Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

Black Sea CROSS BORDER COOPERATION

MICROZONATION FOR RAINFALL AND SEISMICLY INDUCED LANDSLIDE

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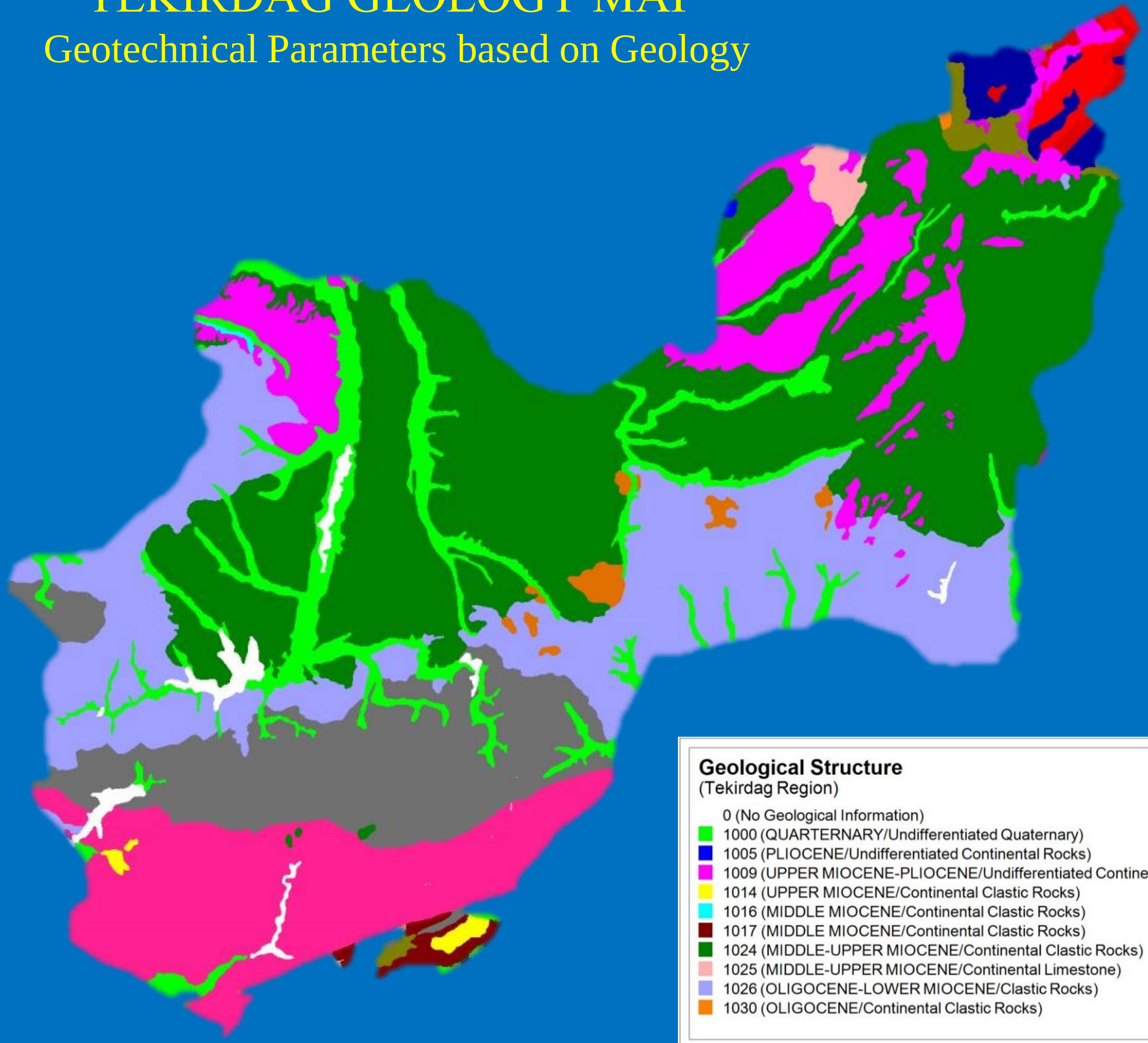
APPLIED METHODS

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

TEKİRDAĞ GEOLOGY MAP

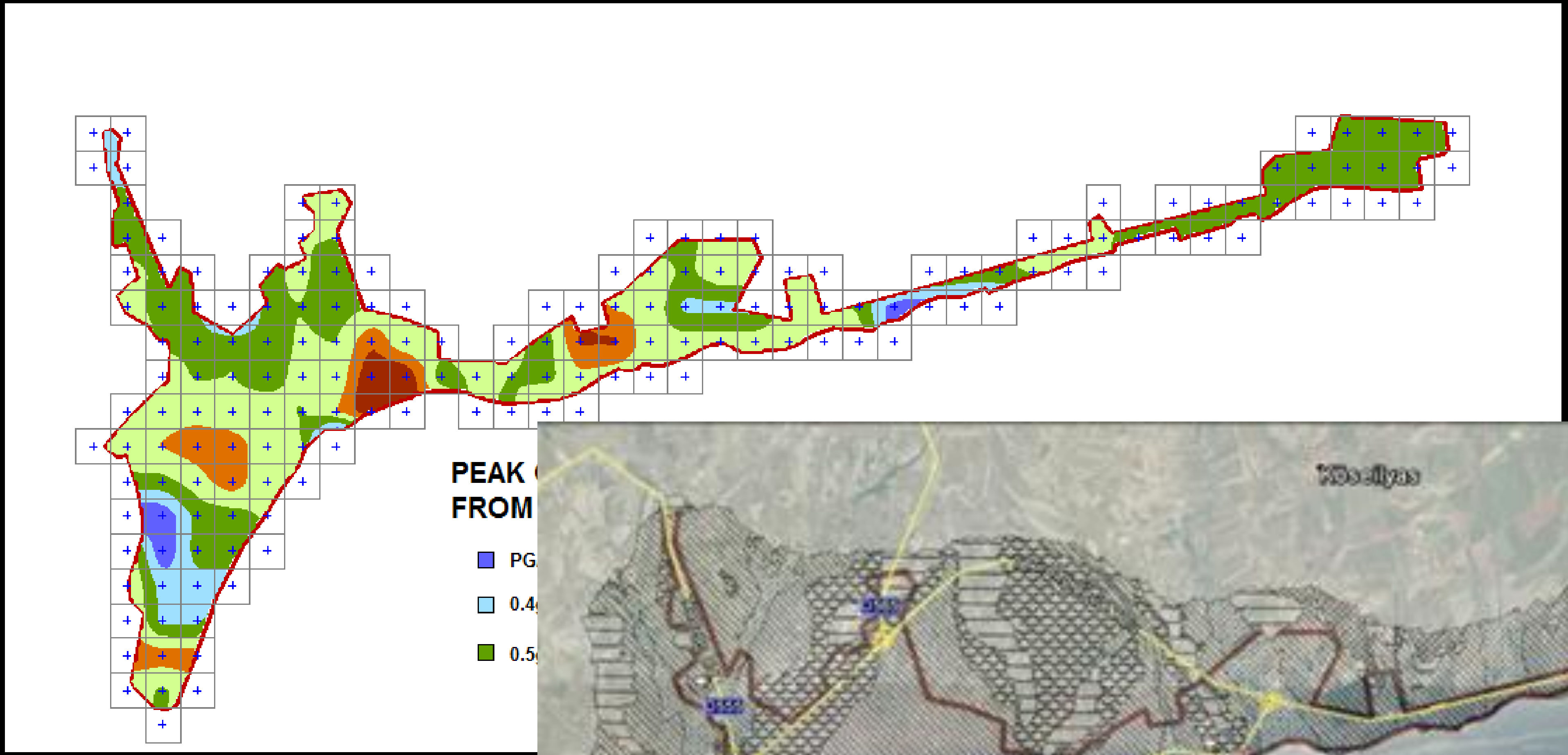
Geotechnical Parameters based on Geology



KOD	PHI	UNIT WEIGHT	KSAT (m/sec)	Z	Sl
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

Geological Structure
(Tekirdag Region)

- 0 (No Geological Information)
- 1000 (QUARTERNARY/Undifferentiated Quaternary)
- 1005 (PLIOCENE/Undifferentiated Continental Rocks)
- 1009 (UPPER MIOCENE-PLIOCENE/Undifferentiated Continental Rocks)
- 1014 (UPPER MIOCENE/Continental Clastic Rocks)
- 1016 (MIDDLE MIOCENE/Continental Clastic Rocks)
- 1017 (MIDDLE MIOCENE/Continental Clastic Rocks)
- 1024 (MIDDLE-UPPER MIOCENE/Continental Clastic Rocks)
- 1025 (MIDDLE-UPPER MIOCENE/Continental Limestone)
- 1026 (OLIGOCENE-LOWER MIOCENE/Clastic Rocks)
- 1030 (OLIGOCENE/Continental Clastic Rocks)
- 1037 (MIDDLE-UPPER EOCENE/Neritic Limestone)
- 1039 (MIDDLE-UPPER EOCENE/Clastic and Carbonate Rocks)
- 110_1 (TRIASSIC-JURASSIC/Schists)
- 110_2 (UPPER PALEOZOIC-TRIASSIC/Schist, Phillite, Marble, Metabasic Rocks etc.)
- 118 (PRECAMBRIAN/Undifferentiated Gneiss, Schist, Metagranite, Migmatite, etc.)
- 119 (PRECAMBRIAN/Gneiss, Schist)
- 122 (UPPER CRETACEOUS/Ophiolitic Melange)
- 22 (UPPER EOCENE/Clastic Rocks)
- 229_5 (UPPER PALEOZOIC/Granitoid)
- 79 (UPPER MIOCENE-PLIOCENE/Basalt)



LOCAL SCALE

TEKİRDAĞ

(Montgomery & Dietrich, 1994)

$$W = \frac{I_z A}{bT\sin\theta} \qquad W = \frac{I_z A}{bT\sin\theta}\frac{K\sin\theta h\cos\theta}{K\sin\theta z\cos\theta} = \frac{h}{z}$$

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

Inclusion of Wetness State

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

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

MORA AND VAHRSON METHOD

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

S_r, S_l and S_h denote the value of relative relief index, the value of lithological susceptibility and the value of index of influence of natural humidity of the soil

T_s and T_p denote the value of influence of seismic intensity and the value of influence of rainfall precipitation intensity

MORA AND VAHRSON METHOD

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

Table 1 Corrected Relative Relief		
Relative Relief	Susceptibility	Parameter, S_r
0 – 0.075m/km^2	Very Low	0
0.076 – 0.175	Low	1
0.176 – 0.3	Moderate	2
0.301 – 0.5	Medium	3
0.501 – 0.8	High	4
> 0.8	Very High	5

Table 2 Classification of the lithological influence according to the general conditions, representative for Central America.		
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

