPPER MIOCENE/Volcanic and Sedimentary Rocks)
- 1039 (MIDDLE-UPPER MIOCENE/Clastic and Carbonate Rocks)
- 1044 (LOWER EOCENE/Continental Clastic Rocks)
- 1047_1 (UPPER SENONIAN/Volcanic and Sedimentary Rocks)
- 1048 (UPPER SENONIAN/Pelagic Limestone)
- 1049 (UPPER SENONIAN/Clastic and Carbonate Rocks)
- 1056 (UPPER CRETACEOUS/Clastic and Carbonate Rocks)
- 1058 (LOWER CRETACEOUS/Clastic and Carbonate Rocks)
- 1061 (UPPER JURASSIC-LOWER CRETACEOUS/Neritic Limestone)
- 1062 (UPPER JURASSIC-LOWER CRETACEOUS/Pelagic Limestone)
- 1067_1 (LOWER-MIDDLE JURASSIC/Volcanic and Sedimentary Rocks)
- 1073 (MIDDLE-UPPER TRIASSIC/Neritic Limestone)
- 1076 (PERMO-TRIASSIC/Clastic and Carbonate Rocks (Partly with blocks...))
- 109_2 (MIDDLE TRIASSIC-JURASSIC/Marble)
- 110_1 (TRIASSIC-JURASSIC/Schists)
- 110_2 (UPPER PALEOZOIC-TRIASSIC/Schists, Phillite, Marble, Metabasic Rocks, etc)
- 122 (UPPER CRETACEOUS/Ophiolitic Melange)
- 123 (UPPER CRETACEOUS/Pillow Lava and Sedimentary Rocks)
- 127 (MESOZOIC/Gabro-Diabase)
- 133_1 (MESOZOIC/Undifferentiated Basic and Ultrabasic Rocks
- 2 (PLEISTOCENE/Undifferentiated Continental Clastic Rocks)
- 227_1 (UPPER CRETACEOUS/Granitoid)
- 230 (PALEOCENE/Granitoid)
- 51 (PERMIAN/Carbonate Rocks and Partly Clastic Rocks)
- 76 (PLIOCENE/Basalt)
- 82 (UPPER MIOCENE-PLIOCENE/Undifferentiated Volcanic Rocks)
- 99 (EOCENE/Undifferentiated Volcanic Rocks)

KOD	PHI	UNIT WEIGHT	KSAT (m/sec)	Z	Sl
110_1	35	22	0.00001	1.5	2
110_2	35	22	0.00001	1.5	2
112	35	22	0.00001	1.5	2
112	35	22	0.00001	1.5	2
133_1	35	22	0.00001	1.5	2
19	35	22	0.000003	1.5	1
2	28	19	0.0001	1.5	4
224	30	20	0.00003	1.5	4
229_1	30	20	0.00003	1.5	4
2302	35	22	0.000003	1.5	1
245	35	22	0.000003	1.5	1
51	22	20	0.00001	1.5	4
76	22	20	0.00001	1.5	4
77	22	20	0.00001	1.5	4
82	22	20	0.00001	1.5	4
100	35	22	0.000001	1.5	1
1012_1	22	20	0.00001	1.5	4
1021	28	20	0.0001	1.5	4
1023	28	20	0.0001	1.5	4
1028_1	28	20	0.0001	1.5	4
1034	12	21	0.000001	1.5	5
1035	12	21	0.000001	1.5	5
1037	12	21	0.000001	1.5	5
1041	30	20	0.00003	1.5	4
1042	30	20	0.00003	1.5	4
1045	30	20	0.00003	1.5	4
1048	30	20	0.00003	1.5	4
1051	30	20	0.00003	1.5	4



Slope Angle (a)
(in Degree)
a >= 45
30 <= a < 45
20 <= a < 30
10 <= a < 20
5 <= a < 10
a < 5
Factor Of Safety (FOS)
(Montgomery & Dietrich, 1994)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Montgomery & Dietrich,
1994
Alaçam
Bafra
Ondokuzmayıs
Samsun
Çarşamba
Terme
Vezirköprü
Gümüşhacıköy
Merzifon
Suluova
Google earth


