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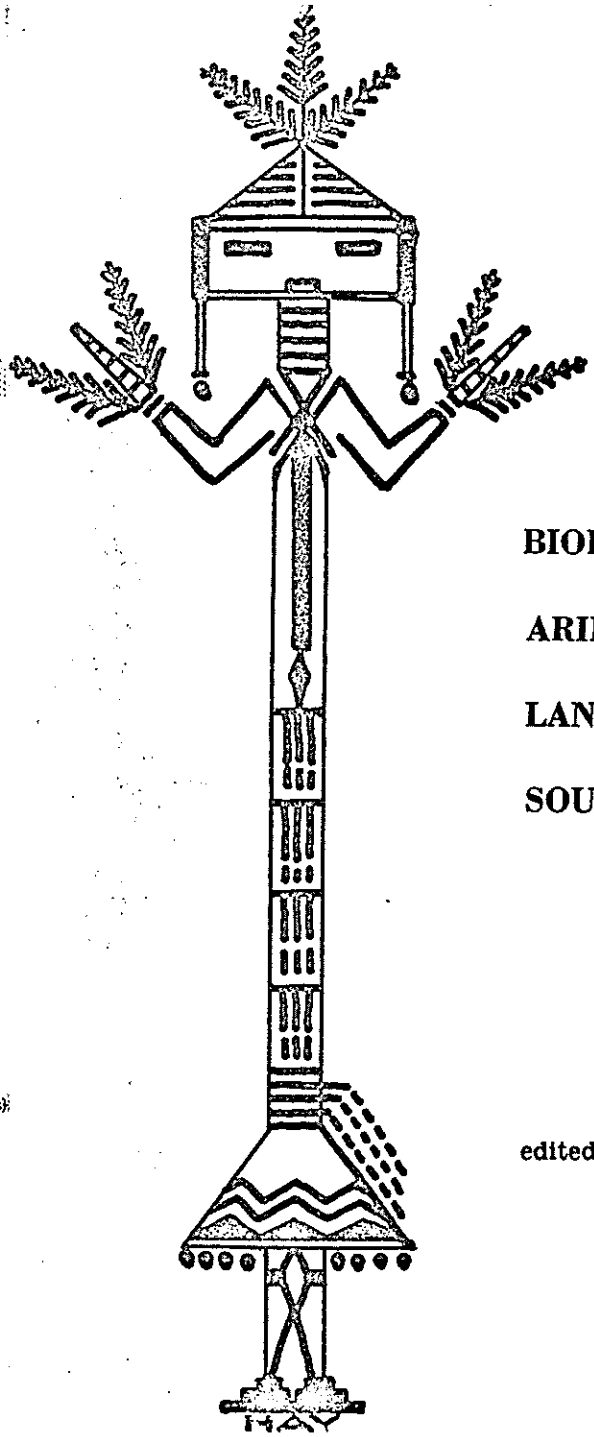

BIOECOLOGY OF THE ARID AND SEMIARID LANDS OF THE SOUTHWEST

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Climate and Soil of the Southwest

by

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Parallelism between climatic zones and soil zones has been noted in Europe by such pedologists as Glinka (3), Jenny (5), Zakharov (19), and others (10, 9). This same situation has been noted in western United States by Glassey (2), Klingebiel, Walker and Stewart (6), Powers (11), Thorp (16), and Vlasoff and Wheeting (18), and in the Southwest by Martin and Fletcher (8). These writers recognized that soil zones did not coincide exactly with elevation, but varied considerably with orographic influences and aspect.

The present paper points out the general climatic zones of the Southwest (specifically Utah, Colorado, New Mexico and Arizona), the indices used to delineate these climatic zones and the generalized location and dominant properties of certain of the zonal Great Soil Groups of this area of the Southwest.

Thornthwaite (14, 15) devised what he called a *Precipitation Effectiveness Index* (PE) which is expressed mathematically in equation (1).

$$(1) \qquad PE = \sum_{1}^{12} 115 \left[\frac{P}{T-10} \right]^{10/9} = \sum_{1}^{12} (pr)$$

In which
P=Mean precipitation for each month
T=Mean temperature in degrees Fahrenheit for each month

The value for each month he called the *Precipitation ratio* (Pr).

One of the obvious weaknesses of the PE index for classification of climate and soils in the Southwest is the fact that areas represented by stations with identical PE indices frequently have widely differing soils and vegetation. Some of this anomalous behavior seems to be due to the time of year that the high Pr's occur. For example, in Figure 1A, Chama, New Mexico with a PE of 68.09 has 75 percent of its effective preciptation during the period between November and June while Cloudcroft, New Mexico, with a PE index of 61.8 has less than 50% of its effective precipitation during the same period. In other words, Chama would yield irrigation water more effectively than Cloudcroft where the redder soils which have developed produce a greater abundance of summer growing plants such as grass.

The Pr values for typical stations in Arizona and New Mexico are shown in Figures 1A and 1B. There is a wide divergence in the seasonal Pr rhythms. The four stations—Chama and Cloud-

croft, New Mexico and Alpine and Flagstaff, Arizona—all have dominantly winter effective precipitation while the remainder have dominantly "warm weather" effective precipitation. This is particularly true of Clovis, New Mexico, which has only one yearly minimum.

