# CLIMATE AS A SOIL FORMING FACTOR IN NATAL

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## Climatic Regions in the Tugela Basin

For the Tugela Basin, which occupies about one third of the province of Natal, a division in eight physiographic-climatic regions has been designed[26] which provided a sound background for the plant ecological and pedological surveys in that area. Most of these climatic regions have similar counterparts elsewhere in Natal and East Griqualand. Some temperature and rainfall figures of representative stations are given in Table I.

Descending from the Drakensberg eastwards, the interior regions form a stepwise sequence from the relatively cool and moist Highlands via the intermediate Interior Basins to the warm and dry Interior River Valleys. The Midlands Mistbelt forms the mild and foggy, eastern extension of the Highlands. From here a second, more gradual sequence leads via the warm but moist Coastal Hinterland down to the very warm and moist Coastal Lowlands. The very warm and dry valley of the Lower Tugela cuts transversely through the coastal sequence.

## Thornthwaite's Rational Classification of Climate

The influence of the climatic factor on soil forming processes is, apart from temperature, largely determined by the balance between precipitation and evapotranspiration. These two opposing agents should be accorded equal importance in any climatic classification that is meant to have pedological significance. This principle is fully acknowledged by Thornthwaite [24,25], who pursues an estimation of the moisture variations in the soil and the resulting water surplus and/or deficiency during the course of the year. His "rational classification" was applied to the climate of South Africa by Schulze[20] who showed that Natal, with adjoining parts of the Eastern Cape, Basutoland and Eastern Transvaal "forms the only area of any size enjoying a water surplus . . .". However, "the Tugela River Valley stands out distinctly as a drier region in the moist coastal plain".

Thornthwaite's analysis is based on a continuous comparison of the precipitation with the potential evapotranspiration — or water need — through all the months of the year. This potential — as distinct from actual — evapotranspiration is defined as "the amount of moisture that would be transferred from a vegetation-covered soil to the atmosphere by evaporation and transpiration, if it were constantly available in optimum quantity".[28] It is considered as "an index of thermal efficiency"[24] and computed by a formula based on mean monthly temperature and length of day.

Values of the water need as calculated according to Thornthwaite's method have been compared with measurements obtained from lysimeter tanks near Pretoria[20] and Popov evaporimeters at Potchefstroom[1] both aimed at the direct determination of the potential evapotranspiration. These comparisons agree in that both show a poor correlation between the measured monthly totals and the calculated estimates, with the former far in excess of the latter. These discrepancies are ascribed to such factors as intense solar radiation, strong wind and low relative humidity which Thornthwaite deliberately eliminated from his formula.

However the installations employed did not meet the requirements for ideal evaporimeters[25]. The evapotranspiration figures obtained — especially those at Potchefstroom — are also far higher than the maximum possible values computed from the solar radiation in California and Florida[25], and the results of these investigations cannot be considered as a valid criticism of Thornthwaite's formula.

## Water Balance and Soil Formation in Some Climatic Regions of Natal

In fig. 1 (modified after De Villiers[4]) the annual march of rainfall and water need according to Thornthwaite's method is shown for nine selected stations in Natal. Since both rainfall and water need reach a maximum in summer and a minimum in winter, the two curves for each station have similar forms. With regard to their relative positions, four cases can be distinguished as outlined below.

1. The humid to very moist subhumid regions are represented by Qachasnek, Nottingham Road and Greytown, situated in the Highlands and Midlands Mistbelt respectively.

After the beginning of the rainy season, rainfall exceeds the water need and the soil is recharged with moisture. This continues until the water lost during the previous winter has been replaced and the moisture content of the soil is again at or near its field capacity (cf.[12], Ch. 7). From then on there is a water surplus, running off and seeping through the soil until, after the end of the rainy season, rainfall drops below the water need. As from then, moisture stored in the soil is utilized until the next good rains have arrived. This occurs before the moisture storage is fully exhausted, so that at no time of the year is there a water deficiency.

A water balance as visualized above is confirmed by the fact that the characteristic upland soils of these climatic regions appear to be permanently moist. They are easy to dig and auger in at all times of the year.

The continuously moist conditions have promoted intense weathering. The really mature and most common soils are rather uniformly red clays when developed from doleritic parent material (Balmoral series*) but have a yellow subsurface horizon over a

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* A few names of exemplary soil series are mentioned for easy reference. These series were defined as a result of the soil surveys of the Natal sugar belt and the Tugela Basin.

