ON THE CLASSIFICATION AND GENESIS OF SOILS, DERIVED FROM ANDESITIC VOLCANIC MATERIAL UNDER A MONSOON CLIMATE[1])

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SUMMARY

Soil formation was studied in a monsoon climate. The Lawu volcano was sampled from an altitude of 500 to 3300 m and investigated morphologically, mineralogically and chemically. Moreover, the soil organic matter was extracted and analysed with respect to its C, H, O and N-content.

Comparison of the soils, developed in a monsoon climate with those, formed in a continuously wet climate (VAN SCHUYLENBORGH, 1958) showed that the process of laterization proceeded to higher altitudes in a monsoon climate. It seems possible to recognize the following belts. A zone from 3300 to 2500 m altitude with Brown Podzolic Soils, a zone from 2000 to 1400 m altitude with Non Calcic Brown Forest Soils, a belt from 1400 to 1000 m with Latosolic Non Calcic Brown Forest Soils and finally a zone from 1000 to 300 m with Brown Latosolic and Reddish Brown Latosolic Soils.

Soil genesis was discussed and it seemed that organic acid was a more important soil forming factor than carbonic acid at altitudes higher than 1000 m and under a monsoon climate. An explanation was proposed for the curious trends of the C/N-ratios of the soil and of organic matter and for the trends in the clay's molar Al_2O_3/Fe_2O_3-ratios.

1 INTRODUCTION

After the extensive work of Mohr, laid down in his well-known work: "De bodem der tropen in het algemeen en van Nederlands-Indië in het bijzonder", the knowledge about the genesis and classification of soils in Indonesia has proceeded relatively slowly. HARDON (1936), KIEL and RACHMAT (1948) have published on the occurrence of Podzols. EDELMAN (1940) reported on the soils of Indonesia and on the soils of Java (1946). DAMES (1955) wrote an extensive report on the soils of the eastern part of Central Java, although he reported little on the genesis. DUDAL and SOEPRAPTOHARDJO published recently (1957) on the principal soil groups occurring in Indonesia. An attempt to elucidate the soil forming process was made by VAN SCHUYLENBORGH and VAN RUMMELEN (1955) and VAN SCHUYLENBORGH (1957, 1958).

The latter authors have shown that the parent material plays an important rôle in tropical soil formation. It was indicated that on dacitic volcanic material quite different soils were formed than on andesitic material under the same climatic conditions. It appeared also that at different altitudes different soils were formed on the same parent matertal, which phenomenon is well-known and the consequence of the with elevation changing climate. The investigations included only the formation of soils under continuously wet tropical conditions and it appeared that the soils derived from andesitic volcanic tuff (Salak-complex) could be divided in a number of belts. From sea-level to about 300 m altitude a belt of predominantly Latosolic soils oc-

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curred, from 300 to 600 m a belt of Podzolized Latosolic soils, from 600 to 1000 m a belt of Acid Brown Forst soils, which is an equivalent to the recently introduced Acid Brown Earths (CLINE, 1955) and finally, above 1000 m, a belt of Podzolic soils. So, the process of laterization reached to an altitude of 600 m above sea level. It was suggested, that the differences in the process of soil formation could probably be explained by considering the different rate of mineralization of soil organic matter. Furthermore it was predicted, that under drier (monsoon) climates the process of laterization will proceed to higher altitudes than under continuously humid climates. To show this is the main purpose of this investigation.

Another purpose of this work is to give more attention to the organic matter problem, which is of extreme importance for the process of soil formation.

2 PARENT MATERIAL AND CLIMATE

The Lawu-volcano in the eastern part of Central Java was choosen for this investigation. According to VAN BEMMELEN (1949) and to DAMES (1955) the "Old" Lawu and "Young" Lawu can be distinguished. VAN BEMMELEN (1949) indicates that the "Old" Lawu corresponds in age with the Notopuro breccias in the Ngawi Subzone north of it. Combining stratigraphical data and fossil-remains he concludes, that probably the Notopuro stage comprises the upper part of the Middle Pleistocene and the lower part of the Upper Pleistocene.

DAMES (1955) claims that an Upper-Pleistocene and a Holocene eruption period can be distinguished. The "Old" Lawu should belong to the Upper-Pleistocene and consists of some quartz-containing andesitic material. The Holocene "Young" Lawu material contains no quartz and its products are limited to the top areas and to the northern half of the complex, where it is strongly intersected, filling up the valleys, forming smooth beds, and building up the plain at the volcano-foot.

This investigation is limited to the soil formation on the "Old" Lawu products.

The, in the introduction mentioned, Salak-complex is built up during three eruption periods in the earlier part of the quaternary period (HARTMANN, 1938; VAN BEMMELEN, 1949). An eventually difference in soils and soil formation can therefore be hardly a consequence of a difference in geological age, and can only be attributed to a difference in the mineralogical composition and/or difference in climate.

In both cases the nature of the parent material is andesitic. The mineral association is different however (see table 1); the "Old" Lawu material has a hypersthene-augite association and the Salak material has a hypersthene to hypersthene-augite association.

Table 1   Composition of the heavy sand fraction and the volcanic glass content of the Salak- and Lawu-products.

Volcano	Hypersthene	Augite	Green hornblende	Volcanic glass
Salak	75	20	5	11
Lawu	50	40	10	28

Moreover, the volcanic glass content of the sand fraction is different. Although both volcanic products are not entirely identic, the authors do not believe that this will have a marked effect on the soils to be formed.

Therefore, if different soils occur on the Salak and "Old" Lawu material, it will be clear, that then the unequal climate will be the reason.

The climate of the Lawu-region is a typical monsoon climate. The dry period falls in the months July, August, and September. Of course the rainfall increases at higher altitudes. Some data of rain stations of the region are given in table 2 (taken from: BERLAGE, 1949). No data on rainfall are available at greater altitudes.

Table 2   Rainfall distribution at different altitudes in mm.

Rainstation	Jan.	Febr.	Mrch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Tasikmadu ..... (100 m altitude)	353	335	333	251	158	102	34	32	36	113	212	306	2265
Karanganjar .... (100 m altitude)	336	273	310	231	142	83	20	29	23	85	194	281	2007
Karangpandan .. (600 m altitude)	429	383	411	324	182	116	31	27	49	119	300	405	2776
Tawangmangu .. (950 m altitude)	551	473	476	337	182	108	40	27	59	104	329	508	3194

The vegetation, however, indicates by its abundance that the maximum lies between 1000 and 2000 metres altitude. The humidity decreases gradually at still higher elevations and, at 2500 m altitude, the natural vegetation changes into a vegetation typical for regions, where frequently fires occur as a consequence of temporarily extreme dryness.

It is therefore pretty sure, that during the months July, August and September no downward movement of moisture through the soil will occur; on the contrary, an upward flow is surely to take place, especially when original forest is present with its high evapotranspiration. In the remaining part of the year, there will be a downward movement of the rainwaters and it is quite sure, that, on the whole, there will be a net downward flow of water through the soil. The difference with the climate of the Salak-region is, that in that region a downward flow occurs throughout the whole year, because no specific dry months are present.

Naturally, the temperature decreases with increasing altitude. The temperature can be calculated with the aid of the formula:

$$t = 26.3 -h \times 0.6 \; °C, \text{ (derived by: BRAAK, 1923/25)}$$

where h is the elevation in hectometres.

Soil temperature deviates from air-temperature of course, and to get an idea about the magnitude of this difference, soil temperature was measured at two depths in some profiles.

3   METHODS

The discussions are based predominantly on: 1) the profile morphology (colour, texture, structure and consistency); 2) the pH-values; 3) the organic matter profile; 4) the mineralogical composition of the sand fraction; and 5) the C/N-values of the horizons. Furthermore the litter of several profiles was analysed, while also the organic matter was extracted from the soil samples and analysed with respect to their C-, H-, O-, and N-content.

Colour. The Munsell scale was used for the indication of soil colour; the colours given in the profile descriptions refer to the air-dry and field-wet state.

