Excellent groundnut growth around an eroding termite mound due to the much higher soil fertility. Photo: Joost Brouwer

Soil and crop growth variability can be an opportunity: examples from Niger

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One of the most striking aspects of crop growth in the Sahel is its extreme variability. In one part of a field the millet or groundnuts may be lush and dark green. Only a few meters away hardly anything may grow at all (see photo). Is this good or is this bad? Or does it all depend on what you know as a farmer, and what you want, and what you are able to do?

We report here on a combined on-farm and on-station research programme at ICRISAT Sahelian Center near Niamey, Niger, that focussed on soil and crop growth variability. Many of the variability principles clarified in this research programme are also relevant to different parts of the world (see Brouwer and Bouma, 1997, a non-technical publication; Brouwer and Powell,1998; Voortman *et al.*, 2002).

Causes of soil and crop growth variability

Variability needs to be placed in the context of its environment. The overall slope of our terrain is only 1%. But the surface is covered with small rises and micro depressions, with short (2-20 m) slopes of up to 10%. Local soils, and thus crops, on these wind-blown sands in Niger are quite sensitive to periods without rainfall. Such intra-seasonal droughts are all too common during the rainy season, which lasts from June-September and averages 500 mm. The original vegetation was thorn scrub or very open woodland, which has now given way mostly to pearl millet fields and fallow. The millet is sown in pockets 1-1.5 m apart. Crop growth is also limited by the inherently poor soil fertility. Traditionally, the fertility of the millet fields closest to the villages was maintained through nutrient transfer: cattle, sheep and goats grazing in fallow and bush areas spent the nights on the millet fields, depositing their manure and urine. But there is no longer enough grazing land to satisfy the fertility requirements of the ever increasing number of fields.

In this setting, soil and crop growth variability plays a very important role. Physical causes of variability include micro topography, surface crusting and water availability, and the interactions of these aspects. Crusting affects seedling emergence, but also water availability: even on our very sandy soils, a slight slope with a slight crust can mean that as little as 30% of the rain infiltrates. A slight depression 5 or 10 m further on, and infiltration may be 300% of rainfall.

Needless to say, big differences in rainfall entering the soil cause equally big differences in leaching. In the depressions, soils are generally more acidic (pH-KCl of 4.0). On the small rises soil fertility is better, though still poor: the topsoil has about 0.3% organic matter, 120 ppm total nitrogen, 3 ppm available phosphorus and a CEC of about 1 meq per 100 g.

Both physical and chemical properties of the soil are influenced by biological factors: soil fauna and vegetation. Mound-building Macrotermes termites bring up less acidic and more clayey soil from lower layers to construct their mounds, and also incorporate plant and crop residues. Total nitrogen in the mound material can be as high as 3000 ppm, 25 times the content of the normal topsoil. Once the mounds have been abandoned, eroded and reworked by other termites, the crop growth on them can be spectacular (see photo). As much as 20% of a field had above average millet growth because of previous soil-enriching termite activity (Rotmans 1994). Trees and bushes also have their effects. Farmers in southwest Niger cut back *Guiera* bushes to reduce their water use and then sow millet more densely around the stumps, where the soil is more fertile. Under *Acacia albida* trees, which lose their leaves at the start of the rainy season, millet grows better because there is no competition for water, while shade from the bare branches lowers the soil temperature for sensitive seedlings. The trees can recycle nutrients from below the millet root zone, and manure left behind by livestock during the dry season also improves soil fertility. Indirectly, human activity can also contribute to crop growth variability: around wells and old dwelling sites soil fertility is relatively high.

What variability means to farmers and how they deal with it

Crop growth variability, much maligned in western agriculture, appears to have one great potential advantage to farmers in the Sahel: it can help stabilise yields (Brouwer *et al.* 1993). In years with good rainfall the best yields may be obtained on the higher, drier, but more fertile parts of a field. In years with poor rainfall, yields may be best on the lower, more leached but wetter parts of a field. Similarly, yields are usually higher on old termite mound sites and under *albida* trees. But as we have witnessed, the crop there may also develop too fast and wither during an intra-season drought, while the smaller millet plants in the open field survive and go on to produce normally.

Farmers react to spatial variability by differentiating their management. In better parts of a field the millet may be sown earlier and more densely, and certain parts of a field may be weeded first. The more demanding sorghum may be sown around termite mounds rather than millet. Sheep manure may be spread on eroded areas to help recover them. Branches may be placed on old termite mounds to speed up mound breakdown by attracting other termite species. Spatial variability may also be increased artificially, for instance by digging shallow holes to trap water. Small amounts of organic matter added as fertiliser also attract termites that improve soil structure ('zaï' technique).

