

A CENTURY OF SOIL SCIENCE IN INDONESIA*)

by

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Introduction

A time comes when it is advantageous to take stock of the results acquired in a branch of science after a long period of activity. The centenary of the Royal Science Society at Batavia offers a good occasion for reflecting on the development of interest in the soil as the most important source of life and culture. In this connection culture must be understood in its widest sense as the history of many parts of the world teaches that, whenever the soil as a producing substratum deteriorates or becomes removed, every civilisation inevitably disappears.

The historical review given in the following pages has been divided into 2 sections in order to promote a better understanding of the interrelationship between the several stages of development. The first section contains a discussion of the problems relating to the natural fertility of Indonesian soils; in the second attention is focussed on the problems of soil conservation. It will be seen that the interest for both aspects of soil science is as old as the Royal Science Society itself.

I. The development of interest in and understanding of the problems of soil fertility.

The oldest paper in which the possibility of increasing the yield of tropical crops is discussed was published in 1854 in the Proceedings of the Royal Science Society, by Dr. Fromberg (1). ***) This author gives a review of the use of guano based on the application of this fertilizer in Great Britain as early as 1840. Fromberg reported that he laid out an experimental plot near Buitenzorg in June 1852 on which he studied the influence of guano on the yield of tobacco. A series of parallel experiments were carried out simultaneously in order to compare the effect of carbonate, water buffalo manure, charred bones, horse manure, and no manure or fertilizer at all. From the results he formulates practical suggestions which indicate a real understanding of the problem. It is pointed out that climate and differences of crop and soil must be taken into consideration, as well with regard to exhaustion or deficiency as to the soil's physical conditions.

Four years later the same investigator (2) reports on the results of fertilizing of coffee trees with guano and other fertilizers in the experimental garden at Genteng. In this case again the effect of guano is compared with that of the above mentioned manures, while the influence of wood ash is also investigated. It is interesting that the latter material has a much better effect than guano; wood ash fertilizer is more stimulating than any of the other compounds. The experiment was carried out with trees of different ages and from the results it appears that other factors influence the yield of coffee, namely the exposure to strong and dry southern winds.

In the same year Fromberg (3) publishes the results of a comparative chemical study of two sugarcane soils from Krawang which, as the author states, are very well suited to demonstrate what a soil needs in order to carry a profitable sugar crop. The soils investigated were totally exhausted owing to 30 years of continuous cultivation; the administrator of the plantation had, however, even that long ago, the sound idea of sending

in soil samples for analysis and advice. In the Laboratory in Buitenzorg both physical properties and mineral content were examined.

Finally Fromberg (4) in 1859 stressed the necessity of fertilizing, especially with regard to the composition of guano and peanut cakes for the supply of phosphoric acid and ammonia.

At the same time Rost van Tonningen (5) published an elaborate chemical and physical study of 50 sugarcane soils of the residency of Pasuruan. This paper also shows a sound understanding of the problem, and this is of more importance than the practical results of the work carried out. The author states that „the aim of the practical farmer is to produce the largest quantity of the most sought-after products from a certain soil area, and to do this with the least cost in the shortest possible time and with the least harm to the soil”. Rost van Tonningen adds that the proper knowledge — and this will always be true — can only be gained by study and research.

In 1863 the Journal of the Science Society contained a report on the chemical research of 39 samples of water of different origin used for the irrigation of rice fields in the Pekalongan Residency. The investigations published by Scharlée (6) were carried out on account of a disease in paddy supposedly caused by the quality of this irrigation water. Water of non-infected rice fields is compared with that of fields infected with omo-mentik or omo-ampeg. The conclusion of the investigation was that the quality of irrigation-water had nothing at all to do with the disease.

In this first period of agricultural research, a clear understanding of the problems of fertilizing was by no means generally evident. In 1866 Holle (7) criticized the contribution of de Sturler on the growth and treatment of coffee. The latter maintained that manure has a disastrous influence on the taste of coffee and he reports a 9-years-old experience that extensive plantations in Kedu have deteriorated owing to „the artificial stimulation of the coffee tree”.

Furthermore de Sturler gives the following rather dangerous comment: „also most soils, especially in Java and in particular on the forest covered mountain slopes, have a sufficient layer of steadily rejuvenated topsoil to carry prolific coffee crops. To these soils notably organic matter mixed with some animal dung is added from the higher mountain regions owing to superfluous rains. These prevent the exhaustion of the soil”.

Especially this statement is criticized by Holle. The cause of de Sturler's misconception is to be found in the set-up of the fertilizer experiments. A rather deep trench was dug around the trees and large quantities of fresh buffalo dung were brought into this gully so that the trees were choked in the dung.

In 1873 van Hall (8) shows a refreshing outlook on the problem of soil fertility. From several publications of the same year it may be concluded that the duties of this official concerned problems of terracing, fish and paddy culture. On 8 September 1872 a „Guide for experiments with paddy” was published. Herein we find a very interesting chapter on „the exhaustion of the soil” from which it may be concluded that the author had very thoroughly studied Adolf Mayer's „Lehrbuch der Agrikulturchemie”. Apart from the technical insight which van Hall seems

*) This article has also appeared in „Honderd jaren Natuurwetenschap” (A century of natural sciences), published by the Royal Physical Society to commemorate its centenary (19 th. July 1950).

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***) See list of references, p. 11.

to have mastered, it is the outspoken feeling of responsibility of this official for the welfare of the native population which is heartwarming. His experiences all point to a steady decrease in the productive capacity of the soil. The means proposed by him to stop further deterioration, as accepted by the native population, are in the first place agricultural improvements. However, in this report, he also points to the core of the problem, viz., the communal possession of the soil. As long as this remains the custom, no agricultural community consisting of individual landowners can develop and only under such a community can further deterioration and exhaustion be prevented, whereby ultimately the greatest evil inseparably linked with communal possession is eliminated, i.e., the nearly absolute power, the almost royal position of the dessa chieftains.