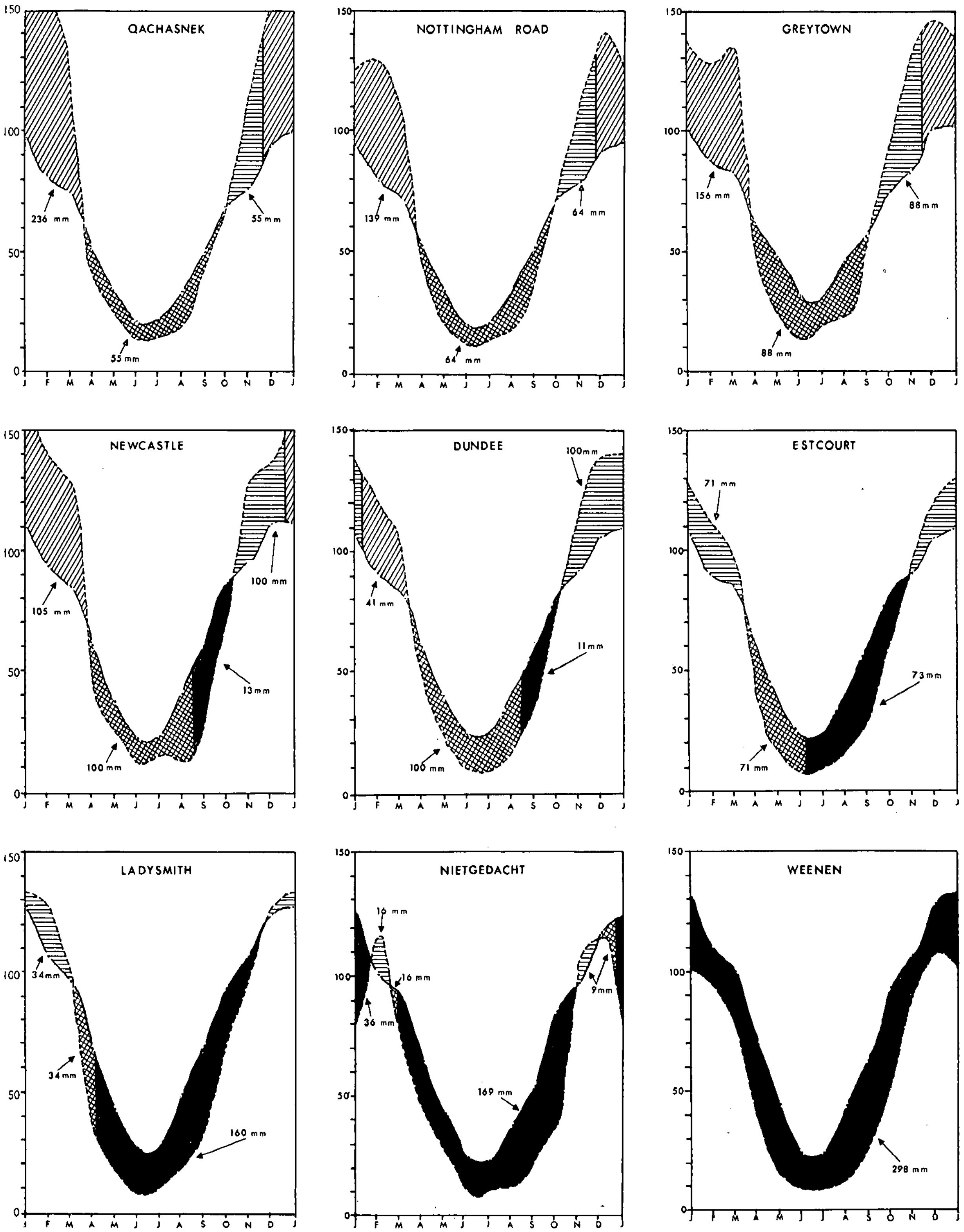

FIG. 1

Annual march of rainfall and water need according to Thornthwaite at selected stations in Natal. (modified after De Villiers)

------ Rainfall

—·— Water Need

▨ Water Surplus

▩ Soil Moisture Utilization

■ Water Deficiency

▤ Soil Moisture Recharge

red subsoil when developed from Karroo sediments — mainly shales — and their colluvia (Griffin series). In both cases the soils are deep and characterized by a highly weathered clay fraction, mainly consisting of kaolinite and a stable form of vermiculite together with gibbsite and iron oxides. Less mature yellowish brown soils from Karroo shales (Clovelly series) also contain lithological illite, inherited from the parent material.