Effective moisture in the spring may be better for crop production in dry farm areas. In order to take advantage of the spring effective moisture factor, Maker and Dregne (7) developed what they called the *Crop Moisture Index* (C-M) determined as shown by (ii).

(ii) C-M index = PE × sum of spring Pr's
Spring = April, May and June

Thornthwaite (15) also proposed another useful index which he called the *Temperature Effectiveness Index* (TE). It was computed as follows:

$$\text{(iii)} \qquad TE = \sum_{1}^{12} \frac{T-32}{4}$$

The monthly TE values are shown for the same ten stations in Figures 2A and 2B. As with the PE indices, there is some discrepancy in the *summer-winter* relationship for stations with the same TE index.

Climatic zones based on the PE index only, for Utah, Colorado, New Mexico, and Arizona, may be seen in Figure 3. In general, the climatic zones progress from dry to wet with increasing elevation. Relative climatic wetness increases from south to north in areas of equal annual rainfall. Some pronounced orographic effects on the precipitation are reflected also in the relative wetness or PE indices.

The relationship between the PE and TE indices for the ten stations is shown graphically in Figure 4. The excellent relationship is confirmed by the simple correlation coefficient of −0.957. The Moisture Index (Im) of Hutchings (4) is closely correlated with PE index (correlation coefficient=0.984) at these 10 locations (Figure 5).

Martin and Fletcher (8) utilized a modified diagram proposed by Thornthwaite (15) to show the relationship between the PE and TE indices and the Great Soil Groups on Mt. Graham, Arizona (Figure 6). The small numbers refer to the ten sites discussed in connection with Figures 1 and 2. The numbers follow each site name in Figures 1A and 1B.

A brief description of some of the major zonal Great Soil Groups of the Southwest, patterned after *Soils and Man* (1), follows:

Brown Soils

The Brown Soils cover a large area of the grasslands across northern Arizona and New Mexico and into eastern Colorado. The surface soils are brown, and the subsoils grade at depths from 1 to 2 feet into light gray or white calcareous layers.

Chestnut Soils

The Chestnut Soils occupy large areas of grassland of northern Utah and northwestern Colorado. These soils are characterized by a dark brown or grayish brown surface which grades into light colored calcareous material at 1½ to 2 feet.

Reddish Brown Soils

The Reddish Brown Soils occupy large areas of the grasslands of southern Arizona and New Mexico. The surface soils are mellow, light textured, and reddish in color. At depths ranging from a few inches to over a foot they grade into a heavier textured, compact material underlain by light colored limey materials.

Reddish Chestnut Soils

The Reddish Chestnut Soils occupy grasslands in northeastern New Mexico and southern Colorado. The surface soil is dark reddish brown underlain by heavier reddish brown or red sandy clay. Lime accumulations occur at depths in excess of 2 feet.

Noncalcic Brown Soils

These Noncalcic Brown Soils occupy oak woodland and other deciduous forest areas of southern Arizona and New Mexico. The surface soils are brown or light brown, friable, medium textured material. The B horizons are reddish brown and finer in texture.

Gray Desert Soils (Desert Soils)

Gray Desert Soils occupy the northwestern portion of Utah and portions of northern Arizona and New Mexico under shrubby desert plants and bunchgrass. The surface soils are pale grayish and grade into calcareous material at less than one foot in depth.

Red Desert Soils

Red Desert Soils occupy the greater portion of southern Arizona and southwestern New Mexico. They are developed under a desert shrub vegetation. The surface soils are light textured and light reddish brown in color. The subsoil is brownish red or red. It is heavier textured than the surface and is underlain by calcareous material, usually light in color.

Brown Podzolic* Soils

Brown Podzolic Soils occupy mountainous areas of all four states where the vegetation is chiefly deciduous or mixed deciduous-coniferous forest. The profile consists of leaf mat and acid humus over a thin dark gray "A" horizon and thin gray-brown or yellowish-brown "A_2" over a brown "B" horizon of slightly finer texture than the surface soil. These soils are shallow and seldom exceed two feet to weathered parent material. In Figure 7 these soils correspond to Podzols except for their occurrence under oak woodland where they are subject to periodic disturbances.

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*The "ic" ending is used to mean "similar to or closely related" to soils of the root group, thusly, Brown Podzolic Soils means soils closely related to or similar to Brown Podzol Soils.

Gray Brown Podzolic Soils (Gray Wooded Soils [17])

Gray Brown Podzolic Soils occupy the mountainous areas principally under coniferous forest in all four states. The soil has a thin litter over wild humus over dark colored surface soil which extends to depths of 2 to 4 inches. This is underlain by a grayish brown leached horizon. The "B" horizon is brown mottled heavy material.

Podzols

Podzols occupy the higher elevations of all four states just below timber line. Their actual area is very small. The soil surface is covered by a few inches of litter and a mat of acid humus. Under this layer lies a thin dark gray "A" horizon over a whitish-gray ash-like "A_2". The latter layer may even be a few inches thick. The "B_1" horizon is darkly coffee-colored and heavier textured than the "A's". It grades undulatingly into the strongly acid yellowish brown "B_2" horizon.