In the meantime the problems of fertilizing the European owned plantations began to get more proper attention. This arose from a favourite topic launched in 1875 by the Board of the Netherlands Indian Agricultural Society. The willingness of the planters to exchange experiences, however, was rather small. Nevertheless the action of the Society is worth mentioning as one can read in the reports both of successes and of failures, both of which help to increase knowledge of the problem (9).

In 1878 this Society organized the third Agricultural Congress. In its 4 sections we find no less than 86 subjects put forward for discussion, covering the whole field of tropical agriculture. The subject which at the moment interests us most is the first of section I, General Agriculture and Animal Husbandry:

"Which soils of the Netherlands Indies are of the highest quality? Which are the favorable and unfavorable properties of clay, sand, and loam soils in relation to the tropical climate and periodical monsoons? What means are to be advocated to neutralize the unfavorable properties of the soils mentioned and to change these into more suitable and favorable ones? Which components of the topsoil of Java are in general deficient so that fertilizing is to be considered a necessity?"

This subject was reported on by van der Ploeg (10), who was rewarded for his essay with the gold medal of the Society. It is not known whether more treatises were sent in, but the present author cannot help having the impression that, even in 1878, there must have been people who could have written a much better contribution than the above mentioned treatise of van der Ploeg. This is of less importance than the fact that, as may be concluded from the questions listed above, attention began to be focussed on the soil and its problems, and that an endeavour was made to handle the latter scientifically. This is also indicated by a paper of van Soest (11) who in 1879 reported on the relationship between tillage and fertilizing and who warns, for sound reasons, against tilling too deep.

The years now passed without notable activities in the field of soil science until, in 1889, the world famous Dutch soil chemist Prof. Dr. J. M. van Bemmelen of Leyden started to take an interest in the soils of the Netherlands Indies. In that year he published detailed chemical analyses of tobacco soils of Deli, Malang and Rembang, the first two being volcanic soils, the third a river clay (12). He was especially interested in the phenomenon of the deterioration of the Rembang soils, which formerly carried a very good crop but in 1889 produced only a very low-grade tobacco. In this paper we find, probably, the oldest soil mineralogical observations on Javanese soils. The decline in tobacco yields however, could not be explained.

It is worth mentioning that van Bemmelen compares the results of his analysis with those of Dutch soils. He finds an interesting concordance between the alluvial river soil of Rembang and the river clay of the river Y near Amsterdam, whereas the high-grade tobacco soils of Deli and Malang, mutually alike with regard to content of

colloidal silica and composition of the weathering silicate are of a distinctly different type (13).

In a concluding paper van Bemmelen once more discusses thoroughly this very urgent problem of deterioration of the quality of the tobacco crops. He analyses the chemical composition of the leaves, takes climatic influences into consideration, and, in short, he studies the whole complex of intricate problems in a very scientific manner. His concluding statement is that the structure and content of organic matter of the original forest soil, probably together with the type of the weathering silicate, characterize the good tobacco soil. However, it should be the task of a special experiment station to be founded in Deli to carry out the scientific investigations relative to tobacco culture: „unter der Leitung eines tüchtigen Agrikulturchemikers, der schon durch frühere Arbeiten bewiesen hat, dass er wissenschaftlichen Fragen zu bearbeiten und zu lösen versteht. Er muss jedoch ganz frei arbeiten und nicht verpflichtet werden in bestimmter Zeit neue Entdeckungen zu machen, oder vorteilbringende Resultate zu erhalten- auf die Gefahr hin, dass die Station sonst aufgehoben wird!" (14).

In 1893 the well-known forester S. M. Koorders (15) drew attention to the new ideas, developed in Germany, concerning the importance of the natural plantgrowth as an indication of the fertility of forest soils. He points out how little is known of the demands of wild plants in the tropics with regard to soil and climate (see also van Steenis (16, pag. 58) on the relative state of our knowledge in 1935!)

Chemical research slowly received more attention. The sugarcane soils were subjected to thorough research by the Experiment Station „Oost-Java" founded especially for this purpose.

In 1893 Kramer (17) takes the viewpoint that science should aim specifically at solving the problem of getting the highest yields from any given soil. Together with specialized biological studies of sugarcane, adequate investigations of the soil should also be carried out. He published in the same year the results for many soils, stating that earlier investigations did not reveal any relationship between soil components and sugar yield. Kramer was convinced that the physical properties are the more important, the better structure being indicated by the higher content of organic matter. Sandy soils without an appreciable amount of humus produce as good yields as heavy clay soils that owe a good structure to an adequate content of organic matter.

The same scientist communicates the first results of research in Indonesia on the possible influence of minor elements on plant diseases, in this special case of copper on the sereh disease of sugarcane (18). Although the results were negative, the investigations indicate an increased scientific interest in the problems related to the plant-soil system.

The findings of Winter (19, 20) in 1896 with regard to aluminium sulphate and ferrous oxide are similar contributions. Kobus (21) in 1896 reported on the enormous increase in the sugarcane industry as a result of the application of commercial fertilizer. He describes the systematic fertilizer experiments with ammonium sulphate on several soil types on different plantations. The steadily increasing realisation that an adequate supply of plant nutrients is indispensable for a constant or higher production leads, however, also to an overestimation of the practical applicability of scientific findings.

In 1897 Tromp de Haas (22) discussed the totality of production factors which dominate the growth process. He pointed out that the economics of fertilizing cannot be concluded from purely scientific considerations. Also one should not exclusively follow the so called „law of full restitution".

The basic growth of scientific understanding and factual knowledge on the part of those directly or indirectly connected with agricultural production will be clear

after a comparison of van der Ploeg's prize essay of 1878 and the treatise of van Lookeren Campagne (23) delivered at the first congress of the Sugar Growers' Syndicate of Java in 1898 on the genesis, composition and properties of the soils of Java. The importance of volcanism for soil genesis is emphasized. The European planter also seems to have benefited by the outstanding work of Verbeek and Fennema on the geology of Java. Chemical analysis of fresh volcanic ash of wet and dry rice soils and, no less, the considerations concerning organic matter and physical properties are equally indications of the prevailing scientific research into the problem of soil fertility.