Hazard Index (Hi)
(Mora & Vahrson, 1994)
I (Negligible)
II (Low)
III (Moderate)
IV (Medium)
V (High)
VI (Very High)
Alaçam
(Mora & Vahrson, 1994)
Ondokuzmayıs
Factor of Safety
(Siyahi & Ansal, 1993)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Siyahi and Ansal (1993)
Alaçam
Bafra
Ondokuzmayıs
Samsun
Çarşamba
Terme
Vezirköprü
Gümüşhacıköy
Merzifon
Suluova
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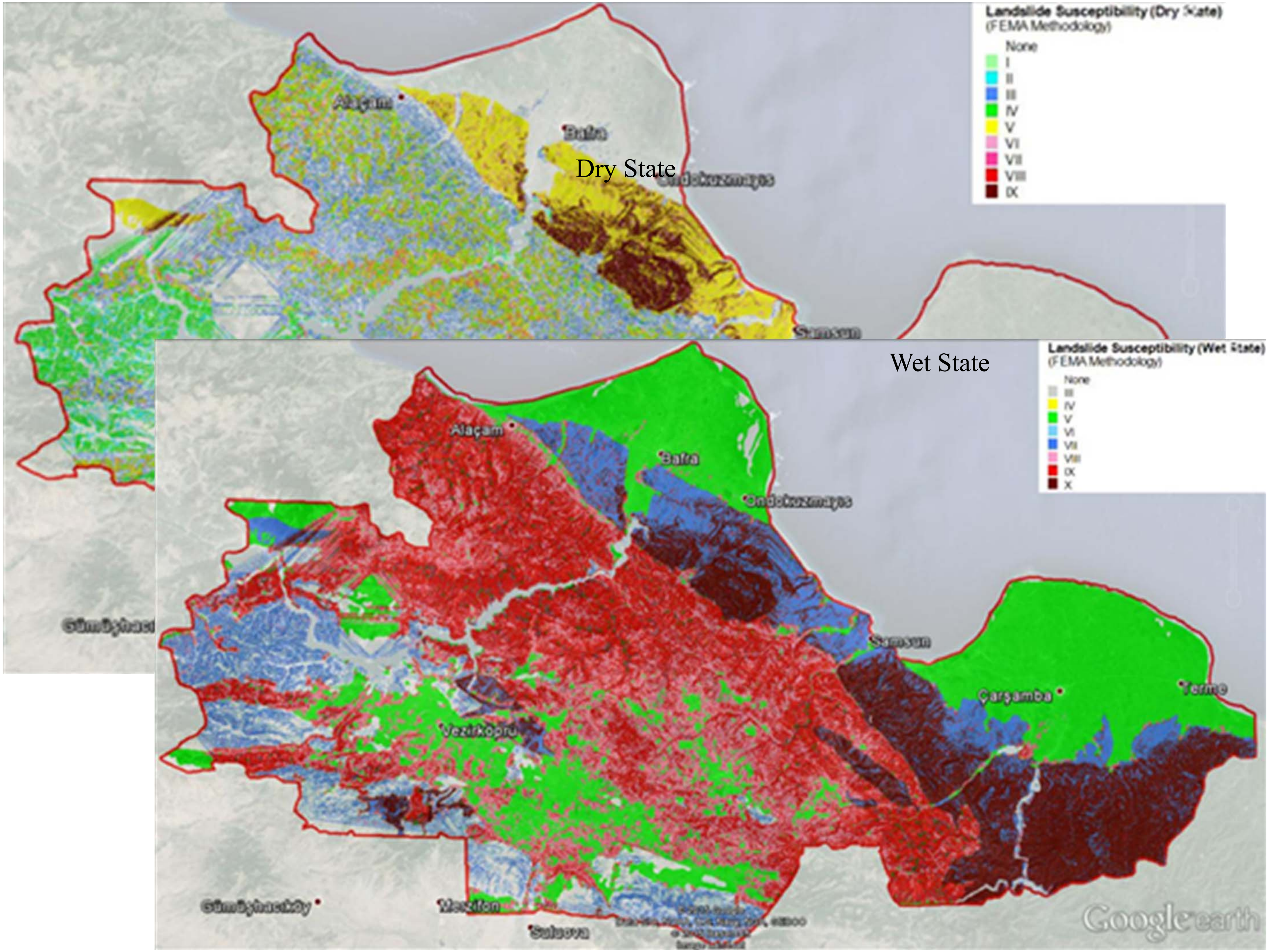


Landslide Susceptibility (Dry State)
(FEMA Methodology)
None
I
II
III
IV
V
VI
VII
VIII
IX
Dry State
Alaçam
Bafra
Ondokuzmayıs
Samsun
Landslide Susceptibility (Wet State)
(FEMA Methodology)
None
III
IV
V
VI
VII
VIII
IX
X
Wet State
Çarşamba
Terme
Vezirköprü
Gümüşhacıköy
Merzifon
Suluova
Google earth