Under the moist and relatively cool conditions, organic matter has accumulated to a high or very high level in the surface soils, which contain 2-9% organic carbon†. The resulting structure and high porosity ensures that a good deal of the large water surplus percolates through the soil, removing the bases liberated by the intense weathering. Thereby all the soils, including the less mature ones, have become highly leached. In spite of their predominantly clayey textures (generally 35-70% clay) the subsurface and subsoil horizons contain less than 1.5 meq.% extractable bases (Na, K, Ca, Mg) giving a base saturation of less than 20%.†

Physically these horizons, be they red or yellow, have a very friable consistency and a very porous, apedal micro-granular structure corresponding to what Kubiena[11] calls a "spongy soil fabric". Since the soils never dry out, and do not shrink and crack, "cleavage blocks" could not be formed. From the microscopic study of this structure its genesis appears to be a matter of aggregation rather than of "micro-erosion" as described by Kubiena[11]. The granulation may be largely due to the "irreversibility of colloidal iron hydroxide".[2]

Free iron ($Fe_2O_3$) is present in amounts ranging from 3 to 10% in the upper horizons and from 6 to 15% in the deep subsoils. The increase with depth is most pronounced in the yellow-over-red profiles. It points to a current eluviation of iron from the upper horizons (a feature of podzolization) superseding or accompanying a relative accumulation of sesquioxides according to the terminology of D'Hoore[5], who considers laterization as an extreme case of the latter

TABLE I

**Temperature and rainfall at representative stations in Natal**

| Climatic Regions | | Highlands | Interior Basins | | Interior River Valleys | Lower Tugela Valley | Midlands Mistbelt | Coastal Hinterland | Coastal Lowlands |
|---|---|---|---|---|---|---|---|---|---|
| | | | Moist parts | Dry parts | | | | | |
| Stations<br>Altitude (ft.) | | Qachasnek<br>6470 | Dundee<br>4114 | Estcourt<br>3875 | Weenen<br>2776 | Mfongosi<br>1401 | Greytown<br>3642 | Eshowe<br>1739 | Stanger<br>400 |
| Mean temperature (°C) | January | 18.5 | 21.1 | 21.1 | 23.7 | 24.4 | 20.4 | 22.2 | 23.7 |
| | April | 13.9 | 17.2 | 17.2 | 18.9 | 21.1 | 17.6 | 20.3 | 22.2 |
| | July | 7.4 | 11.0 | 10.5 | 10.9 | 14.3 | 12.4 | 16.1 | 17.8 |
| | October | 14.9 | 18.8 | 18.3 | 20.2 | 21.9 | 17.8 | 19.5 | 21.4 |
| | Year | 13.6 | 17.0 | 16.8 | 18.4 | 20.4 | 17.2 | 19.6 | 21.4 |
| Mean rainfall (mm.) | January | 161 | 139 | 129 | 101 | 117 | 139 | 166 | 131 |
| | February | 157 | 122 | 113 | 94 | 101 | 126 | 165 | 114 |
| | March | 132 | 106 | 100 | 79 | 101 | 135 | 186 | 138 |
| | April | 43 | 46 | 41 | 39 | 40 | 51 | 80 | 74 |
| | May | 25 | 22 | 17 | 16 | 29 | 26 | 67 | 51 |
| | June | 14 | 10 | 8 | 9 | 15 | 15 | 40 | 31 |
| | July | 15 | 10 | 10 | 10 | 15 | 19 | 33 | 35 |
| | August | 18 | 16 | 16 | 13 | 16 | 23 | 42 | 41 |
| | September | 41 | 36 | 29 | 26 | 34 | 56 | 78 | 61 |
| | October | 68 | 77 | 62 | 53 | 72 | 94 | 120 | 115 |
| | November | 111 | 114 | 92 | 91 | 103 | 130 | 163 | 115 |
| | December | 149 | 138 | 119 | 108 | 128 | 145 | 178 | 122 |
| | Year | 935 | 836 | 736 | 637 | 770 | 961 | 1319 | 1028 |

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† Organic carbon according to Walkley & Black's method [18], extractable cations according to Mehlich's method[15] and exchange capacity as the sum of extractable cations.