A modern vision is also exhibited by Steevens (24) in his paper on the improvement of the soil with sugarcane nutrients. He states, e.g., that a sound fertilizing practice is not only concerned with the application of plant food to the soil but also with stimulating the functions of the plant for the mobilization of the natural plant food resources.

In this same period van Bijlert (25) published a series of very thorough, and, even today, valuable papers on the soils of Deli. The first regional survey of the tobacco soils of Deli was issued in 1898 as a „Short Communication of the Botanic Gardens”. In an introduction by van Breda de Haan, Chief of the 8th section of the Botanic Gardens, the Laboratory for the Research on Deli Tobacco, refers to the previously mentioned studies of Professor van Bemmelen. He states that this work was not based on field observations. For this reason van Bijlert was charged with the survey of the tobacco soils of Deli and adjacent parts of Langkat and Serdang as well as with the subsequent investigations in the laboratory. To the description of the soils, classified according to their genesis as sedimentary or residuary soils, many interesting details on structure, hardpan formation, natural growth etc. are added. The geological-geographical facts of the area were at that time less known than was the case in Java. At least, the rhyolite, rich in biotite, which is everywhere present and today is very well known, is not mentioned in van Bijlert's paper. In 1897 the results of the physical and chemical analysis of many samples of different origin were published (26).

That petrological knowledge indeed was inadequate follows from the indication of the coarse rock fragments occurring in the soil as „trachytic or tufaceous rocks”.

Two years later a final paper was published in which, following van Bemmelen, special attention was paid to the colloidal silicate. Van Bijlert states that red residuary soils are characterized by the weathering silicate $Al_2O_3 \cdot 2SiO_2$ and the grey alluvial soils by $Al_2O_3 \cdot 3SiO_2$. This observation is in appreciable concordance with the modern clay mineralogical conception.

The problem under discussion, viz., the obtaining of a better understanding of the differences in quality of the tobacco soils of Sumatra, was, however, not solved. This solution was reached only several decades later as a result of the geological and mineralogical-pedological studies of Oostingh (27) and Druif (28) respectively.

In the meantime, on Java, the relationship between soil and rock was more clearly understood, although it was realised that from one and the same rock type soils may develop which, from an agricultural point of view, are quite different. This was correctly formulated by Kramers (29) in his discussion on coffee soils. He also mentions that the subsoil, in which the coffee trees root, may be quite different from the topsoil.

Around 1900 the lime problem began to receive proper attention. Van Bijlert warns in his paper on Deli soils against arbitrary use of lime as this compound not only has a destructive influence on organic matter, but also „that, detrimental to plant growth, the mineral components are so severely disintegrated that exhaustion of the soil, caused by leaching, soon results”.

Referring to the fact that in Europe, and more specifically in Germany, the importance of lime is very much stressed, Du Bois (30) expresses the view that the planter must refrain from copying, without further consideration, fertilizing practice based on European experiences, because „probably the whole system has to be adapted by our own agriculturists to tropical circumstances”.

The same holds true for other plant nutrients as was pointed out by van Bijlert (31) with regard to the tobacco soils of Sumatra. He comments that the ideas concerning the role of phosphoric acid in European soils have only a very limited applicability for the red soils of Deli.

It may be stated that, at the beginning of the 20th century, scientific research had reached the stage of critical independence — a fact that is to be observed throughout the subsequent rapid development of the work in Indonesia.

Attention was drawn again and again, especially after large-scale eruptions, to the products of these volcanic phenomena. Kramers (32) reported in 1901 on the ash of the Kelut eruption in May of that year and on the difference between this particular ash and that of Krakatau. Furthermore, he stated that the composition of the ash depends on the location of settlement, i.e., on the distance from the point of eruption — a conclusion which was confirmed 40 years later after detailed mineralogical and chemical analysis by Baak (33).

More generally known names now gradually take their proper place in the literature. Kobus and Marr (34) published in 1902 fundamental considerations on research into tropical soils. They state first of all that experience has without any doubt demonstrated that chemical analysis of soil provides an insufficient means of satisfactorily answering the enquiry of the farmer as to the fertility of his land, and as to whether fertilizing is needed or not. They are nevertheless convinced of the necessity of continuing the investigations, as these alone will supply results which may further a final judgement.

In their papers Kobus and Marr try to contribute to the solution of the problem as to what methods of analysis must be used to determine the content of plant nutrients in order to obtain results in accordance with practical field experiments — a problem which even today is not finally solved.

In 1903 Kobus and Schmit (35) contributed to the classification of sugarcane soils on the basis of mechanical composition. Their so-called „texture maps” played in the first decades of this century an important role in the valuation procedure used in Indonesia. In the long run they could not meet the criticism of soil scientists, as in no case can single value maps satisfactorily cover the whole field of factors which ultimately are reflected in that mysterious quality „fertility”. As a serious attempt, the work of Kobus and Schmit none the less has been of great value.

A modern method was introduced by Kamerling (36) in 1904. He studied microscopically the absorption phenomena of the soil with the aid of alkaline and acid dyes and contributed to our knowledge of the weathering products. He observes among other things that large amounts of iron hydroxide and aluminium hydroxide are of such a constitution that they are non-active with regard to adsorption.

A paper of Wichmann (37) in 1909 in the Proceedings of the Royal Academy at Amsterdam on „The Peats of the Netherlands Indies Archipelago” deserves attention. It gives a very clear review of the peats occurring on Java and the Outer Possessions, thus contradicting the conception of plant geographers who denied that peat formation in the tropics was possible below an elevation of 3600 feet. Even Mohr states in 1920 in his „The Soil of Java and Sumatra” that in Java peat could not be expected to develop, although Wichmann had already pointed to the occurrence of tens of thousands of acres.

