Paper CC5
Unit 2 Topic 8

Climatic Classification after Thornthwaite (1948)

Dr. Mitrajit Chatterjee

- Although the Köppen climate classification is the most common climate classification in use today, the 1948 Thornthwaite classification is frequently cited as an improved climate classification system for its rational approach.
- However, the Thornthwaite classification is infrequently used because it tends to be too complex for use in everyday settings and world maps of the classification were never produced.

- In 1948, Thornthwaite developed a second classification based on improved water balance metrics.
- He also made the system more “rational” by using even class intervals.
- Like Köppen’s classification, Thornthwaite distinguished climates based on two primary factors—relating to moisture and heat—and two seasonality components as secondary factors.

The Moisture Factor

- Thornthwaite realized that precipitation (P) alone is not a good indicator of moisture conditions in an environment.
- He considered this a significant drawback to most climate classification systems.
- Instead, he developed the concept of potential evapotranspiration (PE), derived from temperature and day length, to estimate the water need of plants in a given environment.

- Using PE in combination with P, he developed his water budget methodology to create a moisture index. Unlike other moisture indices, however, Thornthwaite derived his index from separately calculated humidity (I_h) and aridity (I_a) indices, based on moisture surplus and deficit calculations from the water budget
- $I_h = 100\ S/PE$ and
- $I_a = 100\ D/PE$

where S is the water surplus and D is the water deficit.

Moisture Index

- Thornthwaite suggested that perennial plants are sufficiently deeply rooted to be able to access surplus moisture that percolates below the soil layer, thus minimizing the effects of drought.
- For this reason, he decided that 6 inches (~15 cm) of water surplus was sufficient to offset 10 inches (~25 cm) of moisture deficit for deep-rooted vegetation and subsequently developed the following weighted moisture index:
- $I_m = I_h - 0.6I_a$

Values for this index range from -60 to infinity and Thornthwaite used values from -60 to 100 in rational increments of 20 to classify climates into humidity classes, labeled in a similar fashion to the Köppen system with capital letters

Table 1. Thornthwaite Moisture Derived Climate Types

Climatic type	Moisture index
A Perhumid	100 and above
B_4 Humid	80 to 100
B_3 Humid	60 to 80
B_2 Humid	40 to 60
B_1 Humid	20 to 40
C_2 Humid	0 to 20
C_1 Humid	-20 to 0
D Semiarid	-40 to -20
E Arid	-60 to -40

The Thermal Factor

- Thornthwaite based his thermal factor, called the Index of Thermal Efficiency, on PE. Most climate classifications use temperature as an indicator of thermal efficiency.
- However, Thornthwaite recognized that temperature alone was not necessarily an adequate indicator of the productivity of an environment, especially for climate-dependent ecological processes.
- PE represents the potential water use by an ecosystem, and, as such, is a measure of potential plant productivity.

- As with the Moisture Index, Thornthwaite wanted to use a rational scale to delineate his thermal climate classes.
- Starting with the assumption that, at its lower climatic limit, an evergreen tropical climate would have an annual PE of 114 cm (equivalent to a 22°C monthly averaged temperature), he created his five major thermal classes by progressively halving this value (Table 2).
- Like the moisture index, he subdivided the middle classes into equal intervals to further differentiate mid-latitude climates

Table 2. Thornthwaite Thermal Climate Types

Climatic type	TE index (PE; cm)
A′ Megathermal	114 and above
B'_4 Mesothermal	99.7 to 114
B'_3 Mesothermal	60 to 80
B'_2 Mesothermal	40 to 60
B'_1 Mesothermal	57 to 71.2
C'_2 Microthermal	0 to 20
C'_1 Microthermal	-20 to 0
D′ Tundra	-40 to -20
E′ Frost	-60 to -40

Seasonal Variation of Effective Moisture

- Thornthwaite devised separate moisture seasonality classes for wet and dry climates, based on whether climates had moisture index values above or below 0.
- For moist climatic types—those that received more annual precipitation than annual PE—he used the aridity index to identify the intensity of drought conditions and to further distinguish between winter and summer deficiencies.
- For dry climatic types, he used the humidity index to identify the intensity of wet conditions, again distinguishing between winter and summer surplus moisture conditions

Table 3. Thornthwaite Seasonal Variation of Effective Moisture Types

Seasonality type	Index
Moist climates (A, B, C)	Aridity
r little or no water deficiency	0 to 16.7
s moderate summer water deficiency	16.7 to 33.3
w moderate winter water deficiency	16.7 to 33.3
s_2 large summer water deficiency	33.3+
w_2 large winter water deficiency	33.3+
Dry climates (A, B, C)	Humidity
d little or no water surplus	0 to 10
s moderate summer water surplus	10 to 20
w moderate winter water surplus	10 to 20
s_2 large summer water surplus	20+
w_2 large winter water surplus	20+

Table 4. Thornthwaite Summer Concentration of Thermal Efficiency

Seasonality type	Summer PE concentration (%)
a'	<48.0
b'_4	48.0 to 51.9
b'_3	51.9 to 51.9
b'_2	56.3 to 51.9
b'_1	61.6 to 51.9
c'_2	76.3 to 68.0
c'_1	88.0 to 76.3
d'	>88.0

Significance

- Thornthwaite's 1948 climate classification was a significant improvement on the Köppen classification in a number of ways.
- First, the new moisture index made possible the clear distinction between moist and dry climates.
- Second, the Thermal Efficiency index is more closely tied to the plant and energy usage of the environment as compared to temperature-based criteria used by Köppen.
- Third, because it is more systematic or rational in its definition of the intervals used, these two variables are much more straightforward to use and fit better with a systematic view of climate variation.
- Finally, the classification was not so closely tied to vegetation boundaries. It recognized that the variables mapped are continuous in space and therefore the emphasis was not on the exact placement of boundaries but on identifying core climate regions using continuously varying fields.

Limitations

- While the Thornthwaite classification was immediately recognized as a conceptual improvement over the Köppen classification, it never gained much acceptance for several reasons.
- First, the full classification system was just too complex to be used, resulting in well over 800 climate types at the global scale. In fact, neither Thornthwaite nor any subsequent champions of the method ever produced a global version of the system because of its complexity.
- Second, calculation of PE for the classification also was a hindrance to acceptance of the system, especially before the advent of computing resources.
- Simply put, the Köppen system succeeded in large part because of precedence and because it was presented as a world map. By providing a map instead of a methodology, the system alleviated the need for calculations.
- Certainly, most users have little knowledge of how the boundaries are derived or the computational complexities associated with those criteria. The inability of the Thornthwaite system to provide a similar map-based system made it unsuitable for classroom application.

Conclusion

- However, this classification is very cumbersome to use and the large number of classes makes it very difficult to implement the full Thornthwaite climate classification on a global scale.
- In addition, the letter scheme he proposed is difficult follow.