Modified Montgomery-Dietrich Methodology

- The evaluation is performed through two different stages:

✓Short – Term State (Transient Condition) ($t <= H^2 / D_0$)

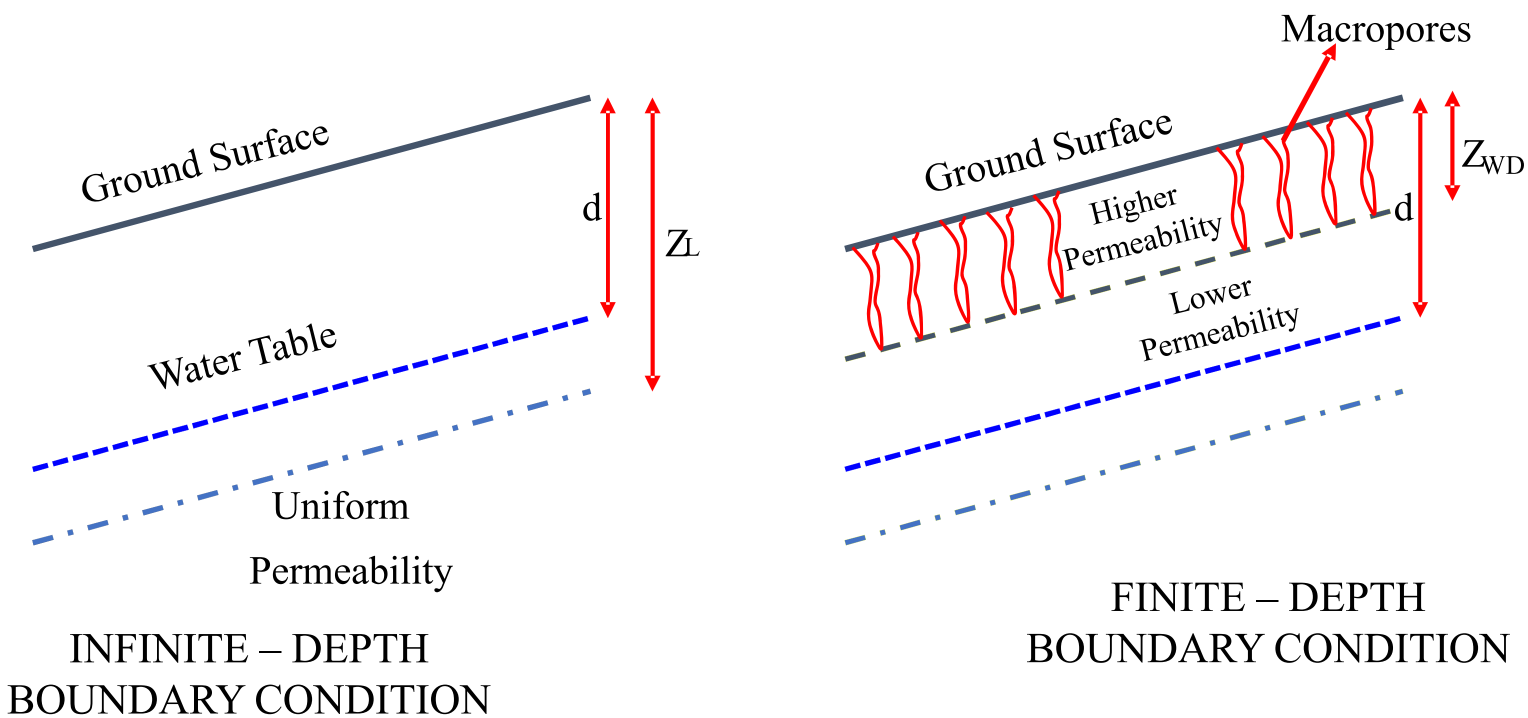
Infinite – Depth Boundary Condition: Permeability contrast between the fractured zone and undisturbed beneath soil.

Finite – Depth Boundary Condition: No permeability contrast between the fractured zone and undisturbed beneath soil. (Uniform permeability through soil layer)

✓Seepage State ($t >= H / \sqrt{A}$)

Seepage force plugged into conventional infinite – slope stability equation.

