A LETTER TO A NEW GENERATION

Greetings on World Soil Day

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It is a long time since I was a student although it seems like yesterday. The main thing we had to learn was to distinguish between what is true and what is false and, if necessary, confidently call out: ‘Rubbish!’ if that is what it was. Science students have to take one step further. As Albert Einstein explained: ‘It is important to be able to distinguish what is true from what is real.’

In my day, much was expected of governments that controlled the commanding heights of their economies; and of the United Nations and its agencies. In those days, we all believed in planning. It was appreciated – at the highest level – that, to meet the challenges of the day, we need intelligence at the point of decision. We need intelligence about the location of resources, their condition, and how this is changing.

In food and agriculture, costly failures in the absence of soil surveys (like the Tanganyika Groundnut Scheme) and urgent demand from decision-makers created a Golden Age of land resources surveys. Belatedly, the decision makers realised that it’s not all the same out there. So, soil surveys were commissioned for development policy and planning from the national or regional level to allocate development funds, for implementation of new schemes, and for extension advice applicable to individual farmers’ fields. There was plenty of work for young scientists. I became a soil surveyor, andover 60 years, I have dug holes in every continent in the service of governments, international agencies, and curiosity.

The fundamental idea, beyond the demonstrable fact that it is not all the same out there, is that different kinds of soils respond differently to any given management. Soil surveys distinguish the different kinds of soil according to the practical purpose of the survey.

Most commonly, soil surveys have supported agriculture where soil texture, structure, porosity and salinity determine the ability to supply crops with water; texture, mineralogy, soil organic matter, and reaction determine the capacity to supply plant nutrients and the response to fertilizers; and landforms, drainage and climate combine with soil attributes to determine land use, crop suitability and the need for irrigation.

Land evaluation may be based on experience in the field or, by correlation, on experience on similar soils elsewhere. In the absence of such experience, field experiments are needed to test new crops or improved management practices; and prior surveys are essential to ensure that trials are placed on soils that are uniform and represent significant areas, so that the results can be extended to similar soils elsewhere.

When my generation was making soil maps, chemistry was king. Agronomic advice relied upon finicky laboratory determinations on soil samples collected in the field but it was hard to join up the dots. Soil maps prepared by departments of agriculture were, commonly, the basket-of-eggs kind with boundaries drawn around the data points of soil chemical analyses.

However, one soil may be distinguished from another in the same way that we differentiate other objects: by their appearance and by measuring differences in the properties that characterise individual species – just as we distinguish between different kinds of plants and animals. As our carrier of information, we adopted the **soil profile**: a vertical slice through the soil, expressed in more-or-less-horizontal layers comprising topsoil, subsoil and any underlying materials; the topsoil commonly darker in colour thanks to the accumulation of organic matter; subsoil horizons exhibiting great variety; and the underlying material sometimes representing the parent material of the layers above, sometimes not. We described each horizon by hand and eye – according to its colour, texture, structure, consistency, stoniness and thickness – sometimes augmented by field tests of reaction and salinity.

Soil mapping units extended the two-dimensional soil profile into a three-dimensional parcel of land, within which soils were found to be much the same, by drawing boundaries in the landscape where critical soil properties changed or, rather, we drew lines on the topographic map or air photo according to visual clues like vegetation and breaks in slope. Finally, when we were confident of the constancy of a mapping unit, we chose a representative soil profile, described it fully from a pit face, and despatched samples to the laboratory.

Digging is hard work and there were always too many acres and too few surveyors. So, we were faced constantly with the need to **predict soil occurrence**. The correctness and, therefore, the usefulness of our maps depended not only on our skill in recognising a given combination of features but, also, our ability to predict correctly where this combination might occur. As we dug our way across the landscape, we created mental models of the pattern of the soil cover as it depended on climate, parent material, landform and position in the landscape, vegetation and land use, and our appreciation of the history of the landscape.

We didn’t dig to find out what the soil was in any particular place. We dug to test our models, and refined them as we went along. They worked pretty well in the landscapes where they were developed, but broke down in other landscapes and, then, we had to construct new ones. Patch by patch, the soil map emerged, depicting the surveyor’s mental model of the landscape by firm but flowing delineations of discrete parcels of land, each defined in the accompanying legend.

These soil mapping units are real things - each a world of its own operating by its own laws. Differences between these worlds matter to whatever lives there, whatever a farmer tries to grow, whatever the engineer wants to build or burrow. But to reveal these differences takes the hand and eye of a Michelangelo who can see David in a block of marble. It goes without saying that the pioneer soil surveyors were dogged individuals – every one revealing individual truths as unique as a Michelangelo, or a Lucian Freud. But our predictive models remained in our heads– our customers only wanted the maps – so the maps couldn’t be replicated. No one but their creator could adjust them to take account of new information. When a soil surveyor died, so did their soil maps.

Soil maps have another fatal flaw. They are a quarry of potentially valuable information but they do not interpret themselves: they can only be interrogated through the legend and, then, only by people who speak their language. So, people who need the information held in soil maps need a priest to interpret them; the world got tired of waiting for soil surveys to produce the information; and planning lost the mandate of heaven – to be replaced by the wisdom of the market.

A revolution in soil mapping had to wait for modern computers, digital elevation models, advances quantitative analysis of landforms, geostatistics, and machine learning. Then, a few of those dogged individuals who made soil maps laboriously wrote down their mental models as quantitative, predictive rules. Rules that others can follow and, thereby, replicate original soil maps, extend them more reliably than the average surveyor can, improve them with new information, and tease out specific soil properties like soil organic matter content, or reaction, rather relying on the soil mapping unit or taxonomic group to carry the information of interest.

Quite suddenly, we could generate digital soil map of the world, not by joining together all the hand drawn maps, but by interpolating between established points of fact on the ground, according to the rules – the mental models - that had been found to work! This was the holy grail of my generation, what we had sweated in the heat, parched in the dry, drowned in the floods and scrambled up mountains to reveal! Now, anyone with a smart phone can now get a soil map or a range of predicted soil properties for anywhere in the world at 250m precision.

And the world yawned. The market does not know what to do with this information! And yet, it has never been needed. The world is changing on our watch. Global heating, more capricious rainfall that turns streams into destructive torrents, more common and more severe droughts, rising sea level and overstretched groundwater resources mean that farming has to change radically. And soon. Not just to produce food and fibre but to capture carbon, infiltrate and store rainfall both for crops for food and crops for energy and for flood control, and to maintain biodiversity.

Probably, planning is part of the answer and that will need soil maps and interpretations of whole landscapes, not just of carbon storage and crop nutrients but infiltration rates, soil water storage and transmissivity, waste disposal and recycling, shear strength and bearing capacity. And it will need young people who understand and can make use of the information.