ADDRESS

The missing scientific links to plan sustainable land management at farm level—past and future

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The land still constitutes one of the great uncertainties in our attempts to manage the environment rationally. To ensure food security at household level, to ensure that farmers are equipped to impose wise management methods on their land in times of drought and in times of flood, these represent real scientific challenges. We may easily overlook the magnitude of these challenges in the gentle temperate environments of rich industrialized nations, where the vagaries of weather are small, soil surveys are completed and massive farm subsidies are in force. Under such circumstances, farmers have a considerable ability to modify the biophysical environment of production, even at short notice: fertilizers, drainage, irrigation, mechanical tillage, herbicides, pesticides and the arsenal of tools in veterinary medicine help farmers to ensure a harvest without great damage to the land. The superior ability of modern technology-oriented farmers to modify the environment to secure economic success—and increasingly in an environmentally benign way—is a considerable success of modern agricultural science in its widest sense. We, who have backgrounds in these sciences, should not forget the contributions made and manifested in the rich cultural landscapes that constitute the lands in which most rich temperate nations take pride and pleasure. Hedgerows may come and go, and the linear elements may be straight or curved as landscape fashions change, but landscapes remain stable and productive, and our ability to sustain them is not seriously challenged. In particular, we should not forget to remind others about it as at present agricultural research and teaching establishments are under threat and we must hold wakes for soil science.

But nor should we remain blind to the fact that without these massive and inherently expensive tools the farmers' abilities to control the environment are limited. In particular, the poor farmer of the developing world is effectively barred from tools that rich farmers use to manipulate the environment for high productivity and certain yields. She or he is barred because of the continuous lack of fundamental knowledge about the biophysics of the soil landscape of many of the environments, the inability of scientists to communicate what is known to the farmers, and farmers' physical and economic inability to implement knowledge and tools even when known. Fertilizers do not arrive without roads, livestock cannot be treated without veterinarians, surplus produce cannot be sold without efficient and fair markets. Many small farmers in the developing world (many of whom are food-insecure) have to farm within the bounds of nature and the immediate environment. They have to do so not because they would not like to benefit from green revolution technology and move up into a higher input-higher output system, but because, realistically, they will not have access for a long time to goods and services that allow the sensible manipulation of the farming landscape for greater food security.

Unfortunately these farmers, and their families, are the among the 840 million food-insecure people of the world. They have been largely overlooked by the politicians of countries rich and countries poor—they rarely have the political clout to make them important. That's politics, and there are close to a billion people to prove it in an otherwise immensely rich world. The politicians should not be proud, and the political systems in developing countries—and in the rich world—have an ugly downside. What we as scientists should ask ourselves, however, is whether we have also got our scientific priorities twisted. As I look over the audience of today, and since I know a bit about how we all came to be here, I must remind ourselves that nearly all of us have been trained in a scientific tradition that aims at controlling the environment for the highest and safest agricultural production. The tools of agronomy, livestock production, modern forestry and aquaculture are inherently tools of manipulation. Furthermore, they are tools that we assume we can muster, because the lack of credit, lack of engineering maintenance skills and lack of purchasing power in the real world are largely inconsequential footnotes in science. The soil landscape as a source of economic and logistic uncertainty for farmers who cannot till deeply, cannot ameliorate deficiencies wherever they may be, cannot irrigate the dry spots or drain the wetlands because the weather plays up, this is not the theme of the science that we learned. Maybe the ideas expressed here that short-range variability in soils in time and space constitute opportunities rather than nuisances were new to some agricultural scientists. But I can assure you that such notions are not new to the farmers of the arid lands of the world—their farming methods, their wanderings with their animals are expressions of realistic and opportunistic approaches to agricultural production when there are no tools available to smother short-range variabilities.

Pedro Sanchez of ICRAF did it at the ISSS conference in Acapulco, and I would like to continue: We wish to confront our teaching and research institutions with the need for a paradigm shift in the geosciences, not dictated by a revolt against the green revolution or a fanatical belief in organic farming, but as a supplement to the positivistic science tradition that made our modern soil science, modern agronomy and modern veterinary sci-

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ences overlook the realities of complex socio-economic worlds where so many people are without access to the tools we assumed they had. While many of us, as political beings, will continue to strive to influence politicians to give poor people access to inputs that can break the vicious circle and create a sensible and environmentally friendly new green revolution, as scientists we cannot continue to deprive poor farmers of science tooled for those who have no tools.

The real environment in which poor farmers find themselves constitutes an extreme case of science with insufficient answers. Not only because these environments are poorly researched and understood, but also because soil science and related sciences have all lacked a deeper understanding of the complexity of the farming worlds which they serve. I therefore greatly welcome the foresight of certain individuals in the International Soil Science Society in calling a conference like this, attempting to stretch into interdisciplinarity, seeking connections with other sciences, to retool for the toolless.

The concept of sustainable development goes beyond the B horizon—and deeper than the deepest pit of the pedologist. Sustainable development is inconceivable without strong links between the physical, biologic, social and economic sciences. Nowhere are these links more important and more challenging than with poor farmers who, with their families, live without the safety nets of the rich world. Soil erosion models provide only a small part of the answer, as do economic models, land reform and high-yielding varieties. Together they provide larger parts of the answer, if scientists of different scientific communities are willing to communicate. They are not asked to abandon their disciplines—the desire and possibly the academic need to publish in disciplinary journals so as not to perish will no doubt remain—but to take a little from their scientific horns of plenty to mingle with other types of scientists.