Modified Montgomery-Dietrich Methodology



d = Water table depth

Z_L = The last depth the pore pressure calculation is performed in infinite – depth BC.

Z_{WD} = The capillary region depth, or *hydrological depth* (where wetting/drying effect prevails)

Finite – Depth Boundary Condition

Carslaw and Jaeger 1959 and its adaptation in TRIGRS (2008)

$$\Psi(Z,t) = (Z-d)\beta$$

$$+2\sum_{n=1}^{N}\frac{I_{nZ}}{K_{sat}}H(t-t_n)[D_1(t-t_n)]^{1/2}\sum_{m=1}^{\infty}\left\{\begin{array}{l}\operatorname{ierfc}\left[\dfrac{(2m-1)d_{LZ}-(d_{LZ}-1)}{2[D_1(t-t_n)]^{1/2}}\right]\\ +\operatorname{ierfc}\left[\dfrac{(2m-1)d_{LZ}+(d_{LZ}-1)}{2[D_1(t-t_n)]^{1/2}}\right]\end{array}\right\}$$

$$-2\sum_{n=1}^{N}\frac{I_{nZ}}{K_{sat}}H(t-t_{n+1})[D_1(t-t_{n+})]^{1/2}\sum_{m=1}^{\infty}\left\{\begin{array}{l}\operatorname{ierfc}\left[\dfrac{(2m-1)d_{LZ}-(d_{LZ}-1)}{2[D_1(t-t_{n+1})]^{1/2}}\right]\\ +\operatorname{ierfc}\left[\dfrac{(2m-1)d_{LZ}+(d_{LZ}-1)}{2[D_1(t-t_{n+1})]^{1/2}}\right]\end{array}\right\}$$

Modified Montgomery-Dietrich Methodology

$$\psi(Z,t) = (Z-d)\beta + \sum_{i=1}^{N}\frac{I_{nZ}}{K_{sat}}\sum_{n=0}^{\infty}\left[R_{1,i}+R_{2,i}\right]-\left[R_{3,i+1}+R_{4,i+1}\right]$$

$$R_{1,i} = A\left[\sqrt{\frac{t_1^*}{\pi}} * \exp(-1/t_1^*) - \operatorname{erfc}\left(1/\sqrt{t_1^*}\right)\right]$$

Treatment of Rainfall Data Sets

- Two types of rainfall records:
  - ✓The daily measurements (In our case: from 1960 to 2007)
  - ✓Rainfall recordes per 10 minutes (In our case: from 2007-2014)

- In each Methodology:
  - ✓Montgomery and Dietrich (1994): *<u>Accumulated daily amount.</u>*
  - ✓Modified method: *<u>Hourly pattern of accumulated daily amount.</u>*

Treatment of Rainfall Data Sets

- Rainfall Hazard Approach – I
  - ✓Daily rainfall;
    Exceedance Probability of 1% (1960-2007) = **22.86 mm/day**
  - ✓Hourly rainfall intensity (I_z) in its pattern;
    Exceedance Probability of 1% (2007-2014) = **4.28 mm/hour (36 mm/day)**

- Rainfall Hazard Approach – II
  - ✓The most common hazard in flood and wind;

Exceedance Probability of 1% within 1 year

(T = 100 years)

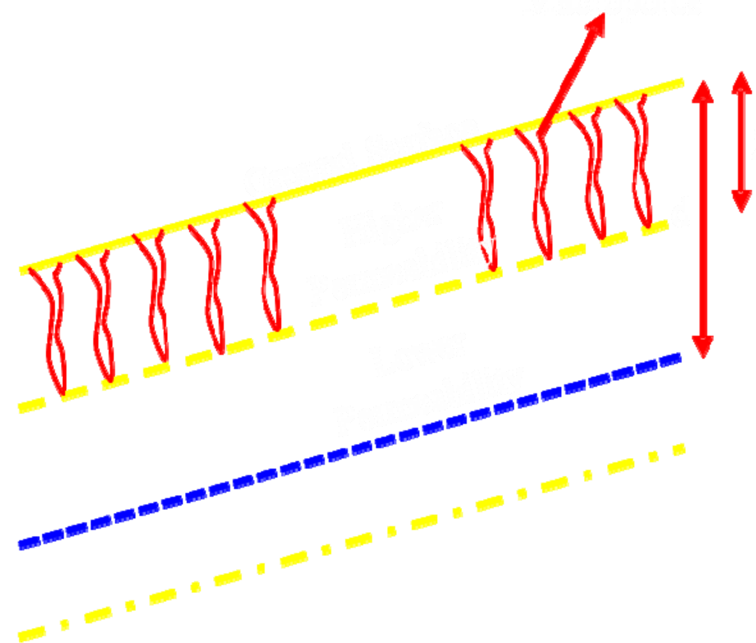
Daily rainfall amount;

E. P. of 1% within 1 year = **120.3 mm/day**

The Main Assumption

- Important affecting phenomenon at the shallow landslides:

  Wetting / Drying Process



✓ the shallow parts of soil layers are exposed to wetting/drying effect, culminating in the volume change and the creation of macropores (Meiers et al. 2011).