Dormaar (38) published in 1909 a very interesting study on the influence of soil differences on the composition of crops. This scientist touches on the most fundamental problem of soil fertility. He proves that it is not the amount of plant nutrients in the soil, as determined by chemical tests, that is of the greatest importance, but the amount taken up by the plant. The interesting fact is noted that, for example, Smeru ash contained 0.4% of P_2O_5 soluble in 2% citric acid and a heavy clay of Pasuruan 0.027%, but that nevertheless in experiments the plants took up more P_2O_5 from the clay soil than from the volcanic-ash soil. The reverse was observed for calcium carbonate: in an assimilable form the clay contained 0.87%, the ash soil 0.10%. The plants used for the experiments, however, took up most from the ash soil. This is a problem which even today seems worthy of further consideration.

In 1912 the regional survey of sugarcane soils received the special attention of the famous Experiment Station of the Java Sugar Industry at Pasuruan. In this year Marr (39) summarized the results of soil analysis carried out over a period of 25 years. On that basis he attempted to delineate the soil provinces of the sugarcane area. The data, however, were of no use as the older investigators had no regional conception in mind. Marr develops a system of soil types based on stage of weathering, assimilability of phosphoric acid and the $K_2O : P_2O_5$ ratio. Many interesting observations give this review a high value for our knowledge of Indonesian soils.

It appears that in 1913 a critical formulation of relevant problems began to take shape also for the other crops. The publications of Galjema Verheul (40) on the conservation of the soil and of Mohr (41) on rubber soils demonstrate this growing interest. Mohr put the capital question whether it is possible to decide which soil is preferred by the rubber tree. The answer had to be in the negative and even now it seems that no reliable answer can be given to the question of which soil is suited for any given perennial crop. Every increase in our knowledge that accrues from the collection of results is of permanent value. The conclusions drawn by Mohr with regard to rubber soils of Indonesia and other tropical regions are of great importance. It is not the geological origin of the weathering crust which decides the yields; it is the root development and the air and water regime which are decisive for perennial crops. Two years later this soil scientist delivered a lecture to the Kediri Agricultural Society. His understanding of the problems of soil genesis and soil fertility appears to have markedly matured (42). The first considerations as to facts of soil genesis are given, considerations which even today are found to be fundamentally correct. The soil profile as a basis for soil valuation is introduced, instead of the generally accepted principle that it is only the topsoil which counts.

Kamerling in 1916 reported further on the microscopic study of the anatomy of the soil (43). The originality of his work is clear on a comparison with modern microscopical research of soil structure as it had developed up till 1947.

In the *Indische Mercur* of the same year we find a report of the discussions on what may be called a milestone in the history of soil science in Indonesia: the General Netherlands Indies Congress of Soil Science, held in October 1916 in Djocjarta under the auspices of the Netherlands Indies Agricultural Syndicate (44).

It is outside the scope of this review to enter into detail concerning the technical importance and the results of this Congress. It need only be mentioned that no aspect of soil management and soil research was left out or neglected. On the contrary, the Congress manifested that scientific soil research in Indonesia had taken its own rightful place among the other sciences. Although after 1916 we of course observe horizontal as well as vertical development, the foundations have been laid by the preceding pioneer work.

With regard to horizontal extension, attention may be drawn to the bacteriological and bio-chemical research for which Gerretsen pleaded in a lecture before the Congress. The results of his investigations have been published elsewhere (45). It has, however, to be acknowledged that in Indonesia the microbiological study of the soil never received proper attention. The vertical extension has been considerable. It is quite impossible to give even a very superficial review of the papers on soil research published in the decades after the year of the Congress. Mention is made only of the authoritative books of Mohr, which drew worldwide attention after having been translated into English (46, 47). The increased scientific activity is best proved by the numbers of contributions listed in Edelman's bibliography of soil science in the Netherlands Indies, viz. 248 in the period 1850—1899, 1111 between 1900 and 1925, and 950 between 1925 and 1940. To these may be added, according to recent data, 175 papers published since 1947.

This chapter may be concluded by referring to work done by the official Government agency, the Institute for Soil Research. This institution undertook soil mapping for the purpose of emigration and colonisation of the surplus population of Java in the Outer Parts of the Archipelago, for the Land Revenue Service and for the systematic soil survey of Indonesia. Forty million acres have been surveyed and, where necessary, mapped. A more detailed discussion may be found in a lecture delivered by the present author before the Royal Science Society at Batavia in May 1948 (48) and in the chapter on „Recent advances in tropical soil science” to be published in „Recent advances in tropical Agriculture” (49) edited in the U. S. A. by Verdoorn and Honig.

II Soil Conservation.

It is interesting to remark that the early years of the Royal Science Society also saw a growing feeling of responsibility — at first on the part of a few soil-users, and later of many — with regard to one of the greatest dangers which threaten mankind, namely the loss of the topsoil, without which no life on earth can be sustained.

In 1866 the first contribution to this subject was published by Holle (50) under the arresting title „A great danger draws near”. The author begins his essay with the words:

„Who does not know that, in the United States of America whole regions are brought to hopeless infertility through a long continued system of reckless and exhaustive cultivation?”

Holle, the pioneer of conservation in the Netherlands Indies, then points to „the danger that draws nearer and will irresistibly reach also those parts of Java” which are not protected against erosion by terracing. Although he occupies himself in his paper mainly with native agriculture he does not fail to warn against the dangers which threaten the Government-owned coffee plantations in Priangan and the privately-owned tea plantations in the Bagelen Residency. He states that the highest producing plantations are those where terracing has already been adopted for many years.

We shall see that, nevertheless, 30 years later the pros and cons of terracing are still being fervently discussed.

Holle worked out several simple methods for the construction of terraces. He discussed the optimal width and calculated the expenses involved, thereby proving that the costs of construction would be amply covered by the increase of yields.

In consequence of the Government Decree no 42 of March 18th 1873, the Secretary for Internal Affairs presented a treatise composed by Holle and entitled „A Guide for the Construction of Terraces” (51). These instructions were especially intended for the native

farmer and were, consequently, translated into the Sundanese and Javanese language. The guide is illustrated with designs of different forms of terraces, and of the shape and handling of a patjul (native spade).