Texture. The evaluation of the texture in the field was always checked with the mechanical analysis. Because it was not possible to analyse the soil samples in the field-wet state, they were dried to some extent and stored in closed bottles for the rather short period between sampling and analysis. The samples, therefore, were not fully air-dry when analysed, so that the physical state will not have changed very much (BIRRELL, 1952; BIRRELL and FIELDES, 1952; VAN SCHUYLENBORGH, 1954). The peptising agent to be used, was 0.003 N hydrochlorid acid for the profiles situated at altitudes of 1000 m and higher, except the profile at 3200 m, which had to be peptised with sodium pyrophosphate. This latter substance was also the best peptizing agent for the samples of the lower than 1000 m situated profiles; the concentration was 0.0006 to 0.0009 molar. The pipette method was used for the separation of the different size-fractions.

pH. The pH-values of the samples were determined in two ways. In the first place the pH of a one day old soil : water suspension (1 : 2.5) was measured electrometrically (using the glass electrode) after vigorous shaking. Secondly a one day old and occasionally shaken same suspension was centrifuged and the pH of the supernatant liquid measured. The latter procedure had the advantage that the suspension-effect was avoided (for a detailed discussion of this effect it be referred to BLOKSMA, 1955), so that the pH-values would approach the real pH-values. The values, given in the tables, refer to the suspension and the supernatant solution, respectively. The electrometer used was the Cambridge Bench pH meter.

Organic matter. The C content was determined according to ALLISON (1935). Sodium fluoride was replaced by phosphoric acid in most determinations because of shortage of the fluoride.

Mineralogical composition. The sand fraction was seperated in different size classes (viz. 2000–500 μ; 500–250 μ; 250–105 μ; 105–53 μ; and 53–50 μ) by means of the Rotap sieve apparatus. The minerals of these fractions were counted according to the normal line-counting method. The means are reported in table 6. Thereafter the fractions were combined and brought in bromoform of a specific weight of 2.90. The heavy minerals, thus obtained, were also counted.

SiO_2. The fusion of the clay fraction ($< 2\mu$) with sodium carbonate and the seperation of silicic acid was carried out as described by BILTZ and BILTZ (1947, p. 380 et seq.) The filtrate, obtained after the removal of silicic acid, was made up to volume and analysed with respect to its iron-, aluminium-, and titanium-content.

Fe_2O_3. Iron was determined by titration with versenate solution (KUANG LU CHENG, BRAY, and KURTZ, 1953) with sulfosalicylic acid as the indicator.

Al_2O_3. Aluminium could be very satisfactorily estimated by titration of a strongly alkaline solution with hydrochloric acid, using a mixture of thymolphtatlein and alizarin yellow as the indicator. (PAULSON and MURPHY, 1956).

TiO_2. Titanium was estimated in a sulphuric acid solution according to WEISLER (1945) after addition of hydrogen peroxide. The optical density of the yellow coloured solution was measured with the Hilger UVISPEK.

N. The nitrogen was determined by the Kjeldahl-method and carried out as described by PIPER (1947, p. 200).

Forest-litter. The analysis of forest litter was conducted in exactly the same way as described by GO BAN HONG (1957).

Extraction of soil organic matter. Extraction of soil organic matter is necessary if its chemical composition has to be determined. The extraction, however, is difficult. One of the difficulties is the impossibility to extract all organic matter from the soil. For a detailed discussion it be referred to BREMNER (1954). Another difficulty is the seperation of organic and inorganic soil colloids, because there exists an intimate interaction between these two parts (see a.o. : TYULIN, 1938; ENSMINGER, 1942; ALLISON, SHERMAN and PINK, 1949;

4

BREMNER, 1954); the bonding is not only physico-chemical but also chemical. It will be evident, that only a destruction of soil organic matter can break this chemical bond. A third difficulty is the fact that the soil organic matter undergoes certain changes in its composition during extraction, especially when using a strong alkaline extractant (FROMEL, 1938 ; WELTE, 1952 ; BREMNER, 1954).

Because it is especially important that the organic matter changes only slightly or not at all during extraction, the milder extractants are favoured by the investigators. It is obvious, however, that they extract considerably less organic matter from the soil than the strong ones. Therefore the mild extraction methods given by PURI and SARUP (1938), and FLAIG (1955) are adapted to our soils.

Ten grams of air-dry soil were extracted, without previous treatment with hydrochloric acid (see : WAKSMAN, 1936 ; PURI and SARUP, 1938), for one hour with 50 ml of a 0.1 N NaOH + Na$_2$CO$_3$-solution at 70° C in an Erlenmeyer flask on a waterbath, while during the heating the flask was repeatedly shaken. After cooling, the mass was transferred into a centrifugal tube and centrifuged for 15 minutes at a speed of 2500 r.p.m. The dark coloured supernatant liquid was decanted off and the remainder transferred to the original Erlenmeyer-flask with 50 ml. 0.1 N NaOH + Na$_2$CO$_3$-solution. The same treatment as described above was repeated and this so often until a colourless supernatant liquid was obtained.

A solution of 4 N hydrochloric acid was added to the collected humate-solutions to precipitate the organic matter. The precipitate was seperated by centrifuging and the supernatant liquid was poured off. The precipitate was then further purified by repeated redissolving in the NaOH + Na$_2$CO$_3$-solution and subsequent precipitation with HCl (4 times). A further purification followed by dialyzing the crude humus in dialyzing tubes of seamless cellulose until the point was reached where the humic acid just began to peptize. As this procedure is rather time consuming, the crude humus precipitate was also purified by filtering off through a Zsigmondy membrane filter and washing with distilled water. Whereas the first procedure took about 4 days, the second only took 1 hour.

The purified humic acid precipitations were then dried at 50° C.

C, H, and O. The carbon, hydrogen, and oxygen contents of the thus obtained humate preparations were determined micro-chemically as described by PREGL (1949). Only very slight modifications were necessary.

To eliminate the influences of the great air-humidity and fluctuations of temperature all the analyses were carried out in an air-conditioned room at a constant temperature of 23° C.

The balance, used for the weighings was the SARTORIUS Micro balance, Model MDP$_4$. The sensitivity at the maximum load of 20 g was the same as when unloaden. After some practice weighings with an accuracy of 1 μ g could be easily carried out.

The automatical combustion apparatus of HERAEUS was used for the oxidation of the organic substances. It consists of a long heater, which can be adjusted at temperatures from 500° to 1200° C, a movable short heater with the same range of adjustable temperature and a "Heissgranat" with a constant temperature of 180° C or 125° C.

An idea about the accuracy of the determinations can be obtained from the tables 3 and 4 where the results of the analyses of m — nitrophenol and oxalic acid are presented.

Table 3   Analysis of m — nitrophenol.

Substance mg	H$_2$O mg	CO$_2$ mg	% H		% C	
			expt.	theor.	expt.	theor.
2.520	0.802	4.784	3.562		51.81	
3.384	1.059	6.433	3.502	3.59	51.87	51.79
3.091	1.000	5.857	3.545		51.71	
mean			3.54		51.80	

N. The micro-analytical, somewhat modified, KJELDAHL-method (PEACH and TRACEY, 1956) was choosen for the estimation of nitrogen. This method is more satisfactory than the DUMAS-method, because organic matter is not likely to contain diazo compounds. Another

Table 4   The analysis of oxalic acid.

Substance mg	Na$_2$S$_2$O$_3$ 0.02 N ml	% O	
		expt.	theor.
1.751	10.00	76.13	
1.503	8.589	76.18	76.16
1.121	6.40	76.11	
mean		76.14	

reason for the selection of the KJELDAHL-method was the fact, that soil organic matter contain heterocyclic compounds. During the combustion according to Dumas, these compounds form N-containing coals, which are very difficult to destruct. Even the introduction of a small amount of oxygen in the carbon dioxide stream did not lead to the complete destruction of the organic matter, as was experienced by the authors.

Five to ten mg of absolute dry sample were mixed in a 30 ml Kjeldahl flask with 40 mg selenium-mixture (1 g CuSO$_4$, 8 g K$_2$SO$_4$ and 1 g SeO$_2$) and 1 ml of concentrated sulphuric acid. The mass was heated in an electrical heater, especially designed for this determination. When the contents of the flask had turned clear, it was essential to continue the heating for at least 5 hours. After cooling, about 1 ml of double distilled water (distilled from quartz) was added and the contents washed quantitatively into a PARNAS micro-steam-destillation apparatus of quartz. After addition of 7 ml of 10 N NaOH-solution the ammonia was distilled off and collected in 5 ml of 0.02 N sulphuric acid and the excess acid was titrated with 0.02 N sodium hydroxide, with the Conway-mixture as the indicator (6 ml of 0.16 % methyl red in 95 % ethanol, 12 ml of 0.04 % brom-cresol green in water and 6 ml of 95 % ethanol).