## TABLE II

## CLASSIFICATION AND CHARACTERISTIC SOILS OF CLIMATIC REGIONS IN NATAL

| Climatic Regions | Highlands | | Interior Basins | | | | Interior River Valleys | | Lower Tugela Valley | Midlands Mistbelt | Coastal Hinter-land | Coastal Lowlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Moist parts | | Dry parts | | | | | | | |
| Stations | Qachasnek | Nottingham Rd. | Newcastle | Dundee | Estcourt | Ladysmith | Nietgedacht | Weenen | Mfongosi | Greytown | Eshowe | Stanger |
| Altitude (ft.) | 6470 | 4718 | 3934 | 4114 | 3875 | 3481 | 2599 | 2776 | 1401 | 3642 | 1739 | 400 |
| Mean temperature (°C.) | 13.6 | 13.7 | 17.3 | 17.0 | 16.8 | 18.6 | 18.0 | 18.4 | 20.4 | 17.2 | 19.6 | 21.4 |
| Mean annual rainfall (mm.) | 935 | 845 | 917 | 836 | 736 | 788 | 664 | 637 | 770 | 961 | 1319 | 1028 |
| Mean annual water need (mm.) | 699 | 706 | 825 | 806 | 809 | 948 | 869 | 935 | 1006 | 805 | 910 | 1042 |
| Need of 3 summer months (%) | 39.1 | 37.8 | 38.4 | 37.8 | 37.5 | 38.0 | 40.3 | 40.0 | 36.9 | 35.8 | 34.3 | 36.0 |
| Water surplus (mm.) | 236 | 139 | 105 | 41 | 0 | 0 | 0 | 0 | 0 | 156 | 409 | 0 |
| Water deficiency (mm.) | 0 | 0 | 13 | 11 | 73 | 160 | 205 | 298 | 236 | 0 | 0 | 14 |
| Index of humidity | 33.8 | 19.7 | 12.7 | 5.1 | 0 | 0 | 0 | 0 | 0 | 19.4 | 44.9 | 0 |
| Index of aridity | 0 | 0 | 1.6 | 1.4 | 9.0 | 16.9 | 23.6 | 31.9 | 23.5 | 0 | 0 | 1.3 |
| Moisture index | 33.8 | 19.7 | 11.8 | 4.3 | –5.4 | –10.1 | –14.2 | –19.1 | –14.1 | 19.4 | 44.9 | –0.8 |
| Climatic type | $B_1B'_1$ ra′ | $C_2B'_1$ ra′ | $C_2B'_2$ ra′ | $C_2B'_2$ ra′ | $C_1B'_2$ da′ | $C'_1B_3$ da′ | $C_1B'_3$ da′ | $C_1B'_3$ da′ | $C_1B'_4$ da′ | $C_2B'_2$ ra′ | $B_2B'_3$ ra′ | $C_1B'_4$ da′ |
| Characterization of climatic regions | humid to very moist subhumid; cool mesothermal | | moist subhumid; mild mesothermal | | dry subhumid; mild to warm mesothermal. | | dry to very dry subhumid; warm mesothermal. | | dry subhumid; very warm mesothermal. | very moist subhumid; mild mesothermal. | humid; warm mesothermal. | (moist to) dry subhumid; very warm mesothermal. |
| Characteristic soils | highly leached; red, yellow-over-red or yellowish brown without mottles; apedal, friable. | | moderately leached; red or yellow with ferruginous mottles, concretions or hardpans; firm and often more or less gleyed at depth. | | superficially leached, greybrown with blocky or prismatic, hard claypan; or slightly leached, black margalitic, strong blocky with slickensides. | | slightly to hardly leached, shallow greybrown or deeper, reddish brown or dark brown, often highly calcareous. | | slightly to moderately leached as leaching increases towards the coast. | highly leached; largely as Highlands. | | moderately leached; as Interior Basins. |
| U.S. Dept. Agr.: Soil classification, 7th approximation | Oxisols, Inceptisols | | Ultisols, Alfisols, Inceptisols. | | Alfisols, Vertisols. | | Aridisols. | | Aridisols-Alfisols. | Oxisols, Inceptisols. | | Ulti-, Alfi-, Inceptisols. |
| S.P.I.: Legend for soil map of Africa 1:5,000,000. | Ferrallitic soils, Ferrisols. | | Fersiallitic soils. | | Solodized solonetz, vertisols. | | Brown soils of arid and semi-arid regions. | | Brown semi-arid to fersiallitic. | Ferrallitic soils, Ferrisols. | | Fersiallitic soils. |

process. A similar simultaneous operation of the processes of laterization and podzolization has been suggested for associated red and yellow-red soils in the U.S.A.[17] and Australia[22].