Holle's plea had not been in vain, at least as regards the official Government point of view concerning soil protection. In 1874 we read in the so-called „Reclamation Ordinance”, article 5, of the Batavia Gazette no 79 that a licence for the reclaiming of virgin land belonging to the Crown domain will be granted only under the restriction that :

On sloping terrains, where there is risk of erosion of the topsoil, terraces must be constructed and also others measures must be taken as local circumstances may require” (52).

In December 1874, in the Journal of the Netherlands Indies Agricultural Society, the Reclamation Ordinance was criticized by van der Elst (53). He points out that, on mountain slopes, coffee plantations have been cultivated for many years without terraces and with very good results. The criticism is principally directed against the fact that as a result of the construction of terraces the subsoil will be brought up and consequently the productive capacity of the land will decrease. This criticism was decisively refuted by Enklaar (54) in his letter to the editor on March 22nd 1875, and also repudiated by Holle (55). The latter quotes a British tea planter of Ceylon who states that the tea plantations on mountain slopes are yearly subjected to such severe deterioration that they never pay. Holle writes in this connection that if the British-Indian tea planters could see „our terraced tea gardens on steep slopes” they would undoubtedly reverse their opinions.

Mounier (56) drew attention to the hydrological aspect of reclamation and stressed the disastrous consequences of unrestrained deforestation on water conditions. He states that there are thousands of examples which testify to the reckless way in which the mountain dweller handles his soil and to the destruction caused by him, directly and indirectly, to the detriment of the lowlands.

In order to safeguard the forest, Mounier gives the following advice :

(I) a critical selection has to be made of sites for forest cultivation on those mountain tops and slopes which are of direct importance for springs and from which therefore useful atmospheric influences are to be expected;

(II) forest should be cultivated, to a certain extent and depending on circumstances, on the banks of rivers, brooks and artificial water works ;

(III) woodland stands should be reserved in the low lands which are of importance for the atmospheric situation ;

(IV) severe measures should be taken against destruction through fires and other causes.

Compulsory terracing as specified in the Reclamation Ordinance is, according to Mounier, as such, hardly applicable. He also believes that too great uniformity for such an extensive and in all respects diverse region as the isle of Java, in many cases will be a hindrance and unprofitable.

In 1883 the Secretary for Internal Affairs once more published directions with regard to the cultivation management of „governmental coffee gardens” (57). These instructions include designs for terraces and they were, accordingly, published under the title : „Construction of terraces on terrains where only a thin layer of fertile topsoil occurs which, during the construction, should not be buried under the infertile subsoil”.

In consequence of a letter of the Secretary for Internal Affairs, dated November 25th, 1889, no 6421, the erst-while forester A. H. Berkhout discussed the aforementioned Reclamation Ordinance of 1874 in a paper published in 1891 (58). Special attention is drawn to the disastrous predatory cultivation which, combined with deforestation, has brought extensive areas to irre-

parable infertility. The cause of the continuing need for new land, i.e., for original forest is attributed to the fact that terracing is insufficiently maintained. Should this be the case, the native population would not feel the need to reclaim new land year after year, but would continuously cultivate the same field. In Sumedang region 64% of the arable surface has been destroyed by this predatory cultivation.

Berkhout's report was distributed among European and native civil personnel of the Department of Internal Affairs, and Sundanese and Javanese translations were prepared. To this translation a set of instructions composed by Holle in popular terms was added. The Dutch text was published in the Journal of Civil Administration in 1892 under the heading : „What is necessary to protect the Javanese population against want and famine in the future ?”

The increased concern for this problem of soil deterioration and erosion can be deduced, e.g., from the extensive discussion by Kievits (59, 59a) who treats the subject in 4 consecutive papers published in „Teysmannia”, and entitled : „Where now ?” In the introduction he points to a score of examples of civilisations destroyed through mismanagement and misuse of the soil. He also mentions that from the start of Hindu tutorship when rice culture was introduced into Java, the indigenous population changed from its nomadic way of life to an agricultural economy. The introduction of rice, which was to replace millet as the main food, had also less agreeable consequences. It must be understood that the first rice variety introduced was mountain rice, which may be cultivated on dry non-tilled soils. Rice culture as a predatory cultivation on *huma* (fields under the system of shifting cultivation) was to be principal means of food production. Kievits holds this *huma*-cultivation system responsible for the large-scale soil depletion. Such was the situation at the end of the Hindu rule and the introduction of the Moslem creed which followed in no way improved the prevailing deplorable system of agriculture.

It was only after the power of the native kings had been severely curbed, thanks to the Dutch influence, that wet-rice culture was generally adopted. Extensive areas no longer suited to any dry culture could now be put into permanent cultivation. According to Kievits this is one of the main reasons for the extraordinary increase in population during the 19th century. The *huma* system, however, did not disappear. On the contrary, the increase in population made larger crops necessary, which it was attempted to obtain with as little labour as possible. Freshly reclaimed virgin forest soil needs hardly any more toil than that of seeding, and if, on sloping terrain, soil and seed are not simultaneously eroded, the native farmer may be sure of a very good crop. To this it must be added that mountain rice is considered to be better flavoured and more nutritive than irrigated lowland rice. The real evil of the uncontrolled reclamation process is to be found in the fact that the native population took to extensive burning to clear the forest. The soil, bared of the natural plant growth, is moreover intensively hogged. The surface is therefore without any protection against the intense tropical rains, which cause the fertile topsoil, rich in organic matter, to be transported extremely rapidly to rivers and brooks. A total loss is the ultimate result.

Kievits also discusses whether the governmental compulsory coffee cultivation was largely responsible for the tremendous deforestation. He is of the decided opinion that this was not the case. Although locally the deforestation may have been accelerated, he is convinced that the forests would have been cleared even earlier by the native population for the cultivation of their rice crops. Kievits finally states that the initiative against soil depletion must be taken by the Government. He doubts whether the issue of the Reclamation Ordinance of 1874, which was hardly or not at all put into practice by the

native farmer, has been of any use. Nor has the private plantation owner always managed his soil with sufficient care.