An idea about the accuracy of the method can be obtained from table 5, where the analysis of diphenylamin has been reported.

Table 5   The analysis of diphenylamin.

Substance mg	NaOH 0.02 N ml	% N	
		expt.	theor.
7.081	2.080	8.26	8.28
4.564	1.335	8.22	
mean		8.24	

4   PROFILE DESCRIPTIONS

Pits were dug on the Lawu volcano from the top at 3300 m altitude to about 600 m. In all cases the drainage conditions were perfect.

Profile 1. Argo Dumilah. Altitude 3200 m. Slope: ± 20 %. Vegetation: Festuca nubigena, Anaphalis javanica, Vaccinium species and Albizzia montana. Mean annual temperature: 7.1 °C.

A$_1$	0–3	cm	Dark grey brown (10YR 4/2; air-dry as well as field wet) loam with weakly developed crumb structure. Loose. Stony. Abundance of roots.
B$_1$	3–20	cm	Pale brown (10YR 6/3) to dark brown (7.5YR 3/2) loam with weakly developed fine nutty structure. Loose. Stony. Abundance of roots.
B$_2$	20–34	cm	Brown (7.5YR 5/4) to yellowish red (5YR 5/6) loam with weakly developed fine nutty structure. Friable. Many roots.
A$_{1b}$	34–45	cm	Dark grey brown (10YR 4/2) to dark brown (7.5YR 4/2) silt loam with moderately developed blocky structure. Friable. Many roots.

A$_{3b}$ 45–57 cm Brown (10YR 5/3) to dark brown (7.5YR 4/2) silt loam with moderately developed fine nutty structure. Rather compact. Few roots.

C$_b$ + 57 cm Very pale brown (10YR 7/4) to dark brown (10YR 4/3) sandy loam. Massive. Few roots.

The three upper horizons are formed from different material than the lower horizons (see table 6) [3]). The upper part can therefore only be used for the genetical discussions.

Profile 2. Between Tjokrosrengenga and Tamansari. Altitude: 2820 m. Slope: ± 20%. Vegetation: Vaccinium species, Rhododendron species, grasses. Mean annual temperature: 9.4 °C.

A$_1$ 0–24 cm Grey brown (10YR 5/2) to very dark grey brown (10YR 3/2) silt loam with a weakly developed crumb structure. Very friable. Abundance of roots.

B$_1$ 24–35 cm Brown (7.5YR 5/4) to dark reddish brown (5YR 3/3) silt loam with weakly developed fine nutty structure. Very friable. Abundance of roots.

B$_2$ 35–60 cm Brown (7.5YR 5/4) to dark reddish brown (5YR 3/4) silt loam with weakly developed fine nutty structure. Loose. Abundance of roots.

C + 60 cm Very pale brown (10YR 8/4) to yellowish brown (10YR 5/6) sandy loam. Massive and compact. Light grey (10YR 7/1) strongly weathered stones. Few roots.

Chemical analyses show that the lower horizon is of different material than the three upper horizons.

Profile 3. Tamansari. Altitude: 2480 m. Slope: ± 15%. Vegetation: Casuarina Junghuniana, Vaccinium-species, grasses. Mean annual air-temperature: 11.4 °C. Soil temperature: at 15 cm depth: 14.4 °C; at 70 cm: 17.3 °C.

A$_{00}$ 1–0 cm Litter.

A$_{11}$ 0–26 cm Dark grey (10YR 4/1) to black (10YR 2/1) silt loam with well developed fine to medium granular structure. Friable. Abundance of roots.

A$_{12}$ 26–33 cm Grey brown (10YR 5/2) to very dark brown (10YR 2/2) silt loam with weakly developed medium nutty structure. Very friable. Abundance of roots.

B$_1$ 33–43 cm Brown (10YR 5/3) to dark brown (7.5 YR 3/2) silt loam with weakly developed fine nutty structure. Friable. Many roots.

B$_2$ 43–55 cm Pale brown (10YR 6/3) to brown (10YR 4/3) silt loam with moderately developed fine nutty structure. Friable. Few roots.

B$_3$ 55–77 cm Very pale brown (10YR 7/4) to dark brown (7.5YR 4/4) silt loam with fine nutty structure. Friable. Few roots.

C + 77 cm Very pale brown (10YR 3/4) to brown (10YR 5/4) silt loam. Massive. Friable. Few roots.

Activity of rainworms can be noticed. The A$_{11}$ horizon consists partly of wormcasts.

Profile 4. Between Tamansari and Puntuk Papon. Altitude 2280 m. Slope: 5%. Vegetation: Quercus lineata, Casuarina junghuniana, and grasses. Mean annual air-temperature: 12.6 °C.

A$_{00}$: 2–0 cm Litter.

A$_{11}$: 0–7 cm Grey brown (10YR 5/2) to black (10YR 2/1) silt loam with well-developed crumbly to granular structure. Very friable. Abundance of roots.

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[3]) At the end of this paper.

A$_{12}$: 7–21 cm Dark grey brown (10YR 4/2) to very dark grey (10YR 4/1) silt loam with well-developed fine to medium nutty structure. Friable. Many roots.

B$_1$: 21–35 cm Dark grey brown (10YR 4/2) to very dark grey brown (10YR 3/2) silt loam. Weakly developed fine nutty structure. Friable. Many roots.

B$_2$: 35–40 cm Brown (10YR 5/3) to dark grey brown (10YR 4/2) silt loam with weakly developed fine nutty structure. Friable. Few roots.

B$_3$: 40–58 cm Light yellowish brown (10YR 6/4) to yellowish brown (10YR 5/4) silt loam with weakly developed fine nutty structure. Few roots.

C: + 58 cm Very pale brown (10YR 7/3) to yellowish brown (10YR 5/4) silt loam. Large grey (10YR 6/1) mottles (stone remains). Massive. Very few roots.

Activity of rainworms is noticeable. The A$_{11}$ consists partly of wormcasts.

Profile 5. Puntuk Papon. Altitude: 2065 m. Slope: 5%. Vegetation: Quercus lineata, Impatiens species. Mean annual air-temperature: 13.9 °C. Soil temperature: at 20 cm depth 15.6 °C; at 50 cm, 18.3 °C.

A$_{00}$ 2–0 cm Litter.

A$_{11}$ 0–13 cm Grey brown (10YR 5/2) to very dark grey brown (10YR 3/2) silt loam with well-developed fine nutty structure. Friable. Abundance of fine roots.

A$_{12}$ 13–25 cm Light brown grey (10YR 6/2) to very dark grey brown (10YR 3/2) silt loam with well-developed fine nutty structure. Friable. Abundance of roots.

B$_1$ 25–46 cm Brown (10YR 5/3) to dark brown (10YR 3/3) silt loam with weakly developed fine nutty structure. Friable. Many roots.

B$_2$ 46–63 cm Light yellowish brown (10YR 6/4) to brown (10YR 4/3) silt loam with weakly developed medium nutty structure. Friable. Few roots.

B$_3$ 63–83 cm Light yellowish brown (10YR 6/4) to brown (10YR 4/3) sandy loam with weakly developed medium nutty structure. Friable.

C$_1$ 83–114 cm Light yellowish brown (10YR 6/4) to brown (10YR 5/3) sandy loam. Massive. Large mottles (stone remains).

C$_2$ + 114 cm Very pale brown (10YR 7/4) to brown (10YR 5/4) sandy loam. Massive. Distinct large light grey (10YR 7/1) stone remnants.

Some activity of rainworms can be noticed.

Profile 6. Between Tjemorosewu and Tawangmangu. Altitude 1650 m. Slope: 10%. Vegetation: Acacia decurrens, Eupatorium species. Mean annual temperature: 16.4 °C.