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

Table 3 The classes of average monthly precipitation.	
Average Monthly Precipitation (mm/month)	Assigned Value
< 125	0
125 - 250	1
250 <	2

Table 4 Weighting for annual precipitation.		
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

MORA AND VAHRSON METHOD

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

Table 5 The influence of seismic intensity (Modified Mercalli Scale) as a triggering factor for landslide generation.		
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

Table 6 The influence of rainfall precipitation intensity as a triggering factor for landslides.			
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

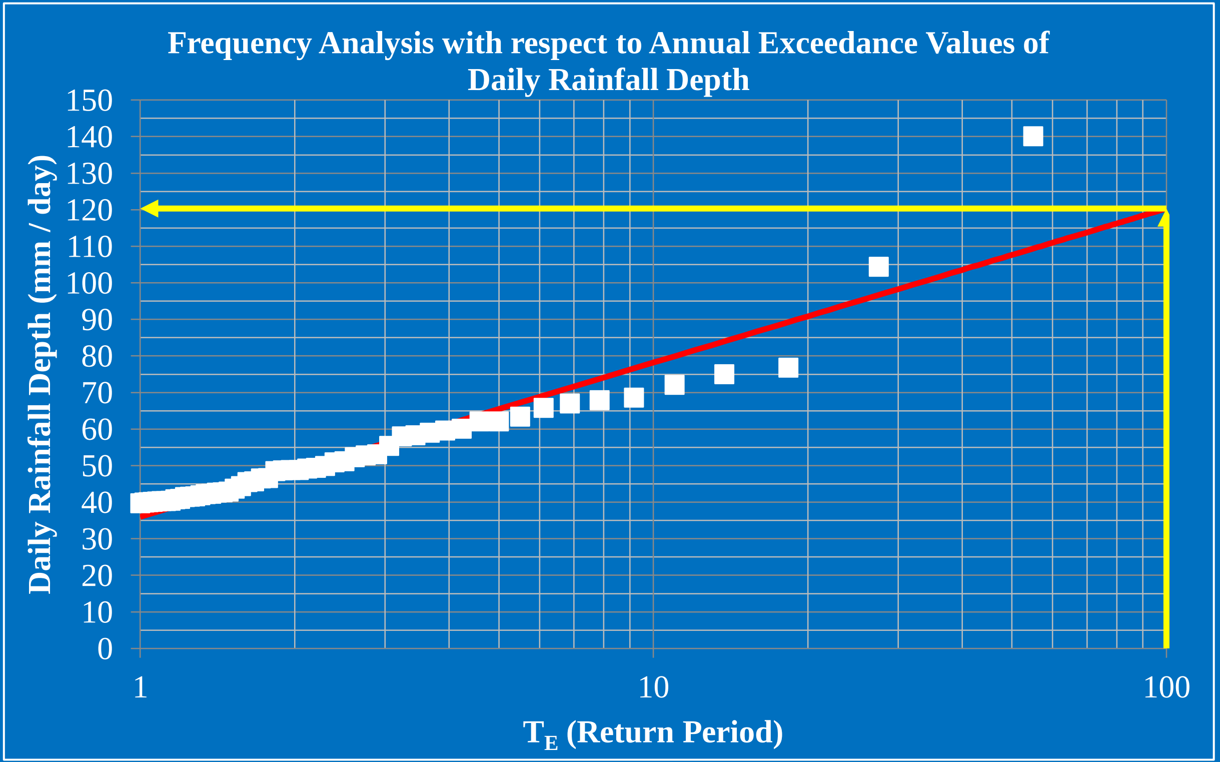
MORA AND VAHRSON METHOD

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

Table 7 The influence of rainfall precipitation intensity as a triggering factor for landslides.		
Value from Eq. (5)	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

RAINFALL FREQUENCY ANALYSIS FOR TEKİRDAĞ REGION (Ven Te Chow, 1953)

Used in Montgomery & Dietrich (1994) Method



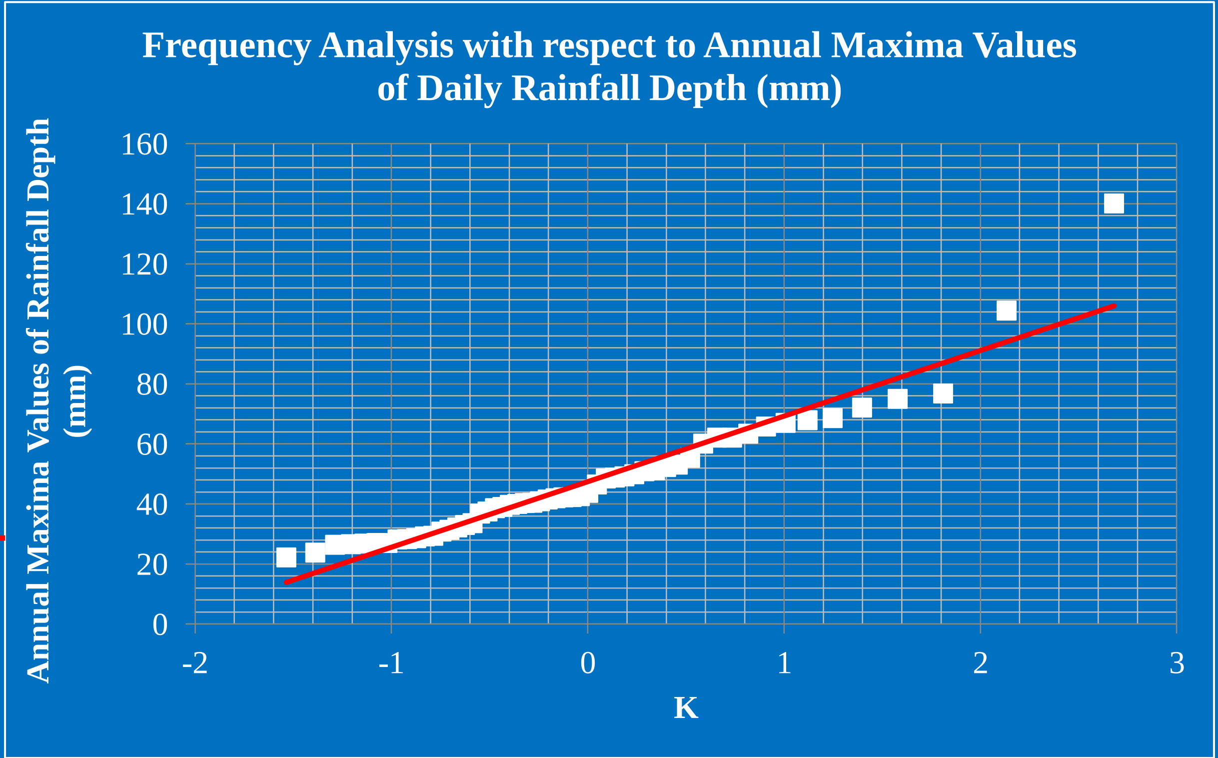
$$RA = 120 \text{ mm/day for } T_E = 100 \text{ years}$$

$$K = -\left(1.1 + 1.795 \log_{10} \log_{10} \frac{N+1}{N+1-m}\right)$$

$$T_M = \frac{N+1}{m}$$

$$RA = 114 \text{ mm/day for } T_M = 100 \text{ years } (K = 3.05)$$

Used in Mora & Vahrson (1994) Method




Tekirdağ Çevre Yolu
D565
Trabzon Cd.
D555
Muratlı Cd.
Tekirdağ
Fatih Sultan Mehmet Blv.
İstanbul Blv.
E84
D110
Kanuni Sultan Süleyman Blv.
Atatürk Blv.
Barbaros Cd.
Bandırma
Slope Angle (a)
(in Degree)
a >= 45

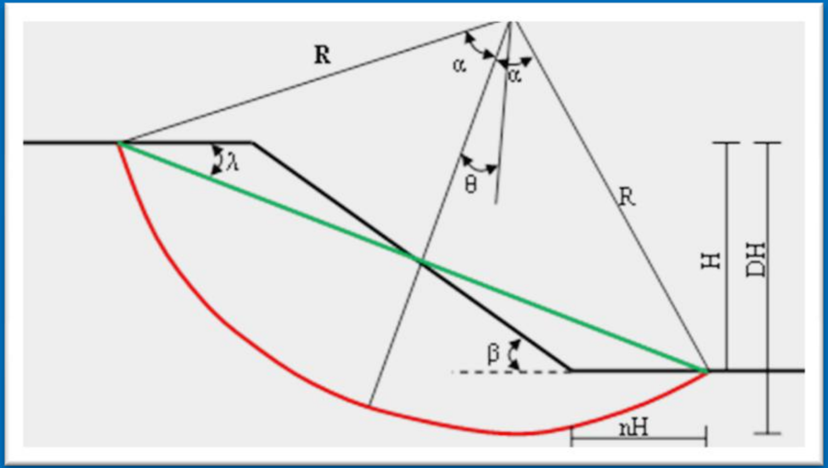

D555
Tekirdağ
Factor Of Safety (FOS)
(Montgomery & Dietrich, 1994
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Google earth


Landslide Susceptibility (Dry State)
(FEMA Methodology)
None
I
II
III
IV
V
Tekirdağ
D565
D555
D110
E84
Trabzon Cd.
Muratlı Cd.
Tekirdağ Çevre Yolu
İstanbul Blv.
Fatih Sultan Mehmet Blv.
Kanuni Sultan Süleyman Blv.
Atatürk Blv.
Bandırma Tekirdağ Feribotu


Landslide Susceptibility (Wet State)
(FEMA Methodology)
None
III
IV
V
VI
VII
VIII
IX
X
Tekirdağ
Google earth

