PRACTICAL VALUE OF A SOIL SERIES CLASSIFICATION TO AGRICULTURAL RESEARCH

By G. MURDOCH

It is much rarer now than it was ten or twenty years ago for the results of a meticulously executed field or pot experiment to be presented exhaustively and exquisitely, but without divulging any hint as to the soil in which the crop grew. The frequent omission in the past of soil data, placing severe restrictions on the successful application of trial results to commercial farmland which would most benefit from them, should not really surprise us, considering how young a discipline *pedology* (soil science) is. Some nonagenarians alive today received their basic education before Dokuchayev (1879) propounded the first maxims of soil genesis and evolution. And so slow has been the infiltration rate since then of soil studies into schools and universities that the American geographer Barnes (1954) can still chide that "soil is something which everyone sees but few observe".

What then is the best way of characterizing the soils of experiment sites, given the need to describe them and to correlate them with farm soils? Clearly the lowest unit in the local soil classification system is the one to choose and in many, probably most, countries of the world this is the *soil series*, a standard definition of which is provided by Kellogg *et al* (1951): "The soil series is a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile . . . * and developed from a particular type of parent material. The soils within a series are essentially homogeneous in all soil profile characteristics . . . * and in such features as slope, stoniness, degree of erosion, topographic position and depth to bedrock".

Soil horizons are layers produced by the soil-forming processes, i.e. by climate, geology, topography, vegetation and the animal kingdom, including man, all acting through time. The "differentiating characteristics" of horizons are notably colour, texture, structure, depth. As to homogeneity, the properties of a soil series are sometimes specified in very simple language, e.g., *blocky black clay*. Invariably each such stark phrase proves to apply unmistakably to only a proportion of the soils concerned: it is important to appreciate that some latitude in interpreting soil series descriptions is not only usual but desirable, otherwise every soil pit would be a series unto itself. To quote Kellogg *et al* (1951) again: "Precise rules governing exactly what characteristics are considered differentiating between series, or exactly what ranges of these characteristics may be allowed within a series, cannot be laid down for all conditions. Generally, it may be said that those observable and mappable properties which are known to have, or are likely to have, significance in soil genesis, in the growth of native or crop plants, in soil management and in soil engineering are to be considered". When a series becomes familiar and fully documented, an authoritative statement of the variation of its salient attributes is possible. The soil surveyor's judgment in this matter profits by experience. Here is an example of the allowed range in one attribute, colour: in the Swaziland Lowveld the Kwezi series *modal profile* (most common view in a pit or cutting) prompts the brief description *black clay* and that does not preclude a *very dark brown clay* or a *very dark grey clay*, matched on the Munsell (1954) colour charts, from qualifying as Kwezi series, but it does debar a *dark brown clay*, which would perhaps fall in Canterbury series.

Series are called after places where they have been discovered or where they commonly occur, and the convention is that their names are national perquisites, so that apparently identical soils on either side of a frontier have different names, e.g. Zikane series (Swaziland) and Phoenix series (Republic of South Africa). For further general information on soil series, with particular reference to the Natal Sugar Belt, the very useful paper presented three years ago to S.A.S.T.A. by Beater and Maud (1962) should be consulted.

Research Station Soil Series

The identification of soil series in Swaziland began ten years ago and to date 92 series have been found and mapped. In preparation for the arrival of the first resident agricultural research workers in 1958 the Department faced up to two fundamental questions — where to site experiments and what major trials to embark on. The "government farm" at Mdutshane, within the developing Malkerns Irrigation Scheme, which Rosenstrauch (1948) had shown possessed soils typical of the surrounding West-Central Middleveld, became the main research station. Doubts as to the best site for the principal subsidiary station were only resolved after soil series mapping of several parcels of Crown Land, in the Lowveld near Big Bend and riparian to the Usutu River. Wisselrode block was eventually chosen, chiefly because it contains a wide cross-section of Eastern Lowveld soils, including those now planted to sugarcane, and since 1960 the block has been known as the Lowveld Experiment Station.