Tundra-like Soils

Tundra-like Soils occur in all four states above timber line. The soil consists of a dark brown highly organic layer over a perpetually frozen subsoil. The soils here classified as Tundra-like are all groups with perpetually frozen subsoils (12).

Prairie-like Soils

Prairie-like Soils occupy mountain meadows and parks in all four states. They are frequently poorly drained and developed almost exclusively under grass. These soils are not shown in Figure 7 because of the small size of their areas. The profile is very dark brown on the surface. It grades through brown to grayish brown between 2 to 5 feet. The surface is invariably slightly acid in reaction. This grouping is not composed of typical Prairie Soils in the Southwest.

The locations of some of the principal Zonal Great Soil Groups are shown in Figure 7. It may be noted by comparison of Figures 3 and 7 that the climate and soil zones coincide rather closely except for certain minor north-south variations which may be explained by variations in the seasonal temperature-moisture relationships and orographic reflections.

SUMMARY

Nearly all of the climatic types found anywhere in the United States occur in the Southwest. Climatic zones are closely related to the soil zones. The present methods of classifying climatic zones need refining to be satisfactory for use in the Southwest to properly delineate either soils or vegetation.

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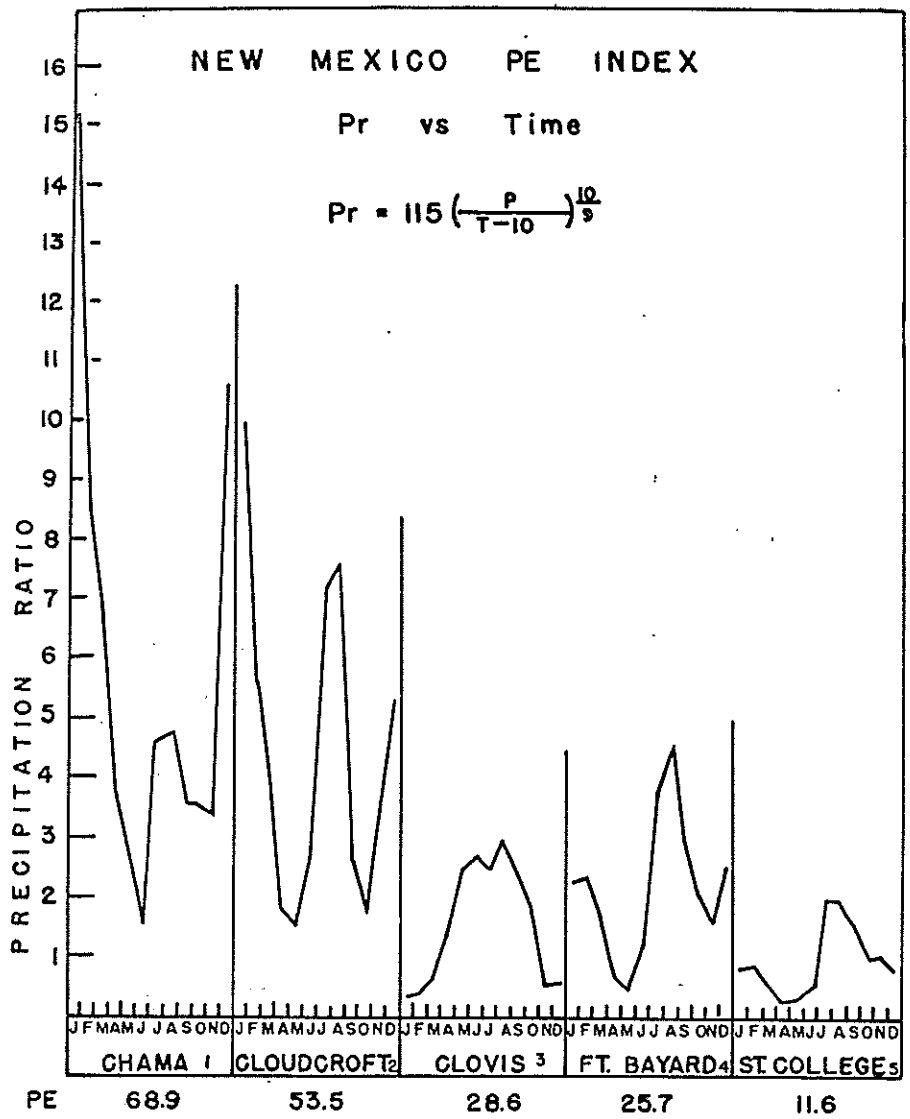

NEW MEXICO PE INDEX
Pr vs Time
$Pr = 115\left(\frac{P}{T-10}\right)^{\frac{10}{9}}$
PRECIPITATION RATIO
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
J F M A M J J A S O N D
CHAMA 1
CLOUDCROFT 2
CLOVIS 3
FT. BAYARD 4
ST. COLLEGE 5
PE
68.9
53.5
28.6
25.7
11.6