(Siyahi & Ansal, 1993)

$$F_s = \frac{a_0}{\gamma} N_1 + \frac{c_0}{\gamma H} N_2$$



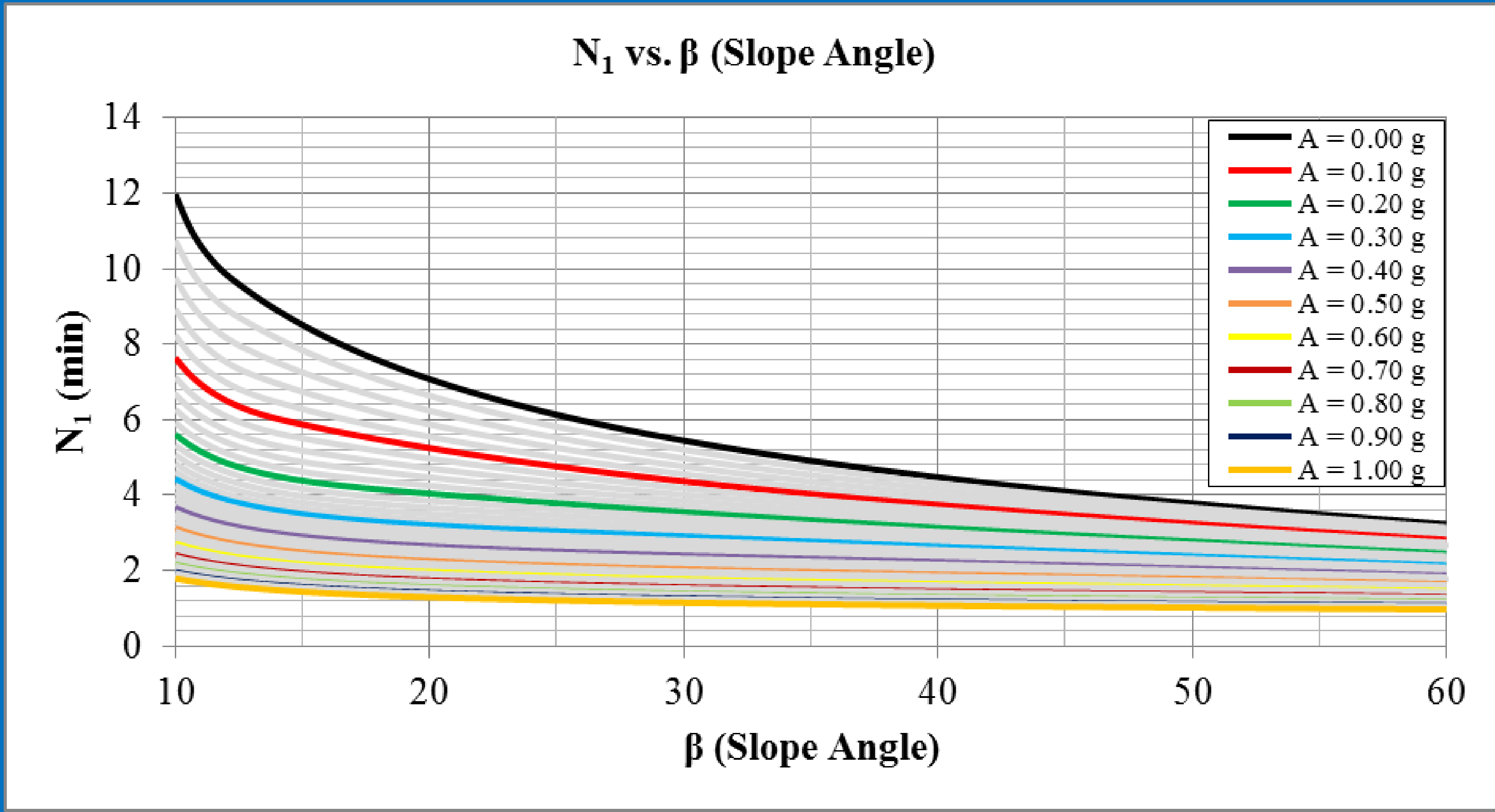
$$N_1 = \frac{3(\alpha + \cot\lambda - \alpha\cot\alpha\cot\lambda)}{DEN}$$

$$N_2 = \frac{6\alpha}{DEN}$$

$$DEN = \sin^2\alpha\sin^2\lambda(D_1 + D_2)$$

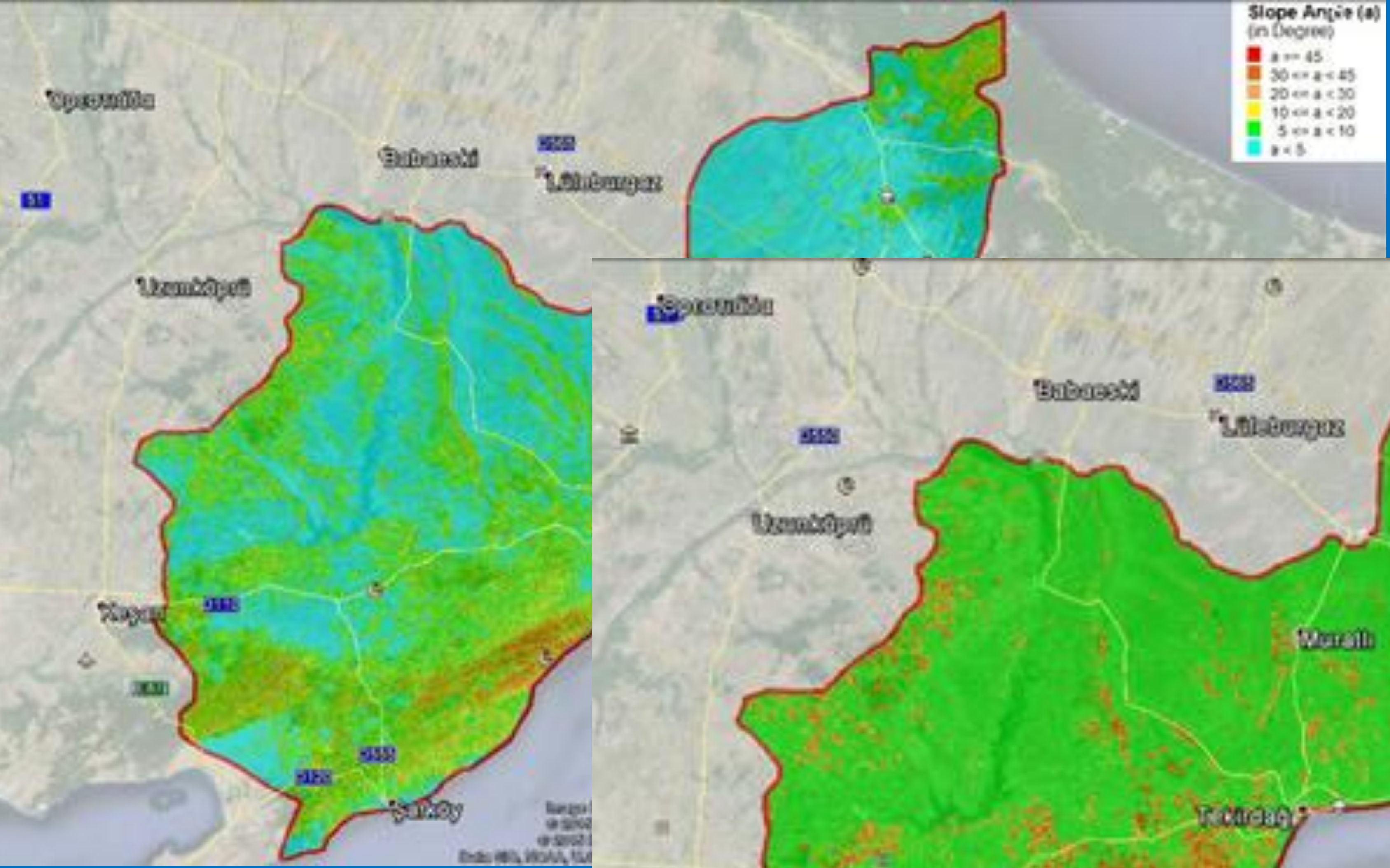
α = 50, ..., 850
β = 100, 10.50,..., 600
λ = 100,..., 550
n = 0 (toe failure presumption)
A (g) = 0.00, 0.02, ..., 1.00

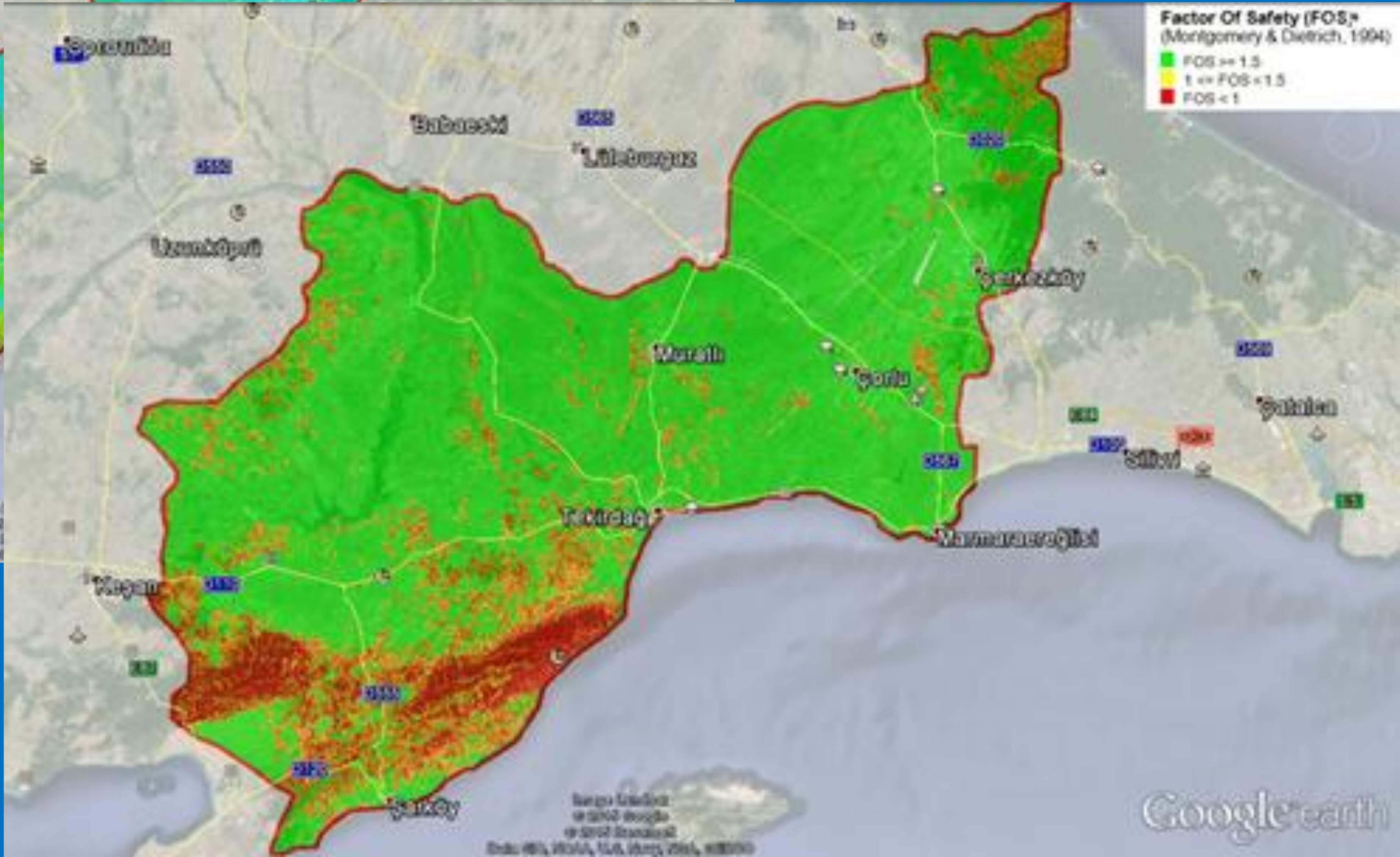
$$F_s = \frac{a_0}{\gamma} N_1 = \frac{\gamma\tan\varphi}{\gamma} N_1 = \tan\varphi N_1$$