A$_{00}$ 0.5–0 cm Litter.

A$_{11}$ 0–12 cm Grey brown (10YR 5/2) to very dark grey brown (10YR 3/1) silt loam with well-developed fine crumbly to nutty structure. Friable. Abundance of roots.

A$_{12}$ 12–23 cm Pale brown (10YR 6/3) to dark grey brown (10YR 4/2) silt loam with weakly developed fine nutty to irregularly platy structure. Friable. Many roots.

B$_1$ 23–43 cm Light yellowish brown (10YR 6/4) to brown (10YR 5/3) silt loam with weakly developed fine nutty structure. Friable. Many roots.

B$_2$ 43–66 cm Very pale brown (10YR 7/4) to brown (10YR 5/3 à 4/3) silt loam with weakly developed fine to medium nutty structure. Friable. Few roots.

B$_3$ 66–97 cm Very pale brown (10YR 7/4) to brownish yellow (10YR 6/6) silt loam with weakly developed medium nutty structure. Friable. Grey stone remnants present. Few roots.

C + 97 cm Very pale brown (10YR 7/4) to strong brown (7.5YR 5/6) silt loam. Light grey (7.5YR 7/0) stone remains present.

Some activity of rainworms can be noticed.

Profile 7. Punden Sekardjinggo, Tawangmangu. Altitude: 1250 m. :Slope 5%. Vegetation: tropical rainforest. Mean annual air-temperature: 18.8 °C. Soil temperature: at 20 cm depth, 19.4 °C; at 50 cm, 22.8 °C.

A_{00}	1–0	cm	Litter.
A_{11}	0–15	cm	Brown (10YR 5/2) to very dark grey brown (10YR 3/2) silt loam with well-developed medium granular to nutty structure. Consists predominantly of wormcasts. Friable. Numerous roots.
A_{12}	15–34	cm	Dark grey (10YR 4/1) to black à very dark brown (10YR 2/1 à 2/2) silt loam with well-developed fine crumbly structure. Very friable. Many roots.
B_1	34–45	cm	Brown (10YR 5/3) to dark brown (7.5YR 3/2) silt loam with weakly developed fine crumbly structure. Friable. Many roots.
B_2	45–75	cm	Pale brown (10YR 6/3) to brown (7.5YR 4/4) silt loam with well-developed fine nutty structure. Friable. Few roots.
B_3	75–114	cm	Brownish yellow (10YR 6/6) to yellowish brown (10YR 5/4) silt loam with weakly developed medium nutty structure. Friable. Few roots.
C	+ 114	cm	Very pale brown (10YR 7/3) to brown (10YR 5/3) silt loam. Massive. No roots.

The activity of rainworms is remarkable.

Profile 8. Road side Tawangmangu — Solo. Altitude: 900 m. Slope: 15%. Vegetation: Zea mays. Terraced. Mean annual air-temperature: 20.9 °C.

A_1/A_2	0–35 cm	Very pale brown (10YR 7/4) to brown (7.5YR 5/4) silt loam with weakly developed crumbly structure. Friable. Many roots.
B_1	35–60/75 cm	Light brown (7.5YR 6/4) to strong brown (7.5YR 5/6) silty clay loam with well-developed fine to medium nutty structure. Clay coatings. Friable. Few roots.
B_2	60/75–87 cm	Reddish yellow (7.5YR 7/6) to brown (7.5YR 5/4) silty clay loam with well-developed fine to medium nutty structure. Clay coatings. Friable. Few roots.
B_3	+ 87 cm	Very pale brown (10YR 7/4) to strong brown (7.5YR 5/6) silty clay loam. Massive. Reddish yellow (7.5YR 7/6) strongly weathered stones are present.

Profile 9. Karangpandan. Intersected region. Altitude: 600 m. Flat and horizontal part of a hill. Vegetation: Manihot utillissima. Mean annual air-temperature: 22.7 °C.

A_1	0–12 cm	Reddish brown (5YR 5/4 to 5YR 4/3) clay with well-developed crumbly to nutty structure. Friable. Many roots.
B_1	12–31 cm	Reddish brown (5YR 5/4 to 5YR 4/3) clay with well-developed fine nutty structure. Iron coatings. Friable. Few roots.
B_2	31–90 cm	Reddish yellow (5YR 6/6) to reddish brown (5YR 4/3) clay with well-developed medium nutty structure. Iron coatings. Friable. Termites and ants activity.
B_3	+ 90 cm	Light brown (7.5YR 6/4) to reddish brown (5YR 4/3) clay. Greyish, strongly weathered stones are present. Friable.

The analytical results of the nine profiles are tabulated in tables 6 and 7 (at the end of this paper).

5   CLASSIFICATION AND GENESIS

a   *Classification*

P r o f i l e s 1 a n d 2. Although the mineralogical composition of the various horizons of the profiles do not show great differences, it is nevertheless evident, that the profiles consists of two deposits. The stoniness, the organic matter

profile and the chemical composition of the clay fraction of profile 1 show that the upper three horizons are genetically related. The same is true for the three upper horizons of profile 2.

Profile descriptions as well as the physical and chemical analyses show that these two profiles belong to the "Brown Podzolic Soil-Group".

It is of special importance to emphasize the facts that the soil formation process has resulted in a rather strong release of iron and aluminium, that the mobilities of iron and aluminium are nearly equal, and that the C/N ratio shows a tendency to increase with depth.

P r o f i l e s 3, 4, 5, a n d 6. The composition of the sand fraction of these profiles do not show fundamental differences, nor the organic matter profile and the chemical composition of the clay. Therefore, these profiles can be used very well for classification and genetic studies.

Formerly, VAN SCHUYLENBORGH and VAN RUMMELEN (1955) proposed the name Tropical Brown Forest Soils for these soils, which is not a very suitable one. Probably, Non Calcic Brown Forest Soil is a better name for these profiles. Whether or not these soils are identical to the soils, classified by DUDAL and SUPRAPTOHARDJO (1957) as Non Calcic Brown Soils, is not known by the authors. Profile 3 seems to be an intergrade between the Brown Podzolic and Non Calcic Brown Forest Soils.

The release of iron and aluminium is less intensive than in the profiles 1 and 2, and the mobility of aluminium and iron is not very different; there is a tendency for a slightly higher mobility of iron. The C/N ratio shows a tendency to decrease with depth.

P r o f i l e 7. This profile seems tolerably autochtonous and can, therefore, be used for our considerations. The profile is different from those, situated at higher altitudes, because the pH and the C/N ratio decreases definitely with depth. Furthermore, there is a release of silicic acid, which points to a lateritic soil formation. Whether these differences have to be ascribed to the enormous rainworm-activity or to pure chemical reaction, cannot be decided to. In any case a lateritic type of soil formation is evident, whereas also characteristics of brown forest soils are present. The name Latosolic Non Calcic Brown Forest soil is proposed for this profile. This soil is quite different from the Latosolic Brown Forest soils (CLINE, 1955).

Just as in the other profiles, the mobilities of iron and aluminium are not very different.

P r o f i l e 8 a n d 9. When comparing the composition of the sand fraction of these profiles with those reported above, it seems that there is a difference in parent material. The plagioclases and volcanic glass grains have nearly completely disappeared. Quartz is present in a noticeable amount, whereas in the upper profiles only traces can be detected. Also iron concretions are more numerous. The heavy sand fraction shows a sharp decrease of augite and increase of hornblende, whereas the percentage hypersthene remains more or less constant. This may be the result of wind selection or of difference in susceptibility to weathering [4]). The latter seems more probable to the authors, although the first reason may also be of influence.

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[4]) Possibly the following sequence in susceptibility to weathering can be stated : intermediate plagioclases and volcanic glass > augite > hypersthene > green hornblende > quartz.

Both profiles show only a slight increase in clay content with depth. There is a definite release of silicic acid, indicating a lateritic soil formation. Combining these facts with the profile description, profile 8 can be classified as a Brown Latosol and profile 9 as a Reddish Brown Latosol.

It should be mentioned here, that the C/N ratio in these profiles remains more or less constant, whereas the clay's molar Al_2O_3/F_2O_3 ratio increases slightly with depth.