Combining local and scientific knowledge

From what is stated above it might appear that farmers are already exploiting all locally available options for yield improvement. Indeed, there are those who say that the only way to improve agriculture in the Sahel is through external inputs. Such a statement ignores two facts:

- Firstly, for many farmers external inputs are unaffordable for the foreseeable future.
- Secondly, there are options that farmers do not know of yet, as they are based on processes they cannot observe, e.g. underground, or on ideas developed in other regions (Brouwer 1998). Here, scientists can assist farmers in making better use of their local resources. This may not result in enormous yield increases, but it can help buy time through small yield increases, thereby reducing pressure on the land. And that is an important aspect of sustainability: buying time so that one's options remain open for when circumstances change (Brouwer 2002). Besides, techniques that help make more efficient use of *local* resources can also help make more efficient use of *external* resources.

One of the things we found at Bellaré is that we are actually dealing with different wind-blown sand deposits (Voortman *et al.* 2002). The farmers already treat these deposits differently, for instance by sowing at lower density in part A. In part A soil surface sealing is a much bigger problem than in parts B and C. It may pay to look at ways of increasing infiltration there, e.g. chemically through addition of Ca or K, or with a grass mulch, making more water available for the millet.

On all three deposits there appears to be excessive manuring: more than 10 tons per hectare of manure plus urine are often found in the field, which leads to enormous annual leaching losses. Our findings suggest that it would be much more efficient to apply not more than 1.5 tons per hectare of manure, as evenly over the field as possible, every couple of years. This would allow regular fertilisation of a much larger area with the same amount of manure (Brouwer and Powell 1998, Voortman and Brouwer in press). In addition, in the relatively acidic depressions, cattle manure is quickly leached away and has almost no effect. It is better applied to the higher parts of the field. Sheep manure and urine, on the other hand, raise the pH of the soil in the depressions, and the slow breakdown of the manure pellets limits leaching losses. Our research suggests that spatial differences in effect and efficiency are also likely to apply to external inputs such as chemical fertiliser.

Ideas for the future

Our variability research has confirmed the rationale of certain current farmer practices in scientific terms, but it has also pointed to alternatives that deviate little from current practices and yet can improve efficiency of labour and input use. The challenge now is to take this further. If scientists know the locations in a field where nutrients are used most efficiently, can farmers devise ways to get them to the right place in the right amounts and at the right time? Knowing that young *albida* trees grow best near old termite mounds, can the survival rate of out-planted *albida* seedlings be improved? Knowing that mound-building termites can greatly improve soil fertility, can farmers and scientists together find ways of tilling the soil without discouraging the activity of these termites? And can they perhaps encourage these termites in areas where soil fertility is presently low? There are many ways in which indigenous farming systems may be fine-tuned, if farmers and scientists work together, really observe what is happening, and learn from each other. Only then can we truly understand how agro-ecosystems function, what role variability plays in them, and how productivity may be increased sustainably in the short term, even without external inputs. ■

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Integration of Soil Management in Farmer Field School Programmes in Uganda

The demand from smallholder farmers for help in overcoming declining soil productivity and low yields is increasing. The programme for Soil Productivity Improvement, Conservation Agriculture and Nutrient Monitoring using the Farmer Field School approach (FFS) is a response to this demand. Its objective is to provide farmers, their communities and service providers with better rain-fed land management skills and decision-making capacity to overcome soil productivity limitations, and to develop and adopt sustainable and economically-viable land management practices.

The pilot programme is being implemented in Eastern Uganda during 2002-2003, through a partnership of concerned governmental, non-governmental, research and academic organisations. The Africa 2000 Network, a recognised NGO in the agricultural sector, is conducting the pilot activities in four districts with over 20 existing FFS groups set up for the IPPM programme (see p.18).

The FFS approach is being adapted for soil management issues. Training materials are being developed and resource persons of various service providers are being trained. Soil Productivity Improvement (SPI) is interpreted in the broader and more holistic sense of "Integrated Land Management". It embraces the management of soils, including soil biota, nutrients, water, crops, pastures, vegetation, livestock and other living organisms, tailored to a particular cropping and farming system, with the aim of improving and sustaining soil fertility and land productivity. Conservation Agriculture (CA) principles and monitoring activities are also being introduced as an integral part of the farmer-driven research and development process.

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