Looking for a useful framework to link knowledge of soil and land sciences to other disciplines has been one of my preoccupations of recent post-UNCED years. The challenge of the concept of sustainable development for the impoverished many is huge, even larger than for the rich few (although sustainable development is a formidable challenge also for fat cats).

I believe that at this time we should explore the powers of the capital components to see whether they may be a useful tool, and whether we can usefully link our knowledge of the properties of the soil landscape to the concept of total capital to be sustained within and between generations. And here I wish to acknowledge the work of the chairman of the CGIAR, Ismail Serageldin of The World Bank and of Egypt. I know that many comments made by Christian Pieri and Julian Dumanski (see this issue) reflect their commitment to contribute in the exploration of these concepts, and I applaud of their endeavours (although we may differ on details). These thoughts are in fact founded on many earlier excursions into environmental economics in the 1970s and '80s, including the creation of green accounting for both nations and companies. They also incorporate our learning experience from the original green revolution, whose not infrequent environmental and social shortcomings should not overshadow knowledge gained about the need for fruitful enabling environments.

The five-year post-Rio experience has taught us that to make the "sustainability concept" agreed to at UNCED in 1992 operational at farm level in developing countries requires commitment by the international community, national governments, local administration and—significantly—by developing country farmers themselves. Of the four capital components that make up the total capital to be sustained (nature capital, human capital, institutional capital and societal capital), individual farmers focus normally on nature capital (soil, water, biodiversity) and human capital (children's education, nutrition, health, cultural values). Higher authorities are primarily responsible for maintaining and increasing institutional capital (infrastructure (roads, telecommunications, schools, health centers), functioning bureaucracy) and facilitating growing societal capital (law and order, freedom of speech, democracy). However, local farming communities must ultimately commit themselves in support of all four components. Sustainable development can be measured as the sum of the normalized values of the four component capitals, allowing reasonable tradeoffs between components (including possibly but not necessarily a reduction in nature capital (*eg*, soil erosion or reduced soil organic matter, water pollution, decreased agricultural biodiversity).

Geographic information systems (GIS) have focused primarily on capturing, storing and displaying elements of nature capital, and have done so quite successfully, also linking analytical capabilities to GIS routines, and including time series analysis as more and better datasets become available at national, regional and global levels. The pace at which datasets relating to nature capital are made available, also to and within developing countries, must be maintained. It is not likely, however, that such datasets will benefit the individual farmer or landholder in developing countries, unless she or he practices very extensive crop or animal farming. The scale and detail of the datasets are not adequate at farm level. At best, they can support advisory services and contribute to setting agricultural research agendas.

GIS technology is being increasingly used to portray human capital datasets (poverty indices, human welfare indices, health variables, literacy variables, demographic variables). Major efforts are underway to create spatially referenced datasets for this component, and significant progress is being made, also at national level. However, the spatial heterogeneity of such variables (*eg*, pockets of poverty or deprivation nested within more prosperous communities) can make it difficult to overlay human capital datasets with nature capital variables at local level. The problems resemble those of soil maps of soil associations or land systems. Exciting work attempting to overcome these obstacles will be reviewed.

GIS technology has been traditionally associated with physical infrastructure, and proximity analysis (*eg*, to roads, markets, administrative centers) now forms part of existing methodology that is useful also at local (*ie*, near-farmer's) level. This offers opportunities of combining datasets of nature capital, human capital and institutional capital at near-local scales. Some institutional capital variables (*eg*, bureaucratic traditions) have so far eluded spatial referencing, but could be contemplated in spatial terms.

Societal capital normally refers to values that are not easily brought into spatial form, but some recent work in

political science (*eg*, in Italy) has suggested much clearer spatial relations than normally considered, thus opening up possibilities of applying GIS technology to this component as well, at least at community level.

The central issue now is to establish joint efforts to identify critical datasets for each of the four capital components, and to ensure that the datasets are identifiable at low cost also at farmer's level—at least for nature capital and human capital components. Current efforts in UNEP, FAO, the World Bank and the CGIAR point to such possibilities. The next step is to combine such datasets in models that are meaningful also for small and impoverished farmers, and to develop dissemination tools that in an age of the digital superhighway also cover the last mile to the farm.

As I conclude, may I make one observation. I do not believe that what has been said here represents revolutions in science. Indeed, much may be uncomfortably mainstream, particularly for the younger scientists in the audience. That is the bad news. The good news is that what we have heard is distinctly different from what would have been said 20 or even 10 years ago, when a hard and mechanistic soil science started marginalizing itself from the global rural development efforts. Although I may have more hair and fewer grey ones than some in the audience, it is still 30 years since I started working with geographic information systems. I can only conclude that I must in my earlier days have contributed significantly to this miserably slow development of marrying the environmental sciences with socio-economic sciences—now common sense to all. I am delighted to have been invited to repent in public at ITC.