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When water is scarce, dust storms strip away the scant soil in Mali.

Save our soils

Researchers must collaborate to manage one of the planet's most precious and threatened resources — for food production and much more, says **Steve Banwart**.

Many researchers focus on how to intensify agriculture for a growing, hungry world. So far, they have largely dodged the question of how global soils will cope.

Our planet's soils are under threat, as witnessed in the past decade by dust-bowl conditions in northwest China, the desertification of grasslands in Inner Mongolia and massive dust storms across north-central Africa. Soil losses in some locations around the world are in excess of 50 tonnes per hectare in a year[1]: up to 100 times faster than the rate of soil formation. In other words, we are losing nearly a half-centimetre layer of this precious resource per year in some places (see graphic).

At the same time, global growth in human population and wealth requires a major intensification of agricultural production to meet an expected 50% increase in demand for food by 2030, and possibly a doubling by 2050[2]. These numbers do not bode well.

Scientists need to develop a predictive framework for soil loss and degradation quickly, to evaluate potential solutions systematically and implement the best ones.

There is a way forward. In the past four years, a global network of research field sites — Critical Zone Observatories — has been established. Multidisciplinary teams are focusing on the fundamentals of soil production and degradation, and aiming to create quantitative, predictive models. This programme has enormous potential. It can and should be accelerated, with stronger collaboration between national programmes and strong links to policy-makers.

CRITICAL LOSSES

Soil lies at the heart of Earth's 'critical zone' — the thin veneer extending from the top of the tree canopy to the bottom of our aquifers. Soil forms as rock breaks up and dissolves, with help from soil organisms, creating particles that bind with decaying biomass and living microbes to form larger aggregates. At least 60% of fertile soil by mass is such 0.25–10-millimetre particles[3]. These aggregates provide a good balance of mineral and organic nutrients, which are processed ▶

by microbes into forms useful for plants. The pores within and between soil aggregates retain sufficient moisture for biological growth, facilitate drainage and allow oxygen to reach plant roots.

The built-up natural capital is lost as soil is washed from fields by rain or snatched away by dust storms during drought. Soil is degraded by pollution, by salts concentrated from evaporating irrigation water, and by compaction by heavy machinery. And it is literally sealed up as cities pave and roof over it — the geographical footprint of Europe's cities has increased by nearly 80% since the 1950s, and continues to expand[4]. In warmer conditions, microbes can degrade organic matter faster, so carbon dioxide and other greenhouse gases are released into the atmosphere, the desired soil aggregates are lost and nutrients are depleted quickly. One study estimates that soils in England and Wales are losing 0.6% of their carbon content each year, probably thanks to climate change[5].

LIFE SUPPORT

Soil does far more than support farming and forestry. It stores carbon, filters water, transforms nutrients and sustains biodiversity[6]. It is not clear how these essential roles will respond to agricultural intensification and other human-driven changes, how they might be enhanced in tandem with farming or how this will affect humanity.

Critical Zone Observatories (CZOs) are designed to help fill these knowledge gaps. The US National Science Foundation (NSF) has invested US$30 million in 6 CZOs and 11 affiliated sites. This is primarily a basic-science endeavour to understand critical-zone development and soil processes in diverse environments — from drylands in Arizona to tropical forests in Puerto Rico, and from coastal Delaware to the Rocky Mountains.

The European Commission funds a $10-million CZO programme with 10 sites in Europe, the United States and China focused on mitigating soil threats. Four core European sites represent key stages of the soil cycle. At the Damma Glacier CZO in Switzerland, researchers study the stages of development of new soil formed over the past 150 years on bedrock exposed as the glacier retreats due to global warming. The Fuchsenbigl CZO in Austria studies the development of soil fertility on a floodplain: sediments deposited along the Danube River since the last glaciation reveal progressive stages of soil formation over thousands of years. The Lysina CZO in the Czech Republic tackles soil recovery in managed forests, in an area damaged by acid rain during the late twentieth century. The Koiliaris CZO in Crete, Greece, has mature soils affected by millennia of agriculture and under imminent threat of desertification because of global warming.

Together, these sites provide data for multiple purposes: to develop a predictive model for soil quality; to put monetary value on soil ecosystem services; and to assess the environmental costs of changing land management. These are essential steps towards proactively designing solutions that could intensify agriculture, halt desertification and store more atmospheric carbon without compromising the future value of soil.

There are now more than 30 CZOs worldwide. They have huge potential to transform soils research. Adding CZOs from the Sahara to the Arctic will help, for example, to assess the impact of climate on soil. This is particularly urgent for the Mediterranean basin, where the Intergovernmental Panel on Climate Change predicts 1–5.5 °C warming this century, mostly in summer, a 30–45% decrease in precipitation and a 6–36% decrease in run-off by 2070[7]. A quantitative model of soil quality could be used to assess the costs and benefits of different mitigation strategies, from enforcing less grazing to revitalizing terracing, encouraging composting or switching to a different mix of crops.

Two key ingredients are still missing from the CZO effort. One is better international integration of research methodology. Work on this is just beginning. In September 2008, the Koiliaris CZO hosted teams from Europe, China and the United States for the first joint training event. In 2010, Pennsylvania State University in University Park ran a field course at the Shale Hills CZO; and the University of Colorado, Boulder, hosts a symposium for young scientists at the Boulder Creek CZO this June. The teams are developing methods to create data sets and models that work across all sites, to study a greater geographical range of critical-zone environments, and to maximize the knowledge being created.

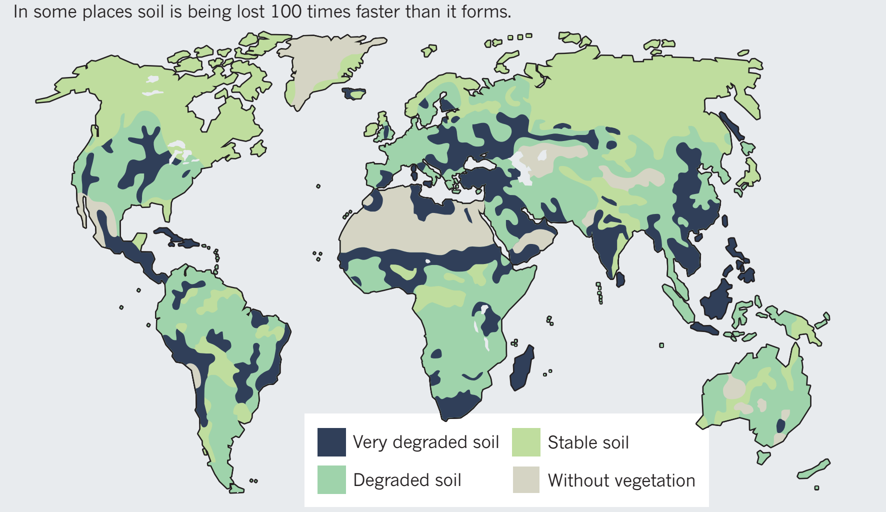
"Soil does far more than support farming and forestry."

The second missing ingredient is a stronger integration with government and commercial activity. The directed research driven by European policy and the basic research of the NSF programme are a powerful combination. Including commercial partners in research planning will help to translate findings into practical solutions.

The challenge is clear. We need rigorous forecasting methods to quantify and best utilize soil's natural capital, to assess options for maintaining or extending it, and to determine how declines can be reversed. And we need these things well within a decade. ■

A THREATENED RESOURCE

In some places soil is being lost 100 times faster than it forms.



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The author declares competing financial interests: for details, and further reading, see go.nature.com/xbjg9j