In the absence of clay coatings, the subsoils show no morphological evidence of clay illuviation. Owing to their permeability the large intermittent water surplus seldom causes waterlogging of these deep horizons. As a rule, they are coloured uniformly red, yellowish red or yellowish brown without any signs of gleying or even ferruginous mottling.

In terms of the American classification[21], the mature Balmoral and Griffin series belong to the order of Oxisols and the less mature Clovelly series to that of Inceptisols. According to the S.P.I. system[6] they are classified as Ferrallitic soils and Ferrisols respectively.

2. The moist subhumid regions are represented by Newcastle and Dundee, situated in moist parts of the Interior Basins.

Contrary to the more humid regions, the utilization of the moisture stored in the soil appears to exhaust the entire reserve in the course of the dry season. This point is assumed to be reached as soon as the accumulated excess of water need over rainfall amounts to the equivalent of 100 mm. water height. This, according to Thornthwaite, is roughly the mean "water storage capacity available to mature plants with fully developed root systems".[24] He admits that this is a gross simplification since, obviously, "the amount of water in the root zone available to plants varies with the soil structure and the distribution of roots". However, for an appreciation of climate as an independent soil forming factor according to Jenny's principles[7] the simplification as such is not only permissible but compulsory since the soil's storage capacity is not a climatic element. The correctness of Thornthwaite's estimate is hard to judge; Mohr and Van Baren's[16] categorical rejection seems unwarranted and since a value must be set, the figure of 100 mm. is accepted in this study.

From the moment the soil's moisture reserves are exhausted there exists a water deficiency. This lasts for about two months, to be relieved when rainfall again rises above the water need after the beginning of the next rainy season. As from then, the soil moisture is replenished, again to a maximum value of 100 mm., when it is assumed to be at or near field capacity. Only thereafter does the excess rainfall amount to a water surplus.

In accordance with the water balance outlined above, the typical upland soils of these regions are found to be moist for the larger part of the year. However they tend to be dry after the winter, especially under a dense grass cover of relatively undisturbed veld. Under the warmer and drier conditions surface soils contain only moderate or even small amounts of organic matter. The carbon content is mostly 1-3%, but where textures are sandy it seldom exceeds 1%.

The periodical lack of moisture in these regions has checked the weathering, and especially the leaching, of the characteristic soils. In so far as these have developed from doleritic parent material, they are rather uniformly red clays of mostly moderate depth (Shortlands series, cf.[14]). The latter's lower degree of weathering as compared to the Highlands' Balmoral series appears from the composition of the clay fraction which, besides kaolinite, contains illite whereas gibbsite is generally absent. The summer water surplus has caused these soils to be leached, but the leaching has not reached a very advanced stage; the subsurface horizons contain 5-20 meq.% extractable bases resulting in a base saturation of 50-80%.

Physically, the subsoils show a moderate to strong blocky structure, whereas in most profiles prominent clay coatings on ped surfaces indicate clay illuviation. Such structural elements are considered as "cleavage blocks"[11] which develop by "fracturation and fragmentation along the cleavage planes"[2]. For this process the swelling and shrinking caused by the alternate moist and dry soil conditions are responsible [2, 10]. Only in areas marginal to the Highlands or Mistbelt, weakly structured red soils from dolerite are found which, in the subsurface horizon, have 1.5-5 meq.% extractable bases and a base saturation of 20-50% (Vimy series, cf.[14]).

The alternate water surplus and deficiency is even more clearly reflected in the properties of the most extensive soils in the Interior Basins (Bergville, Avalon, Leksand series). These have formed from pedi-sediments, mainly derived from and overlying Karroo shales and sandstones. Exhibiting a yellowish brown apedal subsurface horizon, they may be compared with the Highlands' Griffin series, except in respect of their clay minerals which are mainly kaolinite, illite and muscovite. Moreover, gibbsite is absent and leaching is less; extractable bases content is usually 1.5-5 meq. % giving a base saturation of 20-80%. Further, there is a marked increase in clay content in the subsoil which, with depth, gradually assumes a firm consistency and a blocky structure. Clay coatings on ped surfaces may be present.