Field observations further showed, that the zone of Reddish Brown Latosolic soils extends to about 300 m altitude and then changes gradually into the so-called tuffaceous margalitic soils (DAMES, 1955; VAN SCHUYLENBORGH, 1958), because of the worsening drainage conditions.

Summarizing, the following belts can be recognized: A zone from 3200 to 2500 m altitude with Brown Podzolic Soils; a zone from 2500 to about 1400 m altitude with Non Calcic Brown Forest Soils; a zone from 1400 to 1000 m with Latosolic Non Calcic Brown Forest Soils and a zone from 1000 to 300 m altitude with Brown Latosolic and Reddish Brown Latosolic Soils.

Table 8   Composition of litter, roots and soil organic matter of some profiles.

Profile	C %	H %	N %	O %	C/N
3 Roots	50.88	5.87	0.56	36.71	89.58
Soil organic matter ..	53.71	5.11	3.89	31.05	13.81
4 Litter	51.44	5.87	1.72	36.54	29.94
Roots	50.89	5.90	0.93	39.58	71.62
Soil organic matter ..	55.00	4.91	4.32	31.93	12.73
5 Litter	50.41	5.95	1.38	37.27	36.50
Roots	50.04	5.85	0.65	36.78	77.52
Soil organic matter ..	53.53	5.74	4.13	33.36	12.96
6 Litter	51.22	5.84	1.89	37.23	27.14
Roots	48.52	6.04	1.10	n.d.	43.98
Soil organic matter ..	52.04	5.32	3.74	35.61	13.88
7 Litter	49.71	5.94	1.56	36.30	31.86
Roots	48.21	6.03	1.07	38.88	44.93
Soil organic matter ..	53.94	4.49	3.62	34.30	14.89
8 Roots	47.83	6.66	0.57	38.02	84.30
Soil organic matter ..	46.38	6.44	2.89	23.81	16.05

b   Origin of the soils

In an earlier paper (VAN SCHUYLENBORGH, 1958), a hypothesis was suggested for the explanation of the origin of soils under a constantly humid tropical climate. The hypothesis was based on the idea of MOHR (1922), that at higher temperatures, mineralization of the organic matter in and on the soil is more important than humification and on the statement of JOFFE (1931, 1936) that at high temperatures the rôle of organic acids in soil formation is of minor importance, because the organic acids are mineralized too rapidly. The soil forming agent would therefore be carbonic acid. Combining the effect of partial CO_2-pressures of soil air on the pH of soil moisture with the thickness of the litter-layer on the soil, various properties of the soils (such as: the pH-range of the soils, the mobility of iron and aluminium) and the origin of soils could be discussed.

11

Carbonic acid will also be an important factor in soil formation under a "monsoon"-climate. This is indicated by the quite different composition of litter and roots on the one and soil organic matter on the other hand, as is shown in table 8. The lower C/N ratio in soil organic matter indicates that a rapid decomposition to CO_2 occurs, leaving the nitrogen in the soil.

Also the high content of fulvic acids of the soils, originated under a continuously wet climate and a monsoon-climate points to the formation of carbon dioxide (table 9). The fulvic acid fraction contains various compounds such as amino acids, sugars, phenolic glycosides, polysacharides containing uronic groups (FORSYTH, 1947). Of all these compounds the uronic polysacharides constitute the greatest part (WAKSMAN and REUSZER, 1932) and the carbon dioxide production of organic matter can be attributed to these uronic substances (FULLER, 1946; WAKSMAN and REUSZER, 1932). Furthermore WHISTLER, MARTIN and HARRIS (1940, see: FULLER, 1946) showed that the liberation of CO_2 from uronic units takes place rapidly and was complete in a short time. Also the fact, that during hydrolysis of organic matter by dilute acids the uronic acids are considerably stronger destroyed compared with other soil organic compounds points to instability of the fulvic acid fraction.

Table 9   Composition of organic matter in the surface layer.

	"Constantly wet" soils (prof. 3, 4 and 5)[1]	"Monsoon" soils (prof. 1, 5, 7)
Organic matter %	31.7	33.8
relative	100.0	100.0
Fulvic acid %	20.0	28.7
relative	63.0	85.0
Humic acid %	5.2	2.0
relative	16.5	6.0
Totalactive org. acid %	25.2	30.7
relative	79.5	91.0
Insoluble fraction %	6.5	3.1
relative	20.5	9.0

When we accept the idea, that the production of carbon dioxide and the formation of carbonic acid is a very important factor in the genesis of tropical soils, then we can give several indications to explain the fact, that under a "monsoon" climate the process of laterization, with the subsequent formation of latosols, proceeds to higher altitudes than under a constantly humid climate, the parent material being similar. Firstly, table 9 shows that the fulvic acid fraction is higher under a "monsoon" — than under a humid climate, which points to the fact that less fulvic acid is broken down to carbon dioxide. Secondly, the amount of organic matter produced is lower, resulting in thinner A_{00}-horizons. Thirdly, the A_{00}-horizon is very dry during the dry season. Fourthly the rainfall is lower, so that the oxidation of organic matter will be slower. These four facts have the result, that the partial CO_2 pressure will not rise to high values, so that the medium will be less acid, which is favourable for a laterization process. In fact, the soils examined have a higher pH than those formed under a continuously wet climate. Also the very much complete absence of gibbsite and the generally lower content of iron concretions in the sand fraction of "monsoon"-soils compared with the "continu-

Table 10 Some characteristics of soils under monsoon and continuously humid climate.

Monsoon-climate

Altitude and Soil Group	pH-range	Clay Al_2O_3/Fe_2O_3	Soil C/N	sand fraction iron-concr.	sand fraction gibbsite
3200–2500 m Brown Podzolic	5–6	± to –	± to +	± to +	absent
2500–1400 m Non Calcic Brown Forest	5.5–6.5	–	–	±	traces
1400–1000 m Latosolic Non Calcic Brown Forest	7.2–7.6	± to –	–	±	traces
1000–700 m Brown Latosolic	6.6–5.5	+	±	+	absent
700–300 m Reddish Brown Latosolic	6–6.5	+	±	±	absent

Continuously humid climate

Altitude and Soil Group	pH-range	Clay Al_2O_3/Fe_2O_3	Soil C/N	sand fraction iron-concr.	sand fraction gibbsite
?–1300 m Humic Grey Brown Podz.	7–6	max. in A_2	–	+	absent
1300–1000 m Trop. Grey Brown Podz.	5.5–6	+	±	±	+
1000–600 m Acid Brown Forest	4.2–5.5	+	±	± to +	+
600–300 m Podzolized Latosolic	6	+	±	± to +	±
300–0 m Latosolic	6–6.5	–	–	±	±

+, –, and ± mean : increasing, decreasing and constant with increasing depth, respectively.

13

ously wet" soils (see table 10) points to the stronger carbonation in the latter soils.

There are, however, characteristics in the podzolic soils (to which the Non Calcic Brown Forest soils have to be considered here) under investigation, which indicate that apart from the effect of carbonic acid, another process plays a rôle. From table 10 can be concluded that the relative mobilities of iron and aluminium are unequal in the soils, developed under the two types of climate, just like the trend in the C/N-ratio of the soil.

Comparing the clay molar Al_2O_3/Fe_2O_3-ratios with the soil C/N-ratios, then it strikes that a constant C/N-ratio coincides with an increasing Al_2O_3/Fe_2O_3-ratio, whereas a decreasing C/N-ratio coincides with a decreasing Al_2O_3/Fe_2O_3-ratio. The first phenomenon was already discussed (VAN SCHUYLENBORGH, 1958). The second is most commonly encountered in the podzolic soils of temperate humid climates (see: ANDERSON and BYERS, 1934). A with depth decreasing C/N-ratio can indicate, that humification of the organic matter is more important than pure oxidation; in other words, organic acids are here a more important soil forming factor than carbonic acid. The effect of organic acids on soil formation, and especially on the release and leaching down of iron and aluminium, is sufficiently discussed by several authors (e.g. AARNIO, 1913; JONES and WILLCOX, 1929; GALLAGHER, 1942; BLOOMFIELD, 1953, 1954). All their work point to the fact, that both iron and aluminium form complexes with humic acid. The iron complexes, however, are more soluble than the aluminium complexes and this leads to a decrease of the molar Al_2O_3/Fe_2O_3-ratio of the clay in the lower horizons.