Figure 1A

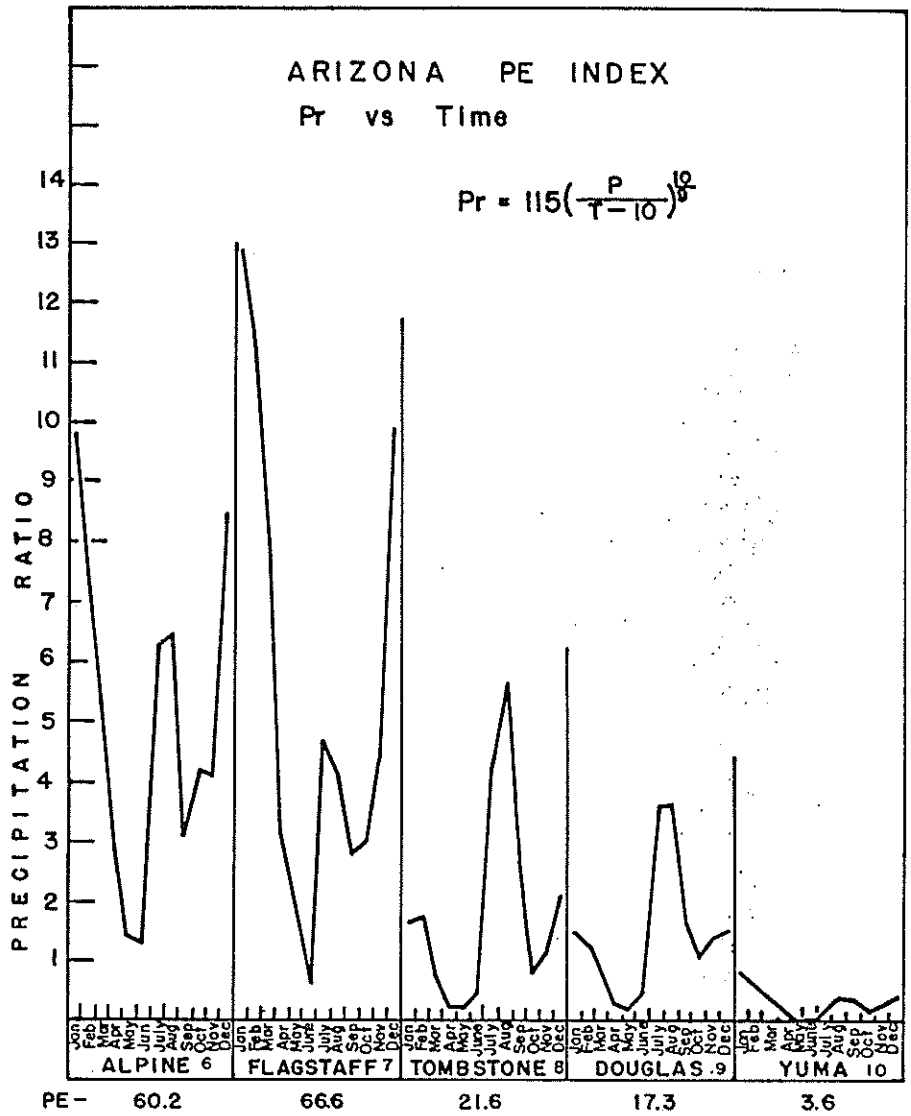

ARIZONA PE INDEX
Pr vs Time
$Pr = 115\left(\frac{P}{T-10}\right)^{\frac{10}{9}}$
PRECIPITATION RATIO
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Jan Feb Mar Apr May Jun July Aug Sep Oct Nov Dec
ALPINE 6
FLAGSTAFF 7
TOMBSTONE 8
DOUGLAS 9
YUMA 10
PE – 60.2
66.6
21.6
17.3
3.6