There is no doubt that the author is very much concerned with the conservation of the soil. Nevertheless he seriously criticizes the aforementioned views of Berkhout in 1893 (59). It is outside the scope of this review to go into the details of this criticism. Kievits's objections are in actual fact more directed against blindly following what he calls a fashion, viz., the construction of horizontal terraces. The disadvantages of this mode of terracing are discussed in detail. One of the points raised is that the horizontal terraces will have to take up all the rain water. This may cause excess of water on certain types of soil, which could be detrimental for certain water-susceptible crops. This excess of water will not only be a harmful physical factor but will also cause a rapid leaching of the soil: the water has to penetrate the soil and will carry off water-soluble components. Fertilizing will then be necessary to make up for the loss of plant nutrients. The role of organic matter is also discussed. One cannot fail to get the impression that his arguments, even then, did not hold good, although it must be acknowledged that there is considerable truth in his reasoning that blindly adopting certain cultivation practices under any climatological circumstances and on any type of soil may very well lead to disappointment.

Kievits, on the other hand, was frustrated through the fact that at that time a planter who did not terrace his plantation was denounced openly as a bungler. He writes accordingly:

"I write these lines especially for those deceived followers; I wish to help them to free themselves of the pressure which the fashion of terracing has for many years now put on them, so that they will put aside their timidity and will dare to declare with raised head: I do not terrace my soil".

Still, he does realise that uncontrolled predatory cultivation such as had been taking place during the last decades of the 19th century should be abolished. On the other hand he hopes that if the Reclamation Ordinance of 1874 is to be put into force for coffee plantations to be newly opened the many disadvantages connected with terracing will be duly taken into consideration.

It seems rather strange that he argues that, on many coffee plantations which then could hardly be exploited profitably, terracing would cause heavy losses with all the consequences thereof. He writes: "Therefore coffee culture is doomed to be a predatory culture, except for those lucky few who, owing to fortunate circumstances, can allow themselves to conserve their soil with terraces. Until the price of quinine improves substantially the same holds true for the culture of this crop, also in connection with aspects which will be discussed later on".

Kievits's criticism was again discussed by Berkhout in 1894 (60) who concludes his essay as follows:

"No further predatory cultivation, but conservation of the topsoil in the interest of mountain crops and for the benefit of the water regime of the lowlands!"

Holle, the champion of terracing, was untiringly active for the good cause (61). He received support in an anonymous paper published in "Teysmannia" (62) although the unknown author pointed out that terraces as constructed on the Governmental plantations on Java, namely, continuing horizontal terraces of one constant width, are for different reasons very impracticable. The writer develops a much more suitable schema for the construction of terraces.

In 1894 Holle published one more contribution on terraces in coffee plantations and in the same year an extensive treatise on native agriculture on dry fields and the effect of terracing (63). In this paper he mentions the experiences of the native civil administration assistant (wedana) of Kawali, residency of Cheribon, who, inter alia, states that terraced fields give better production

and can be more continuously cultivated, whereas the costs of construction of the terraces are amply made good by the higher yields. He writes literally:

"On comparison, terraced fields are far better than non-terraced ones".

"The people now understand the usefulness of terraces"

"There is an increase in the cultivation of polawidjo (dry crops) also in other districts, after the adoption of terracing".

Notwithstanding the active propaganda by several intelligent men, the importance of soil conservation was not always understood around the turn of the century. A good idea as to the best method of reclamation had even less been formed.

In a general meeting of the Malang Society of Coffee Growers on January 27th, 1899 (64) a memorandum, composed by the Board of the Society, was delivered. The paper dealt with the maintenance of coffee gardens, and was entitled "On the importance of the conservation of the topsoil of coffee gardens". It was to be expected that this importance was fully understood but, although this cannot be denied, one notes with wonder the narrowness of view of the composers of this memorandum. The following lines may be quoted as an example: "After cutting the forest the wood has to be chopped and there is no better and cheaper way of clearing the shrub than by using fire. In this way a great part of the stored plant food will be lost which in the cycle of metabolism was destined to sustain the forest; what is left over we hope to use for our future coffee plantations"; and a few lines further, commenting on the consequences of the total destruction of the natural vegetation: "The soil, formerly protected against the sun by a canopy of leaves is now an easy prey as regards destruction of organic matter, solution of plant nutrients and the carrying off of the same by rains. The brooks, formerly containing clear water, are now loaded with suspended soil, part of the most fertile soil being transported to the lowlands. It has to be acknowledged that this loss cannot be avoided if we reclaim virginal land for coffee cultivation".

Although in the memorandum advice is given concerning the ways in which the evil can be at least to some extent limited, one gets the impression that, at that time, some people accepted the idea that the coffee growing is in the highest degree predatory.

Enklaar van Geuricke (65) was one of many who fought the inadmissible views quoted, on the grounds that "this rash destructiveness ruins in a few days what nature has built up in hundreds of years".

Contributions to the several agricultural periodicals kept the interest in erosion and erosion control alive. It seems that at least in respect of the mountain crops soil conservation gradually is accepted as a sound and profitable practice.

In 1905, for instance, de Kock (66) provides technical advice for the construction of drains on tea plantations. He concludes his paper thus:

"The fight against erosion is indispensable. Whatever means are used, it should never be forgotten that during digging the soil must be worked upwards. Only then will other means such as terraces, shrub-protected contours, carrying up in fertile soil etc. be equally fruitful".

Plasschaert (67) reported on the usefulness of terracing in teakwood culture and also stressed the relationship between type of intensive culture methods and type of soil. He deals particularly with marl soils of the forestry Sempuran which are very susceptible to erosion, which could be checked only by terracing. An extensive system of drains, however, is also effective in conjunction with a border of *hemlandingan* (*Albizia montana* Benth.) on the terrace banks.