✓ the hydraulic conductivity of clay samples increase up to approximately three orders.

The Main Assumption
(For Tekirdağ Region Case)

- It is supposed that this depth can be considered as equal or slightly higher than the freeze and thaw depth of the interested regions.

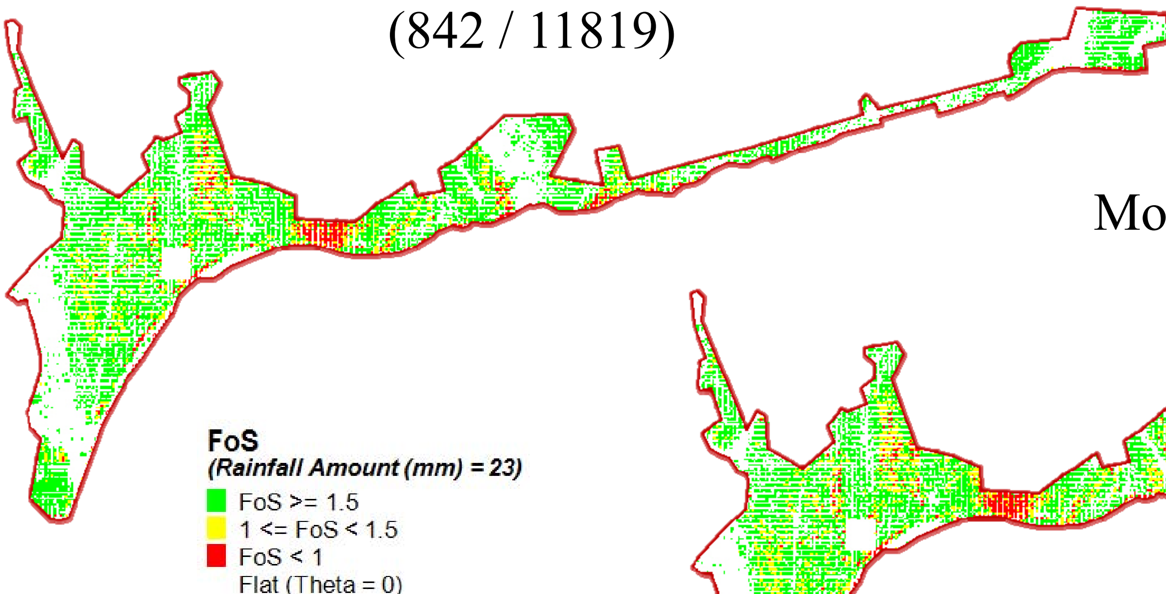
- 1.5m for Tekirdag Region.

- Selected depth: from assessment of each borehole data and stratification of the site