D565
D555
Trabzon Cd.
Köse İlyas Köyü Yolu
Muratlı Cd.
Tekirdağ
Kanuni Sultan Süleyman Blv.
Ekrem Tanrı Cd.
Atatürk Blv.
Fatih Sultan Mehmet Blv.
İstanbul Blv.
E84
D110
Bandırma Tekirdağ Fer
Hazard Index (HI)
(Mora & Vahrson, 1994
I (Negligible)
II (Low)
III (Moderate)
IV (Medium)

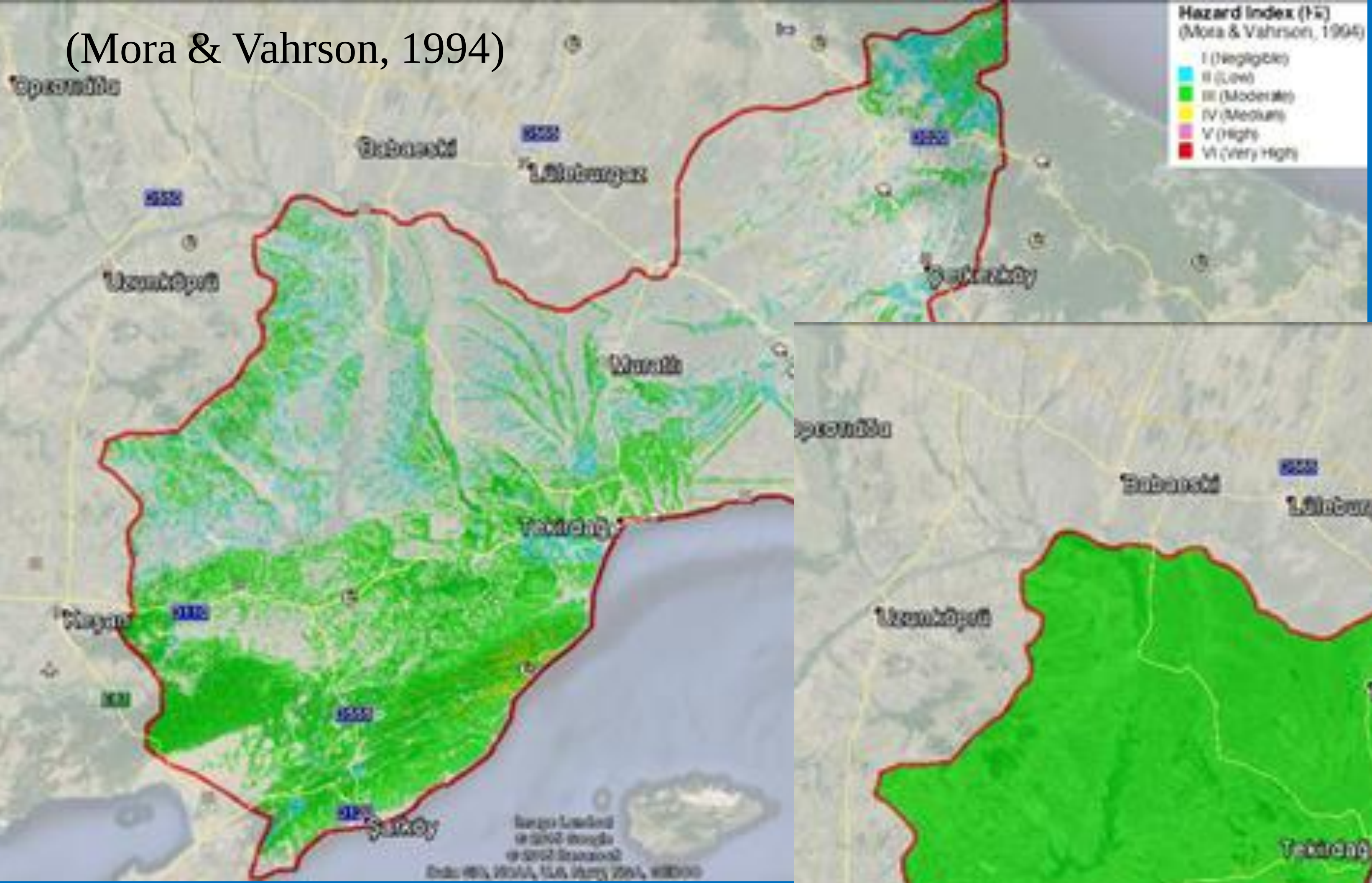

Tekirdağ
Factor of Safety
(Siyahi & Ansal, 1993
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Google earth

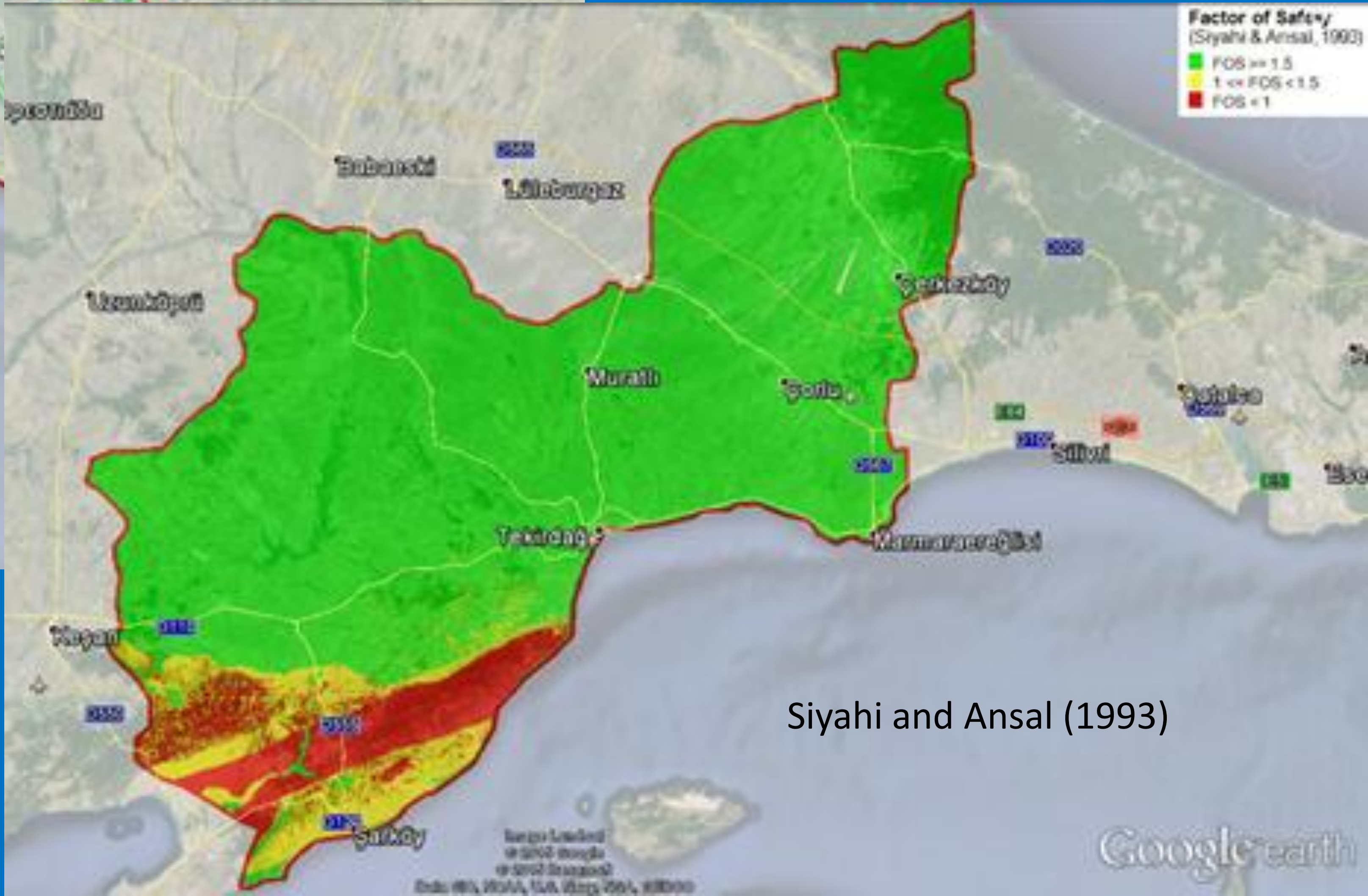




TEKIRDAĞ REGION

(Mora & Vahrson, 1994)