Not only were the Wisselrode soils suitably assorted, they were also as a rule in conveniently large patches to accommodate most trial panels on a uniform soil. Fortunately this was the case with much of Malkerns Research Station too, e.g., the citrus orchards, requiring ten acres, could be laid out on an approximate square that was 90% Mdutshane series orange sandy loam — see Map 1. However, when expansion to remote corners of the 800 acre station took place recently, scarcely a single panel could be designed that

*These gaps referred to permissible variations in texture which have since been discarded as unsound, or unnecessary to stipulate, by soil surveyors, including the Americans themselves,

did not take in two or more contrasting soil series — see Map 2. This unsatisfactory state of affairs, here dictated by land shortage, should naturally be avoided if at all possible. The District Experiment Plots, scattered over Swaziland, which have been set up to augment the station findings, have all been carefully soil-surveyed beforehand to guard against a repetition of this fragmented pattern.

By 1962 it appeared that the dozen most important soil series on the two large stations were representative of about 25% of Swaziland, while seven additional series at the first four District Experiment Plots would be encountered over another 18% of the country. This coverage is considered reasonably good, especially as 23% of Swaziland comprises rocky ground, forest or built-up areas and only 14% is currently cropland.

Answers to the question of what to lead off with, in addition to exploratory NPK experiments, on the land selected for trials were sought by Venn (1962) from greenhouse pot tests at Malkerns of ten major soil series, using the subtractive technique, after Webb (1955). As well as registering the expected nitrogen response, the tomato and maize plants grown in five upland soils (Nduma series from the Highveld: Malkerns, Mtilane and Pofane series from the Middleveld: Lomahasheni series from the Lubombo Range) did badly without sulphur, and there were moreover visual symptoms in several cases of phosphorus, boron and molybdenum deficiency. Only the lightest textured soil in the batch, Gocuka series loamy sand, apparently lacked potassium. These indications, and others provided by Murdoch and Andriesse (1964), of the fertility status of the country's soils paved the way for researches in depth, which are still continuing, for example on the role of trace elements and on forms, rates and times of application of nitrogen.

Some Verdicts from Research on Soil Series

Typical of the more recent detailed results of agricultural investigations which tie in closely with soil series on which the experiments took place are the following, abstracted from annual reports of the Research Section, Swaziland Department of Agriculture:

(1) For maize in the Middleveld Malkerns series deep red loam should be supplied with up to 1,600 pounds per acre of dolomitic lime every few years but needs virtually no potassium. Conversely Pofane and Orrin series, rather shallow grey sandy loam to loamy sand, require annual dressings of around 50 pounds per acre muriate of potash, but no calcium nor magnesium. Maize on all three series responds to nitrogen, phosphorus, molybdenum and zinc.

(2) The cause of iron starvation in Lowveld sugarcane is not necessarily an excess of calcium, for although Kwezi series black clay and kindred calcareous soils often exhibit iron chlorosis, nearby areas with exactly the same series may not do so. Analyses by P. Jackson show that the most likely cause of the yellowing is in fact undue concentration of phosphorus, from fertilizer applications, which is presumably fixing the already small quantity of iron available in the neutral to alkaline moderately shallow root zone.

(3) For pineapples on Malkerns series dressings of ammonium sulphate are in order, but for all other crops grown in this, the commonest of the Middleveld arable soils, forms of nitrogen that do not have an acidifying effect should be used.

(4) On Canterbury series dark brown clay, an important sugarcane soil, the optimum irrigation furrow grades are between 1:170 and 1:300 — see Lea and Murdoch (1964). Estates which had, in the past, attempted to avoid waterlogging by tilting cane-lines as steeply as 1:80 in places, succeeded for the most part merely in aggravating their drainage problems lower down the slope, sending surplus water beyond the point where Canterbury merges into the tougher, less permeable Kwezi, Valumgwaco or Vimy series clays.

(5) In sugarcane trials conducted last year throughout the Lowveld N:Co.382 came third out of seven varieties in respect of sucrose production and fourth as regards cane yield, but despite this mediocre overall performance it is the best variety for "two-deck" soils with a sandy horizon abruptly overlying an impervious clay pan at 15 to 30 inches depth, e.g., Habelo series. Another variety, Salvo, has been found to suffer sunscorch on very shallow soils with low total waterholding capacity, such as Somerling or Sikhutwane series, although it does well on deeper, more productive soils.