The lower subsoils are only slowly permeable and as a result of the summer water surplus they are seasonally waterlogged. Although these soils occupy gently undulating uplands, they exhibit the effects of gleying and the hydromorphic segregation of iron oxides over large areas. Already in the lower part of the subsurface horizons bright red mottles are conspicuous. The subsoils are strongly mottled grey-brown, yellow and red, and often contain large amounts of contemporary iron-manganese concretions. In deep profiles the lowest part of the subsoil is predominantly grey, with yellow mottles only.

The iron-manganese concretions in these soils represent an "absolute accumulation" of sesquioxides in the terminology of D'Hoore[5]. In summer, ferrous compounds are introduced into the profiles by water moving laterally through the saturated zone as can frequently be observed in road cuttings and profile pits. Oxidation and precipitation take place when the soil dries up after the winter. Presumably, the original source of the iron is weathering dolerite (cf.[13]) which occupies the highest parts of the landscape.

In many places the iron concretions have eventually been cemented together to form more or less continuous laterite hardpans. These range from what D'Hoore[5] calls "cuirasse de nappe" (Wesselsnek series) to "laterite de galerie" (Wasbank series). Although some of these hardpans are fossil, many are contemporary. The prevalence of such cuirasses in climates that are alternately wet and dry is a long established fact (cf.[16]) and the moist Interior Basins are obviously no exception.

Shallowish soils formed from drift material overlying Karroo sediments (Southwold, Springfield series) do not show the clay illuviation and hydromorphic effects so well. They rather resemble the Clovelly series, but are less weathered and have a higher base status.

Depending on their base saturation, the soils described above must be placed in the Ultisol and Alfisol orders, but the shallowish soils and those overlying old laterite pans would be Inceptisols[21]. In the S.P.I. system, they belong to the Fersiallitic soils[6].

3. The dry subhumid regions are represented by Estcourt and Ladysmith, situated in increasingly dry parts of the Interior Basins.

Here, the excess of rainfall over the water need during the rainy season is not sufficient to recharge the soil to its full storage capacity, assuming that the latter is equivalent to 100 mm. water height. Consequently, even in late summer there is no water surplus. Further, the meagre recharge of soil moisture is soon exhausted by the following utilization. The water deficiency begins already in early winter or even in autumn, and lasts for five to seven months.

Again, this type of water balance is reflected in the properties of the characteristic soils. As could be expected, the latter when under a grass cover of relatively undisturbed veld are found to be dry, and hard to dig and auger in for a large part of the year.

The characteristic soils have largely developed from the same pedi-sediments, originally derived from Karroo shales and sandstones, as the Bergville and Leksand series. They occupy similar undulating uplands as well as very gentle lower slopes.

Under the dry and rather warm conditions the surface soils contain only small amounts of organic matter. Usually their carbon content is 0.5-1%, and even less than that where textures are sandy. Weathering has not progressed very far in these soils. Their clay fraction consists mainly of illite and quartz, with moderate proportions of kaolinite and often some muscovite.

In the absence of a summer water surplus a thorough leaching of the parent material to any great depth could not take place, although liberated bases could be removed in abnormally wet years. Considerable leaching has, in fact, occurred only superficially, accompanied by a strong eluviation of clay. Thereby, acid, loamy to sandy surface soils mostly one foot thick have formed, with a massive or single-grain structure and a base saturation of 40-70%. They abruptly overlie neutral to alkaline, clayey subsoils with a strong blocky or prismatic structure, a hard consistency and a base saturation of 70-90% or even more. Prominent clay coatings on ped surfaces demonstrate a strong illuviation of clay into this horizon. Blocky structure and clay coatings, indicating shrinkage and cracking through loss of moisture during winter, may continue to a great depth in the underlying pedi-sediment which usually contains lime concretions. In some places the subsoil is residually formed from, and directly overlies, slightly weathered shale or sandstone.

The most striking feature in these claypan soils is the very abrupt transition from the surface soil to the subsoil, where clay contents commonly jump from 24 to 50% or from 12 to 35% (Estcourt and Uitvlugt series respectively). This could be produced by eluvation of clay, continuing laterally above the claypan after the latter is sealed off upon being moistened in summer*.