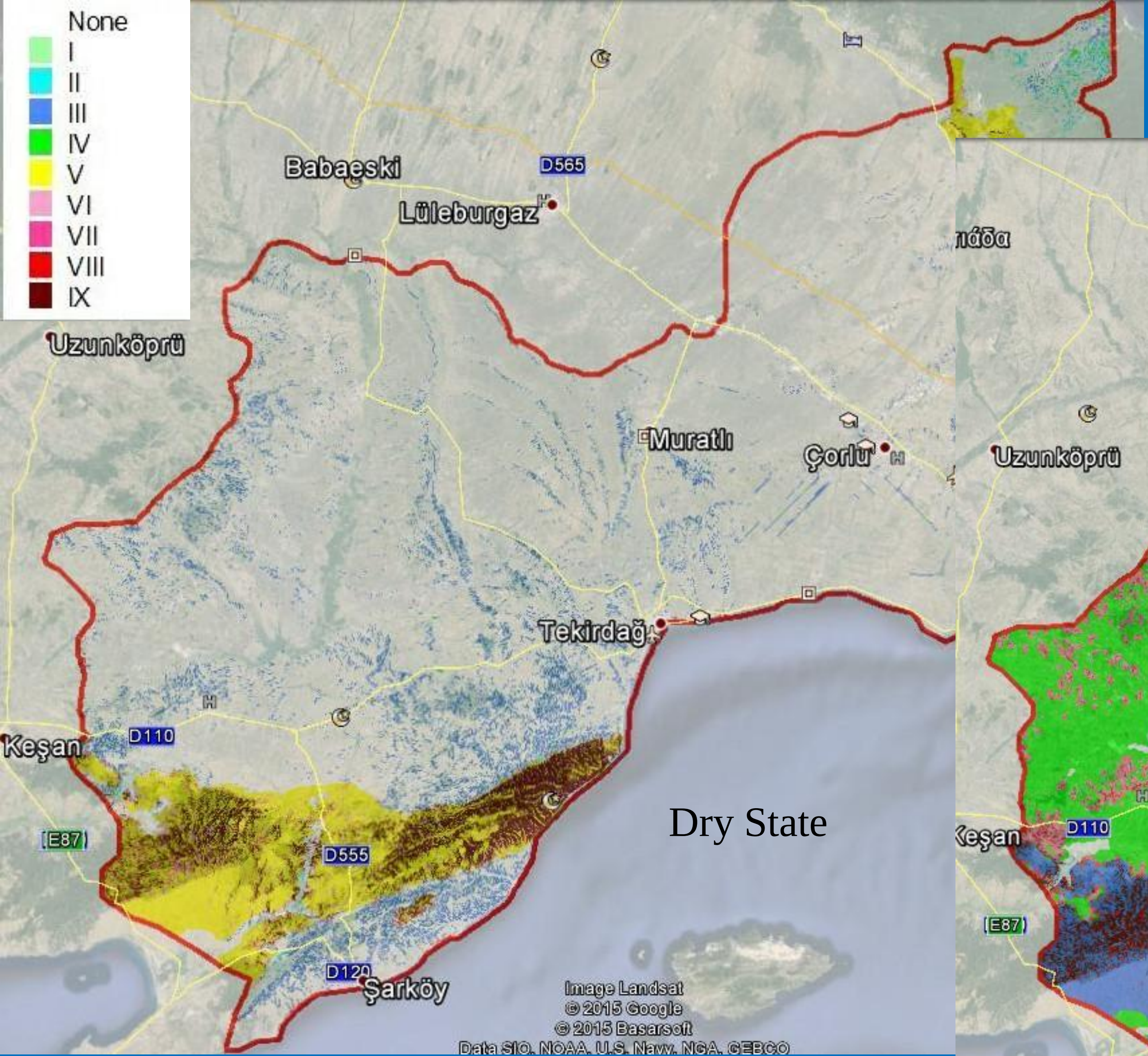




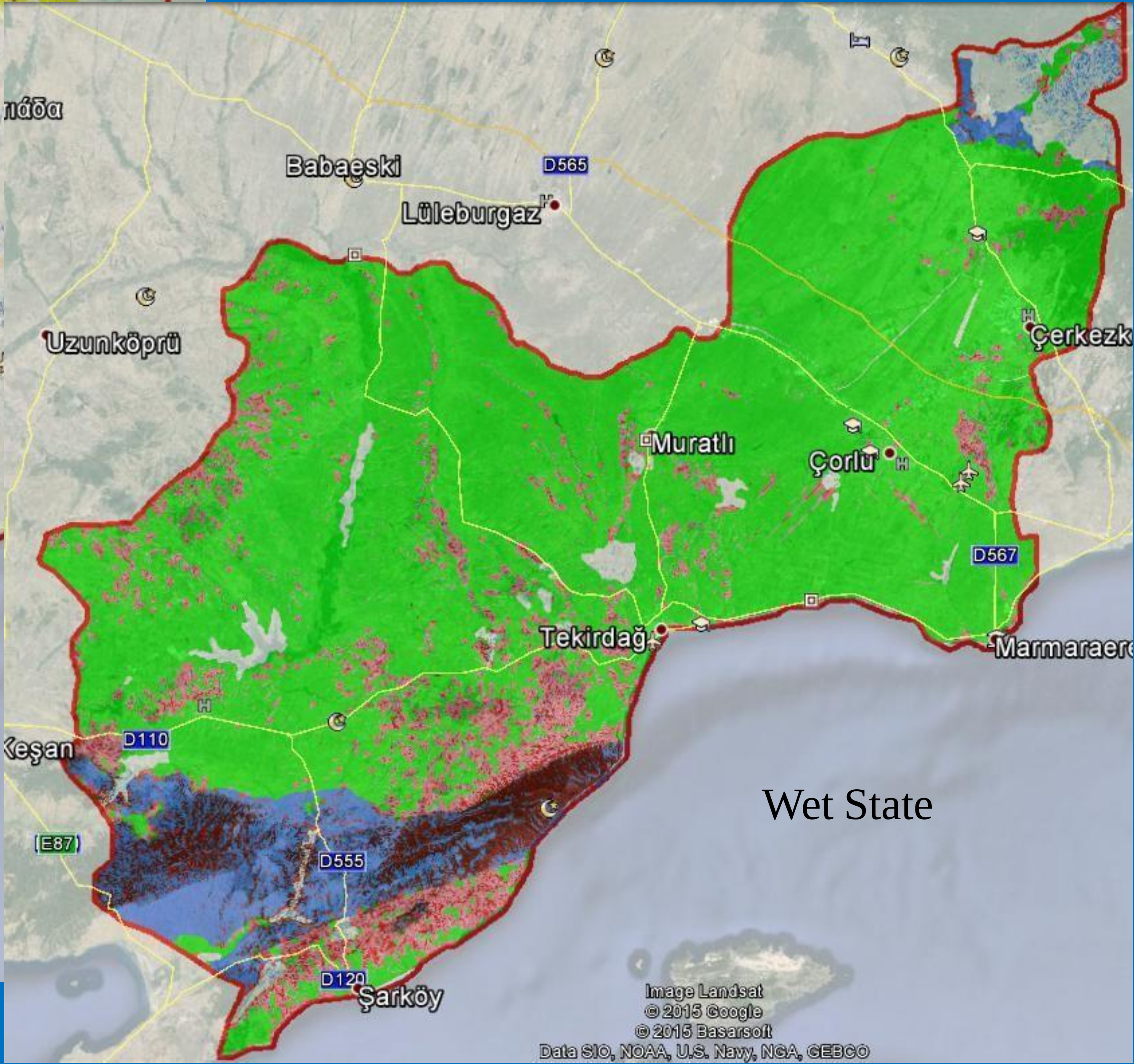
Siyahi and Ansal (1993)