(6) The most intractable plant nutrition problems in Swaziland are associated with Nduma, Alicedale, Tateni and Ongeluk series, exceedingly impoverished soils of the Highveld whose great acidity is illustrated by readings as low as pH 3.8 in water. By contrast the best "all-round" soil in the country, taking into account both chemical and physical constitution, is undoubtedly Lomahasheni series deep red clay loam, the main cultivated soil on top of the Lubombo Plateau. It is a great pity that river and underground water supplies are so paltry there, making irrigation wellnigh impossible.

Soil Series and Farm Crop Performance

Agricultural research does not, or should not, stop at the research station fence, and the transmission to farmers of research service findings is enormously facilitated if farm soils are readily identifiable, preferably on soil maps. The sugar planter who knows he has just cleared bush from Habelo series will put in N:Co.382 — see paragraph (5) above — unless or until an even better variety offers. The planter who is ignorant of his soil may do so too, by chance, but obviously he is not organized to receive the utmost benefit of technical recommendations stemming from work done on particular soil series. More than 600,000 acres or 14% of Swaziland has now (March, 1965) been mapped in detail or semi-detail and another 930,000 acres or 22% of the area is covered by reconnaissance soil surveys.

A further extension of research is concerned with seeking answers, which are among the ultimate goals of applied pedology, to the deceptively naive query "What harvest can be expected from X (crop) on Y and on Z (soil series)?". Only in the most advanced agricultural countries have thorough scrutinies of this avenue of investigation and its devious byways been possible as yet — for a Canadian example refer to Rennie and Clayton (1960).

One method of assessing or forecasting attainable harvests involves qualitatively "scoring" a crop on known soils. In this way Smyth and Montgomery (1963) have successfully portrayed Western Nigeria cocoa soils. They used statistically valid grid-sampling techniques over an area of 8,950,000 acres and found that the heaviest bean production came from Egbeda series, deep red clay loam with a diffuse gravel layer at 6 to 18 inches. Another approach is to run "maximum yield" plots, so establishing upper limits to output as yardsticks on which to judge other results, both from different research treatments on the same series elsewhere and from farm production. At Samaru in Northern Nigeria Jones (1963) has rain-fed cotton trials of this nature, which for seven years in succession gave between 2,200 and 2,650 pounds per acre seed cotton from Karina series yellowish deep wind-blown fine sandy deposits on iron pan. Local yields without fertilizer and spraying are 300 to 400 pounds per acre from Karina soil.

In Swaziland quantitative studies on yield prediction were initiated last year, with the object of ascertaining the expected harvests of three major crops — maize, cotton and sugarcane — from commercial fields varying principally in their soil series. To minimize management disparities maize and cotton are being evaluated at demonstration plots belonging to Swazi farmers and tilled by them in co-operation with junior agricultural extension staff throughout the country. Departmental back-records to 1957 give yields per acre for more than 340 rain-grown maize plots and more than 120 rain-grown cotton plots. This season's observations will be added to these before correlations between soil series and crop weights are determined.

Irrigated sugarcane soils are being compared with the assistance of several estates where reliable crop performance logs are kept, and where land treatment and the managerial factor are either "constants" or have varied fairly uniformly from year to year over the whole area being investigated. An early conclusion from the Ubombo record is that, in the last five years there, average cane yields from the best and worst soil series irrigated with gravity flow have differed by more than a ton per acre per month, or about 17 tons per acre per cut. The best soil has been Winn series deep orange alluvial-terrace sandy loam to loam, closely followed by Rathbone series deep red clay from basalt, while fields of the worst soil, Valumgwaco series deep black calcareous clay in sumps and bottomlands, are now largely being converted to overhead irrigation at the current lowest economic sprinkling rate of 0.13 inch per hour.

These are a few of the contributions that soil series classification has allowed to be made towards improving agriculture and gaining new knowledge of the capability of land to bring forth fruits of the earth.

Drawbacks and Dangers of Soil Series Mapping

Are there then no snags, limitations or deficiencies in the soil series concept? Assuredly there are, as in all man-made attempts to label natural phenomena, and it is only fair that I should allude briefly to some of the perplexities and pitfalls holding challenges to pedologists mapping soil series today. These include difficulties arising from (*a*) the sheer numbers of soil series with which the memory must juggle, (*b*) the manner in which soil series are grouped together, whether taxonomically or for ease of reference, (*c*) the existence of agronomic characteristics that are independent of series and (*d*) the inapplicability of soil series to certain kinds of agricultural research, mainly on very extensive or very intensive farming. Let us consider each in turn.