Figure IB

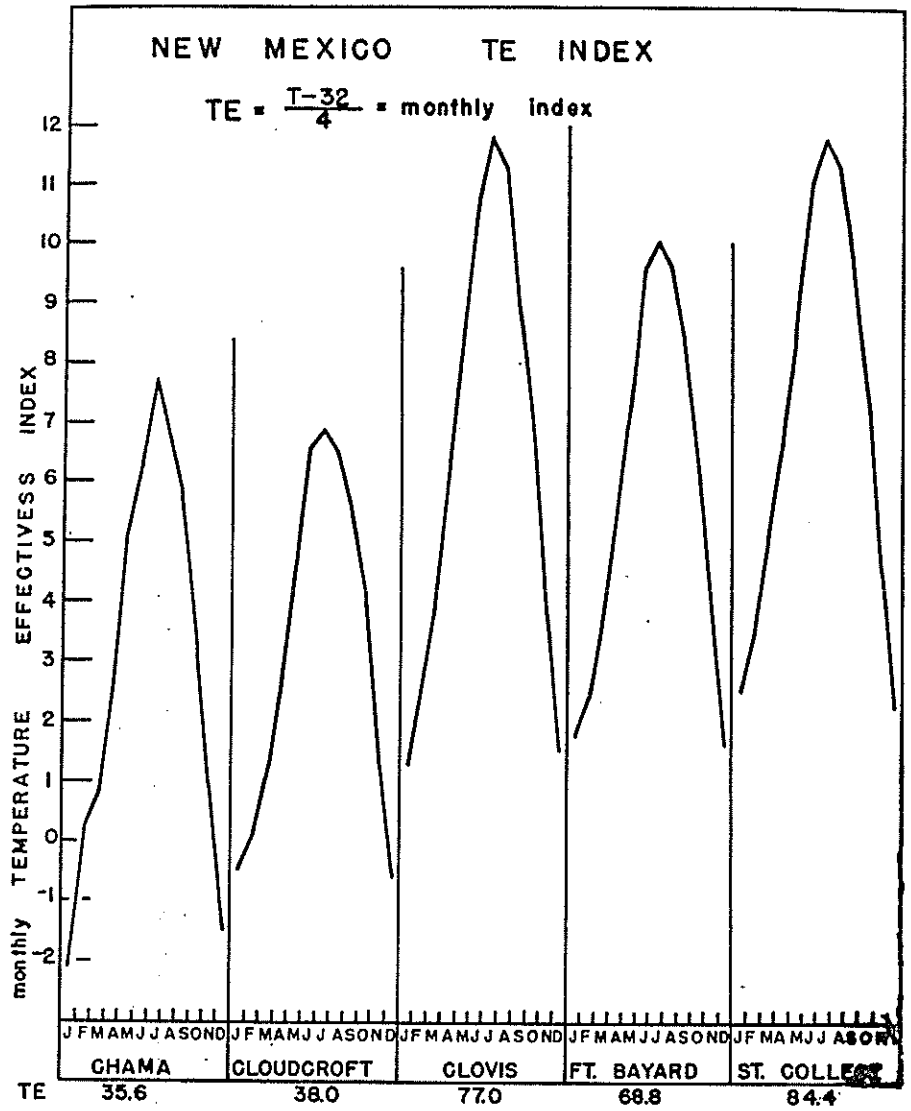
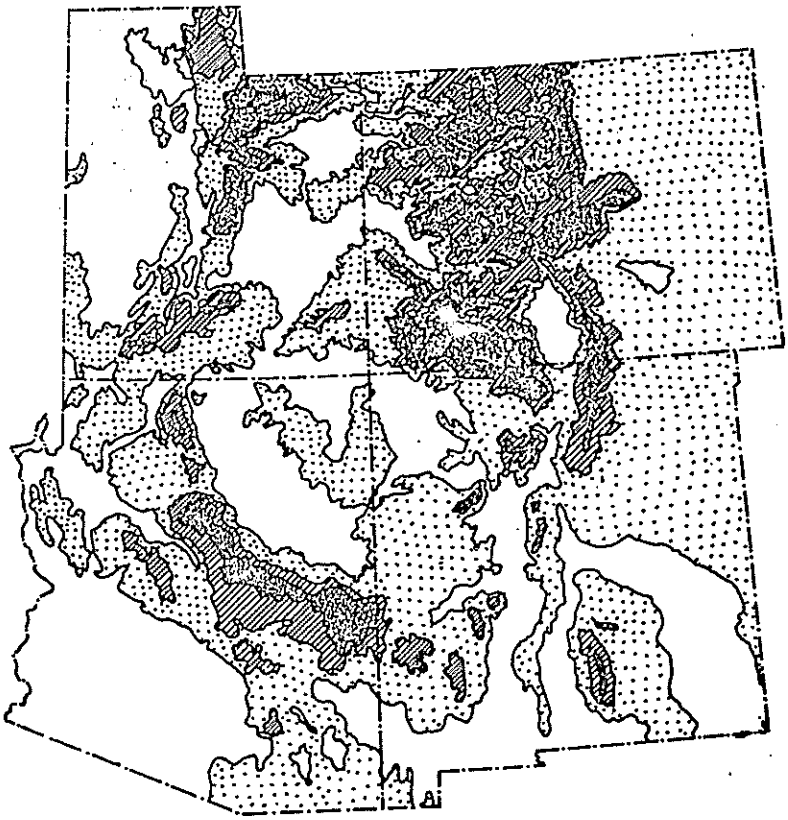

NEW MEXICO TE INDEX
TE = (T-32)/4 = monthly index
monthly TEMPERATURE EFFECTIVESS INDEX
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
J F M A M J J A S O N D
CHAMA
CLOUDCROFT
CLOVIS
FT. BAYARD
ST. COLLEGE
TE
35.6
38.0
77.0
68.8
84.4