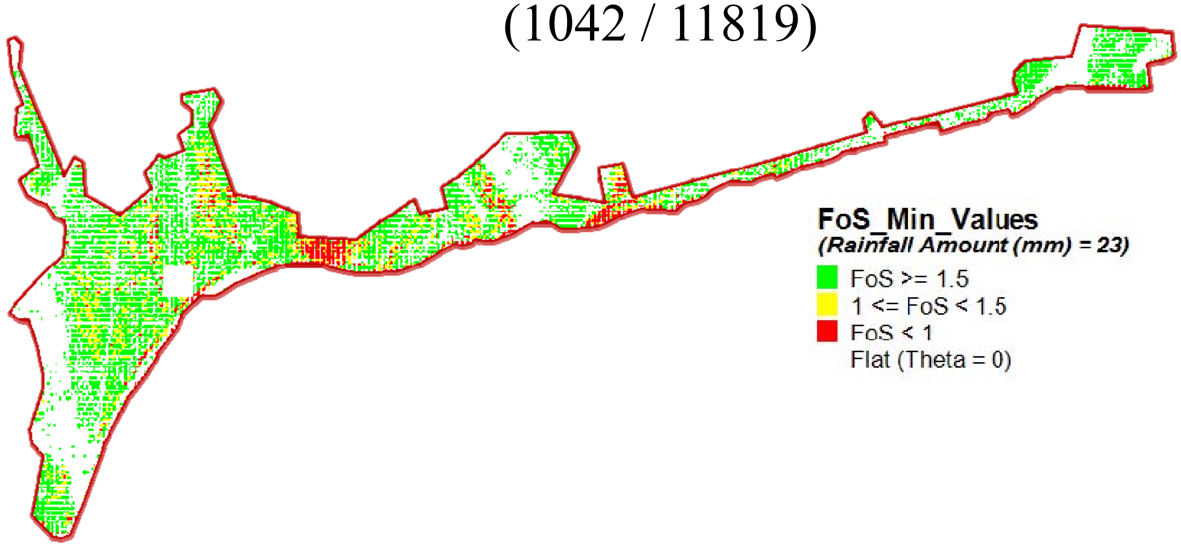
(Rainfall Hazard Approach – I)

Rainfall Amount (23 mm):

Montgomery and Dietrich (1994)
(842 / 11819)

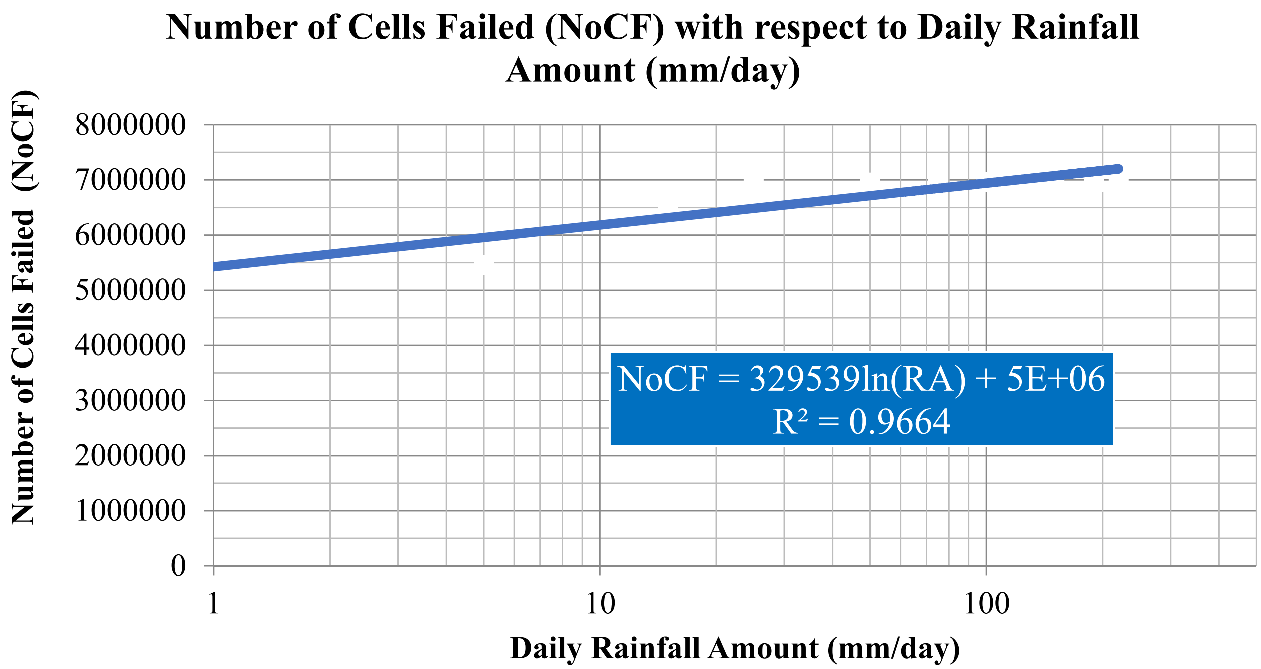


Modified Methodology
(1042 / 11819)



SAMSUN REGION

(Relationship between Number of Failed Cells and Daily Rainfall Amount)



For Samsun Region, Montgomery and Dietrich (1994) Method is also performed for different daily rainfall amounts to derive a relationship between number of cells failed and daily rainfall amount. This figure shows that well – established curve can be used for early warning systems, constructed for estimating the effect of incoming rainfall on interested site.

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THE END