(*a*) Profusion of, if not confusion of, soil series names presents at least three aspects. *First*, several thousand series have been catalogued over the last 60 years in the United States alone. Indispensible international co-ordination is undertaken by F.A.O., but the mammoth task of compiling an inventory of all the world's soil series has yet to be attempted. However, although the parochiality of soil series militates against easy global comparisons, it is some consolation that the chief arable soils of one farm seldom exceed four or five series, of one agricultural zone (say, the Natal Sugar Belt) forty or fifty. *Second*, on occasion renaming of series has to be resorted to, or often rather the excision of part of a series which had initially been too broadly defined. For instance in England the wet phase of Worcester series became known as Spetchley series from 1950 on; even so a Worcester shallow phase remains which has a much poorer agricultural potential than the modal Worcester — the latter is "well suited to" and its shallow phase "unfit for" all temperate fruit trees, according to Osmond (1937). Perhaps yet another hiving off from this old series might be anticipated? In Swaziland last year the Munali series was separated from Malkerns series, amongst which it occurs in small enclaves. Munali has a dense clay-accumulation horizon, typically at 8 to 15 inches depth, which went unnoticed until some Middleveld citrus orchards showed localized stunting due to anaerobicity in the root zone: the temporarily waterlogged soils were nearly all pockets of what was eventually dubbed Munali series. *Third*, if more than one soil survey organization operates in a country, close liaison is required to avoid duplicating series. Loxton and M'Vicar (1965) are currently engaged on the finicky job of examining the credentials of each soil series so far named in the Republic of South Africa for overlapping, whether entire or in part. Until all the series in an area or a country are adequately known, apparently chaotic and baffling conditions such as the above are bound to occur: indeed it would be an unhealthy sign of pedological stagnation if they did not.

(*b*) Most users of soil series abide by the definition cited — Kellogg *et al.* (1951). Agreement is by no means so complete, however, on how best to

marshall series in the next highest bracket of classification, whether by families, associations, consociations, catenas, suites, sets, *agrupomentos*, fascs or other categories, nor is there always unanimity in their position even further up the hierarchy, at soil group and soil order levels. The probability is that countries and organizations employ the best combinations of series to suit their geographical conditions or for their specific purposes. In the coastal belt of Natal, for instance, and also on the Rhodesian plateau, series are gathered together according to parent material as the geology is considered the principal diversifying pedogenetic factor — see Beater (1957) and Ellis (1951). On the other hand Swaziland's altitude range of 6,000 feet brings climatic variation to the forefront and soil series are seen to be more similar in the two most widely differing physiographic zones Highveld (Inkangala) and Lowveld (Lihlanze) when derived from e.g. either granite or sandstone, than are "granite soils" in both regions or "sandstone soils" in both regions. The niceties of grouping and nomenclature touch research whenever any supranational soil correlation is afoot. Non-pedologists should then go straight to series level if they can, rather than wander in the labyrinth of the upper echelons of soil classification.

(*c*) Some soil features relevant to agricultural research bear no relation to soil series. These include both (i) accidents of history, e.g., a field or midden or house once occupied a sector of a research panel hence its "fertility" may be enhanced or jeopardized, even though the soil series is the same as in neighbouring plots, and (ii) as yet unexplained physical or chemical effects: why do some pineapple experiments on Malkerns series disclose molybdenum responses, whereas others on seemingly identical soil a few hundred yards away do not?