Now, the conditions at higher altitudes (lower temperature) in the tropics, combined with the lower rainfall, approach the conditions of a temperate humid climate, resulting in a less rapid decomposition of the organic matter, so that the organic acids formed can effect soil formation. In other words, besides the development of CO_2, formed by mineralization of organic matter, humic acids have a chance to influence soil formation. It will depend on the relative amount and effectiveness of both, which compound bears most to the process of soil formation. In our case of monsoon climates, it appears that at altitudes higher than 1000 m the effect of organic acids is stronger than that of carbonic acid.

At altitudes above 2500 m a different trend can be noticed in the "monsoon"-soils. Here the C/N-ratio tends to increase with depth whereas the Al_2O_3/Fe_2O_3-ratio of clay tends to decrease. This approaches the data found by the authors in true Podzols, originated in the tropics. In table 11 the average C/N-ratio's of three Podzol-profiles are shown, together with the figures of the Brown Podzolic Soils.

Table 11   The C/N-ratio and clay Al_2O_3/Fe_2O_3-ratio in Podzols and Brown Podzolic Soils.

		C/N	Al_2O_3/Fe_2O_3
Podzol :	A_1	17.2	4.00
	A_2	19.2	6.83
	B_1	24.6	11.82
	B_2	25.3	6.69
Brown Podzolic :	A_1	18.8	1.86
	B_1	16.9	1.75
	B_2	21.4	1.67

Probably this peculiarity can be explained by supposing that a humification process only occurs in the surface layers of the soil. The possibility then exists that some of these humic acids percolate through the soil, carrying down relatively more iron than aluminium.

Another difference between the "monsoon"- and "constantly wet"-soils is the stronger release of sesquioxides or relative higher enrichment of silicic acid in the latter soils (see table 12) at comparable altitudes. This may be the result of the stronger carbonation in the soils of the very humid climate, but it is also possible that the vegetation plays a rôle. The silica-content of the litters is high, but different (viz. 3.0 % for the "monsoon"-soils and 3.6 % for the "humid"-soils). When taking into account the fact, that in the monsoon-climates smaller amounts of leaves and twigs are falling, it is obvious, that the supply with silica of the surface layers of the soil is distinctly smaller in the „monsoon"-soils than in the "humid"-soils.

Table 12 SiO_2/R_2O_3-ratio of the soils.

Horizon	"Humid" soils		"Monsoon" soils
	Grey Brown Podzolic	Acid Brown Forest	Non Calcic Brown Forest
A_1	1.62	1.61	1.22
A_2	1.02	—	—
B_1	0.95	1.35	1.10
B_2	0.94	1.30	1.04

Finally the fact should be discussed, that no of only slight migration of clay occurs, whereas in the soils, developed under a continuously humid climate, clay migration can be noticed in all soils with a pH level higher than 5 (with the exception of the latosolic soils). The migration of clay in the "humid"-soils was based on the constantly downward movement of rainwater, on the pH level of the soils, and on the presence of aluminium hydroxide in the clay fraction (VAN SCHUYLENBORGH, 1958). Under a monsoon-climate, however, the downward movement of water is far less intensive, so that the chance for a carrying down of clay particles with the rainwater is very small. Furthermore the clay fraction differs in so far that hydrargyllite could not be detected. The electrokinetic properties of the clay particles of the "monsoon"-soils will therefore be different. Finally the relatively low leaching of the soil results in a base-saturated clay complex, so that the electrokinetic potential will be small. The soils are therefore in a flocculated state and, consequently, the clay particles are fairly immobile.

c   The organic matter in the soils

There are indications, as discussed in the preceding pages, that the organic matter in the soils, developed under the two types of climatic conditions, have a different composition. To gather more information about this, the organic matter of the soils was extracted, as already reported in § 2, and analysed with respect to their C, H, O, and N content. Included were soils, formed under a dry climate.

The soils developed under a dry climate were taken from the old volcano Baluran in the extreme East of Java. The rainfall at locations immediately

West and South of this volcano are given in table 13 (see: BERLAGE, 1949). This table shows that the climate is much drier than in the Eastern Part of Central Java.

Table 13 Rainfall at locations West and South of the Baluran-volcano.

Location	Jan.	Febr.	Mrch.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Djanghar	297	229	172	103	74	44	40	2	1	12	38	151	1163
Perceel (Sf. Assem-													
bagoes	272	228	149	104	92	38	25	2	3	18	32	146	1109
Sumberwaroe	280	240	200	139	67	50	24	3	5	8	39	191	1246
Badjulmati	279	265	240	131	122	75	31	11	3	12	53	176	1400
Alai Boeloeh	257	221	194	119	88	82	36	9	6	10	46	166	1234

The results of the analyses are represented in tables 14 and 15. Considering the data of table 14, it can be concluded, that, in an extremely wet climate, the C-content of the organic matter is less at lower than at higher altitudes; the same appears to be true with relation to the N-content. This indicates that the ammonification and nitrification, or generally the mineralization process, is most intense at low altitudes (high temperature), which is quite understandable. There is a tendency that at low altitudes the C/N-ratio is largest; this supports the conclusion, that the mineralization is highest at high temperatures.

Under a moderately wet, monsoon, climate, it appears, that the C-content is fairly constant at higher altitudes and is lower at altitudes below 1000 m. Here too, the N-content tends to decrease, with decreasing altitude, whereas the C/N-ratio increases, which points to the same conclusion with respect to the mineralization process. As a whole the C-content as well as the C/N-ratio is on a higher level than under extremely wet conditions, possibly indicating that different types of organic matter are present under these climates. This would support our views with respect to the different soil forming process.

The C-content as well as the N-content of the organic matter in soils, formed under a dry, monsoon, climate differ not much with altitude, although there is a slight tendency that both decrease with decreasing altitude. There are only slight differences in the C-content and C/N-ratios of the organic matter, formed under both monsoon climates.

Table 15 Comparison of soil- and organic matter C/N-ratio.

Extremely wet					Moderately wet, monsoon					Dry, monsoon				
Altitude (metres)	org. matter		soil		Altitude (metres)	org. matter		soil		Altitude (metres)	org. matter		soil	
	trend [1]	mean value	trend [1]	mean value		trend [1]	mean value	trend [1]	mean value		trend [1]	mean value	trend [1]	mean value
? 1300	−	10.69	−	8.69	2500—1400	±	14.05	−	18.24	1250—1000	+	15.02	−	13.12
1300—1000	−	12.77	±	13.64	1400—1000	±	15.12	−	20.93	1000	+	13.87	−	10.45
1000— 600	−	12.56	±	16.80	1000— 350	±	16.22	±	11.28	600	+	15.22	−	8.56
600— 300	−	13.82	±	10.18										
300— 0	+	22.39	±	8.76										

[1] +, −, and ± indicate increasing, decreasing, and constant with depth in the profile, respectively.

Table 14 Composition of the organic matter fraction of various soils.