In 1913 van Warmelo (68), in a letter to the Board of the Sukabumi Agricultural Society stated that a good system of terraces changes the soil climate in the sense that in the wet monsoon, without terraces, the greater

part of the total amount of rainfall flows over the soil surface, whereas with terraces the greater part is absorbed by the soil. For crops susceptible to excess of water this is an important difference. It is, for example, well known that quinine trees on terraces are much more subject to cancer than those on slopes.

He points out, furthermore, that unrestricted terracing may be dangerous. Physical as well as chemical properties of the soil must be taken into account, together with the kind of crop (69). It may be quite satisfactory to do without terraces or catchment pits, provided a suitable system of drains is constructed.

In 1916 Bley (70) delivered on the same subject a paper at the Soil Congress at Djocjarta. He acknowledges the usefulness of terraces but stresses the necessity of drainage as an aid to water transport. Such drains are, however, difficult to construct when the terraces are too large. He finds a solution in the construction of small square terraces instead of the long continuous ones. Depending on the distance between the trees or plants, a terrace should be constructed for each plant, or, at the utmost, for a small group of plants. This system of so-called „kotaks” makes the construction of open drains quite possible. His advice receives support in a lecture by Menting (71) in 1918, delivered for the Malang Agricultural Society.

In general the considerations put forward have a wider basis of experience, since the results of foreign investigations are also made use of. It is noteworthy that owing to the shift in cultivation, namely from coffee to rubber, the urgency of adequate erosion control measures is considerably increased.

A. R. Reynst (72) postulates in 1920, in a treatise on topsoil problems, that any drainage of rainwater must be rejected, as in the ditches not only the water is transported but also the soil, which flows into the drains simultaneously with the rain and which then disappears into brooks and rivers. He maintains therefore: „We should not drain the rainwater but catch it by an adequate system of level ditches. Besides this, the force of the falling rainwater should be lessened. This would increase the opportunity for the water to penetrate into the soil instead of running off the surface. The systematic planting of *lamtoro* (*Leucaena glauca* BENTH.) at intervals of 4 x 4 metres provides for an excellent protection against rain and run-off.

The meeting in 1921 at Salatiga of the Society of Scientific Personnel of the Experiment Stations (73) discussed the subject „Soil Management and Erosion”. A resolution was adopted in favour of the conservation of water. To this effect measures should be taken in connection with all crops. Attention is drawn to the fact that soil maintenance is most rationally favoured by an adequate plant cover. Especially a grass sod would be useful, provided soil ventilation was not impaired.

From the foregoing consideration it is clear that, gradually, in papers and discussion, the very important subject of soil conservation came to receive a better founded and more scientific treatment. Also the experience gathered during several decades, in different crops, promoted a better understanding as to which system of terracing should be preferred in relation to soil type and slope. This is clearly exhibited in, e.g., a practical contribution by Dibbetz (74) in 1927, who also stressed the necessity of a good soil cover together with terraces, in order to check run-off.

Of the foresters especially Thorenaar (75) occupied himself with the problem of the restoration of the fertility of heavily eroded soils. In 1928 he made a plea for the so-called forest-fallow, in which the natural forest vegetation is left to restore itself. This restoration results in the production of organic matter which again improves the quality of the soil. Referring to the system of shifting cultivation as practised by the native population in the

Outer Islands, he believes that this could be a constant source of income if the cultivators would refrain from burning. That they, alas, would not, does not affect the truth that the restoration of natural plant growth is the only means of re-creating a certain value in soil which has been so badly treated by man. In 1929 Thorenaar (76) once more contributed to the question of soil conservation again stressing the need for a closed cover to the forest soil.

The growing of soil-protecting plants in different crops leads to the belief that a good soil cover in itself is a sufficient guarantee against erosion, and that terracing is superfluous. In 1931, however, Stadt (77) concluded, in a lecture delivered before the General Meeting of the Coffee and Rubber Growers Association „Kediri” that erosion can be observed not only on steep slopes but also even on slightly sloping terrains notwithstanding the presence of a thick cover of protecting vegetation. Terracing is indispensable on both kinds of terrain. Stadt gives a technical description of methods to be used in both cases, illustrated with designs of projects. His considerations are based on several years of observation, which contributes in a high degree to the thoroughness of his arguments.

In the same year further signs of increased scientific interest are to be noted, in the many studies undertaken, especially by the Forest Experiment Station and its field officers, who were charged with investigations concerning forest reservations for hydrological and orological purposes. The physical structure of the soil is important for the forest cultivation as such, as well as for susceptibility to erosion.

Japing (78) publishes the results of a series of permeability experiments using laboratory methods with different soils. He concludes, among other things, that, in order to get a complete insight into the hydro-orological function of different soil and vegetation types, long-continued observations on well chosen multiple experiment plots are necessary.

In 1933 de Haan (79) published a critical treatise on the influence of forest on river flow as a consequence of the publication of the Hoyt-Troxell report on the same subject in Southern California. He concludes that the run-off phenomena in Java have their own characteristics, whereby the consequences of deforestation are much more serious than under the circumstances of climate and soil prevailing in Southern California. High water tables are markedly higher and erosion is alarmingly increased.

The forest-hydrological investigations in Java are carried out in the Tjiwidaej-Tjisarua experiment plot, established in 1930 on the Patua mountain complex south of Bandung in the Middle Priangan forest district. In elaborate investigations the following series of experiments are included:

- a rainfall in and outside the forest;
- b surface run off;
- c evaporation from and infiltration into the soil;
- d transpiration of the trees.

An extensive study of the literature supports these investigations, in which it is concluded that the hydrological function of the forest, although depending on environmental circumstances, is of paramount importance, and incapable of being performed by any other agency.

Notwithstanding research, reports and conclusions in the field of soil conservation, the disastrous consequences of soil destruction in Java have by no means been prevented.

In July 1933 the press started a campaign to draw public attention to the so-called „dying land”, the hilly and mountainous region south of Madjelenka. The still prevailing system of shifting cultivation on the very erodible marl soils has resulted in irreparable destruction of an extensive area. The need to check the increasing erosion caused by predatory cultivation was also stressed by Fokkinga (80) in his advance paper for discussion prepared for the Association of Foresters. This report was

composed in relation to the erosion and extreme exhaustion of the soil in the Tjilutung basin. He urged the need for direct official supervision of native agriculture by the Government.