Figure 2A



CLIMATIC ZONES OF THE SOUTHWEST
BASED ON THORNTHWAITE'S PE INDEX

ARID 0-15
SEMI-ARID 16-31
DRY SUBHUMID 32-47
MOIST SUBHUMID 48-63
HUMID 64-127
SUPER HUMID >128

Figure.3

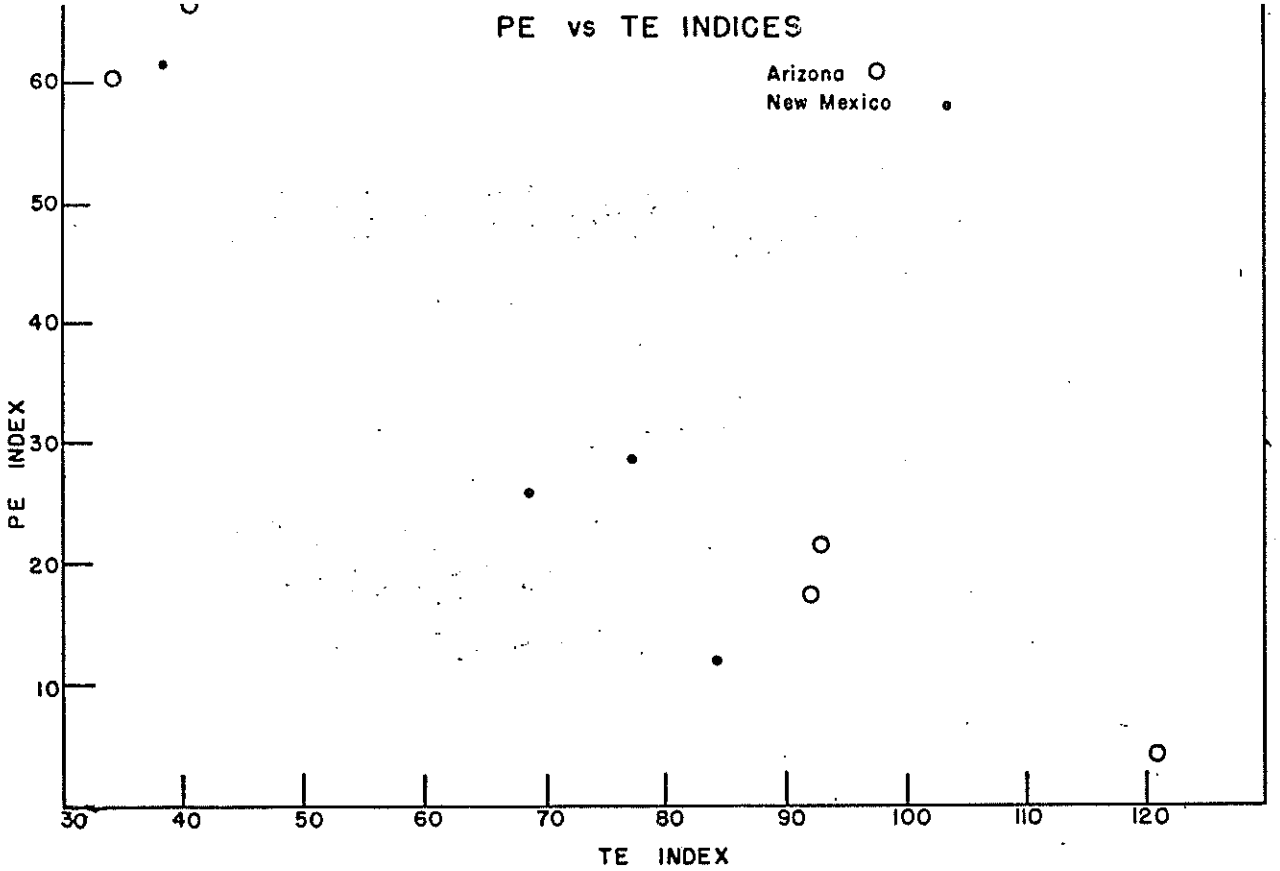

PE vs TE INDICES
Arizona
New Mexico
PE INDEX
TE INDEX
60
50
40
30
20
10
30
40
50
60
70
80
90
100
110
120