Extremely wet climate

Soil group and altitude		C	H	N	O	C/N
> 1300 m Humie Grey Brown Podz.	A₁₁	52.34	5.13	3.56	37.22	14.69
	A₁₂	52.66	4.78	4.16	37.53	12.65
	B₁	50.01	5.32	4.80	34.96	10.42
	B₂	50.51	5.06	4.32	27.56	11.70
	A₁₁	48.73	5.00	4.61	40.57	10.56
	A₁₂	47.41	4.90	4.98	41.45	9.52
	B₁	47.50	5.51	5.94	41.45	7.99
	B₂	45.72	5.15	5.70	39.99	8.02
1300–1000 m Trop. Grey Brown Podzolic	A₁	52.31	4.52	3.28	n.d.	15.93
	A₂	54.07	5.43	4.07	35.14	13.30
	B₁	52.05	4.95	4.24	34.79	12.28
	B₂	50.70	5.36	4.72	34.00	10.74
	C	53.01	6.20	4.56	34.31	11.62
1000–600 m Acid Brown Forest	A₁₁	49.09	5.69	3.67	39.44	13.39
	A₁₂	47.45	6.17	4.01	39.76	11.82
	B₁	48.01	5.42	3.86	36.75	12.47
600–300 m Podzolized Latosol	A₁	44.38	6.30	2.84	36.66	15.64
	B₁	44.88	6.54	3.74	38.55	12.00
300–0 m Latosol	A₁₁	44.43	7.65	2.14	37.96	20.72
	A₁₂	34.37	8.02	1.43	33.14	24.06

Moderately wet (monsoon) climate

Soil group and altitude		C	H	N	O	C/N
2600–1400 m Non calcic Brown Forest	A₁₁	55.80	4.41	4.07	31.62	13.72
	A₁₂	53.86	3.80	3.37	30.41	15.97
	B₁	55.51	4.16	6.06	31.52	9.17
	B₂	53.65	5.71	3.64	31.09	14.74
	B₃	52.56	6.22	3.59	n.d.	14.66
	C	50.91	6.37	2.60	30.60	19.56
	A₁₁	54.50	4.90	4.97	30.85	10.96
	A₁₂	54.58	4.87	4.93	32.43	11.08
	B₁	54.96	4.65	5.29	30.81	10.39
	B₂	55.70	4.47	4.90	n.d.	11.38
	B₃	53.78	5.29	3.51	33.32	15.34
	C	56.51	5.25	2.33	32.24	24.29
	A₁₁	53.85	5.37	4.81	32.24	11.20
	A₁₂	52.54	5.03	5.05	32.55	10.41
	B₁	51.56	4.81	4.97	31.96	10.76
	B₂	51.87	5.61	3.55	34.26	14.60
	B₃	52.64	6.47	2.58	35.28	20.43
	C	58.63	7.13	3.83	33.86	15.31
1400–1000 m Lat. Non Calc. Brown Forest	A₁₁	54.35	4.50	4.04	34.85	13.45
	A₁₂	52.98	4.49	4.27	35.01	12.41
	B₁	50.04	5.68	3.10	38.27	16.14
	B₂	50.79	6.61	3.57	34.92	14.17
	A₁₁	52.85	4.47	3.34	36.23	15.82
	A₁₂	57.75	4.23	3.42	32.13	16.87
	B₁	53.55	4.46	3.95	33.48	13.58
	B₂	53.81	4.48	3.78	34.31	14.23
	B₃	52.56	n.d.	n.d.	n.d.	–
	C	53.13	4.82	n.d.	35.36	–
1000–700 m Brown Latosol	A₁	47.38	6.29	3.18	24.54	14.89
	B₁	45.37	6.58	2.59	23.08	17.54

Dry (monsoon) climate

Soil group and altitude		C	H	N	O	C/N
1250 m	A₁	53.40	4.64	3.77	34.61	14.17
	B₁	52.46	4.61	4.10	31.75	12.78
	B₂	50.52	5.94	3.19	26.95	15.84
	B₃	52.19	6.50	3.14	26.70	16.63
	A₁	52.49	4.60	3.89	33.60	13.48
	B₁	49.29	5.34	3.95	32.03	12.49
	B₂	49.43	5.22	3.28	30.44	15.08
	B₃	47.13	5.44	2.39	25.85	19.72
1000 m	A₁₁	51.73	5.11	3.81	32.55	13.59
	A₁₂	50.22	5.25	4.00	28.99	12.57
	B₁	46.88	6.54	3.04	25.30	15.44
600 m	A₁	50.76	5.50	3.80	30.24	13.34
	B₁	46.06	6.15	2.69	24.41	17.10

It appears from table 15 that the C/N-ratio of the organic matter and of the soil is always different, the differences being greater at lower altitudes generally. It is quite understandable that there must be a difference, since the N-determination in the soil includes all N-forms, inorganic as well as organic. The great difference between soil-C/N and organic matter-C/N at low altitudes indicates that here much nitrogen is present as ammonia.

It is striking that, generally, a with depth decreasing organic matter C/N-ratio coincides with a constant soil-C/N-ratio (under the extremely wet conditions), whereas a constant or increasing organic matter C/N-ratio coincides with a decreasing soil C/N-ratio (under the monsoon climates). Whether or not this peculiarity has any significance for the soil forming process cannot be concluded. More work, especially on the identification of the organic compounds, is necessary to permit any conclusions.

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Table 6   Mineralogical composition of the total and heavy sandfraction of the profiles.

| Profile, horizon and percentage sand | andesine and labradorite | green hornblende | hypersthene | augite | volcanic glass pumice fragments | opaque | gibbsite | iron concretion | rock fragments | miscellaneous | heavy sand fraction ||||||
| | | | | | | | | | | | opaque | mutual percentage of transparent minerals |||||
												green hornblende	hypersthene	augite	olivine	epidote
1 A₁ : 29.7	83	1	3	4	25	5	—	2	20	7	14	3	44	52	1	—
B₁ : 37.4	10	1	4	4	26	2	—	2	22	29	21	11	44	44	1	—
B₂ : 41.7	13	tr	3	4	26	1	—	1	26	26	17	6	45	49	tr	—
A₁b : 29.9	14	—	4	5	29	5	—	4	24	15	20	2	43	55	—	—
2 A₁ : 29.4	19	tr	3	7	31	1	—	2	33	4	29	5	43	52	—	—
B₁ : 34.3	11	tr	3	4	27	3	—	3	40	9	30	4	39	57	—	—
B₂ : 38.0	10	tr	3	6	24	1	tr	4	38	14	24	3	37	60	—	—
C : 68.0	9	—	1	3	21	1	tr	tr	52	13	29	2	36	62	—	—
3 A₁₁ : 22.3	22	2	4	6	46	7	tr	2	8	2	14	8	42	49	1	—
A₁₂ : 6.3	6	1	4	5	63	8	—	3	7	1	17	6	52	42	—	—
B₁ : 28.1	10	2	4	4	55	6	tr	3	14	2	31	tr	66	34	—	—
B₂ : 26.2	13	tr	3	3	46	1	1	1	23	9	16	4	45	50	tr	—
B₃ : 29.3	11	tr	3	3	43	1	tr	1	30	8	13	3	35	62	—	—
C : 33.0	11	tr	2	5	40	1	—	1	31	9	35	3	48	49	—	—
4 A₁₁ : 24.2	21	tr	9	4	39	3	tr	1	21	1	31	6	45	48	—	—
A₁₂ : 24.8	22	1	5	7	39	6	1	2	17	3	27	6	52	42	—	—
B₁ : 22.0	13	1	5	7	40	3	tr	2	27	2	35	7	55	38	—	—
B₂ : 19.7	12	2	5	5	39	4	tr	2	26	5 ·	24	7	49	43	—	—
B₃ : 22.3	11	2	5	7	44	2	tr	tr	26	3	3	6	30	64	—	—
C : 19.5	11	1	3	7	40	2	tr	1	30	5	32	10	27	62	—	—
5 A₁₁ : 22.4	34	tr	3	5	39	5	—	—	11	3	27	5	57	37	—	—
A₁₂ : 22.0	23	1	4	4	51	3	tr	—	12	2	11	7	51	41	—	—
B₁ : 40.1	15	2	5	2	55	2	—	—	9	10	63	7	51	42	—	—
B₂ : 44.1	11	tr	2	4	19	tr	—	—	5	59	30	10	49	40	—	—
B₃ : 55.9	6	tr	2	2	13	1	—	—	6	70	18	18	40	41	—	1
C₁ : 60.9	5	1	1	1	14	2	—	—	10	66	31	22	39	37	tr	1
C₂ : 53.9	8	2	1	3	32	2	—	—	9	43	28	24	39	35	tr	—
6 A₁₁ :	25	1	6	6	24	2	—	1	32	3	31	12	49	39	tr	—
A₁₂ : 24.2	25	tr	6	5	25	1	—	1	30	7	33	12	50	37	tr	—
B₁ : 27.2	26	1	5	5	22	2	—	tr	35	4	24	9	48	41	2	—
B₂ : 16.6	27	2	7	6	19	3	—	tr	16	19	35	11	56	33	tr	—
B₃ : 18.3	15	3	7	7	30	5	tr	2	9	22	23	11	54	32	1	1
C : 18.2	8	tr	7	8	41	3	tr	2	10	21	22	11	48	39	—	1
7 A₁₁ : 12.0	36	1	6	3	25	3	tr	1	20	4	24	9	49	42	—	—
A₁₂ : 16.1	37	tr	6	6	24	3	—	1	17	5	17	6	50	43	1	—
B₁ : 18.5	27	tr	5	5	25	2	tr	tr	24	12	20	9	49	41	1	—
B₂ : 17.3	33	1	3	6	26	2	—	tr	22	7	22	20	42	38	—	—
B₃ : 15.9	17	1	6	8	33	1	—	1	21	12	26	3	42	55	—	—
C : 29.4	16	1	4	6	37	2	tr	tr	30	4	14	5	51	44	—	—
8¹) A₁ : 17.7	7	3	4	3	6	39	—	2	1	33	73	36	40*	22	—	—
B₁ : 11.5	3	2	5	2	3	28	—	2	2	51	94	21	58	20	—	—
B₂ : 5.5	tr	tr	1	tr	tr	53	—	5	tr	39	94	19	58	14	—	—
B₃ : 7.9	tr	—	—	1	1	34	—	5	tr	58	99	21	51	16	—	—
9²) A₁ : 9.6	4	1	1	1	4	22	—	7	3	52	99	27	38	28	—	—
B₂ : 4.5	1	5	1	1	3	34	—	6	1	41	93	58	26	12	—	—
B₂ : 4.7	tr	2	tr	tr	3	21	—	6	1	61	100	61	25	11	—	—
B₃ : 4.1	1	4	1	tr	4	30	—	6	1	45	84	36	37	25	—	—