These soils thus exhibit the morphology of solonetz and solodized solonetzic soils (cf.[9, 19]). However, it seems unlikely that they have developed from solonchaks according to the classical concept of the evolutionary sequence of halomorphic soils (cf.[3]). Nowhere are the Natal claypan soils associated with solonchaks and, unless an even drier climate has prevailed, the initial salinization process can hardly be visualized in the upland positions where these soils are found.

Where parent materials are dolerite, or doleritic colluvium, the characteristic upland soils in the driest parts of the Interior Basins are black clays of the kind termed "margalitic soils" by Mohr & Van Baren[16]. The peculiar properties of these shallowish soils, which show little horizonation, are due to their dominant (sometimes only) clay mineral montmorillonite. The latter's formation may be ascribed to the low "rate at which silica and bases are removed from the zone of rock alteration"[14]. The preservation of montmorillonite in the soil appears to be a consequence of the same dry conditions that prevent thorough leaching.

In view of the dry and warm climate, the organic matter content is somewhat higher than might be expected. The surface soils contain 1.5-2.5% carbon, which seems to be a common level elsewhere too[23, 27]. The swelling and shrinking of the montmorillonitic clay upon wetting and drying is responsible for the development of the strong blocky structure ("cleavage blocks", cf.[11]), slickensides and modest cracking in the long dry season. Since leaching is so limited, base saturation is high; it increases from 80-90% in the surface soils to 90-100% in the subsoils. In the latter as well as in the underlying weathered rock, lime accumulation is common in the deeper soils (Arcadia, Pepworth series).

The claypan soils described above belong in the Alfisol order[21], and in the class of Solonetz and solodized Solonetz[6]. In both the American and S.P.I. systems the margalitic soils are classified as Vertisols.

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*Suggested by J. G. Thompson, of Salisbury, in a private communication.

4. The very dry subhumid regions are represented by Weenen and, to a lesser degree, Nietgedacht, both situated in the Interior River Valleys.

At Weenen the water need exceeds the rainfall in all months of the year. There is a permanent water deficiency; no moisture reserves are built up in the soil and the vegetation has to depend entirely on current rainfall. At Nietgedacht, this droughty condition is relieved during two short periods in early and late summer, but even so there is a water deficiency during nine months.

Under such dry conditions rock weathering is slow and leaching very limited. Except where formed in deep sediments, soils are shallow and most of them abound in free carbonates.

A typical example is the shallow, rather nondescript grey-brown soil formed from Karroo sediments (Muden series). Its surface soil has a pH of about 8, is fully base saturated and already contains finely dispersed carbonate. It merges into, or overlies, slightly weathered shale or sandstone in and above which a strong accumulation of lime has occurred.

Deep soils have only developed in sub-recent colluvial and alluvial deposits which, in general, form gently sloping to nearly level uplands. Characteristic soils are often coloured reddish brown or dark brown (Sunvalley, Weenen series). Their low degree of weathering is demonstrated by their clay minerals which are mainly illite, montmorillonite and their interstratifications, in rather varying proportions. Moreover, it appears from their high content of very fine, slightly weathered rock fragments, mostly Karroo shale. As could be expected, surface soils are low in organic matter, containing 0.5-1% organic carbon.

Since the strong evapotranspiration is so inadequately counteracted by the rainfall, large amounts of free carbonates of calcium and, sometimes, sodium have accumulated in these soils. In many places finely dispersed carbonate is present already in the surface soils, which have a pH of 7-8.5 and a base saturation of 90-100%. With depth$_3$ the content of carbonates increases. In addition to numerous veins and concretions, so much powdery lime is often present in the subsoil that it lightens the colour of the soil mass, changing it from dark (reddish) brown to (reddish) brown or even yellowish red or yellowish brown. These horizons have a pH of 8-9 and are, of course, fully base saturated. Elsewhere, the soils contain thick, solid lime pans.

The soils of these almost semi-arid regions have been placed in the Aridisol order of the American system[21], and in the class of Brown soils of arid and semi-arid regions of the S.P.I. system[6].

## Conclusions

From the values of the total annual water need, water surplus and water deficiency Thornthwaite[24] calculates indices of humidity and aridity and, finally, a moisture index. In table II, all these values are shown for 12 representative stations in Natal, together with the code of the climatic types according to Thornthwaite's classification.