Figure 4

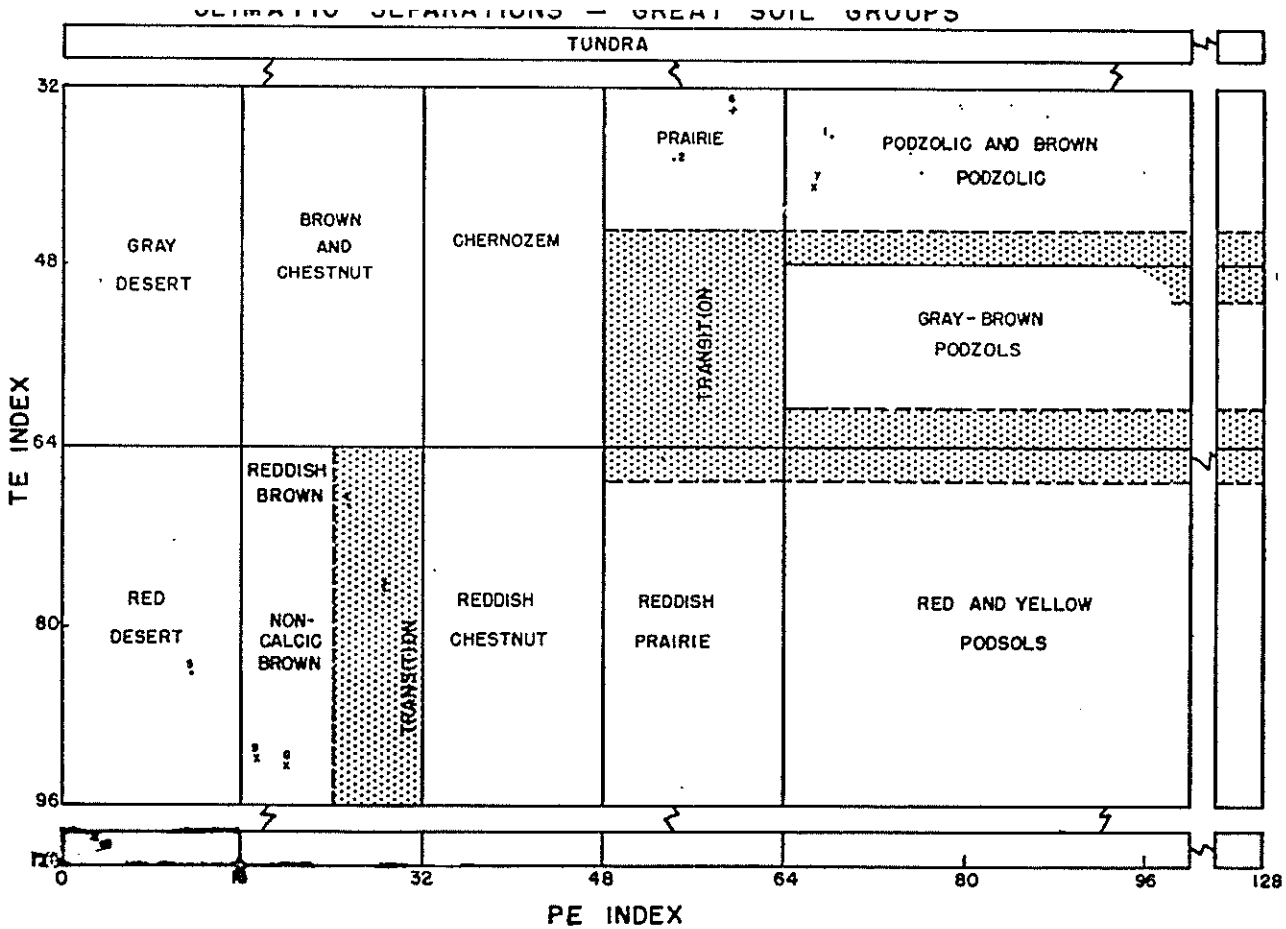

TUNDRA
GRAY DESERT
BROWN AND CHESTNUT
CHERNOZEM
PRAIRIE
PODZOLIC AND BROWN PODZOLIC
TRANSITION
GRAY-BROWN PODZOLS
REDDISH BROWN
RED DESERT
NON-CALCIC BROWN
TRANSITION
REDDISH CHESTNUT
REDDISH PRAIRIE
RED AND YELLOW PODSOLS
TE INDEX
PE INDEX
0
32
48
64
80
96
128