¹)   The heavy sand fractions contain also : —, 1, 8, 7 % corundum respectively.
²)   The total sand fractions contain respectively 3, 7, 5, and 4 % quartz. The heavy sand fraction : 1,1, tr, tr corundum and 6, tr, 1,2 as. amphibole respectively.

Table 7 Physical and chemical composition of the profiles.

Profile		Mech. composition			pH	Organic matter % C	Nitrogen % N	C/N	Chemical composition of clay			
		>50μ %	50-2μ %	<2μ %					SiO_2/R_2O_3	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	Al_2O_3/Fe_2O_3
1	A_1	29.7	33.3	8.8	5.43—5.58	13.5	0.77	17.7	3.37	4.98	10.40	2.09
	B_1	37.4	36.1	10.6	5.65—5.87	9.53	0.59	16.1	1.49	2.31	4.16	1.80
	B_2	41.7	41.3	8.7	5.75—6.13	10.1	0.45	22.2	1.37	2.20	3.61	1.64
	A_{1b}	29.9	59.2	4.5	5.72—6.02	10.6	0.52	20.4	1.12	1.44	4.94	3.97
2	A_1	29.4	50.4	6.5	5.44—5.84	10.5	0.53	19.8	1.96	3.16	5.14	1.63
	B_1	34.3	55.1	6.2	5.65—6.05	6.14	0.33	17.7	1.65	2.62	4.45	1.70
	B_2	38.1	50.9	5.4	5.72—6.08	5.20	0.26	20.7	1.49	2.37	4.02	1.70
	C	67.0	25.3	5.2	5.64—5.83	3.05	0.09	33.9	1.21	1.42	8.03	5.64
3	A_{11}	22.3	39.7	10.0	5.12—5.22	13.0	0.82	15.9	2.89	5.27	6.38	1.20
	A_{12}	25.2	42.0	7.6	4.92—5.06	11.6	0.86	13.5	—	—	—	—
	B_1	28.1	57.0	6.0	5.24—5.41	7.16	0.41	17.7	1.40	2.20	3.60	1.58
	B_2	26.2	59.3	6.5	5.47—5.65	8.80	0.40	22.2	—	—	—	—
	B_3	29.3	58.6	8.9	5.46—5.58	7.51	0.33	22.6	1.01	1.23	5.54	4.51
	C	33.0	58.8	6.7	5.48—5.56	6.44	0.27	24.0	1.09	1.32	7.35	5.58
4	A_{11}	24.2	44.9	8.8	5.48—5.54	23.0	0.94	24.6	1.23	1.58	5.66	3.60
	A_{12}	24.8	44.2	8.9	5.36—5.54	21.8	0.93	22.7	—	—	—	—
	B_1	22.0	52.1	8.2	5.30—5.65	16.7	0.85	19.6	1.11	1.45	4.75	3.27
	B_2	19.7	59.8	7.3	5.28—5.58	15.0	0.74	20.3	—	—	—	—
	B_3	22.3	67.6	7.6	5.20—5.55	8.3	0.36	23.2	1.00	1.16	7.30	6.30
	C	19.5	53.5	9.8	5.39—5.46	3.8	0.15	25.5	1.13	1.34	6.72	5.01
5	A_{11}	22.4	61.0	19.4	5.46—5.81	20.6	0.85	24.2	1.22	1.41	8.88	6.29
	A_{12}	22.0	66.1	17.0	4.93—5.64	15.7	0.68	23.0	—	—	—	—
	B_1	40.0	52.5	8.2	5.46—5.91	10.4	0.43	24.2	1.14	1.33	8.06	6.07
	B_2	44.1	52.9	8.2	5.76—6.08	6.64	0.51	12.9	—	—	—	—
	B_3	55.9	42.2	3.2	5.77—6.06	4.87	0.31	15.9	1.11	1.33	6.68	5.03
	C_1	60.9	36.2	4.3	5.84—6.00	4.92	0.22	20.5	—	—	—	—
	C_2	53.9	27.9	4.8	5.88—6.09	3.32	0.19	17.6	1.18	1.35	6.33	4.69
6	A_{11}	—	—	—	5.63—5.98	9.92	0.74	13.4	1.21	1.39	8.77	6.31
	A_{12}	24.3	49.7	13.8	5.59—6.44	7.82	0.63	12.4	—	—	—	—
	B_1	27.2	60.0	7.2	5.96—6.53	5.14	0.47	11.1	1.04	1.24	6.39	5.18
	B_2	16.6	71.4	9.5	6.31—6.54	3.84	0.41	9.4	—	—	—	—
	B_3	18.3	78.2	7.3	6.32—6.38	2.55	0.25	10.3	1.00	1.18	5.92	4.95
	C	18.2	77.9	6.7	6.25—6.62	2.18	0.23	9.4	1.07	1.31	5.74	4.39
7	A_{11}	12.0	58.1	8.9	6.62—7.08	20.00	0.86	23.2	1.23	1.42	9.05	6.39
	A_{12}	16.1	57.6	12.4	6.62—7.15	15.8	0.62	25.4	1.26	1.48	9.02	6.10
	B_1	18.5	62.0	12.5	6.54—6.94	9.95	0.55	18.0	1.32	1.54	9.01	6.36
	B_2	17.3	66.5	11.0	6.48—6.66	8.25	0.48	17.1	—	—	—	—
	B_3	15.9	72.1	9.5	6.21—6.53	5.73	0.33	17.3	1.17	1.37	7.98	5.80
	C	29.9	61.2	19.0	6.28—6.18	3.07	0.13	24.6	1.14	1.34	8.46	6.35
8	A_1	17.7	60.4	29.3	6.62—6.64	1.38	0.10	14.2	1.92	2.26	12.55	5.67
	B_1	11.5	56.7	32.1	6.14—6.43	0.62	0.10	6.3	1.93	2.29	12.14	5.57
	B_2	5.5	61.5	34.9	5.68—5.79	0.41	0.04	11.4	1.98	2.31	13.82	6.11
	B_3	7.9	58.1	33.3	5.23—5.54	0.21	0.03	6.6	2.02	2.36	13.74	5.82
9	A_1	9.6	25.3	63.5	5.61—5.92	1.56	0.12	13.3	1.58	1.89	9.70	5.14
	B_1	4.5	21.0	72.9	5.80—6.07	0.95	0.07	12.8	1.63	1.93	10.26	5.31
	B_2	4.7	15.2	73.6	5.96—6.00	0.86	0.07	12.8	1.67	1.97	11.12	5.66
	B_3	4.1	20.8	67.3	5.89—6.76	0.82	0.06	12.8	1.73	2.03	11.82	5.82