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



Dry State

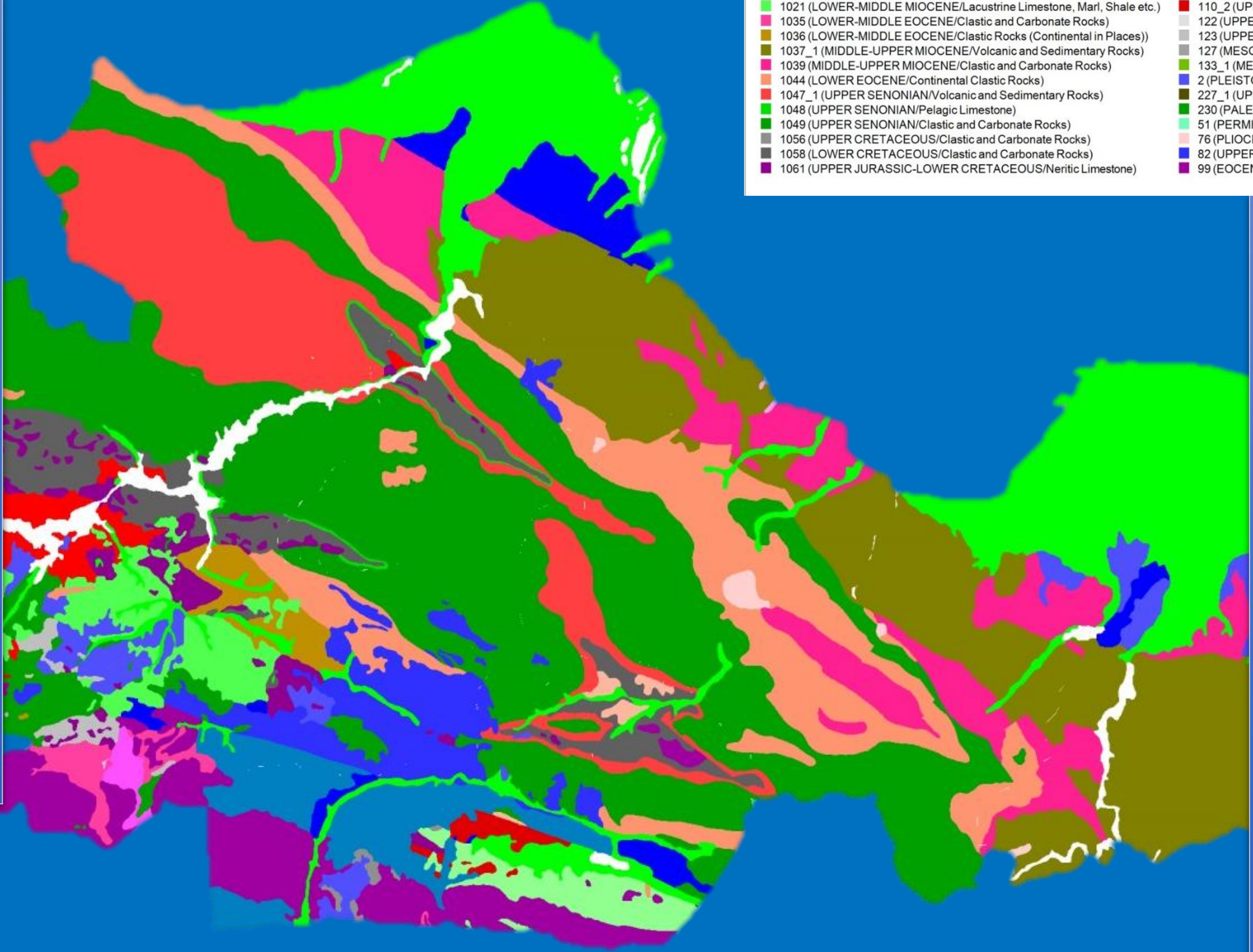


Wet State

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



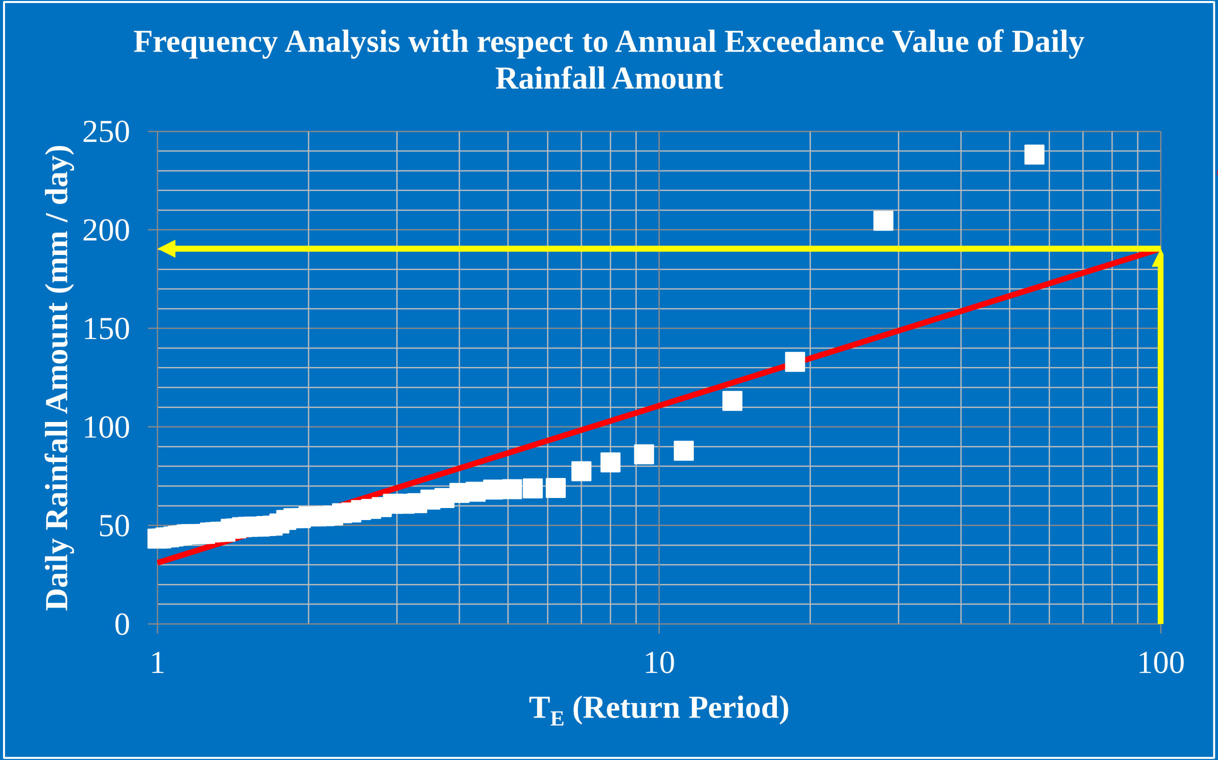
Geological Structure
(Samsun Region)

- 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

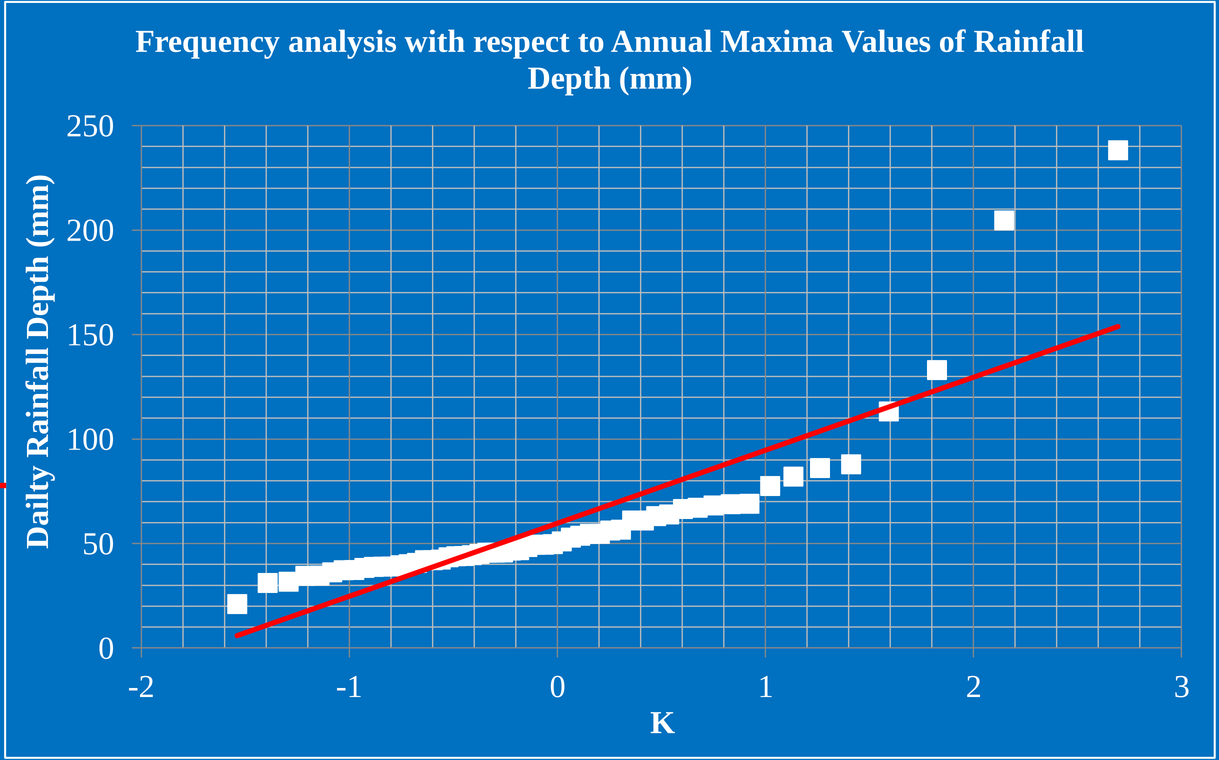
RAINFALL FREQUENCY ANALYSIS FOR TEKİRDAĞ REGION (Ven Te Chow, 1953)