Figure 6

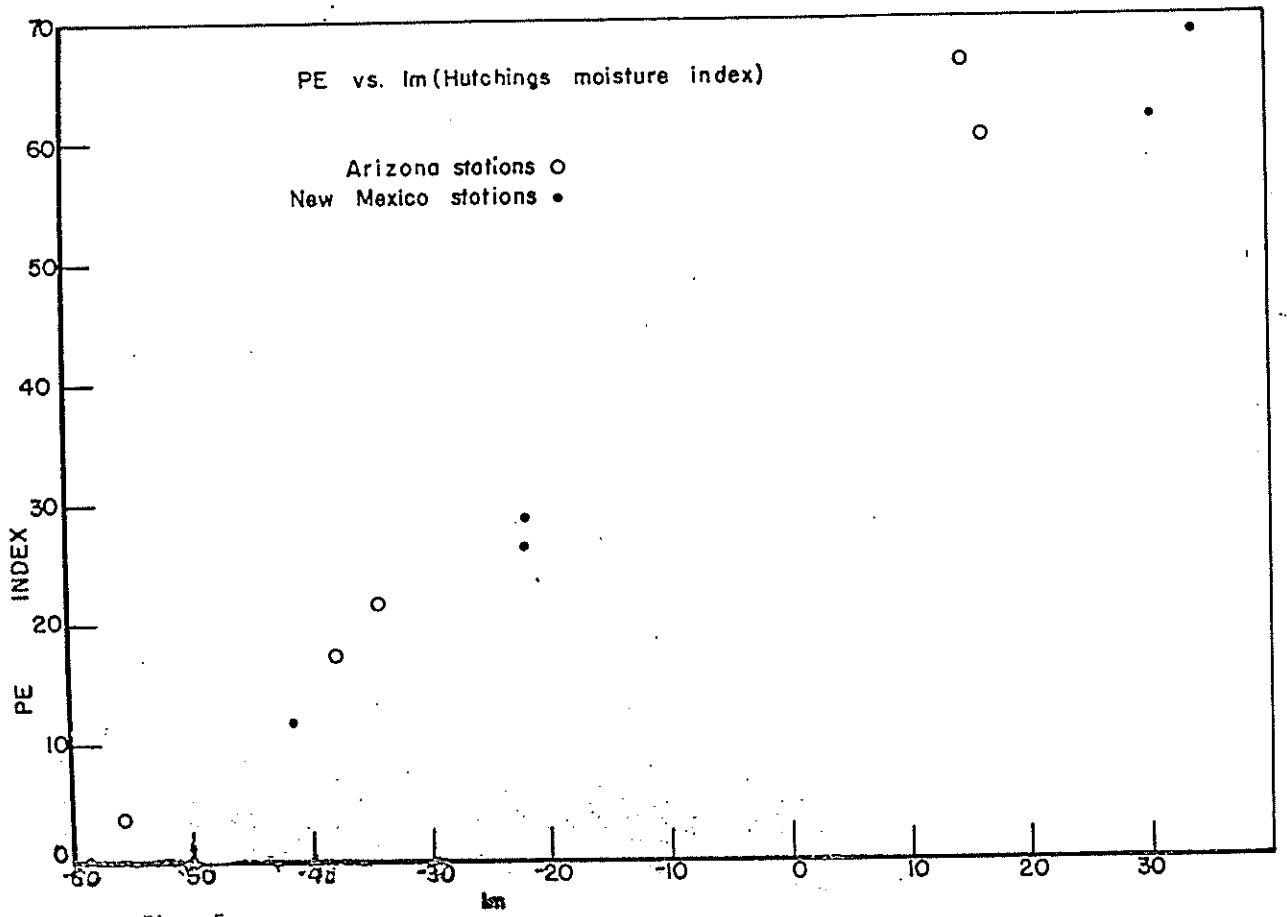

PE vs. Im (Hutchings moisture index)
Arizona stations O
New Mexico stations •
PE INDEX
70
60
50
40
30
20
10
0
-60
-50
-40
-30
-20
-10
0
10
20
30
Im

Figure 5

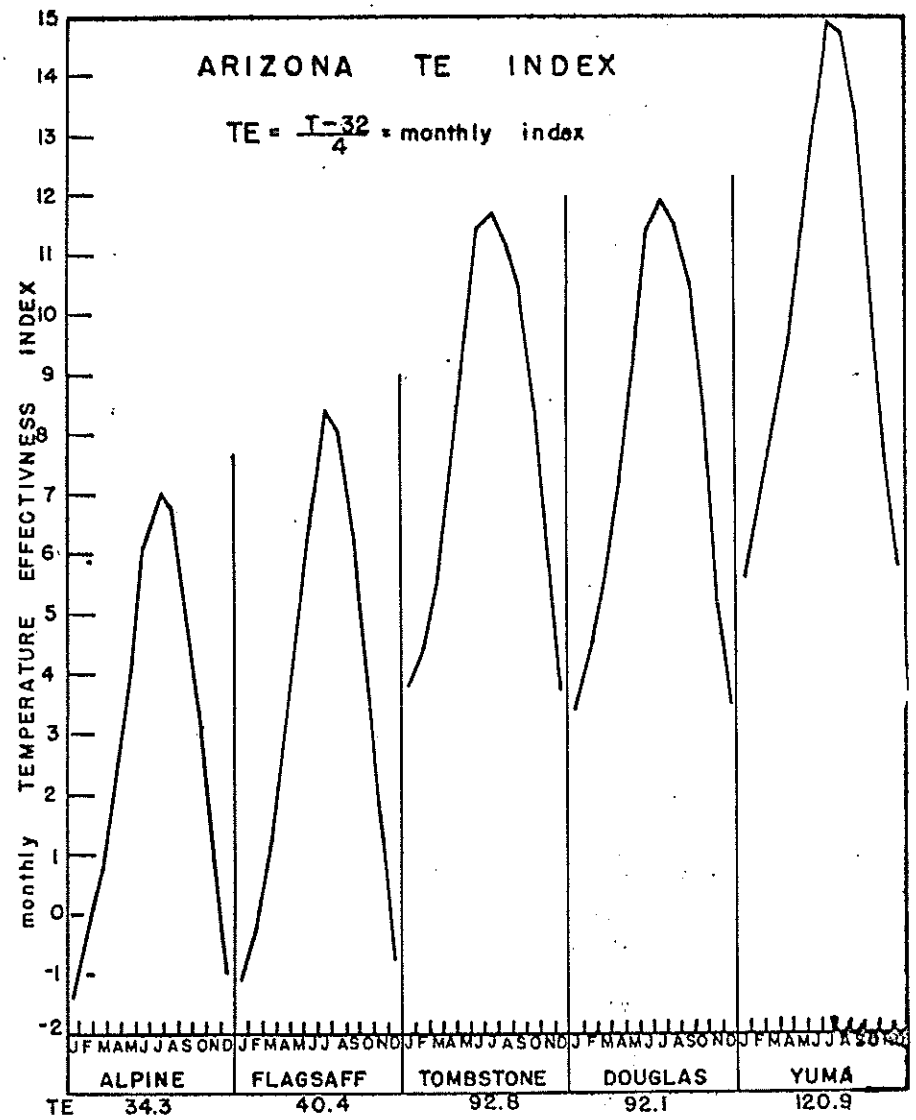

ARIZONA TE INDEX
TE = (T-32)/4 = monthly index
monthly TEMPERATURE EFFECTIVNESS INDEX
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
J F M A M J J A S O N D
ALPINE
FLAGSAFF
TOMBSTONE
DOUGLAS
YUMA
TE
34.3
40.4
92.8
92.1
120.9

Figure 28