(*d*) At times and in places, even for academic research soil series differentiation is a luxury. Dealing with vast Australian rangelands and forests where very extensive farming is the only feasible pursuit, Christian and Stewart (1953) pioneered the mapping of *land systems* or "areas each with its own characteristic combination of landforms, soils and vegetation, and consequently its own potential and own reaction under any given set of conditions". In Africa this same method of broad classification has been employed recently by Bawden and Stobbs (1963) over parts of Bechuanaland, and its more general use in sparsely peopled environments far from sources of irrigation water is commendable. Land systems may yet prove to be the successors to *physiographic regions* that overemphasize climate, geomorphology and plant ecology. Now soil descriptions and distributions are coming into their own as worthy reinforcements to and indeed often summations of these other natural features of the landscape. There is much leeway to make up. The almost total absence of soil studies for regional planning purposes in the past may be gauged from Robinson (1953) and Whittlesey (1954). Paradoxically, soil series may also become less relevant at the other extreme of agricultural activity, in very intensively farmed tracts where costs of materials, labour and transport are so high and operators so skilled that the soil ceases to be a decisive factor in choice of farm or crop. Hydroponics is one end point of this trend, but even where soil is retained as the growth medium it often fails to link up with crop behaviour. To cite one example from many, Zwerman and Prundeanu (1958) in a highly evolved mixed farming area of New York State found no significant correlations between land class (reflecting soil series and slope) on the one hand and such features as strip cropping or grass waterway provision on the other. They conclude that there is little or no relationship between soil qualities and conservation practices because farmers' attitudes and aptitudes are of overriding importance in that locality.

Pros and Cons in Conclusion

In a strong attack on soil series Papadakis (1964) deems them to be empirical units, arbitrarily defined, which are less suitable for soil mapping than what he terms *land types*, described by as many pedological terms as are necessary, for instance "para-chernozem lessivé sandy loam on clay, 25-35 cm humic and 25-60 cm eluvial". The advantages of this procedure, among which he lists exactitude, time-saving and flexibility, seem however to the writer to be more than offset by cumbersomeness, lack of popular appeal and departure from the extremely practical standpoint that there are in a given country a finite number of modal profiles of soil series, each with a declared range in variation. And there is the inconvenience to which Papadakis himself draws attention, the shortage of trained personnel thoroughly acquainted with pedological theory and pedogenetic influences.

Finally I wonder whether, without distracting themselves from their absorbing field and lab work, soil surveyors collectively and individually should not advertise their services more, stressing the technological gains and even monetary profits to be had from following their carefully worked out, disinterested advice, which may not in some instances be sieved quickly enough through office files, reports and extension aids to those it is intended to serve, the farming community. Surely, once a soil series has been established it should be made as well known, by the pedologist-propagandist, to farmers whose fields and pastures contain it as are the names of local hills and streams. Soil maps should become as familiar as topographic maps and soil boundaries as much discussed as are contours or cadastral divisions. Once that stage in awareness of soil is on the verge of being reached, I imagine most fruitful associations could come about between pedologists, others engaged in agricultural research and farmers.

Summary

Soil series is defined, adhering to the United States Department of Agriculture specifications. In Swaziland agricultural research has been based on recog-

nizing and experimenting upon common arable series, both in greenhouse minus-one tests and in field trials. Before being picked for the purpose, research plots were soil-mapped. Instances of research findings that relate to maize, sugarcane and pineapples on particular Swaziland soil series are given. Yield prediction is discussed. Disadvantages as well as advantages of soil series are enumerated. The suggestion that soil surveyors should publicize their own work more is put forward.

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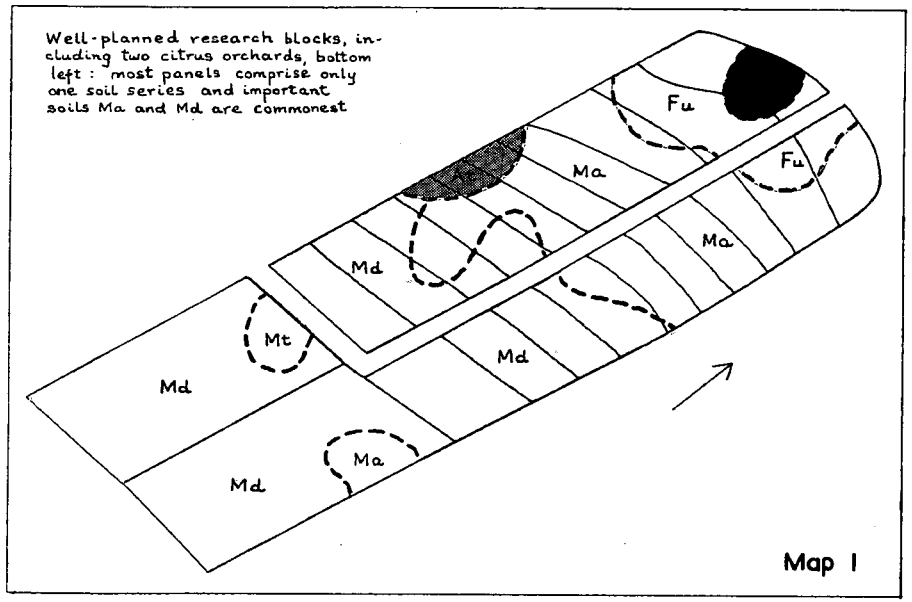
Mr. Hill: Mr. Murdoch's paper shows clearly the application of soil series to agricultural research in Swaziland.