Used in Montgomery & Dietrich (1994) Method



$RA = 190\ \text{mm/day for}\ T_E = 100\ \text{years}$

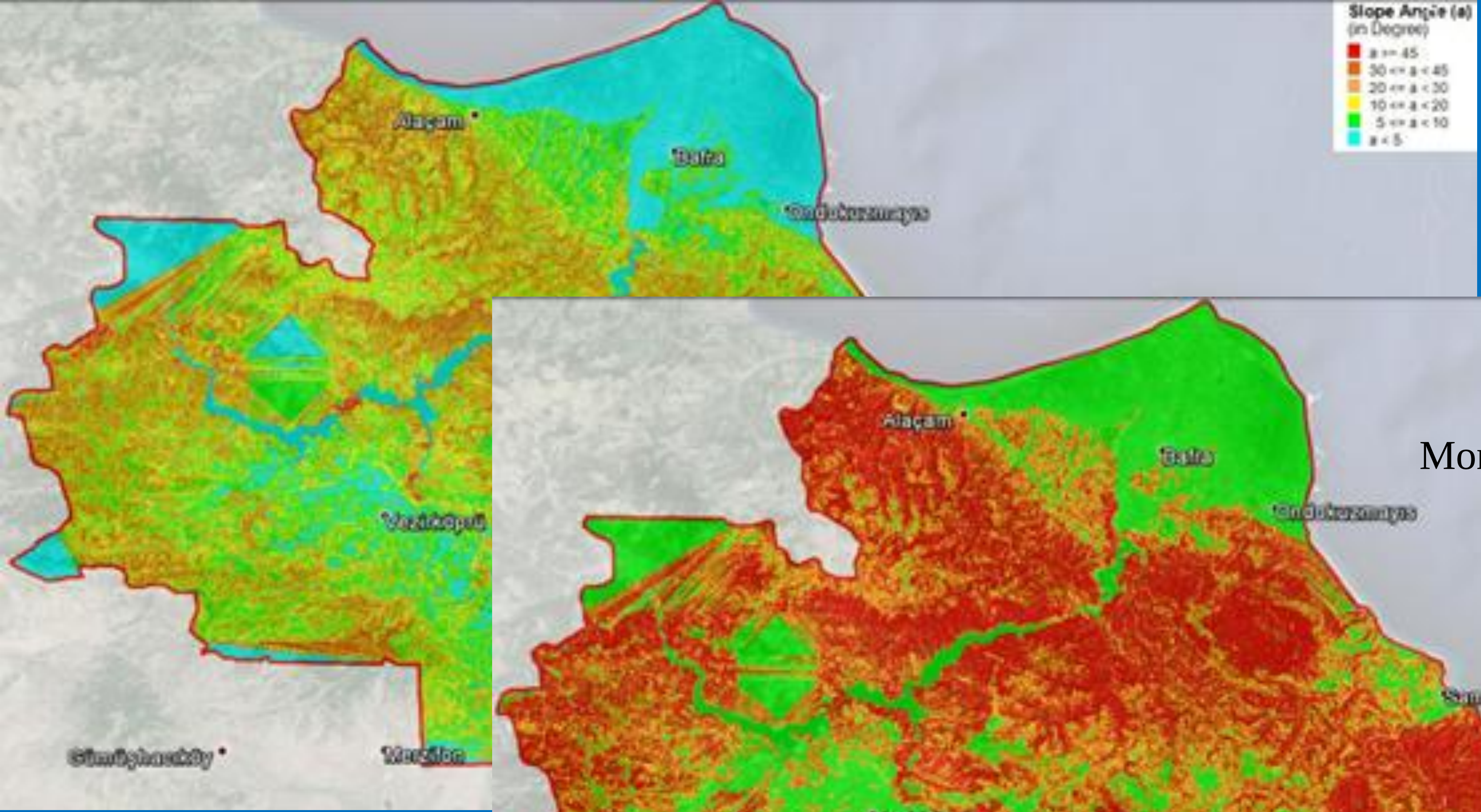
Used in Mora & Vahrson (1994) Method

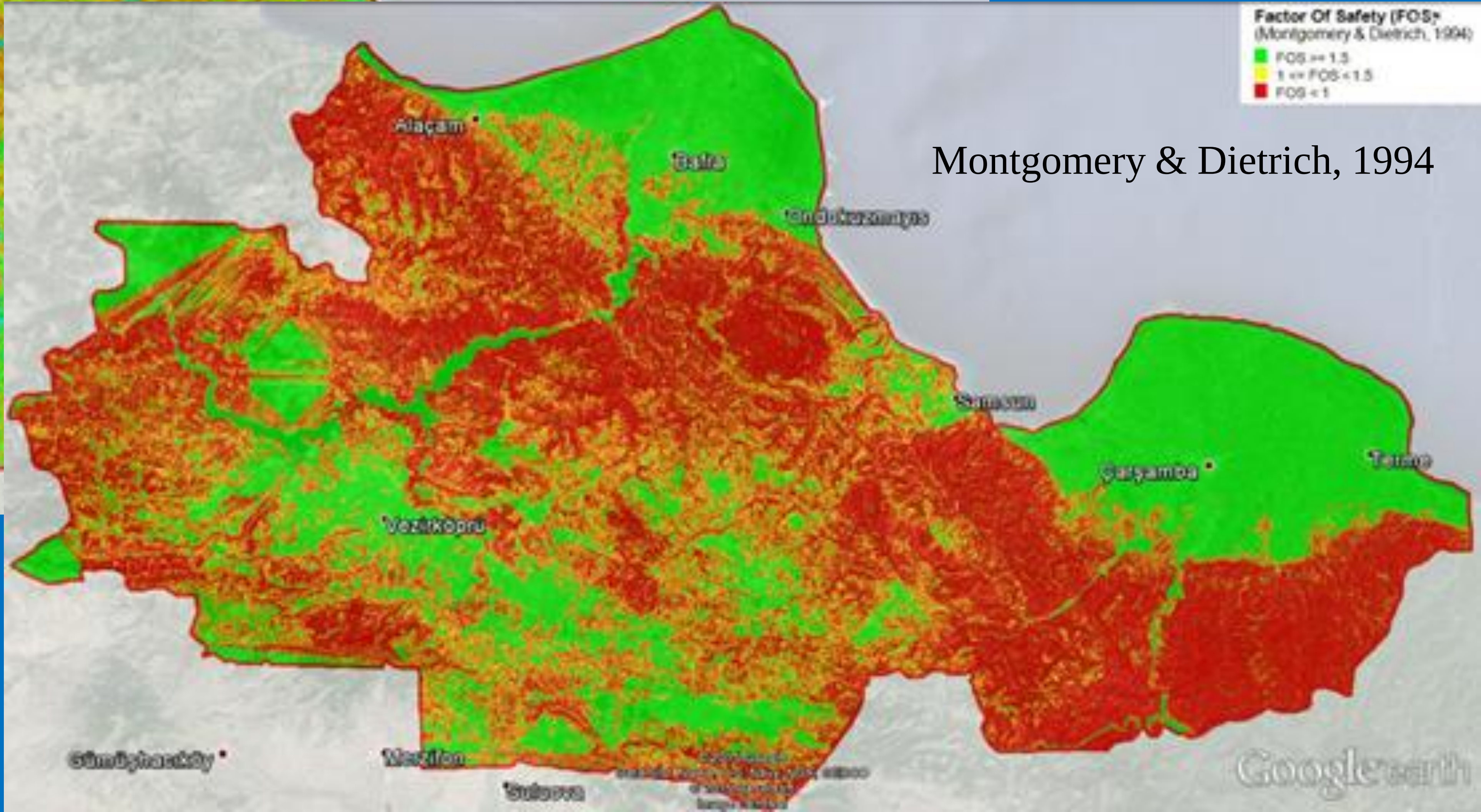


$$K = -\left(1.1 + 1.795\log_{10}\log_{10}\frac{N+1}{N+1-m}\right)$$

$$T_M = \frac{N+1}{m}$$

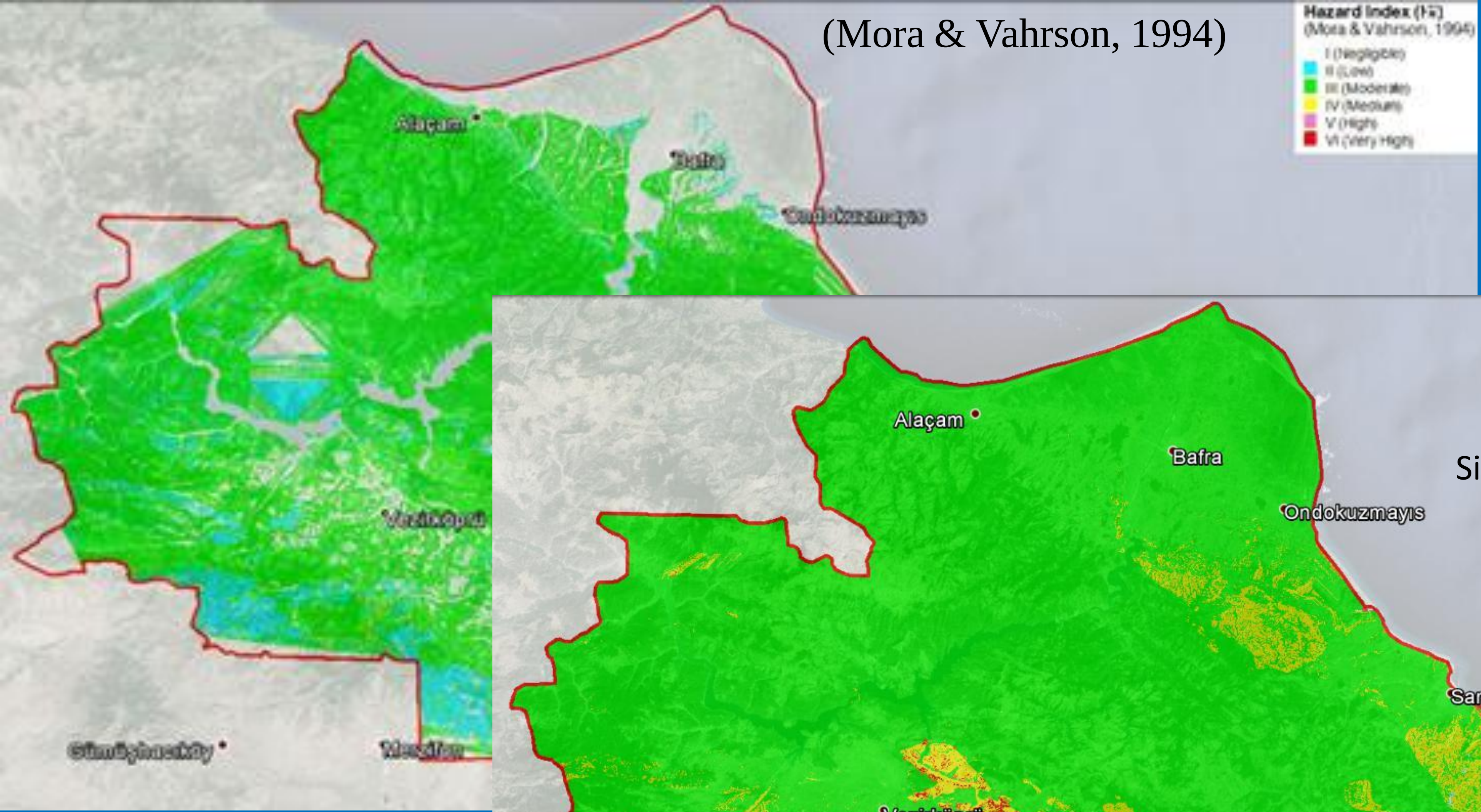
$RA = 166.2\ \text{mm/day for}\ T_E = 100\ \text{years}$