It is considered to be of great importance that, under well-organized supervision, native firewood cultivations should be established. In that case it was deemed necessary that a form of organisation should be worked out, founded in specifically empowered authority with an executive and controlling body. Fokkinga (81) reports his conclusions on the history of the native firewood cultivations established in 1910 in the district of Wonosobo on soils of the Royal Domain.

Owing to the fact that the regulations regarding rights and obligations of the population concerned were insufficiently based on enforceable law, the project failed. Administrative reforms were put into force in 1921 by the Civil Administration. This resulted in the organization of a mutually owned cultivation project with individual rights which comprised, in the same year, 2000 acres of firewood forests. But 12 years later the organization was no longer functioning and nothing was remembered of a firewood project which operated according to certain rules and regulations. Fokkinga finally points out the need to persuade the population to cultivate perennial crops as permanent cultures on terrains specially selected for the purpose. The organization and improvement of the system of shifting cultivation is, however, a very intricate matter. If the population does not cooperate any scheme is bound to fail.

Very detailed observations regarding the *huma*-legislation in Bantam, as communicated by Kools in 1935 (82), are in this respect very illuminating.

The Forest Experiment Station continued as the agency which occupied itself with the study of soil erosion problems. In 1933 Coster's extensive report (83) on run-off experiments was published. These were carried out in different locations in Java on different soil types and under different types of natural vegetation. The conclusions drawn by Coster indicate convincingly that erosion is dominated by one factor, i.e., the degree of bareness of the soil. He indicated which types of vegetation are most effective in checking soil erosion and those which have less effect in this respect. It is principally the natural herbaceous vegetation and forest litter which adequately protect the soil. That the situation in Indonesia is not worse than it is today, writes Coster, we owe to the rapid regeneration of plant cover in the wet tropics when the soil is left untouched. If the soils are excessively susceptible to erosion no restoration is to be expected.

The different investigations carried out, and the conclusions drawn, caused quite a discussion in scientific literature, in which the personal element was not lacking.

In 1939 Roessel (84) published a hydrological study on the character of the retention of drainage water which gave rise to a deep controversy especially in relation to the forest reservation policy as propagandized by Heringa (85). Although the last word on the role of the forest in relation to water regime and spring flow had by no means been spoken, responsible people were increasingly concerned with the destruction of the forest. In 1937 both the Resident Groeneveld (86) and the Advisor Gonggriip (87) called attention to the disastrous devastation of the forest area of Indonesia. Especially Groeneveld pointed out that in the last 20 years the destruction of forest in the Outer Possessions had been nothing less than a catastrophe, a fact which up till then had not been realized by the Government.

Thorenaar (88) also comments on the alarming situation, while Burger (89) published a paper in 1938 in which he urged a revision of the existing agricultural allotment system. This is especially necessary as the agriculture in the densely populated lowland, carrying up to 900 people per square kilometer, is threatened by the activities of the sparse population which cultivates the

adjacent slopes and mountainous regions. Once more attention is called to the lack of supervision and the Government's lack of apprehension of the imminent danger.

In 1940 the division of Agricultural Advisory and Fresh-water Fishery of the Ministry of Economic Affairs prepared a report on „Soil protection as part of the task of the Agricultural Advisory Service". This report resulted from the understanding that the Service should occupy itself more intensively with soil protection and related problems. Exchange of experience between the different agricultural areas of Indonesia was considered indispensable.

A synopsis of the soil-conservation measures to be taken in native agriculture in Java was given by Schuitemaker (90) in September 1941 in a meeting at Batavia of the Supervising Officers of the Agricultural Advisory Service. His very thorough discussions, illustrated with a score of interesting photographs, were published posthumously in 1949, Schuitemaker having perished in Japanese internment.

It is pointed out how, in nearly all the eroded areas in Java, the native population tried to find suitable means of protecting the soil (91). From the results of this initiative, together with the failure of former Government intervention, the conclusion may be drawn that soil conservation is not exclusively a technical problem, which can be solved by the construction of terraces, but an agro-economic problem.

Finally, in 1947 a paper on the problem of shifting cultivation was published by van Beukering (92). It is disclosed that as far back as 1930 an informal committee was appointed to study shifting cultivation in Indonesia. This committee also considered the problem to be essentially one of farm and social economics. The agrarian regulations as enforced by the Government, regularize the reclamation of virgin soils, especially in the Outer Possessions. Van Beukering pleads for mixed farming and is of the opinion that the solution of the problem of shifting cultivation starts with the solution of the problem of pastures and cattle fodder.

At the outbreak of the war in the Pacific we can thus observe a definite concern for the conservation of the soil among both planters and the government officials responsible for agriculture or forestry. This last category, however, complains that the Authorities concerned are insufficiently aware that the fight against soil devastation is a task of the Government itself and has to be founded in regulations having the force of law.

It will be understood that the evil, which had been observed everywhere, alarmingly increased when the Japanese invader stimulated the cutting and burning of plantations and forest reservations by the native population.

This was the reason why in 1946 the Government installed a committee under the chairmanship of the present author to study erosion control and related subjects in the United States of America and to decide on a form of organisation of a soil conservation program suitable for Indonesia.

The report, brought out in January 1947, resulted in the establishment of a Bureau of Land Use, incorporated in the Forest Service. It is the task of this Bureau to study all problems related to soil conservation, including direct erosion control, reforestation, forest reservation, agrarian system etc., and several reports have been issued. De Haan (93) also in 1949 published an extensive review of the form of organization and the programme of the Bureau.

This paper aims at summarizing the development of soil science in Indonesia in the past 100 years. To this end a selection had to be made out of about 2500 papers published in that century. Much had to be left out, so that by no means all aspects could be taken into consideration. The reader requiring further information may however be referred to Edelman's outstanding bibliography on literature relating to soil science in Indonesia (94).

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