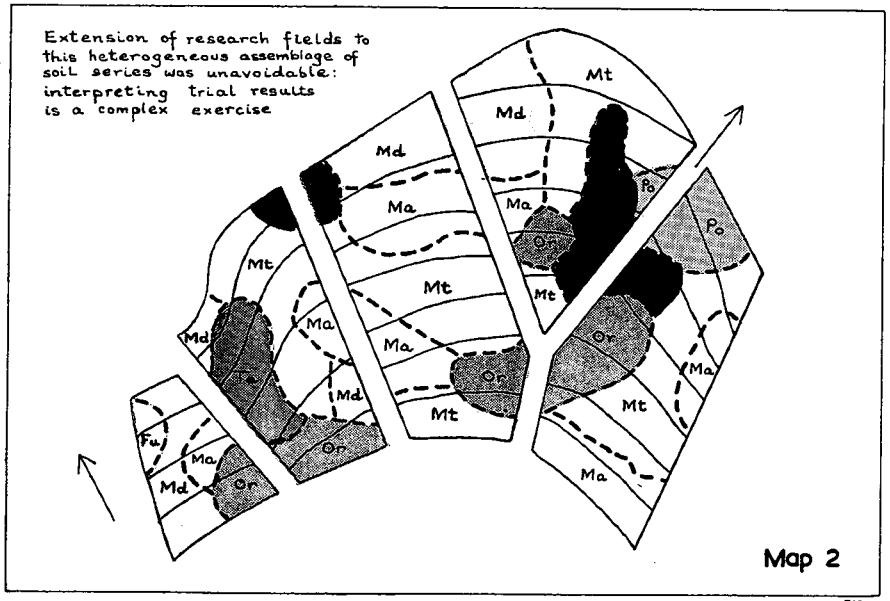
I shall always be grateful for the course in pedology which was included in the University syllabus for a soil scientist.

As a research agronomist I am continually being faced with soil series and it has been encouraging to hear both in yesterday's papers on agricultural subjects and in today's papers continual reference to soil series.

We work with the soil, we have a crop that grows in the soil and so we must know the soil. I think for this purpose the soil series is the ultimate unit of classification and as pointed out by Dr. Macvicar, this will facilitate the correlation of different research findings.

SOIL SERIES ON PORTIONS OF MALKERNS RESEARCH STATION SWAZILAND MIDDLEVELD





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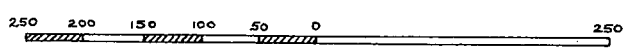

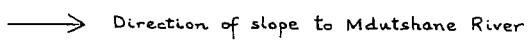

SOIL SERIES DESCRIPTIONS

At Atondozi – yellow sandy loam on mottled heavier subsoil containing iron concretions
Fu Funebizo – orange loam with iron concretions below 2 to 4 feet depth
Ju Juweel – dark brown compact loam to clay loam on thick quartz stone-line over red loam
Ma Malkerns – deep friable red loam, sometimes with dark brown humic nuttier topsoil
Md Mdutshane – deep very friable orange sandy loam
Mt Mtilane – similar to Malkerns series but with thin quartz stone-line in top 3 feet
Or Orrin – grey-brown sandy loam on well-weathered rock within 4 feet
Po Pofane – grey sandy loam for 1 or 2 feet then mottled altered rock, some iron concretions
Sa Sangweni – rather shallow dark brown clay loam
Ta Tateni – thin pinkish-grey sandy loam on very soft rotten rock