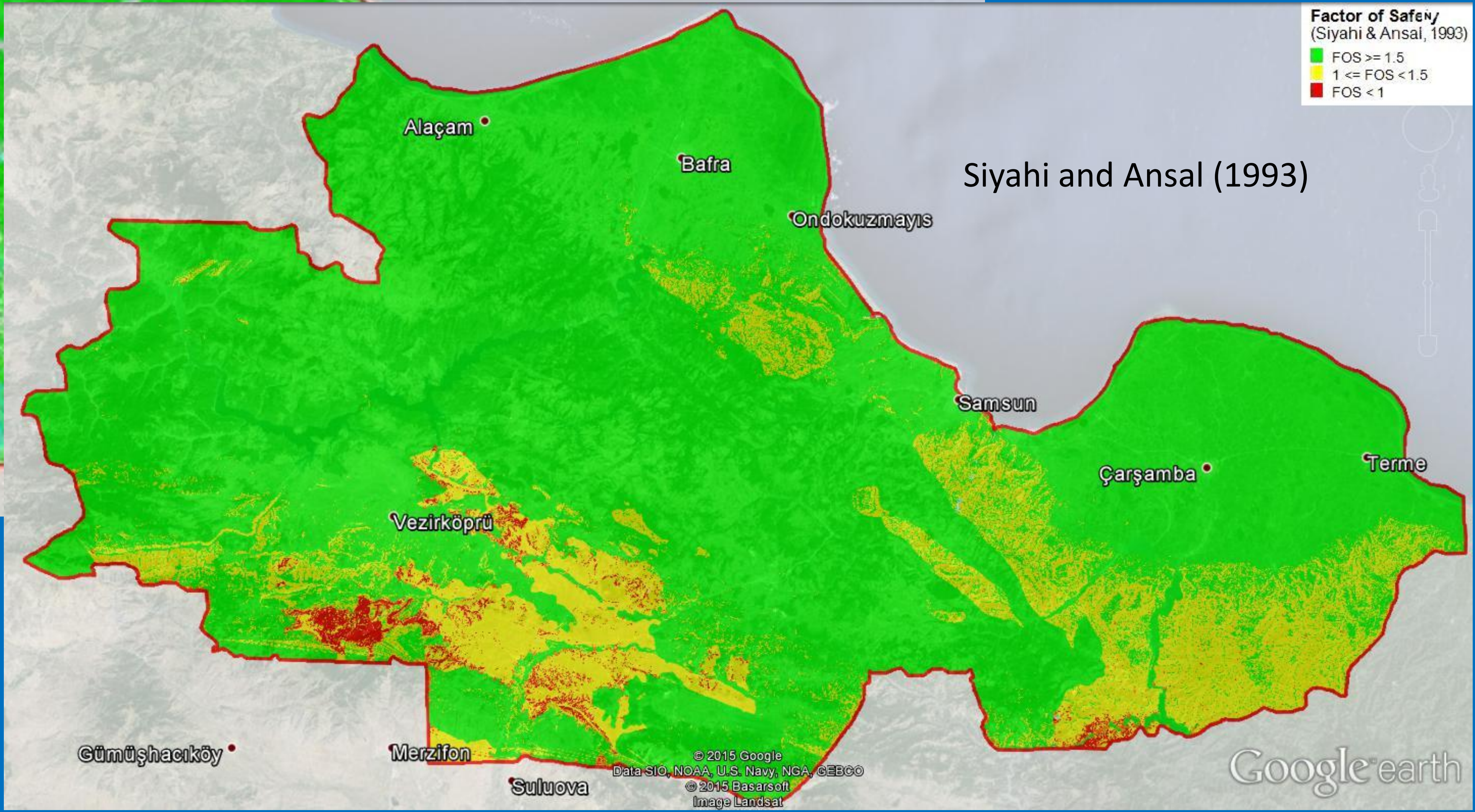


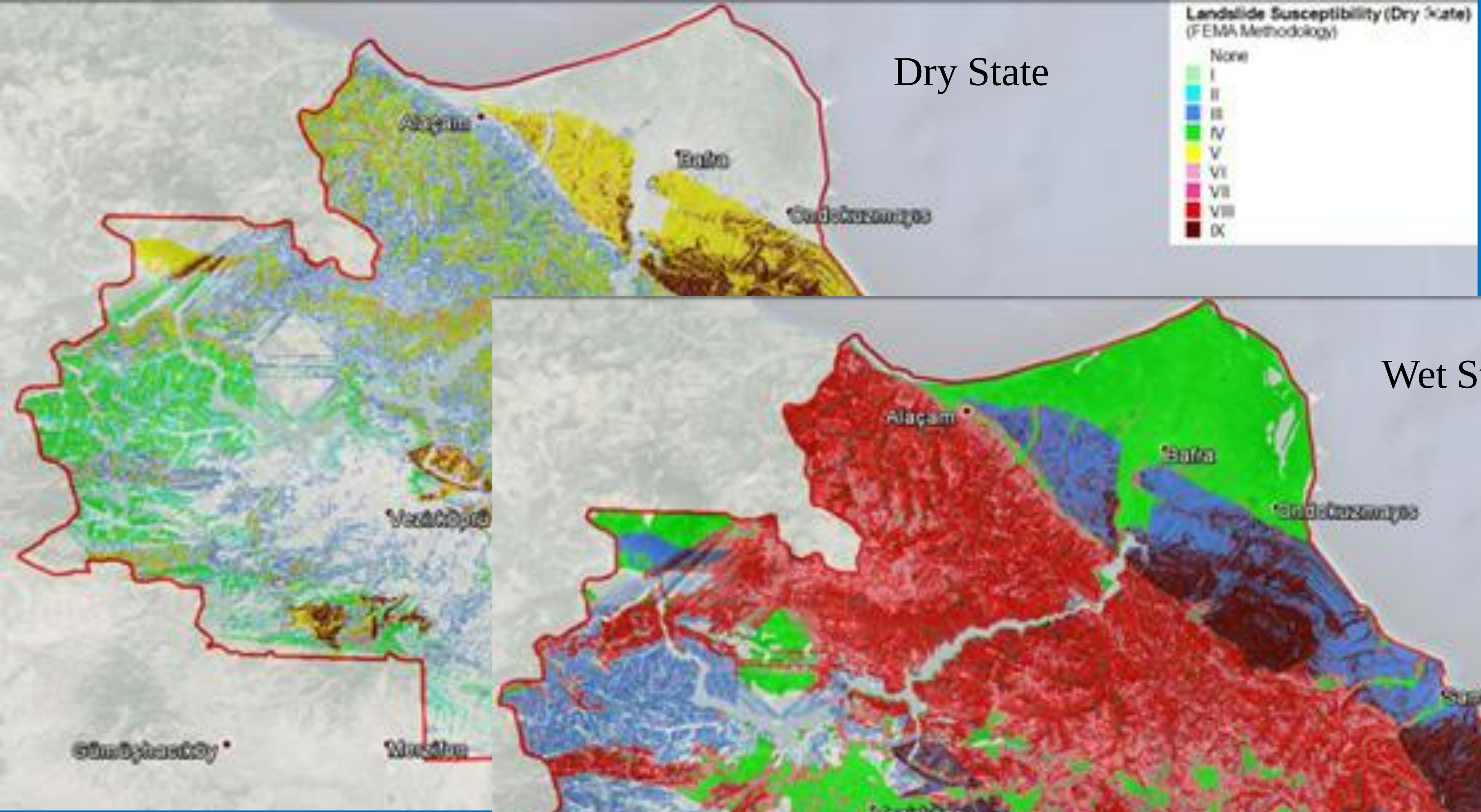
Montgomery & Dietrich, 1994

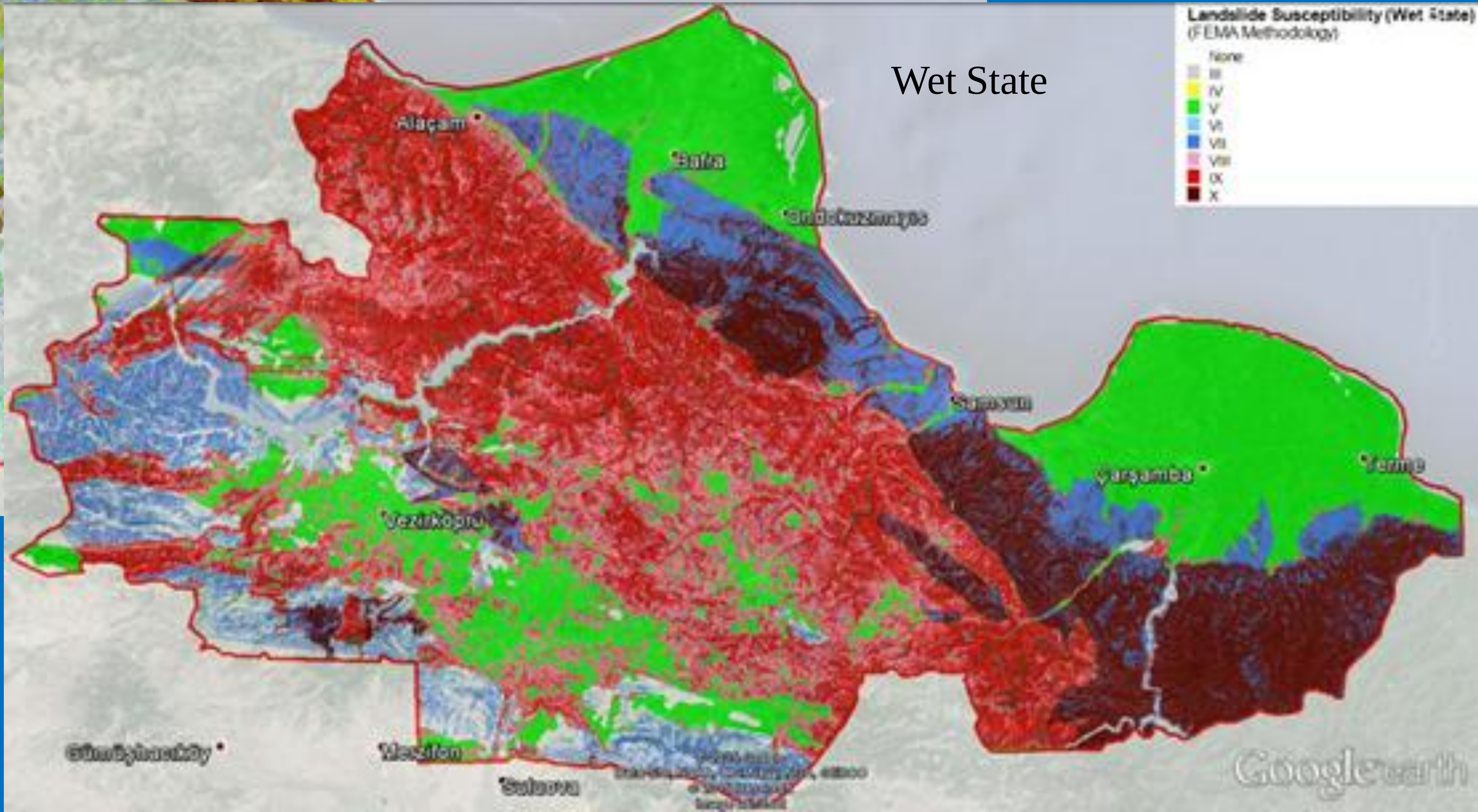
(Mora & Vahrson, 1994)



Siyahi and Ansal (1993)

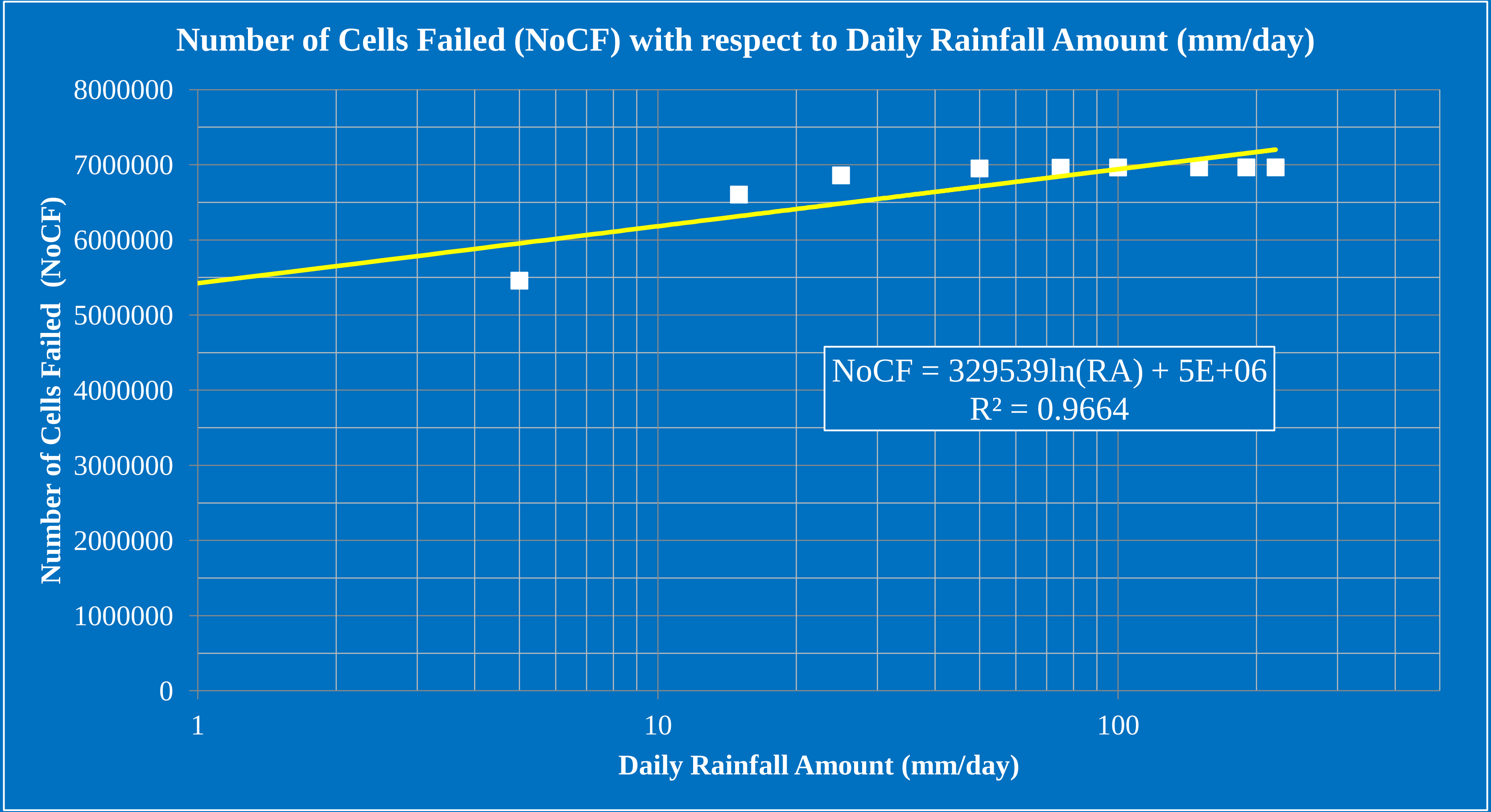



Dry State
Landslide Susceptibility (Dry State)
(FEMA Methodology)
None
I
II
III
IV
V
VI
VII
VIII
IX
Alaçam
Bafra
Ondokuzmayıs
Vezirköprü
Gümüşhacıköy
Merzifon


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

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