Depending on the moisture index, the stations range from humid ($B_2$ and $B_1$) via moist subhumid ($C_2$) to dry subhumid ($C_1$). According to the annual water need, all stations are termed mesothermal ($B'_1$ to $B'_4$). All moist stations have little or no water deficiency in winter (r) and all dry stations have no water surplus in summer (d). At all stations the concentration of the water need in summer is abnormally low with regard to the latitude. It corresponds, in fact, to that of a full megathermal climate (a') and reflects the oceanity of the climate of Natal.

A slightly refined characterization in order to make a clearer distinction between the various physiographic-climatic regions of Natal is also shown in table II. It can be seen that Thornth waite'sclassification ties in fairly well with this climatic division of Natal. It is pointed out that the moisture indices of Nottingham Road and Greytown are only a fraction below the value of 20 which separates them from the humid climatic type ($B_1$) of Qachasnek and Eshowe. Similarly, the moisture index of Weenen is only just above 20, below which value the station would have been classified as semi-arid (D). It seems possible that Eshowe represents a relatively moist part of the Coastal Hinterland, and Stanger a relatively dry part of the Coastal Lowlands. The critical values of the all-important moisture index separating the climatic regions of Natal appear to be 14, 0 and — 14, as compared to the values 20, 0 and — 20 which Thornthwaite has set for the limits between the humid, moist subhumid, dry subhumid and semi-arid climatic types respectively.

A summary of the characteristic soils in each of the climatic regions as discussed above is also shown in table II, together with their classification in terms of the American and S.P.I. systems ([21, 6]).

It is emphasized that this paper deals with the soil forming factor climate only. The modifying influence of the other factors on the processes of soil formation is largely ignored. It should be realized that some of the soils mentioned are not confined to the climatic regions for which they are considered to be typical. In the moist Interior Basins, for instance, the Estcourt series may replace the Avalon series in what Jenny[8] calls a toposequence. Further, the Arcadia series may replace the Shortlands series, not only in a toposequence (cf.[14]), but also in what is believed to be a lithosequence.

## Summary

In Natal a division in eight climatic regions has provided a sound background for plant ecological and soil surveys. Rainfall and temperature data of representative stations are given in table I.

Of nine stations selected in the different regions, the water balance as calculated according to Thornthwaite's method[24] is shown in fig. 1. Soil forming processes, especially weathering, leaching, the translocation of clay and the accumulation of iron oxides, were found to be largely governed by the magnitude and duration of water surplus and/or water deficiency.

According to Thornthwaite's 'rational classification' the climatic regions of Natal range from humid meso-

thermal via moist and dry subhumid to almost semi-arid mesothermal. As is shown in table II, the characteristic soils in these regions vary accordingly, from Oxisols (Ferrallitic soils) via Ultisols (Fersiallitic soils), Alfisols (Solodized Solonetz) and Vertisols to Aridisols (Brown soils of semi-arid regions), in terms of the American and S.P.I. classification systems[21, 6].

Since the paper deals with the factor climate only, the interference by other soil forming factors is deliberately ignored.

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**Professor Orchard**: Climate is only one of five recognised soil forming factors. In explaining scientifically why a particular soil is found in a certain place it is necessary to pay due regard to all these factors.

The Tugela Basin has very varied parent materials, rainfall, temperature, topography, etc., thus it is not surprising to find so many different soils, of which Dr. van der Eyk and his associates have identified approximately eighty different series.

Climate accounts for many of these series differences and soils have been analysed according to how climate has influenced their properties and their distribution.

In large parts of the cane belt, on the other hand, the climate is fairly uniform. Temperature, rainfall, evapotranspiration, etc. are much the same, so that the effect of climate on the soil is not so obvious. Parent material has, therefore, assumed a more important differentiating role than climate in the cane belt and consequently in this area the parent material mainly has been used as a basis for classification.

Sight must not be lost of the very limited application this approach holds. It has been applied in the cane belt area with success, but cannot be applied as a general principle over climatically very different regions.

As the sugar industry expands, as it is doing at the moment, into regions where the climate is different from the standard climate of the present cane belt, into either higher areas or dryer areas where irrigation is practised, any system based on parent material will have its limitations.

That is the reason why it is advisable to use a system that is applicable under all conditions, i.e. an ecological approach where the whole environment of the soil is taken into account and not mainly one soil forming factor.